Analysis and availability of monthly maps of the Temperature and Humidity Index (THI) for Southeastern Brazil

https://doi.org/10.56238/Connexpemultidisdevolpfut-047

Ricardo Guimarães Andrade
PhD in Agricultural Meteorology from the Federal University of Viçosa
Institution: Brazilian Agricultural Research Corporation - EMBRAPA
E-mail: ricardo.andrade@embrapa.br

Lucas Cantarino Soares Garcia
Graduating in Electrical Engineering from the Federal University of Juiz de Fora
Institution: Federal University of Juiz de Fora - UFJF.
E-mail: lucas.cantarino@engenharia.ufjf.br

Marcos Cicarini Hott
PhD in Forestry Engineering from the Federal University of Lavras
Institution: Brazilian Agricultural Research Corporation - EMBRAPA
E-mail: marcos.hott@embrapa.br

Walter Coelho Pereira de Magalhães Junior
Master in Computer Science from the Federal University of São Carlos
Institution: Brazilian Agricultural Research Corporation - EMBRAPA
E-mail: walter.magalhaes@embrapa.br

Maria Gabriela Campolina Diniz Peixoto
PhD in Animal Science from the Federal University of Minas Gerais
Institution: Brazilian Agricultural Research Corporation - EMBRAPA
E-mail: gabriela.peixoto@embrapa.br

Maria de Fatima Ávila Pires
PhD in Animal Science from the Federal University of Minas Gerais
Institution: Brazilian Agricultural Research Corporation - EMBRAPA
E-mail: maria.pires@embrapa.br

Alexandro Gomes Facco
PhD in Agricultural Meteorology from the Federal University of Viçosa
Institution: Federal University of Espírito Santo – UFES, Campus São Mateus
E-mail: alexandro.facco@ufes.br

ABSTRACT
Brazil is among the five largest milk producers in the world. In 2021 the national production was 35.3 billion liters of milk, of this total, 34% refers to milk produced in the Southeast region. Although the Southeast stands out in the national ranking by Regions, its average productivity is still considered low. The Temperature and Humidity Index (THI) has been widely used in research involving the evaluation of thermal comfort conditions related to animal performance. This study aimed to analyze and make available monthly maps of THI for the Southeast of Brazil. Air temperature and humidity data from INMET's automatic stations, from January 2007 to December 2021, were analyzed for consistency and possible failures of observational records were corrected. Subsequently, the THI was estimated and geoprocessing techniques were applied to generate and make available the maps of monthly THI averages for the Southeast of Brazil. According to the results presented in the maps, it is observed the predominance of the THI class ≤ 70 between the months of May and September. In addition, it is noted that classes of high THI values prevail in the months of December to March, indicating an environment condition not conducive to the thermal comfort of cattle.

Keywords: Animal welfare, Caloric stress, THI, Dairy cattle.

1 INTRODUCTION

Brazil is one of the leading countries in terms of milk production volume. According to the IBGE, in 2021 the national production was 35.3 billion liters of milk, of this total, 34% refers to milk produced in the Southeast region. Although the Southeast stands out in the national ranking by Regions, its average productivity remains low (2,537 liters/cow/year). This productivity is lower by 1,163 liters/cow/year than the average of the South region (IBGE, 2021).

As in the entire national territory, it is observed in the Southeast, and probably within each state, a marked heterogeneity of production systems, whether in the facilities, breeds used, or in the adoption of management practices, property management and/or environmental conditions (Zoccal et al., 2011). This is an aspect that certainly contributes to the regional productivity indices observed.

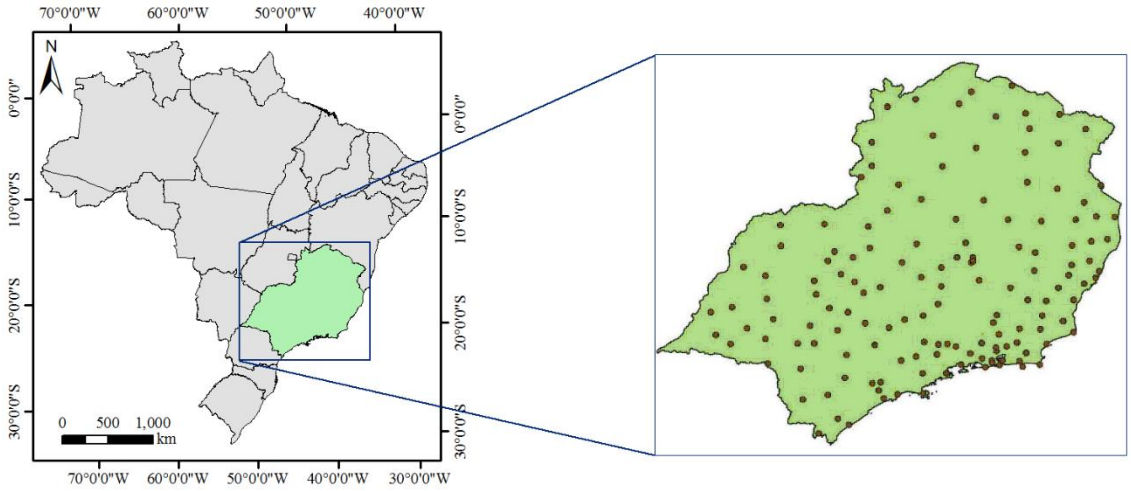
It should be noted that the Southeast region comprises strips of Atlantic Forest, Campos, Araucaria Forest, Cerrado and Caatinga. This diversity of biomes, which also cover a large part of the national territory, makes the issue even more complex. In tropical environments, in greater intensity in summer, the high air temperature associated with high relative humidity can cause thermal discomfort to animals, a process known as caloric stress (Rensis and Scaramuzzi, 2003; West 2003; Nardone et al., 2010; Santana et al., 2020).

There are several indices that can be applied in the analysis of the comfort or thermal discomfort of the animals and, among these, the Temperature and Humidity Index (THI) can be highlighted. In this case, the suitability of the environment can be analyzed or evaluated by combining the effects of air temperature and humidity (Buffington, 1977). The present study aimed to analyze and make available monthly maps of THI for the Southeast Region of Brazil.

2 MATERIAL AND METHODS

In the present study, we used meteorological data (air temperature and relative humidity) from the National Institute of Meteorology (INMET) obtained from automatic meteorological stations located in the Southeast region of Brazil, for the period from January 2007 to December 2021 (Figure 1).

Figure 1 – Southeast region highlighting the points of the meteorological stations used in the present study.



Daily data were analyzed for consistency and possible failures of observational records were corrected. Subsequently, the data were organized and made available in an Excel spreadsheet. Subsequently, the Temperature and Humidity Index (THI) was estimated by applying the equation proposed by Bunffington (1977):

$$THI = 0.8\ Tbs + RH\ (Tbs - 14.3)/100 + 46.3$$

Where: Tbs is the dry bulb temperature, °C; RH is the relative humidity of the air, %; THI is the temperature and humidity index, dimensionless.

With the THI estimated from the meteorological data collected in each automatic meteorological station of the Southeast region, it was possible to apply the method of interpolation by the inverse of the distance to the fourth power, generating the THI maps of the Southeast of Brazil. The class ranges of the THI maps were established according to Du Preez et al. (1990). Class ranges less than or equal to 70 would be a normal condition of thermal comfort for dairy cattle; between 70 and 72 refers to the alert condition; between 72 and 78 indicates alert with restrictions for milk production; between 78 and 82 indicates danger and above 82 an emergency condition.

3 RESULTS AND DISCUSSION

Figure 2 shows the monthly THI maps for Southeastern Brazil, also available on the GeoInfo platform (Embrapa, 2022). Note that, between the months of May (Figure 2E) and September (Figure 2I), there is a predominance of THI class ≤ 70 (class in blue). On the other hand, in the months of January (Figure 2A), February (Figure 2B), March (Figure 2C) and December (Figure 2L) there is a predominance of THI ≥ 72. It is worth noting that milk production can be impaired when the THI is ≥ 72 (Kemer et al., 2020; Santana et al., 2020). Importantly, the THI can vary greatly over time (day,

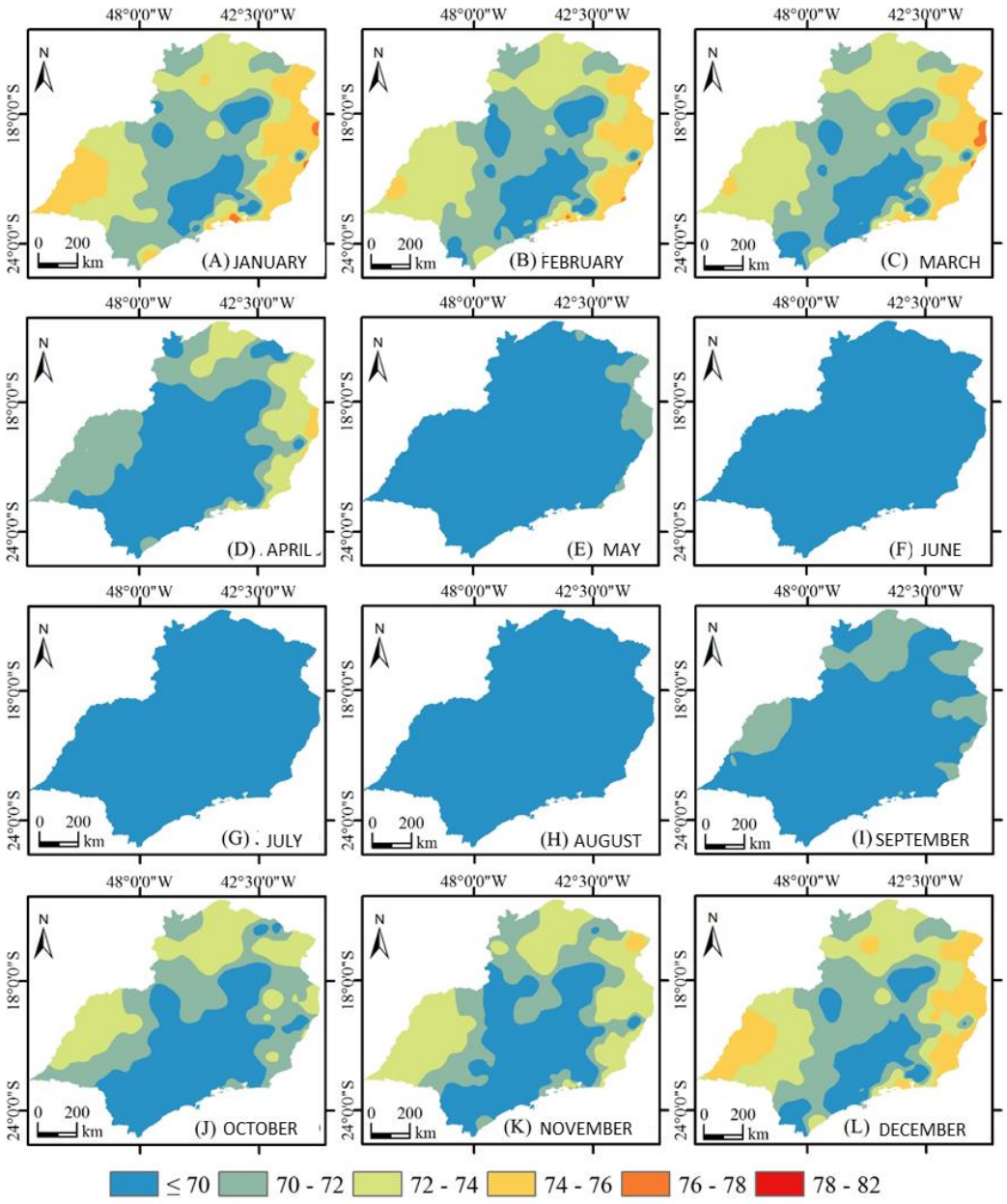
month, or year) so that regions with high average monthly or annual THI may not offer stress to cattle all the time.

From the maps, therefore, it is observed that much of the state of Espírito Santo and Rio de Janeiro, western portion of São Paulo, Triângulo Mineiro, Nordeste and Norte de Minas Gerais are areas in which milk production may be more affected by climatic issues. The Alto Paranaíba, Noroeste de Minas, Sul/Sudoeste de Minas, Campo das Vertentes, Oeste de Minas, Central Mineira, Metropolitana de Belo Horizonte, Macro-metropolitana Paulista, Metropolitana de São Paulo and Itapetininga are the regions that predominated the values of THI $\leq$ 72 in all months of the year. In this case, territorial management can help the public and private sector (rural producers, companies/cooperatives, among others) in adapting the herds to the environment. The climatic data associated with remote sensing data and geoprocessing techniques can be used in the evaluation of territories or regions regarding the suitability of dairy breeds to thermal comfort in a tropical environment, that is, adequacy to the thermoneutrality zone.

Caloric stress responsiveness is race-dependent (Bernabucci et al., 2010; McManus et al., 2011). Studies indicate that genetic groups of cattle have different thermoneutrality zones. For example, zebu generally fall into environments with air temperatures ranging between 10 and 32ºC. In this case, when the air temperature is below 10ºC the animal activates the mechanism of thermogenesis and thermoconservation. On the other hand, when the environment has air temperature above the upper critical limit (32ºC), the animal increases the thermolysis process to dissipate the heat produced by the body and that received by the environment (Berman, 2011; Ferreira et al., 2017).

With regard to the Dutch genetic group, the thermoneutrality zone is between 4 and 26ºC (Huber, 1990). It is also noteworthy that high air humidity and solar radiation can accentuate the negative effect of high air temperatures. The high humidity of the air can reduce the potential for evaporation of the animal by respiration or cutaneously. Solar radiation causes an increase in heat in the metabolic process (Ferreira et al., 2017).

Figure 2 - Maps of the Temperature and Humidity Index (THI) of Southeastern Brazil for the months of January (A) to December (L), using historical series of meteorological data for the period from 2007 to 2021.

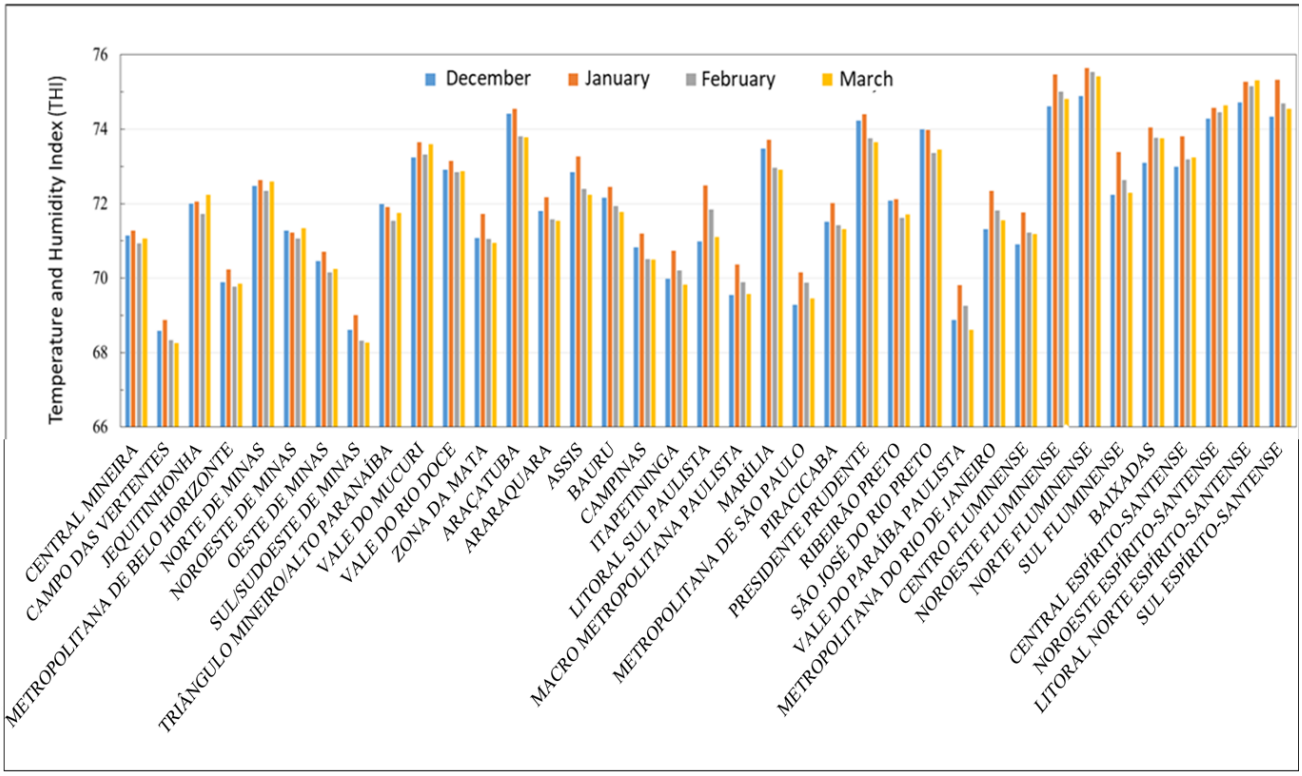


The gains in production and productivity in dairy farming, which have occurred in recent decades, are largely due to animal and plant genetic improvement, as well as the improvement in the adoption of procedures of good agricultural management practices and in the management of the production process (Hott et al., 2022). However, genotype-environment interaction studies have observed the existence of genetic antagonism between the level of production and the response of animals to caloric stress. There is evidence that the high caloric stress tolerance of Zebu animals can likewise be deteriorated by continuous selection for high milk production (Santana Jr. et al., 2015).

Figure 3 shows the mean values of THI, estimated for the summer period (December, January, February and March), for each mesoregion of the Southeast. It is observed that, out of a total of 37

mesoregions, about 30 (80%) had THI above 70 in all summer months. In addition, 16 mesoregions (43%) had a mean THI ≥ 72 in all summer months.

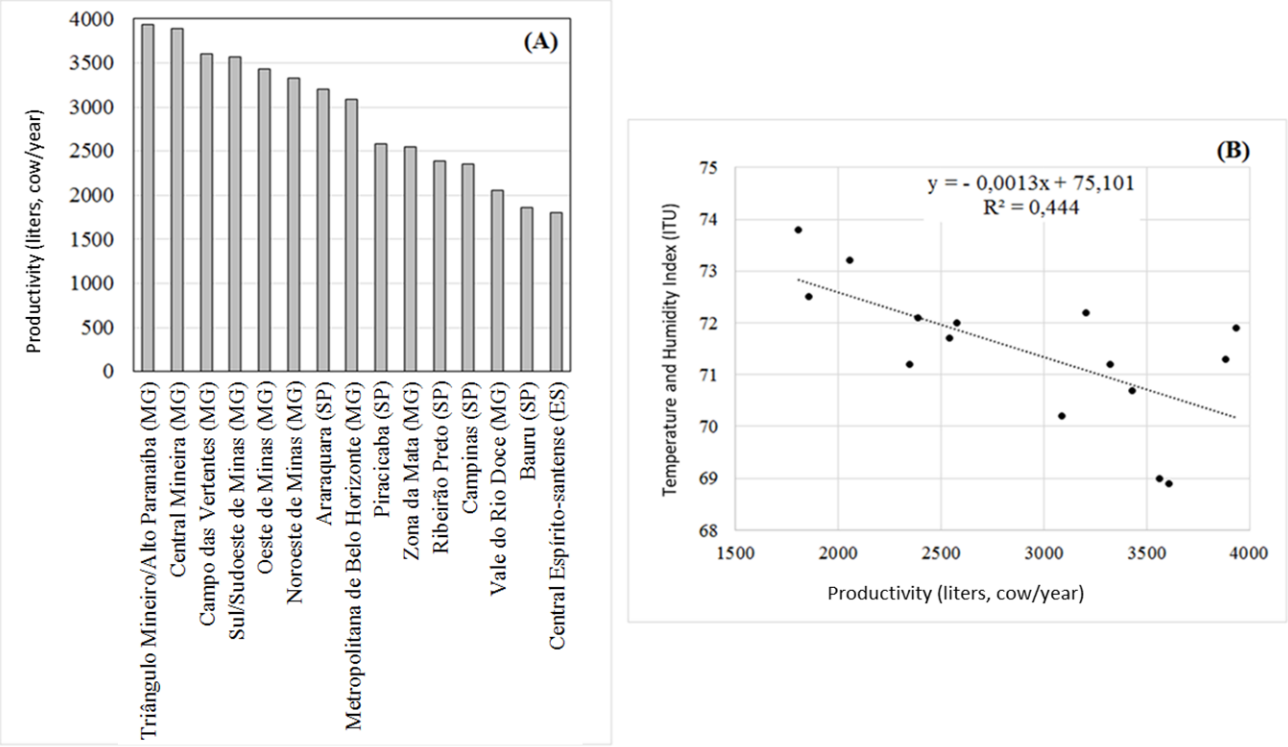
Figure 3 – Mean values of the Temperature and Humidity Index (THI) estimated for the months of December, January, February and March, for each mesoregion of Southeast Brazil, using historical series of meteorological data for the period from 2007 to 2021.



Mean THI values between 70 and 72 were observed in 12 of the 15 mesoregions with higher milk yields (Figure 3). However, mean THI values ≥ 72 were observed for all summer months in only 3 of the 15 mesoregions with the highest productivity, which were the last in the list of the 15 most productive (Figure 4a). The mesoregion of Triângulo Mineiro/Alto Paranaíba (1st placed) has productivity 2.2 times higher than the Central Espírito-santense (15th placed).

Figure 4b shows the scatterplot of the relationship between the THI and productivity (liters/head/year) estimated from the data provided by the IBGE for the 15 most productive mesoregions in the Southeast. Note that the coefficient of determination (R^2) between the variables was 0.44, which corresponds to a correlation (r) of 0.66.

Figure 4 – Graphs of the fifteen mesoregions with the highest milk productivity (A) and the dispersion of the relationship between the average THI of the summer months (December, January, February and March) and the productivity (liters/cow/year) estimated from the data provided by the IBGE for the fifteen mesoregions with the highest productivity in the Southeast of Brazil (B).



4 CONCLUSION

The THI maps for the Southeast region of Brazil show the predominance of the THI class ≤ 70 between the months of May and September. In addition, there is a greater coverage of the THI classes ≥ 72 in the months of December to March, especially in much of Espírito Santo and Rio de Janeiro, western portion of São Paulo, Triângulo Mineiro, Nordeste and Norte de Minas Gerais. However, it is noteworthy that ten of the fifteen mesoregions with the highest milk productivity presented THI ≤ 72 in the summer period. On the other hand, THI values > 72 were observed in only three of the fifteen mesoregions with the highest productivity (Bauru, Vale do Rio Doce and Central Espírito-santense). In this case, they may present some type of regional alert or climatic risk to milk production and, with this, indicate possible suitability of dairy breeds to critical climatic conditions in the summer period.

REFERENCES

BERMAN, A. Invited review: are adaptations present to support dairy cattle productivity in warm climates? Journal of Dairy Science, v. 94, n. 5, p. 2147-2158, 2011.

BERNABUCCI, U.; LACETERA, N.; BAUMGARD, L. H.; RHOADS, R. P. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal, v.4, p.1167-1183, 2010.

BUNFFINGTON, D. E.; COLLAZO-AROCHO, A.; CANTON, G. H.; PITT, D.; THATCHER, W. W.; COLLIER, R. J. Black globe-humidity confort index for dairy cows. St. Joseph: American Society of Agricultural Engineers, 1977. 19p. (paper 77-4517).

DU PREEZ, J. D.; GIESECKE, W. H.; HATTINGH, P. J. Heat stress in dairy cattle and other livestock under Southern African conditions. I. Temperature-humidity index mean values during the four main seasons. Onderstepoort Journal Veterinary Research, Onderstepoort, v.57, n.1, p.77-87, 1990.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – GADO DE LEITE - EMBRAPA. GEOINFO - Metadados: Índice de Temperatura e Umidade (THI) - Média/Mês - Série 2007/2021, Juiz de Fora, 2022. Disponível em: http://geoinfo.cnpgl.embrapa.br/maps/998

FERREIRA, I. C.; MARTINS, C. F.; FONSECA NETO, A. M. da; CUMPA, H. C. B. Conforto térmico em bovinos leiteiros a pasto. Documentos, 342. Embrapa Cerrados, Planaltina, DF. 2017. 47p. Disponível em: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/178289/1/Doc-342.pdf>. Acesso em: 23 fev. 2023.

HOTT, M. C.; ANDRADE, R. G.; MAGALHAES JUNIOR, W. C. P. de. Gestão territorial na cadeia prodTHIva do leite. In: HOTT, M. C.; ANDRADE, R. G.; MAGALHAES JUNIOR, W. C. P. de (org.). Geotecnologias: aplicações na cadeia prodTHIva do leite. Ponta Grossa: Atena, 2022. p. 1-6.

HUBER, J. T. Alimentação de vacas de alta produção sob condições de estresse térmico. In: PEIXOTO, A. M.; MOURA, J. C.; FARIA, V. P. Bovinocultura leiteira. Piracicaba: FEALQ, 1990. p. 33-48.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa da Pecuária Municipal. PPM – 2021. Sistema IBGE de Recuperação Automática – SIDRA, 2022. Disponível em: <https://sidra.ibge.gov.br/home/cnt/brasil> Acesso em fev. 2023.

KEMER, A.; GLIENKE, C. L.; BOSCO, L. C. Índices de conforto térmico para bovinos de leite em Santa Catarina Sul do Brasil. Brazilian Journal of Development, v. 6, n. 5, p. 29655-29672, 2020.

MCMANUS, C.; CASTANHEIRA, M.; PAIVA, S. R.; LOUVANDINI, H.; FIORAVANTI, M. C. S.; PALUDO, G. R.; BIANCHINI, E.; CORRÊA, P. S. Use of multivariate analyses for determing heat tolerance in Brazilian cattle. Tropical Animal Health and Production, v.43, p.623-630, 2011.

NARDONE, A.; RONCHI, B.; LACETERA, N.; RANIERI, M. S.; BERNABUCCI, U. Effects of climate changes on animal production and sustainability of livestock systems. Livestock Science, v. 130, n. 1, p. 57-69, 2010.

RENSIS, F.; SCARAMUZZI, R.J. Heat stress and seasonal effects on reproduction in the dairy cow: a review. Theriogenology, v. 60, p. 1139-1151, 2003.

SANTANA, M. L.; PEREIRA, R. J.; BIGNARDI, A. B.; EL FARO, L.; PIRES, M. F. Á.; ANDRADE, R. G.; PEREZ, B. C.; BRUNELI, F. A. T.; PEIXOTO, M. G. C. D. Dual-purpose Guzerá cattle exhibit

high dairy performance under heat stress. Journal of Animal Breeding and Genetics, v. 137, p. 486-494, 2020.

SANTANA, M.L.; PEREIRA, R.J.; BIGNARDI, A.B.; VERCESI FIHO, A.E.; MENÉNDEZ-BUXADERA, A.; EL FARO, L. Detrimental effect of selection for milk yield on genetic tolerance to heat stress in purebred Zebu cattle: genetic parameters and trends. Journal of Dairy Science, v.98, p.9035-9043, 2015.

WEST, J.W. Effects of heat-stress on production in dairy cattle. Journal of Dairy Science, v.86, p.2131-2144, 2003.

ZOCCAL, R.; ALVES, E. R.; GASQUEZ, J. G. Diagnostico da pecuária de leite nacional: estudo preliminar: contribuição para o plano pecuário 2012. Juiz de Fora Embrapa Gado de leite, 2011.