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Determinants of farmers' perception of climate change

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In front of a jury composed of:

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Abbreviation list

Intergovernmental Panel on Climate Change (IPCC)

temperature-humidity index (THI)

consultative group on international agricultural research gene banks(CGIAR)

greenhouse gases (GHG)

dioxide equivalent per year CO2-eq yr

tricarboxylic acid (TCA)

gonadotropin-releasing hormone (GnRH)

gonadotropins follicle-stimulating hormone (FSH)

corpus luteum (CL)

Topography (TOP)

Total farm land used (TFL)

Irrigated land (IL)

Numbre of cattle (CT)

Genetic structure of bovine herd (GB)

Sheep presence (SP)

Goat presence (GP)

Farming experiences (FEX)

Pluriactivity (PLU)

Training received (TR)

Feeding method (FM)

Sale of milk (SM)

Cattle stable (CS)

Stable size (SS)

Seize stable of cattle (SSC)

Ventilation system (VS)

Abstract:

The dairy production sector has recently undergone significant changes due to climatic factors, such as rise in temperatures, which stands out as one of the main challenges affecting the health, welfare, and productivity of dairy cows. **Objective:** this study aimed to evaluate the knowledge and perception of farmers regarding climate change and to identify the preventive measures they implement to mitigate its impact on animal health and productivity **Methodology:** a qualitative and quantitative approach was used. A questionnaire was applied to 52 dairy farmers in geulma and taref. Data collection was carried out through direct face-to-face interviews, which allowed for clarification of certain questions when necessary and ensured the accuracy and reliability of responses. The questionnaire focused on assessing farmers socioeconomic characteristics, the knowledge and perception of milk producers regarding climate change, its impact on their herds, and milk production, as well as the adaptative strategies that were implemented to mitigate the effects of heat stress **Results:** The findings from this study revealed that out of the eleven factors surveyed; Topography (P= 0,006), pluriactivity (P= 0,081), training received (P= 0,020), bovine breeds (P= 0,010), and cattle's number(P= 0,015) were determining farmers' perception of climate change in the studied area . **Conclusion:** Our results highlight the determinants of farmers' perception of climate change, and gives prove of an important link between farmers perception and knowledge and how it shapes their adaptive measurements and business choices, and therefore their production.

Key-words: climate change; heat stress; dairy production; milk; cattle; perception and knowledge; adaptive measurements'; livestock; farmers.

Résumé

Le secteur de la production laitière a récemment connu des changements significatifs en raison de facteurs climatiques, tels que l'élévation des températures, qui constitue l'un des principaux défis affectant la santé, le bien-être et la productivité des vaches laitières. **Objectif :** Cette étude vise à évaluer les connaissances et la perception des éleveurs concernant le changement climatique, ainsi qu'à identifier les mesures préventives qu'ils mettent en œuvre pour atténuer son impact sur la santé et la productivité des animaux. **Méthodologie :** Une approche qualitative et quantitative a été adoptée. Un questionnaire a été administré à 52 éleveurs laitiers dans les wilayas de Guelma et El Tarf. La collecte des données s'est faite par des entretiens directs en face à face, permettant d'éclaircir certaines questions si nécessaire et d'assurer l'exactitude et la fiabilité des réponses. Le questionnaire portait sur l'évaluation des caractéristiques socio-économiques des éleveurs, leurs connaissances et perceptions du changement climatique, son impact sur leurs troupeaux et la production laitière, ainsi que les stratégies d'adaptation mises en œuvre pour atténuer les effets du stress thermique. **Résultats :** Les résultats de cette étude ont révélé que, parmi les onze facteurs analysés, la topographie (P = 0,006), la pluriactivité (P = 0,081), les formations reçues (P = 0,020), les races bovines (P = 0,010) et le nombre de têtes de bétail (P = 0,015) déterminaient la perception du changement climatique par les éleveurs dans la zone étudiée. **Conclusion :** Nos résultats mettent en évidence les déterminants de la perception du changement climatique par les éleveurs, et confirment l'existence d'un lien important entre leur perception, leurs connaissances, les mesures d'adaptation qu'ils choisissent, leurs décisions économiques, et par conséquent, leur production.

Mots-clés : changement climatique ; stress thermique ; production laitière ; lait ; bovins ; perception et connaissances ; mesures d'adaptation ; élevage ; éleveurs.

الملخص:

شهد قطاع إنتاج الألبان مؤخرًا تغيرات كبيرة بسبب العوامل المناخية، مثل ارتفاع درجات الحرارة، والتي تُعد من بين التحديات الرئيسية التي تؤثر على صحة، وإنتاجية الأبقار الحلوب. **الهدف** :هدفت هذه الدراسة إلى تقييم معرفة وإدراك المزارعين بشأن التغير المناخي، وتحديد التدابير الوقائية التي يطبقونها للتخفيف من تأثيره على صحة وإنتاجية الحيوانات. **المنهجية** :تم استخدام منهجية نوعية وكمية. حيث طُبِّق استبيان على 52 مربيًا للأبقار الحلوب في ولايتي قالمة والطارف. وتم جمع البيانات من خلال مقابلات مباشرة وجهًا لوجه، مما أتاح توضيح بعض الأسئلة عند الضرورة وضمان دقة وموثوقية الإجابات. ركّز الاستبيان على تقييم الخصائص الاجتماعية والاقتصادية للمزارعين، ومعرفتهم وإدراكهم لتغير المناخ، وتأثيره على قطعانهم وإنتاج الحليب، بالإضافة إلى الاستراتيجيات التكيفية المطبّقة للتخفيف من آثار الإجهاد الحراري. **النتائج** :كشفت نتائج هذه الدراسة أنه من بين أحد عشر عاملًا تم دراستها، كانت الطوبوغرافيا ($P = 0.006$)، وتعدد النشاطات($P = 0.081$) ، والتكوين المستلم($P = 0.020$) ، وسلالات الأبقار ($P = 0.010$)، وعدد رؤوس الأبقار($P = 0.015$) ، عوامل حاسمة تؤثر على إدراك المزارعين للتغير المناخي في المنطقة المدروسة، **الاستنتاج** :تبرز نتائجنا محددات إدراك المزارعين للتغير المناخي، وتؤكد على وجود علاقة مهمة بين إدراك المزارعين، ومعرفتهم وكيفية تشكيل ذلك لتدابيرهم التكيفية واختياراتهم في العمل، وبالتالي على إنتاجيتهم.

الكلمات المفتاحية :التغير المناخي؛ الإجهاد الحراري؛ إنتاج الألبان؛ الحليب؛ الأبقار؛ الإدراك والمعرفة؛ التدابير التكيفية؛ الثروة الحيوانية؛ المزارعون

Introduction:

The Mediterranean Basin is considered a climate change hot spot. In the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) in 2013 , the predictions have confirmed a significant intensification of drought and decrease in water availability in the Mediterranean basin and southern Europe with global warming reaching from 1.5ºC to 2°C by 2050. Rainfall events are expected to become less frequent but substantially more intense. The average temperature is expected to rise by 1.2°C-1.8°C by 2050, nevertheless annual rainfall will reduce by 10%. Algeria is especially exposed to the effects of climate change due to its geographic characteristics (Rouabhi et al., 2019) , when assessing the negative effects of climate change particularly on dairy herd performance , heat stress represent a major challenge to the sustainability of the milk production chain ,due the increasing frequency, duration , and intensity of extreme heat events causes driven by climate change. Heat stress specifically related with high air temperature and humidity and intense solar radiation , which impairs the animal's ability to maintain its homeothermy (de Moraes Brettas et al., 2024). Heat stress refers to a state in which dairy cows discomfort and unease due to increased environmental temperature and humidity (Diniso et al., 2022) . For that reason heat stress generates substantial losses in the milk production chain, given that it cause to reduce in dry matter intake, animal growth and welfare milk production and quality, reproductive performance and immune responses of dairy herds. These effects decrease the productivity of dairy farming (Ranasinghe et al., 2023). Furthermore, animals raised in pasture without shade, as is common for dairy cattle in Algeria, are more vulnerable to heat stress due to the intense solar radiation and high temperature, and are therefore more susceptible to climate change, hence , farmers implement measures and strategies to adapt to climate change and its impact on dairy cows (adaptation measures), Pasture diversification, rotational grazing, integrated farming, regular vaccination, and providing cooler conditions to animals are common adaptation strategies followed by dairy farmers in extensive and semi-intensive dairy farming systems (Ranasinghe et al., 2023), increasing the availability of natural shade, and this is the one of the simplest and most economically feasible methods for providing thermal relief and comfort to pasture-raised livestock. These adaptation measures enable and help farmers to reduce and mitigate the severity of climate change impacts and to adopt with its effects. The nature and intensity of climate change impacts are related to the knowledge, perception and strategies of farmers and the cultural and social factors that can facilitate or limit the adaptation processes (Rouabhi et al., 2019).

The results and data presented in this dissertation will be used to mathematically model the impact of weather conditions on cows' milk productivity throughout the year as part of our future studies linked to the PRFU project entitled: milk production and quality in a context of uncertainty linked to climate change "D00L01UN240120230001". This study aims to evaluate and investigate the knowledge and perception of dairy farmers regarding heat stress. The objectives are threefold: (1) assess the awareness and perception of dairy farmers regarding climate change (2) unravels the determinants of farmers' perception of climate change (3) to identify and analyze the mitigation strategies currently employed on farms. Ultimately, the study seeks to identify critical knowledge gaps and provide evidence-based recommendation to enhance on farm resilience and animal welfare under rising thermal challenges.

1. Knowledge and perception about climate change

According to (Diniso, Zhou et al. 2022; Gebrehiwot, Kebede et al. 2024; Byamukama and Agbolosoo 2025), perception is based on observed impacts such as increased drought, reduced rainfall, and animal cues such as lower milk yields, increased sweating, panting, water intake, and drinking frequency, diseases, weight loss, and changes in animal behavior. Knowledge is shaped through both traditional and experiential learning, as well as mass media and extension sources.

To assess knowledge, most studies rely on simple dichotomous questions or self-reported awareness of climate change, which refers to how much individuals think they know or are consciously aware of climate change, and categorize them into groups (Katiyatiya, Muchenje et al. 2014; Arias, Heinsohn et al. 2025). While perception is typically measured as subjective assessments for risk, severity, and susceptibility (Barnes, Beechener et al. 2008), and considered as a key pathway from knowledge to action (Martín-Collado, Díaz et al. 2024). By including them in rural policy development, there is a greater chance of accomplishing food security and environmental conservation objectives.(Oliver, Fish et al. 2012; Barnes, Islam et al. 2013)

1.1 Importance of farmers knowledge and perception

Climate change impacts livestock production through increasing temperature, drought, flooding, and variation in rainfall trends.(Food, Agriculture et al. 2015)

Smallholder livestock farmers in the past have adapted to various climatic change impacts by building on their knowledge of the environment for rearing livestock, (Myeki and Bahta 2021) therefore for any effective adaptation policy, the decisions and strategies in addressing the impact of climate change on farmers must take into account farmers' knowledge and perception of climate change, their potential adaptation and mitigation measures, and possible barriers and constraints to such adaptation(Fosu-Mensah, Vlek et al. 2012; Jones, Jones et al. 2013). While false perceptions of climate change can lead to a lack of adaptation or mal-adaptation, thus increasing vulnerability to climate change. (Idrissou, Seidou et al. 2020)

2. Factors shaping farmer's knowledge and perception about adopting adaptive strategies against climate change

It is clear that the farmers' work enables them to experience firsthand the dynamic nature of climate, and the ability to cope and adaptation strategies largely depend on the quality of perception(Ayal and Leal Filho 2017). Therefore, to ensure a valuable perception, we have to assess the factors influencing it.

2.1 Age of producers

As the age of the producer increases, one can acquire more knowledge and experience and become effective in exploiting these experiences. This variable accumulates and affects efficiently the adaptive strategies therefore, food security status is positively and significantly at a (5%) probability level by using their accumulated adaptation strategies (Frehiwot 2007; Ahmed 2016), and that is through the lessons learned from past extreme weather events. Therefore, farming experience rather than living longer is determining the climate change adaptation choices of farmers. However, it can be negative too, various adaptations might be supported by the fact that youth are relatively innovative compared to older generations, where they are generally less educated (Piya, Maharjan et al. 2013; Ali and Erenstein 2017). Furthermore, as noted in the literature, the influence of age was both positive (Frehiwot 2007; Ahmed 2016; Mulwa, Marenya et al. 2017), and negative (Mbata 2001; Piya, Maharjan et al. 2013; Tesfaye and Seifu 2016; Ali and Erenstein 2017).

2.2 Education level of farmers

The education level of farmers influenced adaptation using enhancing livestock productivity and agroecological practices. Illiteracy could have an implication of less willingness to adopt new technologies and practices in agriculture in general, and for adapting to climate change options in particular. Literate farmers are more likely to react to changes by evaluating choices that fit best to their knowledge, inclination, and capabilities.(Gebrehiwot and Van Der Veen 2013; Piya, Maharjan et al. 2013; Nhemachena, Hassan et al. 2014; Ahmed 2016).

2.3 Gender of farmer

Gender has a positive influence on the adaptation to climate change, where male farmers are more (75.7%) likely to apply adaptation choices to mitigate climate change. Female producers are more susceptible to the climate change. This can be because women are culturally assigned to domestic activities and have limited access to critical resources (land, cash, and labor) in developing countries, which often undercuts their ability to carry out labor-intensive activities that make them economically subordinate to their husbands. (Ayal and Leal Filho 2017). Nevertheless, a few studies have noted that female farmers were expected to adopt crop diversification due to greater experience and more knowledge of various management practices. (Tesfaye and Seifu 2016) Likewise, male-headed households were highly adaptive to resource-intensive decisions, like changes in crop type and irrigation investment due to resource endowment (Mulwa, Marenya et al. 2017); this was probably also a consequence of social structure.

2.4 Family size

Several previous studies produced mixed results on the influence of household size on farmers' associated adaptation choices to climate change. (Yegbemey, Yabi et al. 2013; Ashraf, Routray et al. 2014; Tesfaye and Seifu 2016)

2.5 Cultivated land size

Farmers with larger farms are expected to work on their production intensively rather than going for alternatives, and have better production. The food security status of the farmer increases by a factor of (39.02%) as the farm size increases by 1 ha.(Berman 2014)

2.6 Farm size

Increasing farm area elevates the chances of adaptation. (Milioti, Karlaftis et al. 2015) Many authors agree that farm size is one of the most important variables for classification, and they use this variable when there are considerable differences among farms (Castel, Mena et al. 2003; Nahed, Castel et al. 2006; Usai, Casu et al. 2006). Although several other studies reported mixed results (Piya, Maharjan et al. 2013; Ahmed 2016; Tesfaye and Seifu 2016).

2.7 Income

The percentage of total income coming from the farm was positively correlated with all adaptation choices except change in crop date. However, in the drought model, for all choices, this was not significant. More importantly, this means that the higher the income coming from the farm, the greater the likelihood of adoption of adaptation alternatives. Apparently, the higher the percentage of farm income, the lower the likelihood of diversification; consequently, a higher dependency on farming leads to higher chances of adaptation (Mulwa, Marenya et al. 2017).

3. Adaptive strategies implemented by producers

Adaptation to climate change is a global concern (Alam 2015; Elum, Modise et al. 2017), due to the varied reaction of farmers between “Resistance” which has negative connotation since it is perceived as a brake on progress, an outdated, anti-progressive and excessively conformist attitude (Bellil and Boukrif 2021), and “Resilience” that is the ability to adapt and learn to adjust to uncertainties of predictable internal and external changes, and the ability to reorganize aftershocks (Holling 1973; Milestad 2012), which is consistently linked to socioeconomic factors like extension access, education, and credit availability. (Teklewold, Mekonnen et al. 2017).

3.1 Diversification of livestock and crop varieties

Multi-species farming enhances the producer’s ability to cope with a changing climate and the associated change in rangeland conditions such increase drought, heat wave and climate change-related diseases and pest outbreaks, it improved livestock production by (50%) in the world which led to more sustainable farming by producing more food in less land usage, and spread to two-thirds of the world.(Wani, Rockström et al. 2009; Herrero, Thornton et al. 2010; IFAD 2010; Kurukulasuriya and Rosenthal 2013; Megersa, Markemann et al. 2014; Rojas-Downing, Nejadhashemi et al. 2017; Martin, Barth et al. 2020). These practices can reduce the risk of climate change by promoting higher intake or compensating low feed consumption, reducing excessive heat load (Renaudeau, Collin et al. 2012), decreasing the feed insecurity during dry seasons (Thornton and Herrero 2010), and reducing animal malnutrition and mortality (IFAD 2010).

3.2 Adjustment in stocking rates

According to (Díaz-Solís, Grant et al. 2009) adjusting stocking rate can be helpful to reduce the effect of drought on cattle in the arid areas, while (Mu, McCarl et al. 2013) found that the more stocking rate of cattle decreases the more temperature-humidity index (THI) increases.

3.3 Integration of livestock system with forestry or crops

Such land management approach has positive synergistic effects on soil properties and nutrient cycling, mixed crop–livestock or forestry–livestock can help with soil degradation, reduce chemical use, carbon sequestration to offset emissions, improve quality of air, and water, biodiversity, pests and diseases, from the sector and generate economies of scale at the farm level (Jose 2009; IFAD 2010; Ryschawy, Choisis et al. 2012; Smith, Pearce et al. 2013; Alves, Madari et al. 2017)

3.4 Shifting locations of livestock and crop production

Location shifting could reduce soil erosion and improve moisture and nutrient retention, another adaptive measure could be adjusting crop rotations and changing the timing of management operations (grazing, planting, spraying, irrigating). This measure can be adapted to changes in duration of growing seasons, heat waves, and precipitation variability (IFAD 2010; Kurukulasuriya and Rosenthal 2013)

3.5 Breeding strategies

Changes in breeding strategies can help animals increase their tolerance to heat stress and diseases and improve their reproduction and growth development (Rowlinson 2008; Henry, Charmley et al. 2012). Therefore, the challenge is in increasing livestock production while maintaining the valuable adaptations offered by breeding strategies, all of which will require additional research (Thornton, Herrero et al. 2007). In addition, policy measures that improve adaptive capacity by facilitating the implementation of adaptation strategies will be crucial (USDA 2013). For example, developing international gene banks could improve breeding programs and serve as an insurance policy, as has been done for plants with the In-Trust plant collections in the (CGIAR) consultative group on international agricultural research gene banks (Thornton, Herrero et al. 2007). This would be a breakthrough that requires significant investment and international collaboration to succeed.

3.6 Mitigation measures

3.6.1 Carbon sequestration

As for mitigation measures for carbon sequestration different studies has suggested the following corrective actions: decreasing deforestation rates, reversing of deforestation by replanting (Carvalho, Moutinho et al. 2004). Targeting higher-yielding crops with better climate change-adapted varieties, and improvement of land and water management (Steinfeld, Gerber et al. 2006). Beef sector study that was performed in Brazil estimated a reduction of up to (25%) of greenhouse gases (GHG) emissions related to grazing land use and land use change, accomplished by improving animal and herd efficiency (Gerber, Steinfeld et al. 2013). Soil organic carbon can be restored in cultivated soils through conservation tillage, erosion reduction, soil acidity management, double-cropping, crop rotations, higher crop residues, mulching, and more (Paustian, Andren et al. 1997; Steinfeld, Gerber et al. 2006), as well as earthworms, and fertilization (Conant, Paustian et al. 2001). In addition improving land grazing management could sequester around 0.15 gigatonnes carbon dioxide equivalent per year CO2-eq yr 1 globally. (Henderson, Gerber et al. 2015)

3.6.2 Manure management

While anaerobic digesters are costly for farmers, (Dickie et al., 2014) suggests that the best approach for implementing digesters is through policies that create enough incentive for adaptation. Another solution is to remove the solids from manure streams which reduces methane emissions, increases the time between storage systems cleaning, and prevents crust formation (Dickie et al., 2014).

3.6.3 Fertilizer management

Fertilizer application on animal feed crops increases nitrous oxide emissions. Therefore, mitigation measures such as increasing nitrogen use efficiency, plant breeding and genetic modifications (Dickie et al., 2014), using organic fertilizers, regular soil testing, using technologically advanced fertilizers, and combining legumes with grasses in pasture areas may decrease GHG emissions in feed production (Dickie et al., 2014). Nitrogen use efficiency can be improved by applying the required amount that the crop will absorb and when it needs the nutrients, and placing it where the plant can easily reach it. Regular soil testing can be a part of a nutrient management plan depending on the region and crop, and improve efficiency of nitrogen use (Dickie et al., 2014). As well as plant breeding and genetic modifications which can reduce the use of fertilizers by increasing a crop's nitrogen uptake (Dickie et al., 2014).

3.6.4 Shifting human dietary trends

Changing feeding practices like, changing feeding time and/or frequency (Renaudeau, Collin et al. 2012), modification of diets composition such reducing meat consumption may significantly reduce GHG emissions. Because big livestock animals such cattle accounts for a large portion of GHG emissions and it is the least resource-efficient specie protein producer (Stehfest, Bouwman et al. 2009), and incorporating agroforestry species in the animal diet (Thornton and Herrero 2010) could indirectly improve the efficiency of livestock production (Havlík, Valin et al. 2013).

3.6.5 Adjusting animal diets

GHG emissions can be reduced by balancing dietary proteins and feed supplements. If protein intake is reduced, manure's volume and composition such nitrogen can also be reduced. Supplements such as tannins are also known to have the potential to reduce emissions, by displacing the nitrogen excretion from urine to feces to produce an overall reduction in emissions (Dickie et al., 2014).

Using measurements of (Gunderson 2000): increasing the system's buffer capacity (room for maneuver), enhancing the adaptive nature of management by operating across different spatial and temporal scales, creating conditions that favor the emergence of innovations (learning capacity, etc.) that support adaptation. We categorized the previous explained strategies in (table 1).

Table 1. Efficiency assessment of adapted strategies by farmers

Strategy type	Implemented strategies		Efficiency	Availability	Adoption	references
Managerial/Structural	Adjusting herd/farm size		Yes	Partial	Yes	(Abazinab, Duguma et al. 2022)
	Stall feeding, purchasing feed additives					
	Water management and mitigation					
	Adjusted planting					
	shifting grazing timing and places					
	bathing animals during heatwaves					
	Pest management					
	constructing shelters, planting shade trees and alternative fodder					
Genetic	Including HS resistance among selection parameters		Partial	Partial	Minimal	(Rowlinson 2008; Henry, Charmley et al. 2012)
Financial/Institutional	Credit	Access to extension	Yes	Minimal	Qualitative	(Rojas-Downing, Nejadhashemi et al. 2017)
	Insurance	Training				(Rojas-Downing, Nejadhashemi et al. 2017)

	Trade	Cooperative learning networks				(Rojas-Downing, Nejadhashemi et al. 2017)
Collective/Indigenous	/		Partial	Minimal	Qualitative	(Barnes, Islam et al. 2013)
Technological	Cooling systems, automatic milking and feeding systems...		Yes	Minimal	Qualitative	(Dickie, Streck et al. 2014)
Mitigation	Adjusting animal diets		Partial	Partial	Partial	(Abazinab, Duguma et al. 2022)
	shifting human dietary trends					
	fertilizer and manure management					
	Carbon sequestration					
	Enteric fermentation					

1. Heat stress

The term heat stress is often used broadly and imprecisely, encompassing references to environmental conditions, the effects of climate on dairy cattle, or the animals' physiological and productive responses to such conditions (West, 2003).

Heat stress is an increasingly critical issue in sustainable dairy production due to rising global temperatures and the growing frequency of extreme heat events in temperate regions. In addition to the substantial internal heat generated naturally by dairy cows through metabolic processes involved in milk production, prolonged exposure to high temperatures and humidity can surpass their capacity to effectively dissipate this accumulated heat (Chen et al., 2024). Heat stress is a non-specific physiological reaction in animals to thermal conditions, occurring when the amount of heat produced by the animal exceeds its capacity to dissipate it (Liu et al., 2019a)

Temperature-Humidity Index (THI), a composite indicator that integrates ambient temperature and relative humidity to reflect environmental thermal conditions. Traditionally, heat stress was considered to occur when THI values exceeded 72. However, more recent studies have indicated that dairy cows may begin to exhibit signs of heat stress at THI levels as low as 68. Exposure to heat stress has been associated with a range of adverse effects, including reduced milk production, impaired reproductive performance, increased standing time, decreased feed intake, and elevated water consumption. These physiological and behavioral changes underscore the significant impact of thermal stress on dairy cow welfare and productivity (McDonald et al., 2020). .

2. Thermoregulation

Dairy cattle are homeothermic animals, meaning they possess the ability to regulate and maintain a stable core body temperature within a narrow range, despite fluctuations in ambient temperature or physical activity. Heat stress arises when environmental temperatures exceed the animal's thermal comfort zone. Within the thermoneutral zone, metabolic heat production remains consistent, and no additional energy is required to initiate thermoregulatory responses, thereby allowing the animal to achieve its full productive potential. However, once ambient temperatures surpass the upper critical limit, the animal must activate physiological mechanisms to dissipate excess heat, resulting in increased energy expenditure and heat production in an effort to maintain homeothermy and a stable internal temperature (Oliveira et al., 2025).

3. Effects of heat stress on dairy cattle

3.1 Effects of heat stress on milk yield and component

3.1.1 Milk

Global demand for milk is projected to rise by approximately (35%) by the year 2030 (Adesogan and Dahl, 2020), it is a widely available and fundamental component of the human diet (Lajnaf et al., 2023). Milk refers to the lacteal secretion, practically free from colostrum, obtained through the complete milking of one or more healthy cows. It may be clarified and its fat content may be adjusted by removing part of the milk fat. This definition includes concentrated milk, reconstituted milk, and whole milk powder. Water may be added in sufficient quantity to reconstitute the concentrated or dried forms. Cow's milk is an opaque white liquid, with a slightly yellowish hue depending on the β-carotene content of its fat. It has a mild flavor and a faint yet recognizable odor. Its pH is close to neutrality.

Cow's milk is a nutritionally rich fluid composed of water and a complex mixture of macronutrients and micronutrients. It typically contains approximately (87.4%) water and (12.6%) milk solids, which include essential components such as carbohydrates, fats, proteins, vitamins, and minerals. Cow's milk is recognized as a rich source of essential nutrients, containing varying levels of fat and water-soluble vitamins, minerals, trace elements, and salts. Lactose is the primary carbohydrate present in milk, and its concentration varies depending on the animal species. Cow's milk is a complex and heterogeneous fluid containing more than 20 distinct proteins. The majority of these approximately (80%) are casein proteins, while the remaining (20%) consist of whey proteins (Taylor and Kabourek, 2003). The following table 2 presents the average values and variability of key physicochemical parameters of raw milk collected from local cows.

Table 2 Physical and chemical composition of raw milk from local cows. (zohra et al.) .

physico chemicale Parametres	Average	Maximum	Minimum	Standard deviation
Dry matter (g/L)	111,33	116	108	4,163
Fat (g/L)	28,5	32	26,5	3,041
Density	1,028	1,029	1,027	0,001
Protien(g/L)	26,48	27,8	25,8	1,140
Lactose(g/L)	44,66	47	40,5	3,617
PH	6,46	6,72	6,58	0,070

3.1.2 Effects of heat stress on milk yield

With the advances in nutrition and continued highlight on improving and increasing milk production, hear stress has emerged as a significant concern in dairy farming(Becker et al., 2020). The decline in milk production, which significantly affects farm income, is a direct consequence of disrupted metabolism and behavior in cows during periods of high heat. Only 35% of this drop in production can be directly attributed to the reduced feed intake observed in heat-stressed cows. Heat stress leads to increased maintenance energy demands, reduced nutrient absorption, impaired rumen function, and significant metabolic and hormonal changes all of which limit the energy available for milk production. Consequently, cows are unable to sustain optimal milk yields. Additionally, metabolic disruptions reduce glucose supply to the mammary gland, thereby impairing lactose synthesis and ultimately decreasing milk output (Vallée, 2021). Metabolic alterations also lead to a reduced supply of glucose to the mammary gland, which is the main precursor for lactose synthesis required for milk production.

A study examining the seasonal effects on milk production found that the milk yield of Holstein cows declined by (10%) to (40%) during the summer compared to their yield in winter (Liu et al., 2019b)

The stage of lactation plays a critical role in determining the severity of heat stress and the extent of milk loss. During the first 60 days postpartum, cows experience a negative energy balance, and to compensate for the energy deficit, body reserves are mobilized. Due to the increased metabolic heat during this period, early lactation and peak milk production are especially vulnerable to heat stress, making effective management essential to minimize its impact on milk yield.

Calving season also play a role in the reduction of milk yield. To mitigate the adverse effects of heat stress, some producer strategically schedules calving during the fall and winter months. This practice helps to ensure that the dairy cows do not reach peak of lactation during the summer, when elevated temperature could negatively impact milk production (Becker et al., 2020). Heat stress not only decreases milk yield, but also affects milk content and somatic cell count (Liu et al., 2019a)

3.1.3 Effects of heat stress on milk components

Heat stress has a detrimental effect on animal well-being and productivity, posing a significant economic challenge to the global dairy industry. A common physiological response in animals subjected to heat stress is a reduction in feed intake, likely as a means to decrease metabolic heat production. In lactating dairy cows, heat stress alters metabolite levels within the mammary glands, affecting critical processes such as glycolysis, lactose synthesis, ketone body formation, the tricarboxylic acid (TCA) cycle, and the metabolism of amino acids and nucleotides. These changes impair the supply of essential components required for milk production in lactating Holstein cows. As a result, heat stress influences both the synthesis and composition of milk by disrupting metabolic processes within the mammary gland tissues. Additionally, it raises core body temperature, which further affects fat production in the mammary gland, reduces dry matter intake and milk yield, and alters milk components such as fat, protein, lactose, and solids-not-fat percentages. These changes may be partially attributed to the decrease in milk yield commonly observed during the summer months, However, the effects of heat stress on milk fat and protein percentages are inconsistent across studies, Some research has reported up to a (9.7%) reduction in milk fat in heat-stressed cows, along with decreases in milk protein and nonfat solids, Overall, the impact of heat stress on milk component concentrations remains variable, with findings ranging from reductions to increases, or no significant changes (Becker et al., 2020).

When the Temperature-Humidity Index (THI) exceeded 75, a reduction in milk fat content was observed. Specifically, the average milk fat content was 3.46 g/100 g when THI was below 75, compared to an average of 3.17 g/100 g when THI reached 75 or higher (Becker et al., 2020). The table 3 illustrates the seasonal impact of heat stress on dairy cow performance by comparing key production parameters between spring and summer.

Table 3 Heat stress (THI) impacts on feed intake, milk yield, milk composition, food efficiency (Bouraoui et al., 2002) .

Parameters	Spring (THI 68)	Summer (THI 78)
Dry matter intake (kg/d)	18.00 ± 0.24	16.27 ±0.16
Forage intake (kg/d)	9.98 ± (0.24)	8.25 ± (0.16)
Milk (kg/d)	18.73 ± (0.18)	14.75 ± (0.18)
Milk fat (%)	3.58 ± (0.06)	3.24 ± (0.06)
FCM 4% (kg/d)	17.83 ± (0.36)	13.25 ± (0.36)
Food efficiency (kg FCM per kg DMI)	0.99 ± (0.02)	0.82 ± (0.02)
Milk protein (%)	2.96 (0.03)	2.88 ± (0.03)
Fat yield (g/d)	681 ± (15)	480 ± (15)
Protein yield (g/d)	562 ± (11)	433 ± (11)
Somatic cell counts × 10^5	4.1 ± (0.9)	8.6 ± (0.8)

FCM: fat-corrected milk; DMI: dry matter intake.

3.2 Effects of heat stress on reproduction

Heat stress significantly impacts the reproductive performance of dairy cattle by affecting various physiological, hormonal, and behavioral parameters. The following table 4 summarizes key indicators used to assess these effects, alongside their measurement methods and consequent reproductive outcomes in both males and females.

Table 4 Impact of Heat Stress on Reproductive Functions in Dairy Cattle.

Type of indicator	Parameter (Sex)	Effect of Heat Stress	Measurement Method	Reproductive Consequence	References
Physiological	Rectal temperature, respiratory rate	Increased core body temperature and panting	Thermometry, visual observation	Reduced general reproductive efficiency	(Jordan, 2003)
Hormonal	LH, FSH, Estradiol, Progesterone (♀)	Disrupted hormonal patterns	Blood assays (ELISA/RIA)	Impaired ovulation and luteal function	(Ţogoe and Mincă, 2024)
	Testosterone, LH (♂)	Decreased testosterone, altered LH pulses		Reduced spermatogenesis and libido	(Ţogoe and Mincă, 2024)
Behavioral	Estrus signs, sexual receptivity (♀)	Weak or absent estrus (silent heat)	Visual observation, sensors	Missed mating opportunities	(Young et al., 2020)
	Libido, mating activity (♂)	Reduced sexual interest		Fewer successful copulations	(Collier et al., 1982)
Semen Quality	Motility, morphology, viability (♂)	Reduced sperm motility, more abnormalities	Semen analysis (microscopy, CASA)	Lower fertilization potential	(Chitkara et al., 2025)
Reproductive Outcome	Pregnancy rate, embryo survival (♀)	Lower conception, higher embryo loss	Ultrasound, pregnancy diagnosis	Infertility, longer calving intervals	(Ambrose et al., 1999)
	Fertility rate, pregnancy per AI (♂)	Decreased fertilization success via AI	AI records, genetic markers	Lower herd productivity	(Wolfenson and Roth, 2019)

3.2.1 Affects ovarian activity

Ovarian function is primarily regulated by a complex interplay between hypothalamic and pituitary hormones, notably gonadotropin-releasing hormone (GnRH) and the gonadotropins follicle-stimulating hormone (FSH) and luteinizing hormone (LH) secreted by the anterior pituitary. These hormones are essential for the coordination of follicular development, ovulation, and corpus luteum (CL) formation. Among these, (LH) and (FSH) play pivotal roles in steroidogenesis and the maturation of ovarian follicles. Although discrepancies exist within the literature regarding the precise mechanisms of gonadotropin regulation, there is a general consensus that heat stress exerts a suppressive effect on (LH) secretion and function. Empirical studies have demonstrated that exposure to elevated ambient temperatures can impair the ovarian response to gonadotropic stimulation, as evidenced by reduced steroidogenic activity in follicular tissues of heat-stressed cattle. These findings suggest that thermal stress may compromise reproductive efficiency through endocrine disruption at both the hypothalamic-pituitary and ovarian levels.

A reduction in luteinizing hormone (LH) concentrations and/or diminished sensitivity of follicular cells to (LH) can disrupt the cascade of endocrine and cellular events necessary for ovulation and the establishment of a fully functional corpus luteum (CL). Additionally, the decline in estradiol levels observed in heat-stressed cows approaching ovulation may impair the pre-ovulatory (LH) surge, further compromising ovulatory success. In contrast to (LH), follicle-stimulating hormone (FSH) levels tend to increase under heat stress conditions, a response that has been associated with enhanced follicular recruitment and development within the ovary. Complementary to these findings, (Roth et al., 2000) reported a significant reduction in plasma inhibin concentrations in heat-stressed cows, which may contribute to the altered (FSH) dynamics. These endocrine disturbances may underlie the increased incidence of double ovulation and the corresponding rise in twin births observed following summer inseminations. Inadequate (LH) secretion can also impair (CL) function, resulting in suboptimal progesterone production. Such disruptions in the hormonal milieu whether due to insufficient or excessive secretion can profoundly compromise fertility in dairy cattle.

Heat stress also affects embryonic development, representing another critical factor influencing the fertility of dairy cows. Its impact is particularly significant during the first two weeks following insemination, as it can hinder embryo formation and development. In addition to delayed embryo development in its early stages and the slow growth of the fetus, elevated body temperature in the cow also impairs the development of the fertilized egg, in which leads to a reduced embryo survival rate. High ambient temperatures have lowered embryo viability and development during oocyte maturation, ovulation, and the first 3–7 days of pregnancy. While greater temperatures influence the embryo's pre-attachment stage, as the embryo grows, the impact lessens (Chawicha and Mummed, 2022)

3.2.2 Reduce the bull's fertility:

Heat stress is a significant negative factor affecting bull fertility, as sperm production is highly sensitive to temperature. An increase in peripheral body temperature can lead to reduced fertility, potentially causing temporary sterility for several weeks after exposure to heat stress. Since the bull represents half of the reproductive capacity of the herd, its reproductive efficiency is extremely important for fertilizing oocytes and producing healthy offspring with high genetic quality. It is worth noting that male mammals possess a specialized physiological mechanism for testicular thermoregulation, which enables them to maintain reproductive function even under harsh environmental conditions.

The effectiveness of local thermoregulation relies heavily on the high density of sweat glands in the scrotum of ruminants. This temperature differential is crucial for effective sperm production in bulls, as testicular temperature must be 4–5°C lower than rectal temperature. The ideal ambient temperature for efficient spermatogenesis is estimated to range between 15 and 20°C. Male fertility is negatively affected by the combined impact of high ambient temperature, relative humidity, solar radiation, and wind factors that particularly affect males. Elevated temperatures often interfere with the oxidative metabolism of glucose in sperm cells due to mitochondrial dysfunction, accumulation of reactive oxygen species, and increased lipid peroxidation. These effects contribute to a rise in primary sperm defects.

Additionally, bulls experience a decrease in libido, and spermatogenesis is inhibited by heat stress. This result in lower sperm concentration, reduced motility, and increased abnormalities. These effects on breeding bulls ultimately reduce the conception rate in naturally serviced herds. Anatomically, the bull's scrotum consists of a thin, low-fat, sparsely haired, and highly vascularized skin layer. It acts as a thermoregulatory organ in coordination with a physical counter-current heat exchange mechanism in the spermatic cord, which regulates blood flow and temperature. This complex system maintains testicular temperature between 2 and 6°C below body temperature. Studies have shown that semen from heat-stressed bulls exhibits reduced volume and motility, along with multiple secondary sperm abnormalities. Furthermore, extreme environmental temperatures can prevent both male and female animals from reaching puberty (Chawicha and Mummed, 2022).

3.3 Impact of heat stress on animal health and welfare

Climate is an important factor that can influence the spread and severity of diseases. It is expected to have a strong negative impact on the health of both humans and animals (Lacetera, 2018)

Behavioral changes observed in cattle during heat waves are indicative of significant thermal discomfort. This is particularly evident through increased competitive interactions among animals, especially when shaded areas in pastures are limited and insufficient to meet the thermoregulatory needs of the herd (Schütz et al., 2010).

Heat stress not only imposes physiological strain on animals but also disrupts their behavioral patterns, notably reducing the time allocated for resting and rumination. This shift adversely affects their overall physiological balance and health status. Under prolonged heat exposure, animals face an increased risk of health deterioration, particularly a rise in the incidence of metabolic and digestive disorders. One of the primary concerns is the disruption of rumen function, especially a decline in ruminal pH levels.

Hyperventilation, a thermoregulatory response to heat stress, results in increased expulsion of carbon dioxide (CO_2), leading to reduced blood CO_2 concentration and consequently a rise in blood pH (respiratory alkalosis). To restore acid-base balance, the kidneys compensate by increasing the excretion of bicarbonate ions (HCO_3^-), the principal buffering agents in saliva. This reduction in salivary bicarbonate concentration, compounded by the decline in salivary production due to decreased rumination, diminishes the buffering capacity in the rumen, thereby causing a drop in ruminal Ph. Such a condition predisposes animals to subacute ruminal acidosis and other associated health complications (Schneider et al., 1984).

Heat stress leads to a decline in feed intake and rumen motility, contributing to the acidification of the rumen and disrupting its normal digestive function through an imbalance in the ruminal microflora. Additionally, the glucose deficiency caused by metabolic adaptations to heat impairs the liver’s ability to properly metabolize mobilized fat reserves, resulting in the accumulation of ketone bodies in the bloodstream. These physiological disturbances together contribute to a rapid deterioration in the health status of affected cows. Furthermore, cows tend to remain standing for longer periods than normal in an effort to dissipate heat, which negatively impacts their rest and feeding behavior (Lacetera, 2019).

Clinical cases of mastitis are also more frequent during heat stress, with an increased risk especially in high-producing cows, during mid and late lactation stages, and in multiparous cows (Vitali et al., 2020).

3.4 Physiological and behavioral responses to heat stress

When environmental conditions change, cattle respond first through their behavior. In hot weather, they try to reduce the impact of heat by moving around, seeking shade, or changing their posture. These actions aren't random they reflect the animal's attempt to cope with the situation. So, by observing their behavior, we can understand how much they're affected by their surroundings Heat stress isn't caused by temperature alone; sunlight, airflow, and humidity especially in unshaded areas of the barn also play a major role. Sunlight, in particular, contributes significantly to increasing the heat load on cattle, prompting them to seek shade or other ways to cool down and relieve the thermal pressure on their bodies. Cattle respond to high environmental temperatures through noticeable behavioral changes, primarily aimed at reducing heat stress. One of their main strategies is seeking shaded areas when available.

Well-designed shade structures are considered one of the most effective ways to protect livestock from solar radiation and reduce heat stress. In areas lacking shade or shelters, cows tend to spend more time around water sources as a cooling behavior. Studies have shown that cows with greater access to shade exhibit fewer signs of heat stress, such as lower respiratory rates and reduced time spent near drinkers. While shade is important, some research suggests that fans and sprinkler systems may be even more effective in reducing heat load compared to shade alone. Cows that rely solely on shade have been found to have higher body temperatures and respiratory rates than those cooled with fans or sprinklers. Although water sprinklers or fountains may be more effective in reducing the animals' heat load, cattle still demonstrate a strong preference for using shaded areas during the summer. Therefore, designing shelters with ample shade and effective cooling systems is beneficial not only for animal welfare but also for production efficiency.

Dairy cows typically rest or lie down for 8 to 16 hours a day, which is essential for enhancing blood circulation, rumination, milk production, and reducing physical stress. However, high temperatures often reduce lying time and increase standing behavior, as cows try to avoid heat transfer from hot surfaces and maximize evaporative cooling.

Water is a vital nutrient for dissipating body heat during thermal stress. Water intake is highly correlated with both milk yield and dry matter intake. Ruminants generally need water equivalent to 3–4 times the amount of dry matter consumed. In heat stress conditions, cows lose more water through increased respiration and sweating, leading to higher water needs. If cows do not consume enough water, their feed intake also drops; a phenomenon attributed to heat stress and associated hormonal changes.

Environmental temperatures influence cows' drinking behavior. In winter, cows tend to drink during the hottest hours of the day, while in summer, they prefer to drink during cooler periods. Water intake also increases significantly after milking and feeding, with cows consuming around (30–50%) of their daily water intake within one hour after milking. Therefore, it's crucial to ensure constant access to clean, fresh water for all cows in the barn to alleviate heat stress and maintain performance (Okuyucu et al., 2023).

1. Study area:

This study was conducted in the states of Guelma and Taraf, located in the northeastern region of Algeria. And it was carried out within the framework of the PRFU project entitled ‘Milk Production and Quality in a Context of Uncertainty Related to Climate Change’ (reference: D00L01UN240120230001). These two states are characterized by a Mediterranean climate, with hot, dry summers and mild, wet winters. These climatic conditions make dairy cattle vulnerable to periods of climate change and heat stress, particularly during the peak summer months from June to August, when temperatures can exceed 40°C. Guelma, and Taraf covers an area of approximately 7440 km² and consists of mountainous, plain and Piedmont regions. Its elevation and varied topography influence local microclimates, affecting dairy farming practices. These regions have a significant number of small to medium-sized dairy farms, where milk production is a key source of livelihood. Cattle breeds raised in these areas include local and crossbred types, which differ in their adaptability to thermal stress. Most dairy farmers rely on traditional farming methods with limited access to modern cooling or shelter systems, increasing the risk of heat-related issues in livestock.

The study targeted several communes within the area, which were selected based on the prevalence of dairy farming and accessibility. These included areas such as Guelma city, Bouati Mahmoud, Héliopolis, El Fedjoudj, Ain Makhlouf, Tamlouka, Aïn El Assel, Raml Souk among others. The selection aimed to represent a range of farm sizes and management practices under varying microclimatic conditions. This regional context is essential for understanding the knowledge and perception of milk producers regarding climate change and their adaptive strategies.

2. Study population:

In Guelma Province, northeastern Algeria. Initially, 41 farmers were identified using a list provided by the Chamber of Agriculture of Guelma, and 11 farmers from Taraf. These farmers were contacted directly, and the purpose of the study was explained to them. Participation was voluntary, and after several follow-ups and clarifications, 52 farmers agreed to participate and completed the questionnaire with transparency. The participating farmers represented a range of production scales and geographic locations across different bioclimatic zones (humid, sub-humid, semi-arid, and arid), providing a diverse and representative sample of the local dairy sector. This diversity was essential to ensure that the collected data accurately reflected variations in knowledge and perception related to climate change in dairy farming across the regions.

3. Data collection:

The study involved 52 respondents, distributed across several municipalities of Guelma and Taraf. Data collection was carried out through direct face-to-face interviews made in darja, which allowed for clarification of certain questions when necessary and ensured the accuracy and reliability of responses. The questionnaire focused on assessing the knowledge and perception of milk producers regarding climate change, its impact on their herds and milk production, as well as the adaptation strategies they employ. The remaining 14 farmers in the provided list either declined to participate or submitted incomplete and inaccurate/ transparency lacking responses, which were excluded from the final analysis.

1. Descriptive study of farms

The results of the survey on the socio-economic, structural, and functional characteristics of the farmers surveyed are presented in Table 5. All the farm managers surveyed (100%) were men. The average age of the farmers was 54.76 years, and the average household size was 7 people. More than half the farm managers (65.4%) have primary to secondary education, while 13.5% are illiterate. The breeders surveyed are mostly experienced, and herds are generally acquired through inheritance. The average length of time in the breeding business is 28.55 ± 15.39 years. This average is largely influenced by the high proportion of farmers with over 20 years' experience, representing (67.27%) of all farms surveyed. In the surveyed region, where land is fragmented, livestock farming essentially takes the form of a family activity. Farmers' limited financial resources generally preclude intensive livestock production. The average utilized agricultural area (UAA) per farm is 9.75 ± 14.37 ha, of which 0.98 ± 1.93 ha is irrigated, i.e., (10.05%) of the total UAA. This low proportion of irrigated land can be explained by the fact that over (67.3%) of farmers surveyed do not irrigate their plots. This situation bears witness to the importance of extensive, which characterizes our samples, in fact, (37.04%) of farmers who use irrigation irrigate more than (20%) of their UAA. Analysis of the data in Table 1 reveals that (50%) of farms own no land at all. Farms of 0.21 to 5 ha account for (3.84%) of all farms, while those of 5.1 to 10 ha and over 10 ha represent (15.38%) and (30.78%) of all farms, respectively. Farmers use one or more ruminant species, depending on the possibilities offered by local food resources and practices. Results have revealed that (9.6%) of units farm all three species (cattle, sheep, and goats), (22.23%) of all farms only have cattle and sheep, while cattle are farmed alone on (71.2%) of farms. The average cattle herd size is 29.88 head. Table 1 show that (17.3%) of farms have a cattle herd of less than 10 head, while (51.9%) have relatively large herds of over 20 head. The dominant genotype is of exotic origin, mainly represented by the Holstein, Montbeliarde, and Fleckvieh breeds, with a proportion of (53.8%). This is followed by the crossbred genotype, which accounts for (26.9%), while (17.3%) of breeders have a local genotype resulting from crossbreeding between individuals of the local breed. The majority of farmers surveyed prefer to raise cattle, with little emphasis on small ruminants. In fact, only (19.2%) of farmers own sheep, with a very small flock averaging 3.23 ± 10.44 head. Goat farming is even less represented, accounting for only (9.6%) of farms surveyed, with an average of 3.50 ± 16.46 head. Cattle farming is tending to become a secondary activity, particularly as farmers diversify their sources of income. The latter are increasingly turning to crop production, in particular market gardening, industrial crops, and plasticulture. It is also worth highlighting the growing importance of off-farm pluriactivity, with livestock farmers turning to other sectors deemed more accessible, such as commerce and various activities considered more profitable and less restrictive. Thus, (38.5%) of livestock farmers declare that they carry out an activity outside the agricultural sector. The majority of farmers surveyed (76.9%) had benefited from agricultural training, the duration of which varied from one farmer to another. However, this training is still mainly focused on the technical aspects of livestock management and the mastery of certain farming techniques, while notions linked to climate change and adaptation strategies are totally absent. Grazing in natural meadows, on the edges of farms, in scrubland and forests, and moving around farms, is the main source of food for (11.5%) of farmers surveyed. On the other hand, grazing combined with supplementation with concentrates, hay, and by-products remains the most widespread feeding method, practiced by (71.2%) of breeders. Feeding exclusively on supplements is practiced by (17.3%) of farmers, mainly fatteners or breeders of exotic breeds. Milk is the main source of income for only a third of the farmers surveyed. In fact, (32.7%) of them do not market the milk they produce, which is generally destined for family consumption or calf feed. These farms are mainly local breed herds, where breeding is geared towards meat production or the sale of young, lean animals (bull calves or heifers) at an early age, which then represents the main source of income. Conversely, around two-thirds of farmers sell their milk production via collectors. Milk production varied considerably from one farmer to another, with a standard deviation (304.16 kg/day/head) above the average (205.99 kg/day/head). This heterogeneity can be explained by numerous factors, including herd management, genotype, and farm orientation. Thus, 46.2% of farmers produce less than 100 kg of milk per herd per day, while (30.8%) produce more than 200 kg per herd per day. In terms of animal welfare, the traditional nature of farming practices remains very pronounced in the farms surveyed, with a high proportion of farmers (73.1%) housing their animals in precarious conditions. Analysis of systematic density, calculated by dividing the total number of cattle (all categories taken together) by the surface area of the barns, reveals a high level of overcrowding, with an average of 11.37 ±14.32 cattle. M-2. Very few farmers have a ventilation system, with only (15.4%) of farms equipped.

Table 5 Characteristics of the surveyed farms (N =52)

Variable	Categories of the farmers	Scoring Method	% respondents	Range Min	Range Max	Mean	SD
General information (breeder)							
Age (AGE)	Young (18 - 35) Meddle aged (36 - 50) Old aged (>50)	Years	5,76 36,53 57,71	29	82	54,76	13
Education level (EL)	Illiterate (0) Primary (1 - 5) Secondary (6 - 12) Higher studies (>13)	Years of Schooling	13,5 19,2 46,2 21,2	0	14	8,40	8.32
Family size (FS)	Low (<5) Medium (5à 6) High (>6)	Number	28,8 19,2 51,9	4	14	7,26	2,47
Family income	Low Medium High	-	3,8 32,7 63,5	-	-	-	-
General information (farme)							
Topography (TOP)	Montain Piedmont Plain	Number	11,5 19,2 69,2	-	-	-	-
Total farm land used (TFL)	Landless & Marginal (Up to 0,2 ha) Small (0,21 - 5 ha) Medium (5,1 - 10 ha) Large (>10,1)	Hectare	50 3,84 15,38 30,78	0	70	9,75	14,37
Irrigated land (IL)	0 1-6 > 10	Hectare	67,3 30,76 1,92	0	10	0,98	1,93
Animal diversity							

Numbre of cattle (CT)	Low (0 to 10) Medium (10,1 - 20) High (>20)	Number	17,3 30,8 51,9	0	115	29,88	24,55
Genetic structure of bovine herd (GB)	E (exotic) L x E (local x exotic) E + E x L L x L	Number	26,9 53,8 1,9 17,3	-	-	-	-
Sheep presence (SP)	No Yes	Number	80,8 19,2	0	66	3,23	10,44
Goat presence (GP)	No Yes	Number	90,4 9,6	0	114	3,50	16,46
			Labor				
Farming experiences (FEX)	Low (0-10) Medium (10.1-20) High (>20)	Years	13,5 19,23 67,27	2	70	28,55	15,39
Pluriactivity (PLU)	No Yes	Number	61,5 38,5	-	-	-	-
Training received (TR)	No Yes	Number	23,1 76,9	-	-	-	-
			Production System & Feeding				
Feeding method (FM)	Pasture Pasture + supplement Supplement	Number	11,5 71,2 17,3	-	-	-	-
			Valorization of farm products				
Sale of milk (SM)	No Yes	Number	32,7 67,3	-	-	-	-
Liters of milk /day	< 100 100-200 > 200	Liters	46,2 23 30.8	5,15	1802,5	205,99	304,16
			Animal wellbeing				
Cattle stable (CS)	Hard stable Traditional stable	Number	26,9 73,1	-	-	-	-

Stable size (SS)	< 100	m^2	28,9	36	980	220,11	206,11
	100-200		38,46				
	> 200		32,64				
Seize stable of cattle (SSC)	0 – 5	$cattle.m^{-2}$	32,7	0,59	80	11,37	14,32
	5,1 – 10		30,8				
	> 10		36,5				
Ventilation system (VS)	No	Number	84,6	-	-	-	-
	Yes		15,4				

SD : standar deviation

2. Breeders' perception of climate change

As part of this study, farmers interviewed were asked a dichotomous question ("yes" or "no") to determine whether they had perceived climate change in their region over the past decade. Following this first question, they were asked to specify their perception of various climatic events generally associated with the effects of climate change in the study area. For each event, respondents were asked to indicate whether they had observed a decrease, an increase, no change, or no opinion at all. Figure 1 illustrates the responses to the initial question. It can be seen that (76.9%) of farmers claim to have observed changes in climate over the last decade in line with the results found (Uddin et al., 2017) .

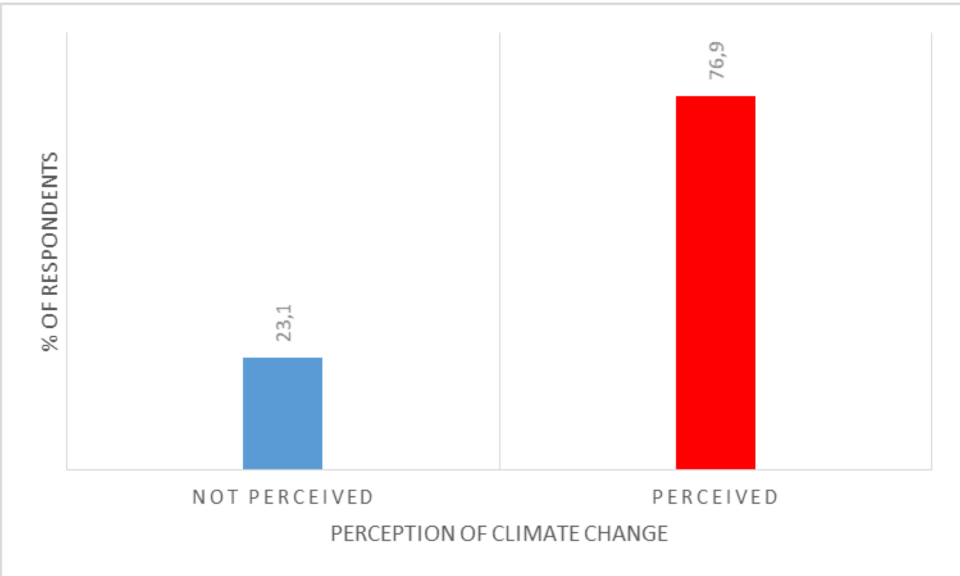

Figure 1. Proportion of respondents by self-reported experience of climatic change.

2.1. Factors influencing farmers' perception of climate

A bivariate analysis was carried out between the perception of climate change and various intrinsic factors linked to the breeders. These factors include several socio-demographic and economic characteristics of the farmers, their environment and certain functional and structural characteristics of the farms. The results of this analysis are presented in Table 6, with the aim of assessing the individual effect of these variables on the perception of climate change. Of the 12 variables considered in this analysis, 10 are categorical and 2 are continuous. Of all these variables, only 4 had a significant effect on farmers' perceptions, as shown in Figures 2 and 3. The perception of climate change is predominantly positive in lowland farms, with a rate of 89%, compared with 50% in mountain and piedmont regions. This difference is mainly due to the genetic type of animals raised: lowland farms prefer large, exotic breeds. This finding is also confirmed for the "bovine.breeds" variable (p = 0.009), where a positive perception reaches 100% for the exotic genotype, compared with only 44% for the local genotype.

Pluriactivity in agriculture had an almost significant influence on farmers' perceptions of climate change (p = 0.081). Farmers practicing exclusively agriculture are the most affected by the effects of climate change, with a positive perception of 84%, compared to 60% among those practicing extra-agricultural activities.

Table 6 Influence of farmers' characteristics, environment and breeding practices on their perception of climate change

Caractéristique	**Perception**		**Overall N = 52**[1]	**p-valeur**[2]
	Yes N = 40[1]	**No N = 12**[1]		
Topography				**0,006**
Mountain	3 (50%)	3 (50%)	6 (100%)	
Piedmont	5 (50%)	5 (50%)	10 (100%)	
Plain	32 (89%)	4 (11%)	36 (100%)	
Age				0,5
Meddle aged	15 (83%)	3 (17%)	18 (100%)	
Old aged	21 (70%)	9 (30%)	30 (100%)	
Young	4 (100%)	0 (0%)	4 (100%)	
Pluriactivity				**0,081**

Plu_no	31 (84%)	6 (16%)	37 (100%)	
Plu_yes	9 (60%)	6 (40%)	15 (100%)	
Training.received				**0,020**
T_no	6 (50%)	6 (50%)	12 (100%)	
T_yes	34 (85%)	6 (15%)	40 (100%)	
Education				0,2
Higher studies	10 (91%)	1 (9,1%)	11 (100%)	
Illiterate	4 (57%)	3 (43%)	7 (100%)	
Primary	6 (60%)	4 (40%)	10 (100%)	
Secondary	20 (83%)	4 (17%)	24 (100%)	
Family.size				0,3
High	20 (71%)	8 (29%)	28 (100%)	
Low	13 (93%)	1 (7,1%)	14 (100%)	
Medium	7 (70%)	3 (30%)	10 (100%)	
Bovine.breeds				**0,010**
E	14 (100%)	0 (0%)	14 (100%)	
E X L	21 (75%)	7 (25%)	28 (100%)	
E+E X L	1 (100%)	0 (0%)	1 (100%)	
L X L	4 (44%)	5 (56%)	9 (100%)	
Cattle.stable				>0,9
Hard stable	11 (79%)	3 (21%)	14 (100%)	
Traditional stable	29 (76%)	9 (24%)	38 (100%)	
Family.income				0,8
High	12 (71%)	5 (29%)	17 (100%)	
Low	2 (100%)	0 (0%)	2 (100%)	
Medium	26 (79%)	7 (21%)	33 (100%)	
Cattle	18 (14 – 34)	40 (24 – 71)	23 (15 – 39)	**0,015**
Milk	108 (39 – 267)	111 (83 – 270)	108 (40 – 267)	0,9
[1] n (%); Median (Q1 – Q3)				
[2] fisher's exact test; test of Wilcoxon-Mann-Whitney				

Farmers who had received specific training or assistance in agriculture or livestock breeding were significantly more attentive to climate change ($p = 0.020$), with (85%) expressing a positive perception, compared with just (6%) among those who had received no training.

Although farmers' level of education did not show a significant effect on their perception of climate change ($p = 0.186$), a trend did emerge: (91%) of farmers with a high level of education had a positive perception, compared with only (57%) of illiterate farmers. This finding is in line with the results observed among breeders from small, generally better-educated households, (93%) of whom expressed a positive perception of climate change, compared with (71%) of breeders from large households.

According to Figure 3, the modalities of the variables explaining the level of perception with a (100%) positive perception rate are: the genetic type of animals farmed, notably exotic breeds (E) as well as exotic and crossbred breeds (E + E x L), as well as breeders belonging to small households.

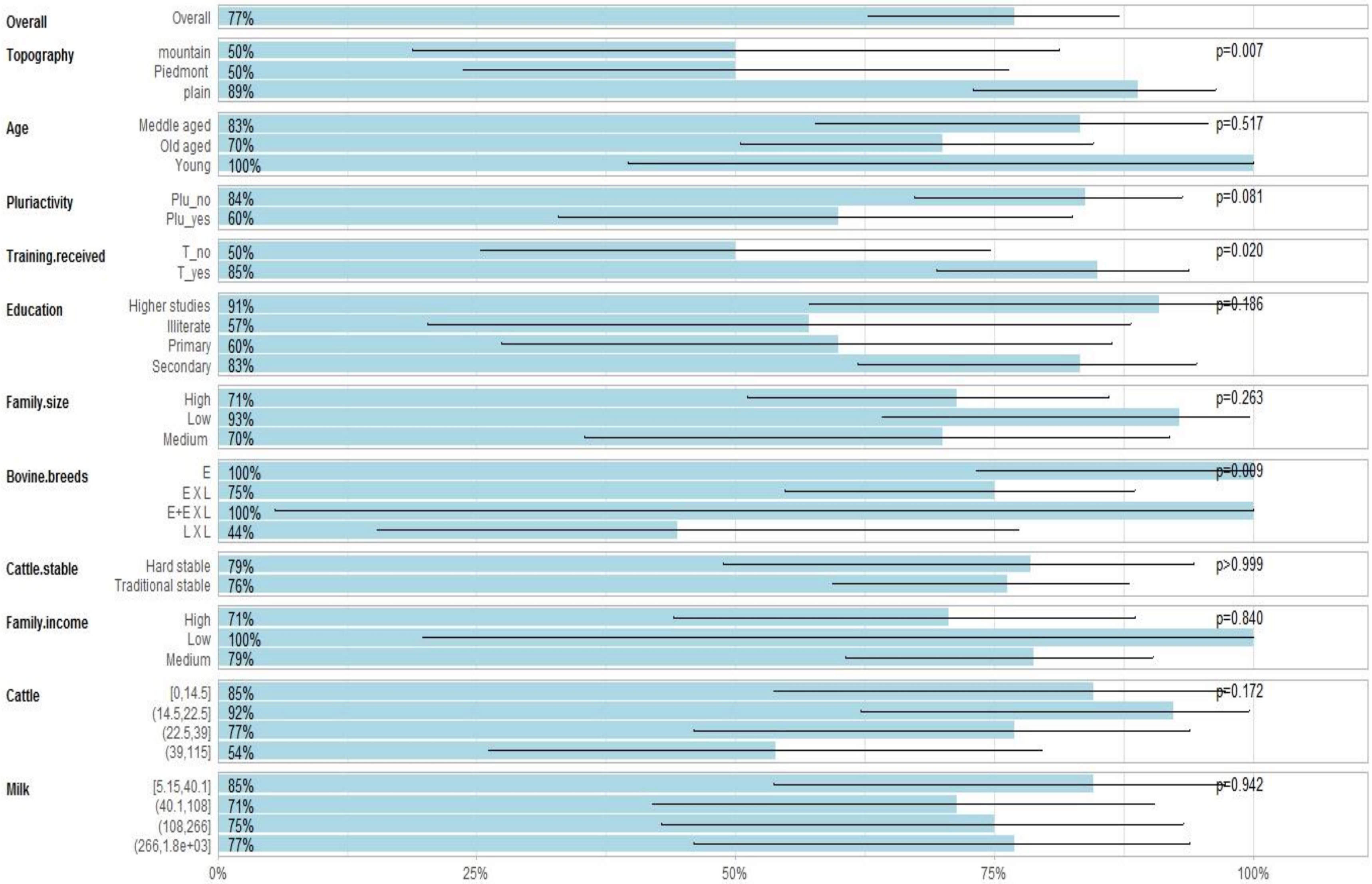

Figure 2. Impact of different modalities on farmers' perception of climate

Figure 3. Variation in farmers' perceptions according to modalities of the selected variables

2.2. Farmers' perception of climate change over the past decade

After their initial response, the farmers were asked about their perceived experience in relation to a series of climatic events commonly associated with climate change effects in their area. This part of the questionnaire had closed questions where they could respond selecting the following; experienced decreases, increases, no change, or they did not know, in the occurrence of the event, (table 7) present their responses regarding climatic events. Results of (table 7) show a noticeable awareness among farmers regarding the climatic changes and phenomena that have occurred in their environment in recent years. All farmers (100%) reported a noticeable increase in temperature, which aligns with global reports on climate change and global warming leading to a clear observation of drought increase reaching (100%) of farmers who stated that drought periods have become more severe and considered it as an alarming sign of climate change's impact on water resources and agriculture. However, farmers experience with floods has varied as the following: (17.3%) reported an increase in floods, (55.8%) perceived no change, while (26.9%) observed a decrease. This variation suggests that the impact of floods might be localized and depends on the specific location of the farm. As for wind intensity, (26.9%) of farmers noticed an increase, while (71.2%) reported no change, and only (1.9%) indicated violent winds. This indicates that wind is not perceived as a major threat by most farmers. As for rainfall, all respondents (100%) noted a decrease in precipitation, with no one reporting stability or increase, reflecting a direct impact on rain-fed farming systems. These results are consistent with those reported by (Uddin et al., 2017), the same percentage (100%) also observed a longer summer season and a shorter winter. In terms of rainfall regularity, (48.1%) of respondents stated that rainfall has become more unpredictable, while (51.9%) reported no change, showing a divided experience likely influenced by geographic variability and years of experience. Regarding the rainy season, (75%) of farmers said it starts later than usual, while (25%) noted a decrease in rainfall during this period. Similar results were found by (Dhaka et al., 2010).

Table 7 Perception of change in climatic factors over the past decade

Climatic event	% of Respondents			
	Increased	No change	Decreased	Late
Temperature	100	0	0	0
Rainfall	0	0	100	0
Drought	100	0	0	0
Flood	17,3	55,8	26,9	0
Wind	26,9	73,1	0	0
Short winter season	100	0	0	0
Long summer season	100	0	0	0
Unpredictable rainfall	48,1	51,9	0	0
Rainy season	0	0	25,0	75,0

2.3. Farmer's awareness of climate change effect on their livestock

Most farmers according to (table 8) have shown awareness about climate change effect on animals. (88,7%) of respondents answers have aligned on that the major impact of climate change on livestock harms animal health, which leads to more frequent disease appearance, and (81,1%) have experienced a decrease in food intake, therefore causing a decrease in milk production, whom (75,0%) had experienced, and which is more by (4,2%) than those who were able to notice the deterioration in animal welfare, which can help them with an earlier intervention and avoid the worst of its impact and production losses (Amamou et al., 2018) .

Table 8 Farmers awareness of climate change effect on their livestock.

Effects on animals	% of Respondents		
	Yes	No	I don't know
Decrease in milk production and composition	75,0	19,2	5,8
Deterioration in animal health: disease occurrence	88,7	9,4	0
Deterioration in animal welfare	79,2	15,1	3,8
Reduction in ingestion (food intake)	81,1	17,0	0

3. Farmers' adaptation strategies

(Figure 4) and (Table 9) zeros on the adaptation strategies adopted by dairy farmers to cope with the effects of heat stress on their herd. The data were collected through a field survey and aim to assess the extent to which various practices aimed at improving animal comfort and maintaining productivity under changing climatic conditions have been implemented. This analysis provides insights into the prevailing trends among farmers and helps identify areas where awareness or technical support is needed.

Table 9 Options for measures that minimize the effects of heat stress in dairy herds

Options	**N**	**%**
a) Increased supply of drinking water	19	36,5
b) Greater provision of shade (natural and/or artificial) for the cows	22	42,3
c) Access of animals to lakes or ponds to cool down or provision of baths	14	26,9
d) Changes in the nutritional management of the animals (time and type of food provided)	11	21,2
e) Preference for raising crossbred animals, more adapted to the heat	9	17,3
f) Cooling of installations using fans, nebulizers or sprinklers	3	5,8
g) Greater ceiling height to favor natural ventilation, adequate position of buildings	2	3,8
h) Other (describe)	8	15,4
None	9	17,3

The analysis of adaptation strategies adopted by dairy farmers in response to heat stress reveals a clear preference for practical, low-cost measures. The most commonly reported strategy was the provision of shade**,** whether natural or artificial, adopted by (42.3%) of respondents. This was followed closely by increasing the supply of drinking water (36.5%), a crucial measure to prevent dehydration and maintain thermoregulation in livestock. Access to lakes or ponds, or the use of baths for cooling**,** was implemented by (26.9%) of farmers, highlighting the importance of direct cooling methods in hot climates. Nutritional adjustments, such as changing the type or timing (changing grazing times) of feed, were employed by (21.2%) of the respondents, reflecting recognition of how feeding strategies can mitigate heat-related metabolic stress. Meanwhile, the use of heat-tolerant or crossbred breeds was adopted by (17.3%), indicating a moderate shift toward genetic adaptation. Technologically advanced solutions, such as fans, sprinklers, or nebulizers, were the least used (5.8%), likely due to higher costs or limited infrastructure. Similarly, only (3.8%) reported design modifications like increased ceiling height and optimized building orientation to improve ventilation. However, interestingly, (15.4%) of respondents selected “Other”, suggested the use of locally adapted/ traditional practices like for example “blossom water”. Finally, (17.3%) of farmers reported resistant to adaptation strategies, which indicate a lack of awareness, resources, or perceived need for change. This distribution underscores the need for tailored extension services and awareness programs to promote both low-cost and sustainable adaptation measures among small-scale dairy farmers.

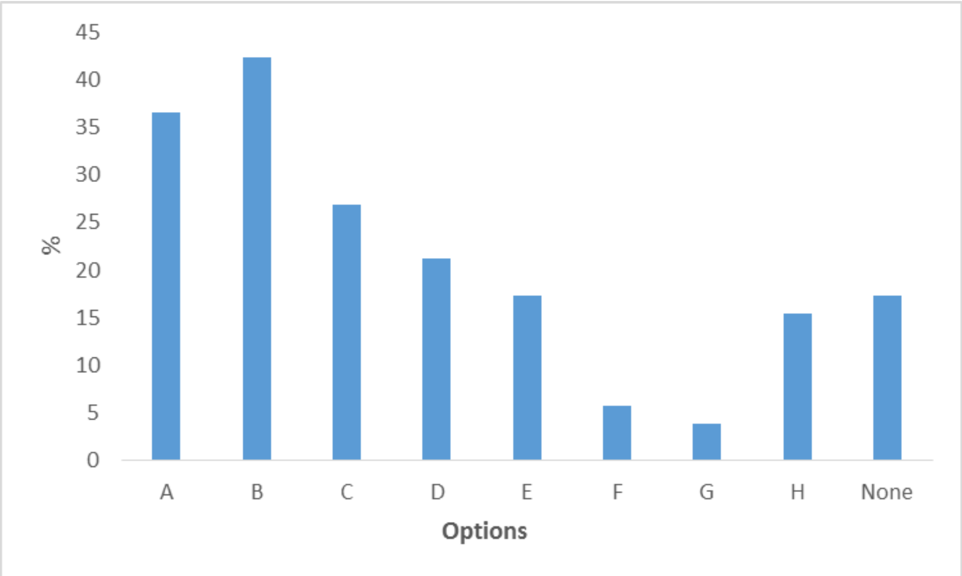

Figure 4: Distribution of the various adaptation strategies implemented by dairy farmers in the face of climate change

Conclusion

The findings from this study revealed that the majority (76, 9%) of the farmers in the research areas perceived changes in climatic conditions, whereas only (23, 1) % did not acknowledge it. The majority of farmers reported increases in temperature, droughts, and summer, winter period, and a decrease in rainfall, as well as declaration of “no change” relating to flood, wind, and unpredictable rainfall with late rainy season. Increasing temperature along with decreasing precipitation may enhance the water scarcity from resulting droughts which will negatively affect milk production of those who are strongly relying on natural water sources. The logit model explained that out of the eleven factors surveyed; Topography (P= 0,006), pluriactivity (P= 0,081), training received (P= 0,020), bovine breeds (P= 0,010), and cattle’s number (P= 0,015) were found to be significantly related to the farmers’ perception of climate change. Governmental respective authorities, organizations, should create policy measures that consider these influential factors of farmers’ perception of climate change. This, in turn, may have a significant contribution to farmers reducing the risks that they face against climate change effects. The policy measures may be focused on capacity building of the farmers, availability of technological materials, aimed trainings on climate change and heat stress mitigation, and forming more collective activities, groups under the supervision of specialists, that gathers farmers together where they can form a rich perception and chare their experience.

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