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Research Article

Temperature Elevation Effects on Livestock Production-A Study and Forecast of Bengaluru Climate Data

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Abstract

Background and Objective: Temperature elevation causes stress in livestock via reduction of blood flow to the digestive tract, induction of metabolic stress and nutritional imbalances. These compromises, animal performance, therefore, this study aim was to explore changes in temperature over the years for the study area in order to forecast future temperature ranges as a way of identifying increasing temperature as potential source of stress for livestock performance and health. **Material and Methods:** Bengaluru climate data spreading over 40 years were obtained; these data were categorized into 10 years group; in each 10 years group, a year was divided into 4 quarters (3 months units) giving a total of 16 quarters for the 40 years period used in the analysis. Specifically, records of temperature, relative humidity and dew point temperature were used in this research. **Results:** Time series model and descriptive statistical analysis were carried out which showed increasing trend of temperature; from average of 26.32°C in the 4th quarters of 1974-1984 to 29.99°C in the 4th quarters of 2007-2017 and forecasted to increase to 31.21°C by the 4th quarters of 2018-2028. **Conclusion:** It was concluded from these outcomes that increasing temperature is a source of stress for livestock production in Bengaluru and a mix of strategic animal production management and research were suggested for development of climate resilient livestock production system for the area as a model implementable at similar locations worldwide.

Key words: Heat stress, temperature-humidity-index, thermo-neutral-zone, oxidative stress, Bengaluru

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Biologically, increasing impacts of changing temperature, humidity and radiation are negative on animals. Apart from impacting negatively on animal physiological functions, it leads to economic loss in livestock productivity due to poor yield and increase cost associated with animal health management. Heat stress affects normal mechanisms of thermoregulation in animals resulting to failed physiological processes. Identification and management of negative impacts of Temperature-Humidity-Index (THI) represent an excellent approach to adaptive response to climate changes as it affects livestock production and well-being.

Bengaluru located in Tropical Savannah area with moderate climate throughout the year experience occasional non-continuous thermal elevation. It is the capital of Karnataka state of India reported for production of 45,000 MT of milk, 114 000 MT of meat and 18.6 million eggs annually ranking the state as 10th and 3rd for milk and egg production respectively in India¹; hence livestock production is an economic inclusion platform for many households and promotion of food security through increasing production to meet local demand and exportation of surplus^{2,3}. Climatic factors contributing vulnerable impacts on livestock production is commonest scenario associated with heat stress which cannot be an exception for livestock production in Karnataka State of India. Therefore, considering status of Bengaluru as centre for development of viable livestock husbandry and transfer of technologies to rural farmers, analysis of its climate data is necessary in order to identify potential impacts of thermal conditions as relative factor in livestock performance for the purpose of developing resilient animal husbandry solutions for changing climate conditions. This is important because despite glaring effects of temperature elevations on reduction of animal productivity; no much has been done to identify physiological basis of the impacts and as such more research in this area is highly necessary; this was conclusion of Polsky and von Keyserlingk⁴ after their extensive review of heat stress on performance of cattle. Similarly, Bernabucci *et al.*⁵ also stated that there is need for more studies covering understanding of animal interactions with the environment as these will lead to improving animal welfare and productive capacities because stress is a mediator of the two entities and can have direct negative consequences on both metabolic and physiological functions of animals which could reduce productivity.

After an extensive studies on adaptation of animals to temperature changes in the tropics that continuous selection of animals for growth and milk production increase are

potential risk factors that could make animals susceptible to environmental impacts of elevated temperature through stress; therefore, the workers suggested research studies focusing on better prediction of environmental changes as solution for effective management of heat stress on animals⁶. Therefore, this present study built on the understanding of past historical climate data of Bangalore over a period spanning up to forty years for projection of possible future scenario of temperature and estimation of possible future temperature-humidity-index as a way of establishing potential roles of temperature elevation as a source of stress against optimum animal production and health in order to devise ameliorative livestock production and management strategies cutting across breeding, nutrition and housing management practices⁷. This study aim was to explore changes in temperature over the years for the study area in order to forecast future temperature ranges as a way of identifying increasing temperature as potential source of stress for livestock performance and health.

MATERIALS AND METHODS

Data collection: This research project was conducted from July, 2018 to January, 2019 at the ICAR-National Institute of Animal Nutrition and Physiology, Bangalore; India. Bengaluru climate data recorded for period spreading over 40 years were obtained from public sources including National Oceanic and Atmospheric Administration (NOAA), climatemps.com and www.timeanddate.com. These data were organized into 10 years groups including 1974-1984, 1985-1995, 1996-2006 and 2007-2017 in each 10 years group, a year was divided into 4 quarters (3 months units) giving a total of 16 quarters for the 40 years period which represented the unit time used in the analysis. In addition to these groups, another 10 years group was forecasted covering period of 2018-2028. Specifically, records of temperature, relative humidity and dew point temperature were used in this research.

Statistical model and analysis: Time series model and descriptive statistical analysis were carried out with the aim of understanding patterns of temperature changes over the years to identify contributions of seasonal, irregular and trend components to temperature elevation in Bengaluru in order to forecast future temperature values as a way of exploring thermal elevation as environmental source of stress for livestock production in the study area. Time series model used for this study is presented in Eq. 1 describe by Pollock *et al.*⁸ below as adopted from general simple time series model:

$$y(t) = S(t) \times I(t) \times T(t) \quad (1)$$

where; $y(t)$ is the time series value of a parameter over a given period of time, $S(t)$ is the seasonal component associated with the parameter changes over a given period of time, $I(t)$ is the irregular component associated with the parameter changes over a given period of time and $T(t)$ is the trend component associated with the parameter changes over a given period of time.

Time series plots for recorded temperature and its trend for the period of 40 years in relation with temperature forecasted for another 10 years; forecasted temperature, forecasted THI in relation with animals Thermo-neutral-zones (TNZ) and recorded temperature, forecasted temperature in relation to the trend of seasonal changes were all produced. In addition to time series plots; all the parameters were statistically analysed to produce summarized descriptive statistic. Recorded and forecasted values of temperature, relative humidity and dew point temperature were used for calculating THI using Eq.1 and 2 below recommended for estimation of THI by Dairy Australia⁹ and Marai *et al.*¹⁰, respectively as reported by Sikiru *et al.*¹¹.

Outcome of these evaluations were related with biological impacts of elevated temperature impact as environmental source of stress in livestock production. In doing this, a general literature search using keywords including Temperature-Humidity-Index, livestock, Bengaluru, Karnataka, heat stress and climate change were used in Google Search engine and Google Scholar database; bulk result of the general search was filtered for choice of relevant articles used in discussion of the results. Specifically, major criteria used for selection of relevant article were reports on "Temperature-Humidity-Index", "heat stress" and "oxidative stress" as they affect livestock performance:

$$\text{Temperature humidity index (THI)} = t + (0.36 + Dt) + 41.2 \quad (2)$$

where, t is the dry bulb temperature ($^{\circ}\text{C}$) and Dt is the dew point temperature ($^{\circ}\text{C}$)⁹:

$$\text{Temperature humidity index (THI)} = t - \left[\left(0.31 - 0.31 \left(\frac{RH}{100} \right) \right) (t - 14.40) \right] \quad (3)$$

where, t is the dry bulb temperature ($^{\circ}\text{C}$) and RH is the relative humidity (%)¹⁰.

RESULTS

Climate data of Bengaluru revealed overall thermal elevations over the years as presented in Table 1, it is indicative and can be deduced from these data that patterns of temperature over the years is mediating THI above food producing animals TNZ and hence capable of limiting performance. The time series analysis showed increasing temperature trend; from average of 26.32°C in the 4th quarters of 1974 -1984 to 29.99°C in the 4th quarters of 2007-2017 and forecasted to increase to 31.21°C by the 4th quarters of 2018-2028.

Positive correlation ($r = 0.76$) exist between the recorded and forecasted temperature in our model supporting our observation of future thermal elevation for the study area; a situation posing threat to animals TNZ because as shown in the time series analysis plotted in Fig. 1, the TNZ slightly remained unchanged and below a changing and increasing

Table 1: Climatic parameters associated with changes in temperature in Bengaluru

Parameters	Mean $\pm$ SEM
Seasonal changes in temperature (%)	10.00 ± 0.17
Forecasted temperature ($^{\circ}\text{C}$)	28.30 ± 0.58
Recorded temperature ($^{\circ}\text{C}$)	27.69 ± 0.75
Baseline temperature ($^{\circ}\text{C}$)	28.33 ± 0.42
THI calculated	82.95 ± 1.06
Animal TNZ	75.20 ± 3.26
Minimum recorded temperature ($^{\circ}\text{C}$)	22.33
Maximum recorded temperature ($^{\circ}\text{C}$)	32.33
Minimum forecasted temperature ($^{\circ}\text{C}$)	24.00
Maximum forecasted temperature ($^{\circ}\text{C}$)	33.70
Minimum seasonal changes (%)	9.15
Maximum seasonal changes (%)	11.00
Minimum THI	75.37
Maximum THI	92.66

Source: NOAA¹², Climatemps¹³, Time and Date¹⁴

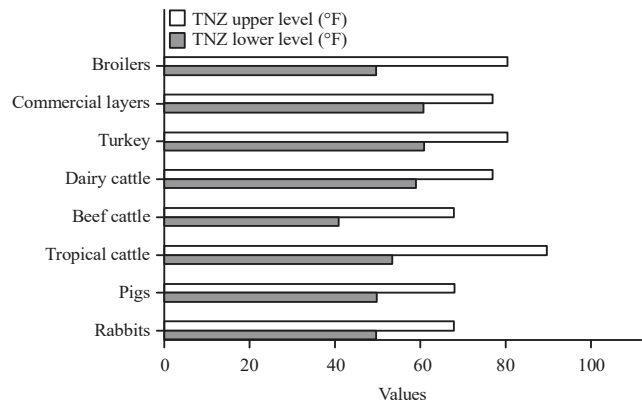


Fig. 1: TNZ values for common food producing animals

Sources: Deyhim and Teeter¹⁵, Belay and Teeter¹⁶, RCI¹⁷, AMS¹⁸

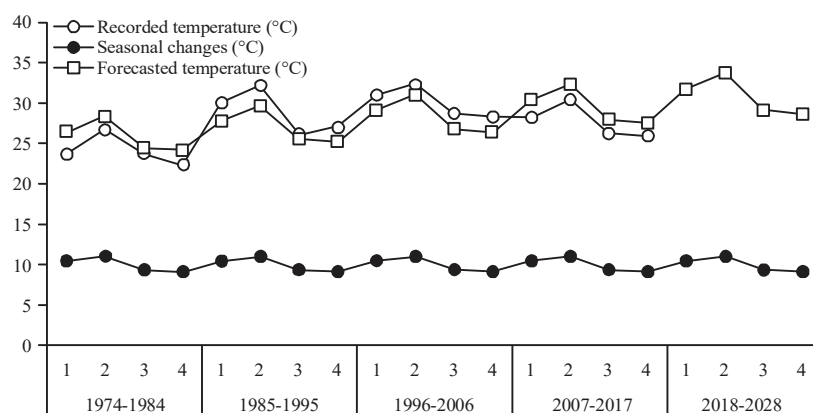


Fig. 2: Time-series plot of recorded temperature, seasonal changes and forecasted temperature for Bengaluru from 1974-2028

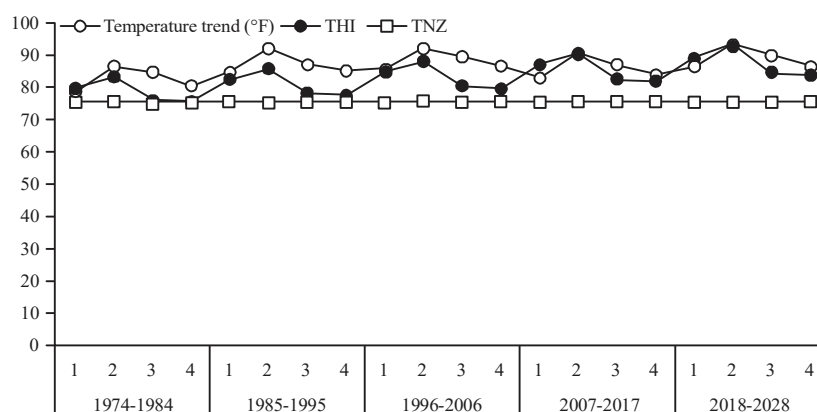


Fig. 3: Time-series plot of temperature trends and forecasted temperature in relation with average thermo-neutral zones of food producing animals for Bengaluru from 1974-2028

THI which follow similar pattern as the temperature trend for the study area. Average TNZ for most animals in the area is 75.2°F while the minimum and maximum THI are 75.37 and 92.66°F respectively. Seasonal changes associated with recorded and fore casted temperatures also indicated increasing trends-a situation pointing to future possibility of higher temperature in the study area as showed in time series plot of Fig. 2.

The result also showed equilibria THI and TNZ during some specific period in a quantifiable pattern but after some period the pattern seized to re-occur; this is a possible signalling of climate change in the study area. The equilibria pattern was observed in 3rd and 4th quarters of 1974-1984 where THI and average TNZ were equal, the trend closely similar to that pattern also occurred during 3rd and 4th quarters of 1985-1995 and nearly repeated but did not occurred at about the same time between 1996 and 2006 and since then not repeated as showed in Fig. 3.

DISCUSSION

Bengaluru is theoretically referred to as a place with moderate climate but with increasing temperature over the years (Fig. 4), the reason for this is not far fetch because the months with high temperature only come in between months with low temperature for three consecutive months then followed by another 7 months of low temperature. However, for animal production, the increasing change in temperature over the years negatively affecting livestock performance a situation of increasing seasonal temperature changes.

The increasing temperature observed for Bengaluru through this study represented a confirmation of the fact that the world is getting warmer-reasons which are linked with human anthropogenic factors. Global average temperature since 1975 was reported to be increasing rate of about 0.15-0.20°C/decade¹⁹. According to our study as presented

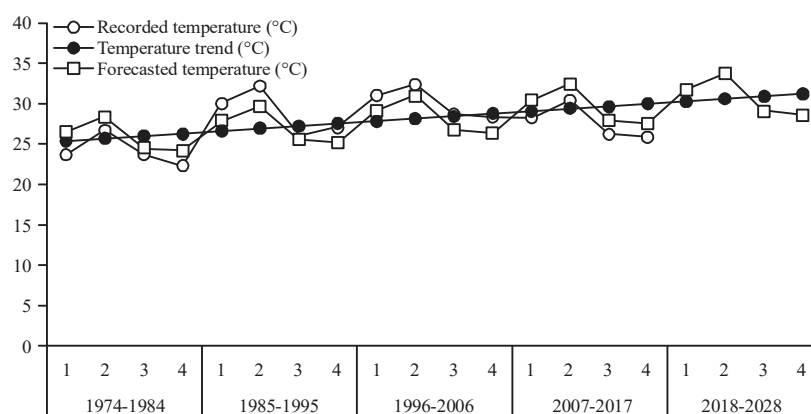


Fig. 4: Time-series plot of recorded temperature, temperature trends and forecasted temperature of Bengaluru from 1974-2028

in Table 1; average increasing temperature was about $0.61^{\circ}\text{C}/\text{decade}$ as from 1974 which fall within the range $0.15\text{-}0.20^{\circ}\text{C}/\text{decade}$.

In agreement with our findings that temperature increase in Bengaluru require attention, Dhorde *et al.*²⁰ also submitted that distribution of increasing change in temperature over India is extreme for extremes over Maharashtra and Karnataka States of India; our research can then regard as presentation of empirical data from Bengaluru which is capital of Karnataka state of India. This type of agreement on climatic condition required actions for resilience adaptability because increase in hot temperature extremes can lead to compromised livestock performance which consequence can lead to increase food insecurity and economic loss.

This observation is important because at high temperature especially when aggravated by high dew point temperature in a given location; there will be saturation of the water vapour causing discomfort conditions for animals because air movement is compromised²¹. In livestock production poor air movement even under low temperature may be dangerous as it will encourage accumulation of toxic gases such as ammonia within the animal house. Whenever air moves fast in cross-ventilation even under high temperature conveyance of ammonia away from pen will comfort animals as against when ammonia is built-up un-conveyed. Ammonia gas has a characteristic pungent odour and at high concentrations it is irritating to mucous membranes of respiratory tract and conjunctivae as well as animals' eyes corneas. Damage to these systems increases susceptibility to bacterial respiratory infection such as *Escherichia coli* infection²².

Improved housing modification can be of use for management of negative influence of high THI by enhanced ventilation as a way of housing modification practices. In a

modified housing for better ventilation, conveyance of ammonia builds up will contribute to animal welfare. According to Bhatta *et al.*²³ in a research at a location in semi-arid area of India sheep reared under same general environmental conditions but different micro-climate through housing differs in their physiological response under elevated THI. Two types of housing were provided (open corral and closed shed) and it was reported that shed and rectal temperature as well as rate of respiration were better for sheep in open corral. Therefore, for this study area; housing modification is a way of THI management for promotion of production and animal welfare.

Temperature-Humidity-Index above comfort zones as discovered through our study (Fig. 2) can cause physiological failures first on the gut health as result of lowered pH which reduce gastrointestinal motility and poor feed passage-risk factors for activeness of parasitic microorganisms to colonize animal gut to cause infections. In this condition, immediate survival strategy by animals becomes compromised by diversion of nutrients meant for growth into maintenance of homeostasis balance.

In a situation whereby the condition persists, what follows is impairment of immune functions and reproductive failures because of alteration in the production of reproductive hormones essential for pregnancy, changes in balance of developing follicles in the ovary, impaired embryonic development, poor conception rates and increased foetal and postnatal mortalities²⁴. These are direct implications of elevated thermal changes on animal physiological performance which are measure of animal productivity. Thermo-neutral-zone an indicator of comfort and discomfort for interpretation of THI varies from one animal to another and as presented (Fig. 3) has both lower and upper levels; animals perform better at the lower ranges although at increasing

level of temperature performance may not be hamper but exceeding the range is always of negative consequences for animal welfare, health and productivity.

Temperature Humidity Index calculated from the recorded data and forecasted data were above even the upper critical level of the animals TNZ which capable of causing physiological stress including increased respiratory rates and elevated rectal temperature in animals. This condition is directly associated with livestock reproductive dysfunction, enzymatic compromise, impairment of metabolic pathways and poor products qualities because of increased generation of reactive oxygen species²⁵⁻²⁸.

Alleviation of this heat stress condition can improve livestock productivity using nutritional and management manipulation as ways of limiting negative impacts of the high THI. This is an area of possibility for increasing milk yield in both Tropical and Temperate cattle used for milk production in the study area because THI above 65 was reported to cause an average of 2.2 kg daily reduction in milk yield²⁹. Meanwhile the THI as discovered in this study is even higher than the recommended minimum THI which is confirmation that elevated temperature and THI widespread in the Tropics is a factor capable of affecting milk yield. Therefore, implementation of antioxidant administration as part of nutritional husbandry practices is required and research to further elucidate these practices are necessary³⁰.

The suggestions made above can be a viable way out of heat stress negative impacts because a similar recommendation was made after supplementation of broiler chicken with vitamin E which is well-known antioxidants. This was in report of Maini *et al.*³¹ who reported that administration of vitamin E supplementation improved protection against lipid peroxidation and increased level of enzymatic antioxidant activities in the broilers chicken. The study also reported improved health of the broilers chicken from observations made in the erythrocytes that contain more protective enzymatic antioxidants; it was concluded by the authors that administration of vitamin E as antioxidants during hot season is a management practice capable of ameliorating oxidative stress in broiler chicken which is a consequence of heat stress.

Although thermal condition can negatively impact animals as discovered in this study where by temperature trend pointing towards continuous increase (Fig. 4); but explanation of thermal impacts beyond physical principles will be more important because complexity of animal factors in energy utilization. Therefore, investigation of animal response to thermal elevation and management at different production and physiological stages using biomarkers is futuristic strategy

for better understanding of biological impacts of climate on livestock productivity making use of some of the forecasted values from this study. Unlike physical evaluation principle, this approach can yield animal condition specific markers for improving animal production performances³².

The need for evaluating physiological response to thermal elevation by livestock cannot be overlook because it was reported in goat that even at high THI physical observations were not glaring, but respiratory rate increased and there were also clear changes in blood parameter which both positively correlated with poor rumination and general decrease in feeding efficiency. It was therefore, suggested that blood parameters be investigated as markers of heat stress under elevated thermal level and management³³.

CONCLUSION

In conclusion, environmental induced heat stress has negative biological impacts on livestock production performance and available climate records of Bengaluru revealed that thermal elevation causes THI above TNZ for most domestic food producing animals. Hence, a mix of production cum management strategies is suggested for producing animals in the study area. In addition to these, research bothering nutritional supplementation of natural antioxidants and identification of molecular markers associated with improved performance under stress conditions by animals can contribute to development of climate resilient livestock production in Bengaluru and model adopted in this study can implemented as part of building climate resilient livestock production strategies in other similar locations.

SIGNIFICANCE STATEMENT

The study finds out that in Bangalore India, there is increasing trend of temperature from average of 26.32°C in the 4th quarters of 1974-1984 to 29.99°C in the 4th quarters of 2007-2017 and forecasted to increase to 31.21°C by the 4th quarters of 2018-2028. These temperature changes are not suitable for livestock comfort hence the need to plan for livestock coping strategies in the study area is necessary.

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