Influence of topographical variation on the physiological performance of Indonesian local sheep under changing climate conditions

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Abstract. Climate change has a significant impact on livestock by altering their physiological responses and overall production performance. Rising temperatures, increased humidity, and unpredictable weather patterns create thermal stress, which affects animals' metabolism, feed intake, and reproductive efficiency. This study aimed to analyze the differences in physiological responses of sheep raised at different altitudes. The research was conducted in Karanganyar Regency, Central Java, July-December 2025. The study was carried out in two altitude regions: highland areas (Tawangmangu and Jatiyoso Districts) and lowland areas (Jaten and Kebakkramat Districts). Samples were selected using purposive sampling, with a total of 400 local sheep. Data were analyzed using an independent t-test. The results showed that in male sheep, significant differences were found only in heart rate ($P<0.05$), while body temperature, respiratory rate, and Body Condition Score (BCS) did not differ significantly. In female sheep, significant differences were observed in heart rate, respiratory rate, and body temperature ($P<0.05$), whereas BCS showed no significant difference between altitudes. Female sheep exhibited more sensitive physiological responses to environmental changes compared to males. Overall, local sheep in Karanganyar Regency demonstrated good physiological adaptability to varying environmental conditions across different altitudinal regions in the tropical area.

1 Introduction

Sheep are one of the small ruminants that play an important role in providing a source of animal protein for society. Based on data from the Central Statistics Agency (BPS) for 2025 [1], national lamb meat production in 2024 will reach 34,585.66 tons. Sheep are able to adapt well to various environmental conditions, both in highland and lowland areas. However, environmental factors in the rearing area have a major influence on the physiological responses of sheep, such as body temperature, respiratory frequency and heart rate. This

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physiological response is an important indicator in assessing the metabolic status and health of livestock.

The livestock sector around the world is currently facing climate change. The rise in global temperatures requires farmers to find solutions to various challenges in animal production. These challenges include identifying livestock that can adapt to heat stress, finding high-quality yet heat-tolerant feed, and determining suitable farm locations where animals can grow and develop optimally to maintain high productivity. According to Maulana et al. [2], physiological parameters such as body temperature, respiration frequency and heart rate can reflect the ability of livestock to adapt to the rearing environment and determine the welfare and performance of sheep. Apart from that, Body Condition Score (BCS) is also used as an indicator of body energy balance and physiological condition of livestock. Sheep with a BCS value between 2-3 are in good body condition and physiological status. This condition reflects the balance between nutritional intake and metabolic needs, which is an important indicator for livestock health and performance. Thus, the ideal BCS can describe the physiological ability of sheep to maintain their body condition under the influence of the rearing environment [3].

Physiological responses are an important indicator in assessing an animal's adaptability to its environment. Physiological parameters such as body temperature, respiratory frequency, and heartbeat frequency are some of the variables that are often used to measure the level of stress or homeostatic balance in animals. The physiological adaptation of livestock animals to environmental conditions is the result of complex interactions between the nervous, endocrine and metabolic systems of the body which attempt to maintain homeostatic balance. Differences in altitude, such as between highlands and lowlands, can influence physiological parameters in sheep due to changes in temperature, air pressure and humidity which affect the body's thermoregulatory mechanisms [4]. Livestock that live in the lowlands usually experience an increase in body temperature and a higher heart rate, possibly due to the air temperature which tends to be hotter than the highlands.

Karanganyar Regency has a variety of topography that includes lowlands to mountains with a height of more than 1,000 meters above sea level. This condition allows for variations in microclimate that affect the physiology of sheep. Karanganyar is also one of the sheep farming development areas in Central Java with a population of 22,940 head [1]. There has been no previous research examining the most suitable location for raising thin-tailed sheep, or Indonesian local sheep, whether in lowland or highland areas. Through this study, it is expected that a solution can be provided to help farmers determine the appropriate location for sheep farming in accordance with climate change while maintaining optimal animal productivity. Therefore, this research was conducted to analyze differences in the physiological responses of sheep at different altitudes in Karanganyar Regency, with the hope of providing scientific contributions and practical recommendations for the development of sheep farming in this area. This study aims to analyze differences in the physiological responses of sheep including body temperature, respiratory frequency, heart rate, and Body Condition Score (BCS) kept at different altitudes in Karanganyar Regency.

2 Materials and Methods

The research was conducted from July to November 2025. Located in Karanganyar Regency, Central Java. This research uses a survey method with an exploratory approach to obtain primary data regarding the physiological response of local sheep in areas with different altitudes. Research activities were carried out in two stages, namely pre-survey and survey. The pre-survey stage was carried out by visiting the Karanganyar Regency Agriculture, Food and Fisheries Service, animal husbandry and animal health sector, to obtain information about the local sheep population and research location permits. Apart from that, a

questionnaire was prepared as a supporting instrument in collecting primary data through interviews with breeders.

The survey stage was carried out by taking direct measurements of the sheep's physiological parameters, including body temperature, respiration frequency, heart rate and Body Condition Score (BCS). Measurements were carried out in two areas with differences in altitude, namely the highlands (Tawangmangu and Jatiyoso Districts) and the lowlands (Jaten and Kebakkramat Districts). Supporting data such as livestock age, gender, and rearing system were obtained through direct interviews with farmers.

2.1 Sample determination technique

Determining the location of research samples was taken using purpose sampling through direct measurements of sheep's physiological parameters including rectal temperature, respiration frequency, heart rate, and BCS at locations with different altitudes in Karanganyar Regency, Central Java. The sample is part of the number of characteristics possessed by the population. The criteria for determining the location used in this research are highlands and lowlands. Altitude data for various sub-districts and sheep populations in Karanganyar Regency are presented in Table 1.

Table 1. Sheep population in Karanganyar Regency

No	Distric	Altitude (masl)	Sheep population (Head)
1.	Tawangmangu*	1200	139
2.	Jatiyoso*	950	1735
3.	Ngargoyoso	880	195
4.	Jatipuro	770	233
5.	Jenawi	750	8021
6.	Karangpandan	500	734
7.	Jumapolo	470	767
8.	Matesih	450	71
9.	Jumantono	450	3359
10..	Kerjo	450	2497
11.	Mojogedang	403	3488
12,	Karanganyar	320	211
13.	Gondangrejo	150	706
14.	Tasikmadu	140	223
15.	Colomadu	140	179
16.	Jaten**	98	273
17.	Kebakkramat**	95	109
	Total		**22940**

Source: Central Statistics Agency BPS (2018, 2023, 2024).
Description:
* : Plateau in Karanganyar Regency
** : Lowlands in Karanganyar Regency

The results of determining the location using the purpose sampling method showed that the sub-districts included in the highland area were Tawangmangu District (2,000 masl), Jatiyoso District (1,500 masl), as well as lowland areas, namely, Jaten District (90 masl) and Kebakkramat District (80 masl).

The total population of sheep in Karanganyar Regency is 22,940 heads. The percentage of allowance used is 5%, the results obtained can be rounded to obtain suitability. The results

of the slovin formula calculation for livestock samples that must be taken from 4 sub-districts were 400 heads of sheep.

2.2 Data Collection Techniques

The data collection techniques used in this research were observation, recording and documentation. Observations were carried out by directly measuring physiological variables and direct BCS observation. Observation has specific characteristics when compared with other techniques, namely interviews and questionnaires. This technique requires communication with people, so it is not limited only to people, but also to other objects. The variables observed in this research include:

2.1.1 Measurement of heartbeat frequency

The sheep's heartbeat frequency was measured using the auscultation method with the help of a stethoscope placed on the sheep's left chest for 15 seconds. This measurement was carried out three times, then the value obtained was calculated and converted to minutes [5].

2.1.2 Measurement of body temperature

Sheep's body temperature is measured through the rectum by inserting the tip of a digital thermometer into it. Before use, the thermometer is cleaned using cotton wool soaked in 70% alcohol to maintain sterilization. After the tool is inserted, measurements are taken until the numbers on the digital thermometer show stable results. This procedure was repeated three times, then the results were averaged to obtain a more accurate temperature value. This method is in line with that applied in research by Sari et al. [6].

2.1.3 Measurement of respiratory frequency

The sheep's respiratory frequency was measured by observing the rising and falling movements of the abdomen for 15 seconds. This observation was carried out three times to ensure the accuracy of the data, then the average of the results obtained was calculated [5].

2.1.4 Body Condition Score (BCS)

The Body Condition Score (BCS) assessment is carried out by feeling several parts of the sheep's body, such as the back area (loin), base of the tail (tail head), hip bones (pins and hooks), ribs (ribs), and lower chest (brisket). The BCS score is determined based on the level of fat thickness felt in these parts, so that it can describe the overall body condition and nutritional status of the animal [3].

2.3 Data Analysis

The data obtained from this research was then processed using Microsoft Excel. Data from the highlands and lowlands were then tested using the t-test. This test will show whether there are significant differences between the two groups [7].

3 Results and Discussions

3.1 Physiological status in male sheep

The physiological response of rams reared at two different heights showed variations in several physiological parameters such as body temperature, respiration frequency, heart rate, and BCS. This difference reflects the adaptability of sheep to changes in environmental conditions, especially temperature and humidity in each region. The average value of each physiological parameter of rams at different heights is presented in Table 2.

Table 2. Physiological responses of male sheep reared at different altitudes

No	Variable	High land	Low land	P-Value
1.	Pulsus (times/minute)	65.1±5.8	68.6±9.9	0.017
2.	Respiration (times/minute)	58.4±9.1	57.6±12.0	0.801
3.	Rectal temperature (°C)	39.2±0.4	39.2±0.3	0.509
4.	BCS	2.6±0.5	2.7±0.5	0.395

The results showed significant differences in heart rate ($P<0.05$) between rams in the highlands and lowlands. The average heart rate in the lowlands (68.6 times/minute) was higher than in the highlands (65.1 times/minute). This value is still within the normal range of 60–90 times/minute, but the increase at low altitudes indicates a physiological response to higher environmental temperatures. Increasing temperature can stimulate the work of the cardiovascular system to maintain the body's thermal balance [8].

The parameters of respiration frequency, body temperature, and Body Condition Score (BCS) did not show significant differences between altitudes ($P>0.05$). The average respiration frequency of sheep in the highlands is 58.4 times/minute, relatively the same as in the lowlands, 57.6 times/minute. This value is still within the normal range reported by Hamdani et al. (2018), namely 32–60 times/minute in local sheep in tropical environments. The absence of significant differences indicates that local sheep have good respiratory adaptability to variations in environmental temperature and humidity.

The average body temperature of sheep in the highlands of 39.2°C and the lowlands of 39.2°C was also not significantly different. This temperature range is normal for local sheep, namely between 38–39.5°C. Stable body temperature in local sheep reflects an efficient homeostatic ability to adapt to environmental changes [3].

The BCS value of sheep in both regions (2.6–2.7) indicates fairly good and stable body condition, indicating a balanced nutritional status. A BCS value between 2.5–3.0 describes the physiological condition of livestock in sufficient energy status, both for growth and body maintenance. This value can be increased further to achieve optimality, in accordance with the opinion of Tunggadewi et al. [9] which states the optimal BCS for local sheep is 3.

3.2 Physiological status in Female Sheep

The physiological response of female sheep reared in areas with different altitudes shows variations in environmental conditions. Altitude factors influence air temperature, humidity and oxygen pressure, which can have an impact on the physiological mechanisms of livestock, especially in the process of thermoregulation. To determine the influence of environmental differences, observations were made on the parameters of body temperature, respiration frequency, heart rate and BCS in female sheep in the highland and lowland areas as presented in Table 3.

Table 3. Physiological responses of female sheep reared at different altitudes

No	Variable	High land	Low land	P-Value
1.	Pulsus (times/minute)	67.1±5.1	64.1±5.9	0.005
2.	Respiration (times/minute)	60.2±5.5	58.2±10.1	0.022
3.	Rectal temperature (℃)	38.8±0.3	39.2±0.4	0.004
4.	Body	2.2±0.3	2.3±0.4	0.060

The results showed that there were significant differences in several physiological parameters of ewe sheep between the highlands and the lowlands. Parameters that were significantly different included heart rate, respiration frequency, and body temperature, while the Body Condition Score (BCS) showed no significant differences.

The average heart rate of ewe sheep in the highlands was 67.1 times/minute, slightly higher than that of sheep in the lowlands, namely 64.1 times/minute. This condition shows that sheep raised in lower temperature environments require greater heart work to maintain stable body temperature and blood circulation. This is in line with the opinion of [10] which states that changes in environmental temperature can affect heart rate frequency as a physiological adaptation mechanism to maintain body temperature balance.

Respiration frequency parameters also showed significant differences ($P>0.05$). Ewes reared in the highlands had a higher respiratory rate (60.2 times/minute) compared to sheep in the lowlands (58.2 times/minute). This is likely caused by lower oxygen levels at high altitudes, so the livestock's body increases the frequency of respiration to maintain tissue oxygen supply. Field studies in Indonesia report that differences in altitude and environmental conditions can influence the respiration rate of livestock, where decreasing air pressure and changes in microclimate in the highlands cause an increase in respiratory frequency as a form of adaptive response [4].

Meanwhile, the body temperature of ewes in the highlands (38.8°C) was lower than that of sheep in the lowlands (39.2°C), and this difference was significant ($P<0.01$). Higher body temperatures in the lowlands are thought to be influenced by hot environmental temperatures, which increases the risk of heat stress in livestock. According to Krishnan et al. [10], an increase in environmental temperature can cause an increase in the body temperature of livestock due to reduced effectiveness of heat dissipation mechanisms such as evaporation and conduction, so that livestock increase their physiological activity to maintain the body's thermal balance.

The BCS of sheep in both locations was relatively similar, respectively 2.2 in the highlands and 2.3 in the lowlands ($P>0.05$), indicating that the nutritional status and feed management in the two regions were quite balanced. BCS is an indicator of body energy reserves that reflects the balance between feed intake and metabolic needs of livestock. A BCS value of around 2–3 indicates a body condition that is good enough for maintenance, while fattening programs generally target increasing BCS to 3.0–4.0 to achieve optimal body condition [3,9]. Differences in physiological responses between male and female sheep reared at different heights can be caused by differences in physiological, hormonal and body metabolism characteristics between the sexes.

Rams tend to have a more stable heart rate and body temperature, while ewes show a more sensitive physiological response to environmental changes, especially in the parameters of body temperature, respiration and heart rate. This is in line with the opinion of Rama [11] who states that changes in levels of reproductive hormones such as estrogen and progesterone during the estrus cycle can affect the physiological activities of female livestock. These hormonal fluctuations play a role in increasing body temperature, blood flow and respiratory frequency due to increased metabolic activity. This condition shows that the endocrine system in females is more dynamic than in males, so that their physiological responses to environmental changes also tend to be more varied.

Apart from hormonal factors, body composition and metabolic activity also play an important role. Male sheep with greater muscle mass have more efficient thermoregulatory abilities than females. Differences in morphology and body composition between sexes influence physiological adaptation to environmental temperature, where females with higher fat reserves tend to be more sensitive to heat. Other influencing factors are physiological activity and environmental stress levels. Females are generally more sensitive to changes in temperature and humidity, especially during the heat or early pregnancy phase. An increase in environmental temperature can trigger physiological stress which is characterized by an increase in cortisol levels, respiration frequency and heart rate as a form of adaptive response to heat [2]. This condition shows that female sheep are more sensitive to heat stress than males, so they require more optimal environmental management to maintain physiological stability.

4 Conclusion

Altitude influences several physiological parameters of local sheep. In rams, heart rate at higher altitudes was higher, whereas in ewes, significant differences were found in heart rate, respiration and body temperature. Ewes show more sensitive physiological responses to environmental changes than males. In general, local sheep have good adaptability to high and lowland conditions in tropical regions. Indonesian local sheep, or thin-tailed sheep, especially males, are able to adapt well when raised in hot lowland areas. This indicates that local livestock have the potential to cope with climate change. However, further research is needed to determine the productivity of sheep under various environmental conditions, mainly climate change.

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