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BIOCLIMATIC SCENARIOS FOR SHEEP PRODUCTION SYSTEMS IN CIEGO DE ÁVILA, CUBA

ESCENARIOS BIOCLIMÁTICOS PARA LOS SISTEMAS DE PRODUCCIÓN DE OVINOS EN CIEGO DE ÁVILA, CUBA

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This paper interprets the bioclimatic scenarios for sheep production systems in Ciego de Ávila for 2030, 2050 and 2100 in the scenarios called representative concentration pathways 2.6, 4.5 and 8.5. Data of accumulated ambient temperature and average relative humidity from the PRECIS-CARIBE regional model were monthly used for this purpose. The interpretation was based on scientific literature on the behavior of sheep under heat stress. The results showed a future environment with favorable meteorological conditions for the development of heat stress in sheep. Temperatures will range from 28.5 to 39.6 °C, depending on the type of scenario and the year. Relative humidity will reach values between 60.5 and 85%, which will generate temperature and relative humidity indices of 89.5 to 95.2 u. The optimal conditions for sheep to be in thermal welfare are lower than the scenarios for 2030, 2050 and 2100. The presence of trees and the development of silvopastoral systems constitute an alternative to mitigate adverse climatic conditions. Bioclimatic scenarios provide information for future planning and management of sheep rearing, selection of actions and care that promote the application of a climate-smart agriculture from the climatic point of view, which contributes to the sustainable production of these animals.

Keywords: *animal welfare, climate forecasting, heat stress, modeling*

En este trabajo se interpretan los escenarios bioclimáticos para sistemas de producción de ovinos en Ciego de Ávila para 2030, 2050 y 2100 en los escenarios denominados rutas de concentración representativas 2.6, 4.5 y 8.5. Se utilizaron para ello datos mensuales de acumulados de temperatura ambiente y humedad relativa media del modelo regional PRECIS-CARIBE. La interpretación se apoyó en la literatura científica acerca del comportamiento de los ovinos ante el estrés por calor. Los resultados mostraron un ambiente futuro con condiciones meteorológicas favorables para el desarrollo de estrés por calor en ovinos. Las temperaturas oscilarán de 28.5 a 39.6 °C, según el tipo de escenario y el año. La humedad relativa alcanzará valores entre 60.5 y 85 %, lo que generará índices de temperatura y humedad relativa de 89.5 a 95.2 u. Las condiciones óptimas para que los ovinos se encuentren en bienestar térmico son inferiores a los escenarios para 2030, 2050 y 2100. La presencia de árboles y el desarrollo de sistemas silvopastoriles constituyen una alternativa para mitigar las condiciones climáticas adversas. Los escenarios bioclimáticos ofrecen información para la planificación futura y el manejo para la crianza de ovinos, selección de acciones y atenciones que propicien la aplicación de una agricultura inteligente desde el punto de vista climático, que contribuya a la producción sostenible de estos animales.

Palabras clave: *bienestar animal, estrés por calor, modelación, pronóstico climático*

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Introduction

Climate change is a determining phenomenon for food production, not only at present, but also in the future. This is explained by the effects it has on agro-productive biodiversity and by the alterations and changes that occur in natural systems. Agriculture in the 21st century faces the challenge of satisfying food demands and, at the same time, fulfills the sustainability goals (Nicholls and Altieri 2019). Evidence of global warming in recent decades and the high probability of increased occurrence of extreme weather events are factors that, directly and indirectly, affect the loss of productive capacity, production levels and food security (Casanova-Pérez *et al.* 2019).

Sheep farming will continue to be an important pillar in global livestock production (Ferguson *et al.* 2017 and Vera-Herrera *et al.* 2019). According to data from CEPAL and UNICEF (2013), 98 million heads of sheep employ 1.5 million people in the European Union. Around 81 million sheep are part of livestock production systems in Latin America and the Caribbean and are an important resource for local inhabitants and economies. Cuba has 1,536,611 sheep heads. In particular, Ciego de Ávila registers 53,403 in total. Sheep stock is mainly based in the east-center. In this part of the country, it reaches 87.06% of the total mass (ONEI 2021).

Rojas-Downing *et al.* (2017) state that among the factors that modify sheep productivity are the stress caused by adverse environmental conditions, including hot. Climate change increases ambient temperatures and changes circannual rainfall patterns in different agroecological regions of the world, resulting from greenhouse gas emissions. The productive potential of sheep in tropical regions is mainly affected by exposure to high temperatures. This is the main phenomenon that threatens the production of animal origin foods and, consequently, food security (Sejian *et al.* 2017). Regarding the forecast of future climatic conditions based on bioclimatic scenarios, there has been performed studies in Ciego de Ávila province aimed at the development and interpretation of bioclimatic scenarios for banana cultivation and the behavior of diseases in plantations of interest (Hernández-Mansilla *et al.* 2017 and Pérez *et al.* 2018). These researchers have been carried out from different positions and contexts. Their results contribute to predicting and outlining strategies for adaptation to climate change and mitigating its effects. They also respond to the actions of the Cuban state (Tarea Vida) to confront the climate crisis and represent a direct contribution to the efforts being made to guarantee food security.

The studies designed with bioclimatic scenarios have been contextualized in regions, agricultural crops of interest and plant pests that affect them. Despite the importance of these researchers, there is no evidence of its application in animal production systems. Therefore, the objective of the study was to interpret bioclimatic scenarios of low, medium and high emissions for 2030, 2050 and 2100 in sheep production systems in the territory of Ciego de Ávila.

Materials and Methods

The study was carried out in Ciego de Ávila province of, located in the central region of the Republic of Cuba, with a surface area of 6971.64 km^2 and a land area of 6194.90 km^2. Its main economic activities are agriculture, livestock, forestry and tourism (De la Rosa *et al*. 2015).Ciego de Ávila province is characterized by very hot summers and short winters. During the year, the temperature generally varies from 18 °C to 33 °C. It rarely drops below 14 °C or rises above 36 °C with easterly to northeasterly winds, from Cayo Coco to Júcaro. The average relative humidity annually fluctuates from 72 to 85 % (Sorí-Gómez *et al.* 2014).

The distribution of bioclimatic conditions in Modesto Reyes popular council (Ciego de Ávila municipality) was used for a period of 45 years (1960-2004) and for the future based on outputs from the PRECIS Regional Climate Model (Jones *et al.* 2016) for three scenarios called representative concentration pathways (RCP) 2.6 (van Vuuren *et al.* 2011), RCP 4.5 (Thomson *et al.* 2011) and RCP 8.5 (Riahi *et al.* 2011). The data was obtained from information available from the Superclima project.

The reference period (1960-2004) was defined based on the historical RCP. For future scenarios (RCP 2.6, RCP 4.5 and RCP 8.5), although data from 2005 to 2099 are considered, information from 2021 was used. The performance of the variables that influence on the calculation of the THI (temperature and relative humidity index) was analyzed. The analysis was carried out at different scales (months and years), with emphasis on the performances corresponding to 2030, 2050 and 2100.

The domain where the study area is located is a subdomain of the central region, for which the regional climate model was run, with the coordinates (21 52´48.6´´ N, 78 41´32.6´´ W). For the interpretation and analysis of the results, the physiological ranges of the vital indicators for sheep and the record studies of the effect of heat stress for this species were considered.

Results

The prediction of AT (ambient temperature) and RH (relative humidity) for the baseline (1960-2004) and for the scenarios up to 2100 are shown in figure 1. It was seen that, in general, the temperature trend is to increase, while the humidity trend is to decrease. The baseline showed values ranging between 20 and 21 °C for AT and 75.5 to 72 % for RH, generating a THI between 66 and 68 u (figure 2).

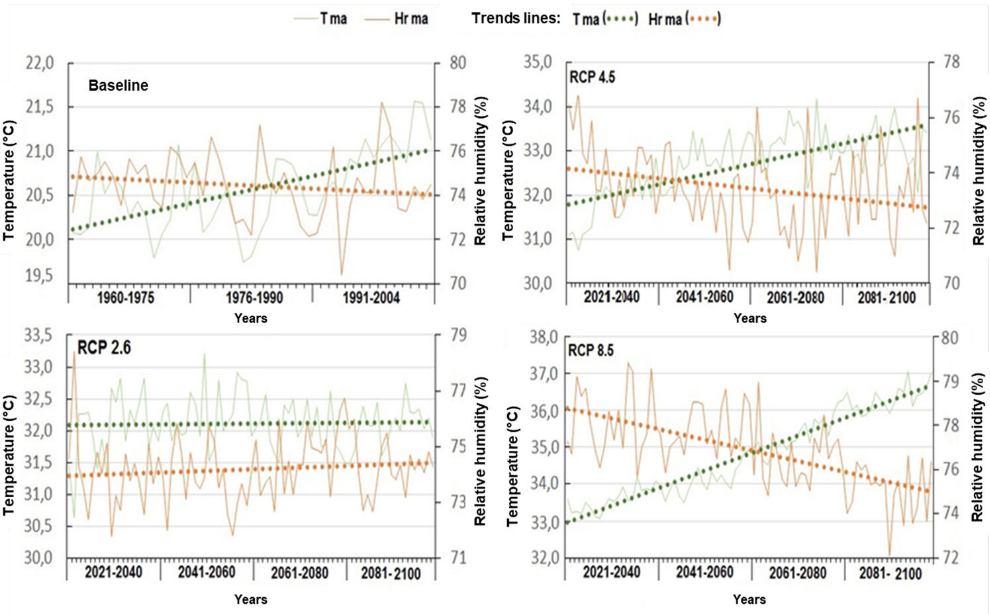

Figure 1. Trends in temperature and relative humidity variables (baseline and future scenarios)

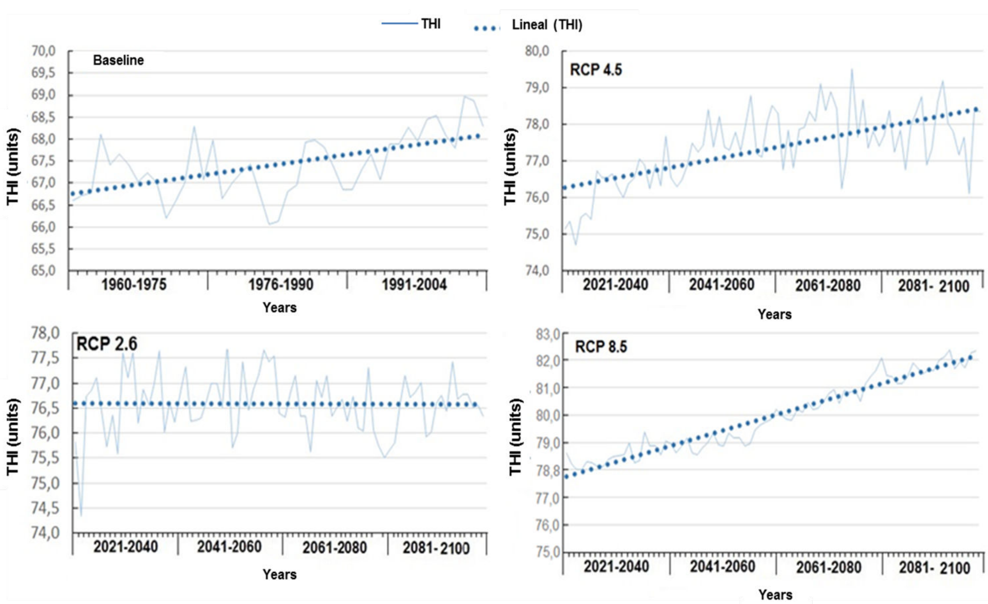

Figure 2. THI trend (baseline and future scenarios)

In future scenarios, for RCP 2.6, the temperature will maintain a stable value of 32 °C and the humidity will range between 74 and 74.5 %, for RCP 4.5. The temperature will progressively increase from 31.7 to 33.5 ºC and the RH will oscillate between 72.7 and 74.2 %, generating THI from 76.4 to 78.5 u. Scenario 8.5 predicts the greatest deterioration with THI values above 78 u, which exceed 82 u around the year 2100.

The analysis of the monthly performance of the AT and RH variables, for the baseline and the RCP 2.6, 4.5 and 8.5 scenarios, was specified in the years 2030 (figure 3), 2050 (figure 5) and 2100 (figure 7). Figures 4, 6 and 8 show the monthly performance of the THI, the baseline and the RCP 2.6, 4.5 and 8.5 scenarios for 2030, 2050 and 2100, respectively.

In 2030 (figure 3), according to an RCP 2.6 scenario, the temperature will range between 28.5 and 35.5 ºC, with July and August being the months with the highest temperatures. Humidity will range between 60.5 and 80 %. For a RCP 4.5 scenario, temperatures will reach peaks of 34.9 °C in

July and August, remaining at 29 and 30.9 °C, and humidity will range between 64.5 and 75.5 %. The RCP 8.5 forecasts temperatures of 28 to 36.2 °C with sustained peaks covering July, August and September. The THI values in 2030, generated for RCP 2.6, 4.5 and 8.5 scenarios (figure 4), will reach 89.5, 89 and 92 u in July and August, respectively.

The performance of the AT and RH variables for the year 2050 (figure 5) shows for a RCP 2.6 that the temperature will have sustained values above 32 °C during all months, reaching 35.5 °C in July. Humidity will be between 63 and 83 %. For a RCP 4.5 scenario, temperatures will range between 31 and 35.9 °C and will remain above 34 °C from April to September, with humidity between 64 and 84 %. In the case of the RCP 8.5 scenario, the temperature will vary between 30 and 39 °C, with values above 37 °C from May to September, and humidity between 65 and 86 %. The performance of the variables described above between July and September will generate THI values in 2050 of 90, 90 and 91.2 u for RCPs 2.6, 4.5 and 8.5, respectively (figure 6).

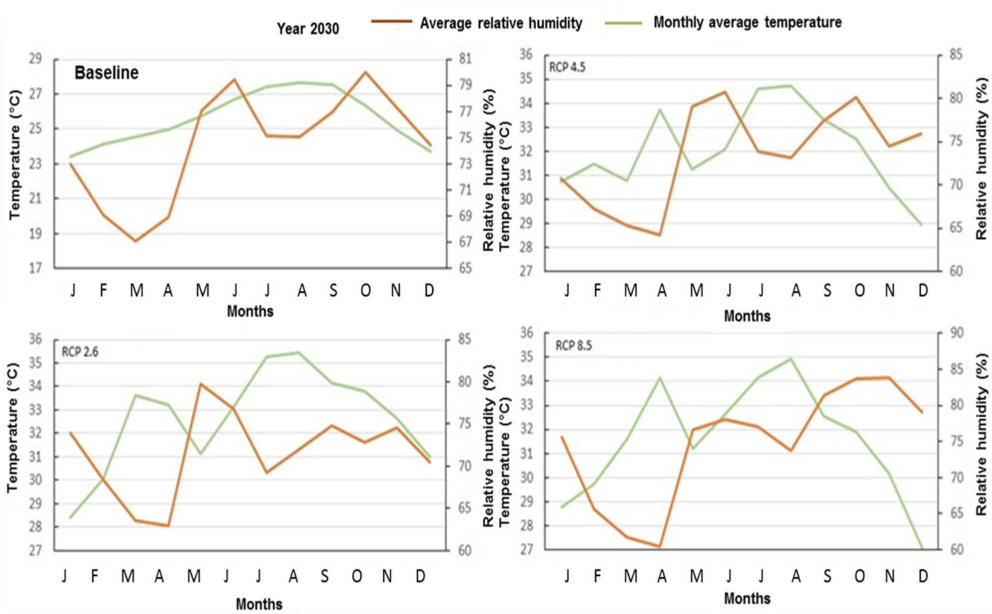

Figure 3. Monthly performances of temperature and relative humidity variables (baseline and 2030 scenarios)

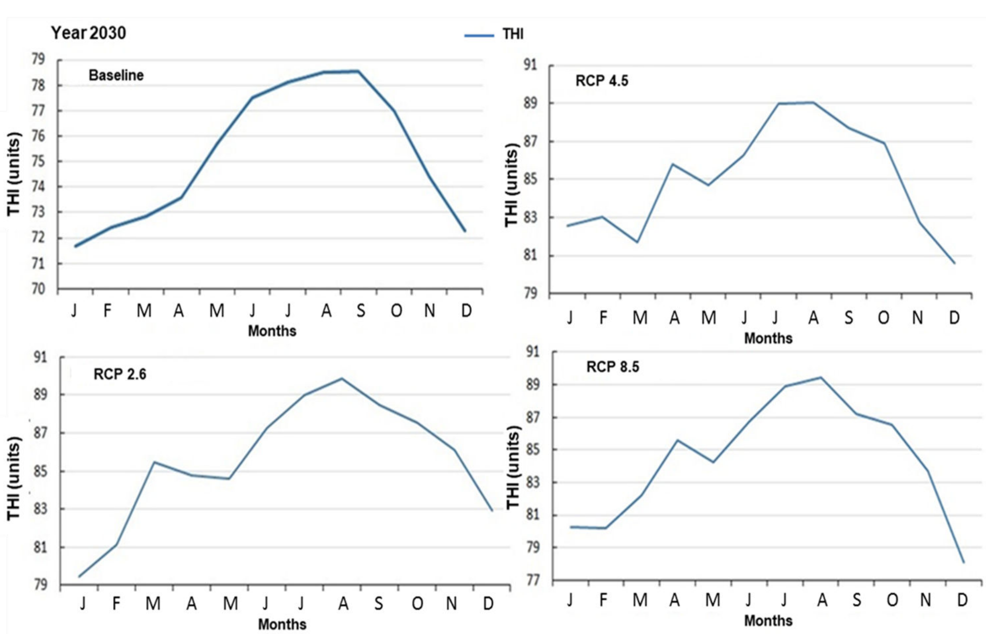

Figure 4. Monthly performance of the THI (baseline and 2030 scenarios)

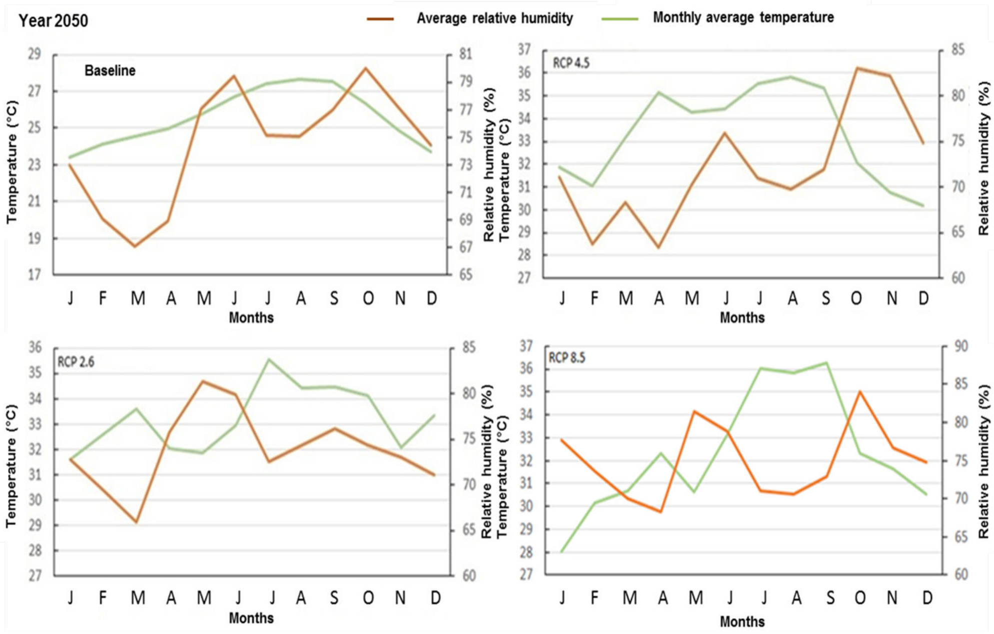

Figure 5. Monthly performance of the temperature and relative humidity variables (baseline and 2050 scenarios)

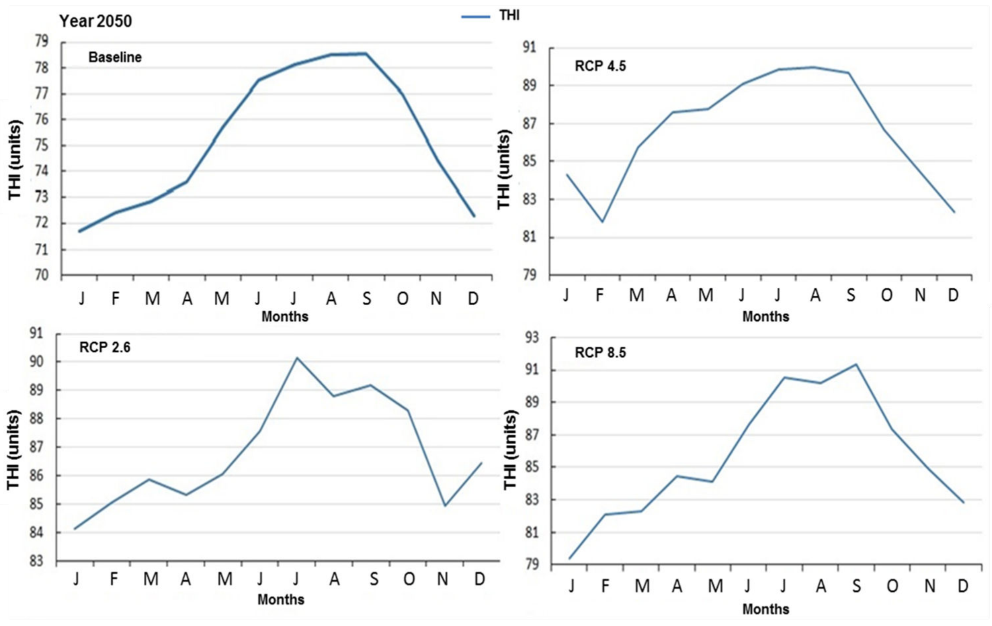

Figure 6. Monthly performance of the THI (baseline and 2050 scenarios)

For the year 2100, the performance of the temperature and humidity variables is shown in figure 7. For RCP 2.6, temperature values will range between 29 and 35 ºC, with sustained values above 34 ºC from July to October. Humidity will be between 73 and 83 %. In RCP 4.5, temperature values will range from 30 to 36.8 °C with sustained values above 34 °C from June to November. Humidity will be between 63 and 83 %. For RCP 8.5, temperature values will fluctuate from 32 to 39.6 °C, with values below 34 °C only in December. Meanwhile, humidity will vary between 65.2 and 85 %. The performance of the variables described between May and October 2100 generates THI values of 89.91 and 95.2 u for RCP 2.6, 4.5 and 8.5, respectively (figure 8).

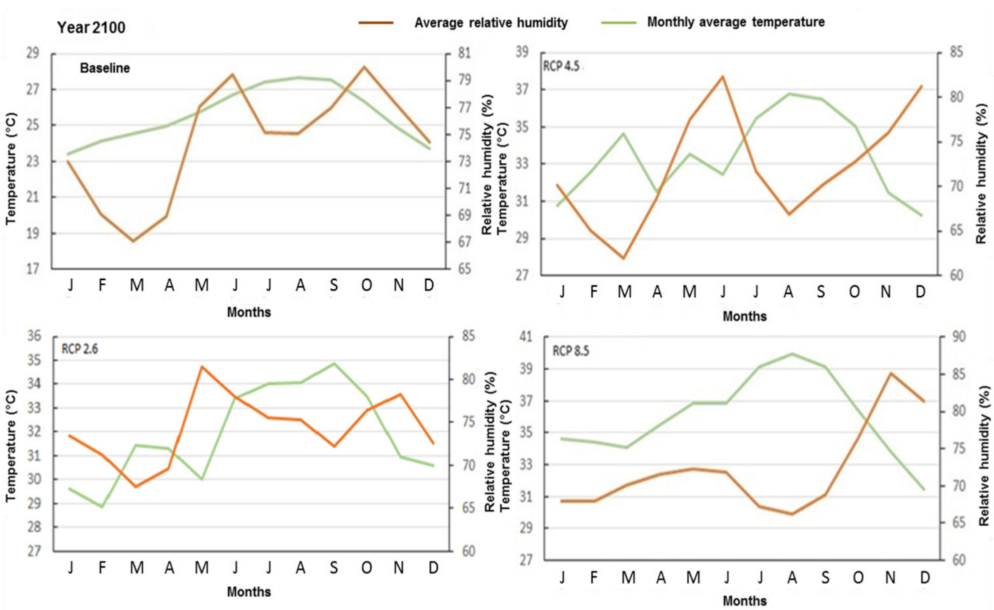

Figure 7. Monthly performance of the temperature and relative humidity variables (baseline and 2100 scenarios)

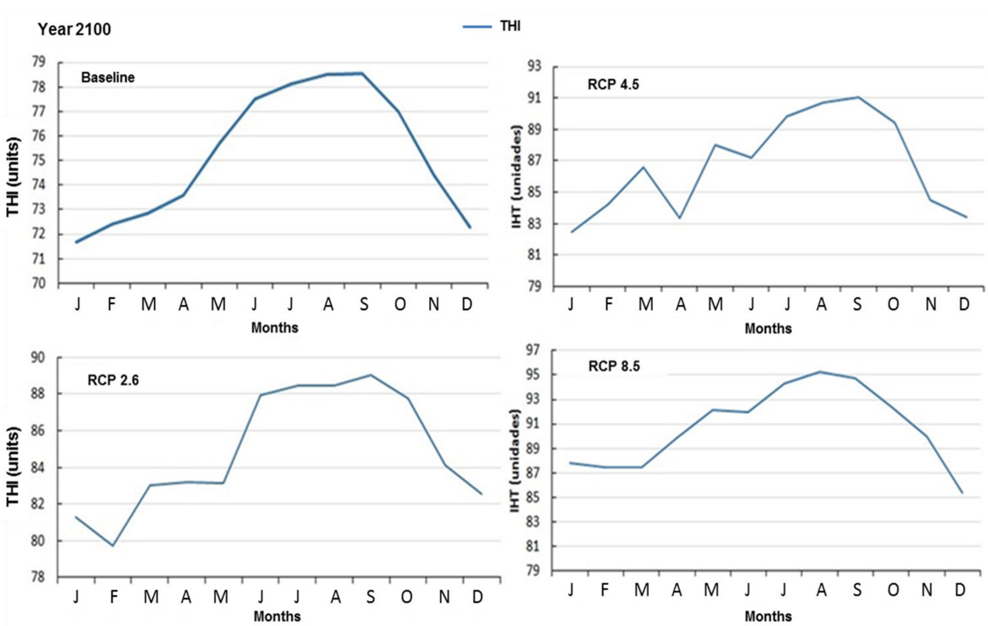

Figure 8. Monthly performance of the THI (baseline and 2100 scenarios)

Discussion

The estimated values for the scenarios developed coincide with previously conducted studies. Karmalkar *et al.* (2013) and Rodríguez De Luque *et al.* (2016), in studies on climate change in the Caribbean, and in researchers by CEPAL (2018), developed particularly in Cuba, suggest that the air temperature could increase and rainfalls decrease at the end of the 21st century, especially during the rainy season. According to Schewe *et al.* (2014), the global trend is towards increasing air temperature and changes in rainfalls.

According to reports by Pérez *et al.* (2018), global changes in the performance of different meteorological variables and a greater frequency of extreme events are estimated. In particular, the probable temperature increase between 1.8 and 4.0 °C could reach up to 6.4 °C by 2100 (with respect to 1980-1999). However, in the fifth IPCC report (2014), based on the use of RCP scenarios, the results show the probability that the average global surface temperature will increase between 0.6 ºC and 4.5 ºC (with respect to the period 1986-2005) by the end of this century. In short, global warming and the magnitude of the projected climate change depend on the emissions scenario considered.

The interpretation of the bioclimatic scenarios described above allows suggesting that there will be favorable conditions for the development of heat stress in sheep in Ciego de Ávila areas, mainly due to the increase of temperature caused by climate changes. According to Pereira *et al*. (2014), the thermal comfort zone for sheep varies from 15 to 30 °C and the upper critical temperature is from 35 °C, although Reyes *et al.* (2018) consider this state from 39.1 ºC.

For Oliveira *et al.* (2013), who observed greater grazing intensity in Santa Inés sheep, related to better atmospheric conditions; the first manifestation that the sheep will show is in grazing behavior, with the reduction of grass intake. López *et al.* (2015) refer that in response to heat stress in sheep, food intake is reduced. These results coincide with those reported by De la Rosa *et al.* (2017) and Solórzano-Montilla *et al.* (2018), who report that when temperature values are high, animals considerably reduce the intake and remain resting and ruminating for longer.

Other aspects of animal physiology may be affected by the predicted conditions, such as body temperature and respiratory rate. Seixas *et al.* (2017) suggest that environmental conditions can compromise the maintenance of body temperature. Heat stress conditions will cause sheep to activate defense mechanisms to maintain body temperature.

Respiratory rate measurements are widely used to assess heat stress. The increase in this indicator is the first control mechanism for sheep in heat stress environments. Habeeb *et al.* (2018) found variations in respiratory rate in response to changes in ambient temperature and THI, both recorded during the day. Seixas *et al*. (2017) report that the physiological variables increased with the increase in temperature during the course of the day, under heat stress and thermo neutrality conditions. Other authors have reported increased respiratory rate in response to increased temperature. This is showed by Srikandakumar *et al.* (2003) in a study with Omani and Merino sheep and Romero *et al.* (2013) with Pelibuey. Macías-Cruz *et al*. (2016) reaffirm it in studies with Dorper x Pelibuey.

The conditions described in the developed scenarios predict THI values from 76.4 to 78.5 u, even for low-emission scenarios. For medium and high scenarios, THI figures will be reached from 75 to over 80 u, stressful conditions for animals, including sheep. Marai *et al.* (2007) proposed an indicative scale of the degree of heat stress experienced by sheep. According to this categorization, THI between 82 and 84 u is indicative of heat stress.

The monthly performance for the studied years coincides with presenting THI peaks in June, July and August, with values that oscillate in the low emissions scenario between 89 and 90 u. For medium and high scenarios, they range from 89 to 95 u. Neves *et al.* (2009) highlighted that hair sheep begin to experience heat stress when the THI is between 78 and 79 u. Likewise, López *et al.* (2015) observed that hair sheep begin to experience heat stress when the THI is higher than 72 u. According to the forecast of the scenarios developed, sheep will face severe stress conditions.

Despite the assessments carried out in attention to the bioclimatic scenarios in their different emission scenarios RCP 2.6, 4.5 and 8.5 for 2030, 2050 and 2100, and considering the indicators of the used method, it is important to reflect on the effect that the rearing system, type of grazing and incorporation of the tree component can have in some of the modalities of silvopastoral systems. The presence of shade can create an environment favorable to grazing conditions (Aengwanich *et al.* 2011, Barragán-Hernández *et al.* 2015, López *et al.* 2015 and Lins *et al.* 2021).

Regardless of the interpretations of the bioclimatic scenarios, the fact that there will not be favorable conditions for the development of sheep production systems in the future by 2030, 2050 and 2100 due to the effect of climate change, various studies agree in raising the importance of natural shade and silvopastoral systems as one of the alternatives to mitigate the negative effect of adverse environmental conditions (Vieira *et al.* 2021).

In an environment that is increasingly affected by unfavorable conditions (high temperatures and relative humidity), the introduction of trees is one of the ways to transform the microclimate, so that it is suitable for ruminant production and contributes to animal welfare (López-Vigoa *et al.* 2017). This translates into the regulation of solar radiation, which directly affects grazing animals and promotes thermal well-being (Sousa *et al.* 2015)

Conclusions

The predicted bioclimatic scenarios, low, medium and high emissions for 2030, 2050 and 2100, show that future environmental conditions will be unfavorable for grazing systems. The forecast describes that the climatic variables will reach levels that cause heat stress in sheep, which will intensify according to the type of scenario predicted. These results provide information for reorganizing sheep production systems to face climate change.

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