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# Silvopastoral System Mitigates the Thermal Stress and Benefits Water Buffaloes' Comfort in the Eastern Amazon, Brazil

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**Abstract**

Twenty female Murrah buffaloes between four and five years old were randomly distributed into two groups (traditional system - TS and silvopastoral system - SPS) with 10 animals each and an average weight of 477.78 kg and 456.10 kg, respectively, for the TS and the SPS. The TS had a management regime with no canopy cover and no shade coverage over the drinking and feeding troughs. In the SPS, Racosperma mangium (Fabaceae) trees were used to provide shade, with an estimated 10% shading. The physiological variables studied were rectal temperature and respiratory frequency measured every three days from 6 to 7 AM and from 12 to 1 PM. The following environmental indices were calculated: Temperature Humidity Index (THI), Black Globe Humidity Comfort Index (BGHI), and Benezra's Index of Adaptability (BIA). The THI values were high in both management systems, between 76.27 and 86.73, higher than the limit of comfort level for buffaloes, which is 75. The maximum values of BGHI for the afternoon were 92.0 and 87.62, for TS and SPS, respectively, and the maximum values of BIA for the afternoon were 4.4 and 3.8, for TS and SPS respectively, which were higher than the critical level of adaptability and represented an uncomfortable condition that causes a reduction in animal performance. It was concluded that the silvopastoral management system is more efficient in terms of animal comfort for the female buffaloes as a result of the shade that provides a more amenable microclimate.

**Keywords:** Amazon, bioclimatology, buffaloes, thermoregulation, welfare

## 1. Introduction

The Thermal Comfort Zone (TCZ) is an environmental temperature zone where domestic animals exhibit higher productivity, lower energy expenditure, minimal effort of thermoregulatory mechanisms, better feed conversion, fast body development, and low mortality rates.

Buffaloes reared in Amazon produce beef and milk, and provide labor for farmers (ALMEIDA et al. 2019). Although buffalos reached satisfactory performance indices due to their capacity for adaptation to different environments (DAMÉ et al., 2013), under thermal stress, buffaloes change their physiological and behavioral reactions (GARCIA, 2013), because of their inability to cope with heat due to strong melanin concentration in the skin and hair, low number of sweat glands, and extremely thick epidermis, which reduce skin evaporation capacity ( GUDEV et al., 2007)

Thus, environmental variables have a direct influence over the animals' regulating mechanism, possibly affecting growth, reproduction, and disease resistance (ALMEIDA et al., 2011; AHIRWA et al., 2018). In the Amazon region, silvopastoral systems are a viable alternative for ruminant farming. The tree canopy interferes with the passage of solar radiation and allows the temperature to drop between 2 and 3 °C when compared with that under full sunlight. That reduction in temperature contributes to reduced heat increment in animals and provides them thermal comfort (FAÇANHA et al., 2013; LOPES et al., 2016). Therefore, this research aimed to evaluate the thermal comfort of female buffaloes of the Murrah breed under traditional and silvopastoral systems in the eastern Amazon, Brazil.

## 2. Material and Methods

The experiment was conducted at the Senador Álvaro Adolpho Animal Research Unit (01°26'03"S and 48°26'03"W), property of the Brazilian Agricultural Research Corporation –Embrapa Amazônia Oriental, Belém, State of Pará, Brazil, from January to December 2009.

The Köppen-Geiger climate classification is Afi (KOTTEK et al., 2006), and the region has a mean annual rainfall of 2,876.9 mm with a heavy rainfall period from January to June and a lighter rainfall period from July to December. The mean annual temperature is 26.8 °C, with average relative humidity around 83% (PACHÊCO et al., 2009). The soil is of clay texture and is classified as stony phase I (USDA SOIL SURVEY, 1951).

An area of 10.94 ha was divided into six paddocks, three for the traditional system (TS) and three for the silvopastoral system (SPS), both under *Brachiaria humidicola* intensive rotational management, with 0.8 animals (A.U) $ha^{-1}$ and 1.2 A.U. $h^{-1}$, respectively, at the beginning and at the end of the experimental period. Over a 45-day grazing cycle the occupation period was 15 days and the rest period was 30 days.

The traditional system (TS) had a management regime with no canopy cover, and the drinking and feeding troughs were not covered and thus did not provide shade. In the silvopastoral system (SPS), *Racosperma mangium* (Fabaceae) trees were used to provide shade, with an estimated 10% shading. The trees were planted at four-meter intervals, following the internal and perimeter electrified fences which were made of two smooth steel wires (MOURA CARVALHO et al., 2001).

Twenty female, cyclical, non-pregnant, dry, clinically healthy female Murrah buffaloes between four and five years old were randomly distributed into two groups with 10 animals each, with an average weight of 477.78 kg and 456.10 kg, respectively, for the TS and the SPS, feeding exclusively on pasture, with water and salt *ad libitum*. Both groups underwent an adaptation period of 14 days and were maintained under intensive rotational management, with a 1.78 UA.ha-1 stocking rate. In order to determine the bioclimatic indices, meteorological data were measured using an Instrutherm heat stress meter model TGD-300.

The equipment was installed in both the TS and SPS experimental treatments to evaluate differences between the two microclimates. Air temperature (maximum, mean, and minimum), relative humidity, dew point temperature, and black globe temperature were recorded on a data logger every other minute. The readings of environmental variables were performed from 6 to 7 AM and from 12 to 1 PM, simultaneously for both groups, and physiological evaluations were conducted.

The physiological variables studied were rectal temperature (RT) and respiratory frequency (RF) measured every three days from 6 to 7 and from 12 to 1 PM. In order to obtain the RT in degrees Celsius, a clinical veterinary thermometer was used with a scale up to 44 °C. The RF was taken by inspection and counting of thoracic-abdominal movements over 1 minute.

From the environmental variable data, the following environmental indices were calculated: Temperature Humidity Index (THI), Black Globe Humidity Comfort Index (BGHI), and Benezra’s Index of Adaptability (BIA). The THI was calculated using Thom’s (1959) formula: THI = Tdb + 0.36Tdp + 41.5, with Tdb = dry bulb temperature (°C) and Tdp = dew point temperature (°C). A THI around 75 shows a better tolerance to heat stress in the tropics.

The BGHI, proposed by Buffington et al. (1981), was determined through the formula BGHI = Tbg + 0.36Tdp + 41.5, with Tbg = black globe temperature (°C) and Tdp = dew point temperature (°C). BGHI values up to 74 define the comfort zone, between 74 and 78 is the alert zone, 79 to 84 is the dangerous zone, and over 84 is the emergency zone (SOUZA et al., 2002).

In order to obtain BIA, the formula BIA = (RT/38.8) + (RF/23) was used, with RT the rectal temperature in degrees Celsius (°C) and RF the respiratory frequency in movements per minute. Indices with values close to two are considered beneficial to the animals' adaptability and comfort (BENEZRA, 1954).

The experimental design was completely randomized in split-plots in a 2 x 3 factorial design with two treatments (TS and SPS), and three paddock replications, considering the animals as experimental units and three periods of the year (heavy rainfall season, transition season, and lighter rainfall season) as split-plots, and the morning and afternoon periods as split-split-plots.

Statistical analyses were performed using the Statistical Analysis System software (SAS, 2007) in order to determine the effects of treatments and periods of the year, and their interactions, on animal comfort. The data were expressed in terms of means and standard deviation. The data were subjected to analysis of variance as well as graphical trend analysis. For a significant result from the analysis of variance, means were compared by Tukey's test at 5% probability ($\alpha = 0.05$).

In the environmental data analysis, a transition phase in May, June, and July, between the heavy rainfall and lighter rainfall seasons, was observed with a significant reduction of relative humidity (RH) and a significant increase in air temperature (AT). Thus, the data were organized into three time periods: heavy rainfall season (January to April), transition (May to July), and lighter rainfall season (August to December).

## 3. Results and Discussion

The THI values were high in both management systems, between 76.27 and 86.73, higher than the limit of comfort level for buffaloes, which is 75. The maximum values in the afternoon, all year long, are above the emergency level of 82, which, according to Lourenço Júnior et al. (2006), imposes the need for environmental management practices.

The THI levels were statistically different between management systems, with higher values in the TS, which indicates that the SPS represents a favorable alternative to animal welfare. This system is responsible for an increase in productivity due to the shading and the resulting mild microclimate (LOURENÇO JÚNIOR et al., 2002).

It must be taken into consideration that the indices used were developed for temperate climates and bovine animals, so some distortions may occur in their evaluation when used for a tropical climate. Tables 1 and 2 show that the THI has a double interaction between the seasons and periods of the day.

Table 1. Temperature Humidity Index - THI in mornings and afternoons in Belém, state of Pará, Brazil

| Season | Temperature Humidity Index | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | | Afternoon | | |
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Heavy rainfall season (January to April) | 76.37 | 80.11 | 77.53±1.20[aB] | 81.88 | 86.00 | 83.61±1.36[bA] |
| Transition (May to July) | 75.00 | 78.57 | 76.87±1.50[aB] | 83.71 | 88.60 | 86.73±1.84[aA] |
| Lighter rainfall season (August to December) | 73.90 | 77.85 | 76.27±1.37[aB] | 83.50 | 87.57 | 85.98±1.17[aA] |

Means with different lowercase letters in columns are significantly different ($p < 0.05$).

Means with different capital letters in lines (between periods of the day) are significantly different ($p < 0.05$).

Table 2. Temperature Humidity Index - THI in Belém, state of Pará, Brazil

| Management System | Temperature Humidity Index | | |
|---|---|---|---|
| | Minimum | Maximum | Mean |
| Traditional System | 72.98 | 84.4 | 81.84±1.4[a] |
| Silvopastoral System | 71.77 | 82.4 | 80.33±1.5[b] |

Means with different letters in columns are significantly different ($p < 0.05$).

It is evident that climate conditions caused the animals to be in an alert situation in the morning and in an emergency situation in the afternoon, considered an uncomfortable heat condition for the animals. The maximum values of BGHI for the afternoon of 92.0 and 87.62, for TS and SPS, respectively, also indicate uncomfortable heat, which can cause a reduction in animal performance because they are above the comfort level of 74 (SOUZA et al., 2002). The highest values of BGHI under TS shows the need for environmental management through SPS as a way to provide the buffaloes adequate comfort indices. That can be achieved by planting trees that enable a higher productive performance of the buffaloes under tropical conditions (LOURENÇO JÚNIOR et al., 2002). Double interactions between seasons and periods of the day, as well as between management systems and periods of the day, can be seen in the BGHI evaluation (Tables 3 and 4).

Table 3. Black Globe Humidity Comfort Index – BGHI in Belém, state of Pará, Brazil

| Treatment | Black Globe Humidity Comfort Index – BGHI | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | | Afternoon | | |
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Traditional System | 75.75 | 80.55 | $78.23 \pm 1.26^{aB}$ | 84.11 | 92.00 | $89.11 \pm 2.74^{aA}$ |
| Silvopastoral System | 73.50 | 78.50 | $75.80 \pm 1.32^{bB}$ | 80.88 | 87.62 | $84.68 \pm 2.17^{bA}$ |

Means with different lowercase letters in columns are significantly different ($p < 0.05$).

Means with different capital letters in lines (between periods of the day) are significantly different ($p < 0.05$).

Table 4. Black Globe Humidity Comfort Index – BGHI in Belém, Pará state, Brazil

| Season | Black Globe Humidity Comfort Index | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | | Afternoon | | |
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Heavy rainfall season (January to April) | 76.00 | 80.55 | $77.65 \pm 1.50^{aB}$ | 80.88 | 86.87 | $83.93 \pm 2.20^{bA}$ |
| Transition (May to July) | 75.37 | 79.71 | $77.47 \pm 1.85^{aB}$ | 83.71 | 91.40 | $88.16 \pm 3.13^{aA}$ |
| Lighter rainfall season (August to December) | 73.50 | 78.85 | $76.34 \pm 1.8^{aB}$ | 84.80 | 92.00 | $88.47 \pm 2.72^{aA}$ |

Means with different lowercase letters in columns are significantly different ($p < 0.05$).

Means with different capital letters in lines (between periods of the day) are significantly different ($p < 0.05$).

The maximum values of BIA for the afternoon of 4.4 and 3.8, for TS and SPS respectively, were higher than the critical level of adaptability and represented an uncomfortable condition that causes a reduction in animal performance (SOUZA et al., 2002).

The means of either management system were higher than those of Lourenço Júnior (1998) for buffaloes, which were 1.75 and 1.92, in rainy and dry seasons, respectively.

This information shows the need for managing the physical environment to provide the animals with adequate comfort indices, which consequently results in better productive performance.

The higher BIA values under TS prove the need for SPS implementation, considering the shading provided by the trees as a promoter of buffalo welfare, with a consequent increase in their productive performance (LOURENÇO JÚNIOR et al., 2002; MARAI & HAEEB, 2010). For BIA, double interactions were found between management systems and periods of the day as well as between seasons and periods of the day (Tables 5 and 6).

Table 5. Benezra's Index of Adaptability: BIA in Belém, state of Pará, Brazil

| Treatment | Benezra's Index of Adaptability | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | | Afternoon | | |
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Traditional System | 1.80 | 2.80 | 2.25±0.18[aB] | 1.90 | 4.40 | 2.50±0.32[aA] |
| Silvopastoral System | 1.60 | 3.10 | 2.22±0.19[aB] | 1.70 | 3.90 | 2.41±0.27[bA] |

Means with different lowercase letters in columns are significantly different ($p < 0.05$).

Means with different capital letters in lines (between periods of the day) are significantly different ($p < 0.05$).

Table 6. Benezra's index of adaptability in Belém, state of Pará, Brazil

| Season | Benezra's Index of Adaptability | | | | | |
|---|---|---|---|---|---|---|
| | Morning | | | Afternoon | | |
| | Minimum | Maximum | Means | Minimum | Maximum | Means |
| Heavy rainfall season (January to April) | 1.60 | 3.10 | 2.22±0.21[bB] | 1.70 | 4.40 | 2.47±0.39[aA] |
| Transition (May to July) | 1.80 | 2.70 | 2.22±0.16[bB] | 1.80 | 3.10 | 2.39±0.22[bA] |
| Lighter rainfall season (August to December) | 1.70 | 2.80 | 2.26±0.18[aB] | 1.90 | 3.80 | 2.47±0.23[aA] |

Means with different lowercase letters in columns are significantly different ($p < 0.05$).

Means with different capital letters in lines (between periods of the day) are significantly different ($p < 0.05$).

## 4. Conclusion

According to the results found in this research, it was concluded that the silvopastoral management system is more efficient in terms of animal comfort for the female buffaloes as a result of the shade that provides a more amenable microclimate. Nevertheless, during the afternoon, regardless of the season, the female buffaloes were exposed to an unfavorable environment, with higher THI, BGHI, and BIA, as a result of higher temperature and air humidity in that period. These conditions during the afternoon negatively affect physiological variables, with consequent thermal stress, due to animals having difficulty in releasing body heat.

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