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Full Length Research Paper

Effects of climate change on dairy cattle, South Africa

E. Nesamvuni[1], R. Lekalakala[1], D. Norris[2]* and J. W. Ngambi[2]

[1]Research Services, Limpopo Department of Agriculture, 69 Biccard Street, Polokwane, South Africa.
[2]Department of Animal Science, University of Limpopo, Private Bag X1106, Sovenga 0727, South Africa.

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The aim of this study was to assess the impact of heat stress on dairy cattle productivity and reproductive performance under projected future climate conditions. Temperature-Heat Index (THI) was used as an indicator of the degree of heat stress likely to be experienced by dairy cattle. Daily climate stations across South Africa were selected to be spatial representative of the country's climate which was used to extract the downscaled daily climate projections. Projected heat stress under mean daily climate conditions suggested no stress in the present and mild stress in the intermediate to distant future climate projections along the Northern border. The mild stress projected under mean conditions implies that the impact on milk production might be minimal. For maximum daily conditions, all the projections suggest that dairy cattle might be severely stressed under present and intermediate future climate scenarios over most of the country, while in the more distant future climate scenario, very severe stress was projected in parts along the northern periphery.

Key words: Climate projections, dairy cattle, heat stress, temperature-humidity index.

INTRODUCTION

There is growing evidence that climate changes will cause considerable damage to the agricultural sector worldwide. In Africa, the livestock sector will suffer the most from the adverse effects of climate change because the major proportion of agricultural production is from livestock. According to reports by Seo and Mendelsohn (2006), environmental warming will be harmful to livestock owners especially, cattle owners. Economic losses from reduced cattle performance as a result of adverse climate changes are likely to exceed those associated with death losses (Mader, 2003). Increased performance expected from livestock coupled with sub-optimal environment will increase animal vulnerability and risk (Hahn, 1999). The study by Klinedinst et al. (1993) revealed that abnormally high temperatures may reduce milk production by up to 20% and conception rates by as much as 35% in dairy cattle. Most of the work on the impact of climate change has been focused on areas such as water resources, rangeland ecosystems and Human health etc, while in agriculture, impact assessments focused more on major crops, such as grains. While these assessments are of importance, they have small contributions to the South African agricultural economy which is dominated by animal production with dairy production accounting for about 20% of the total number of cattle in South Africa (DoA, 2008). The possible effects (both direct and indirect) of climate change on dairy cattle in South Africa have not been thoroughly investigated. The aim of this study was to assess the impact of heat stress on dairy cows (cattle) productivity and reproduction, under projected future climate conditions.

MATERIALS AND METHODS

Climate modelling

Climate projections (scenarios) used in this study were the ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 General Circulation Models (GCMS) at A2 emissions scenarios, documented in Intergovernmental Panel on Climate Change 4th Assessment Report of 2007. The downscaled temperature values derived from the GCMs were extracted at station level. The extracted climate projections were for the following time periods

*Corresponding author. E-mail: David.Norris@ul.ac.za. Tel: 015 268 2376.

Present (1971 to 1990), Intermediate Future, (2046 to 2065) and more Distant Future (2081 to 2100).

Thermal heat stress model for livestock

In this study, heat stress on dairy cattle (Bos taurus) was assessed using a Thermal Heat Index equation (Yousef, 1985):

$THI = T_{db} + 036T_{dp} + 41.2$

Where,
THI = Thermal Heat Index
T_{db} = Dry Bulb Temperature (°C)
T_{dp} = Dew point Temperature (°C)

Daily temperature output generated from the ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCMs to project THI values at present (1971 to 1990), intermediate future (2046 to 2065) and distant future (2081 to 2100) climate conditions 21st century for South Africa. Dew point temperature (T_{dp}) was computed as follows:

$T_{dp} = -273.16 + \{273.16 + 2.0765. \ln(e_s/0.6108)/[1 - 0.0570. \ln(e_s/0.6108)]\}$

Where, T_{dp} is in °C

$e_s = 0.6108.\exp[17.2694T_d/(237.3 + T_d)]$

Where, e_s saturation vapour pressure at the air temperature T (kPa) and T air temperature (°C).

Since the aforementioned equation is non-linear, the mean saturation vapour pressure for a day was computed between saturation vapour pressure at the mean daily maximum and minimum air temperature as:

$e_s = [e°(T_{max}) + e°(T_{min})]/2$

Estimated saturation vapour pressure is related to air temperature. Threshold THI values for heat stress in dairy cows is ≈ 70 to 72 (St. Pierre et al. 2003). A heat stress index:

< 72 THI – No stress
72 to 78 THI – Mild stress
78 to 89 THI – Severe stress
89 to 98 THI – Very severe stress
> 98 THI – Death

Spatial representation

Climate station locations indicated in Figure 1 were used for extracting climate projections from the aforementioned GCMs. The climate stations were selected to represent the climate over South Africa. The THI were computed for each of climate station and spatial interpolated over the country using Inverse Distance Weighting techniques in ArcView 9.3.1.

RESULTS AND DISCUSSION

In Figure 2 ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCM projections of heat stress in dairy cattle for mean daily climate under present climate conditions generally indicate no stress over the study area. In the intermediate future climate all GCMs indicate a similar signal of mild stress likely to be experienced in cows along the North borders of South Africa, which extents further inland in the distant future climate conditions.

For maximum daily climate conditions heat stress indicated in Figure 3 across all projections under present climate conditions indicates that severe stress is likely to be experienced over most of the study area, with mild stress in the Eastern interior. In the intermediate future climate, severe stress is likely to be over the whole country, while in the distant future climate conditions, very severe stress is projected for parts of the northern to eastern borders and other parts of the study area.

As shown earlier, the ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCM projections of heat stress indicates likely mild stress along the Northern periphery and no stress over the rest of South Africa for mean conditions. According to Chase (2006), dairy cows under mild stress will adjust by seeking shade, increasing respiration rates and dilation of blood vessels. The effect on milk yield is expected to be minimal. This is a scenario that is expected for dairy cows along the Northern periphery of South Africa. For maximum daily conditions, heat stress projections indicate that over most of the country, severe stress will be experienced by dairy cattle with patches of very severe stress along the Northern periphery. Dairy cattle under severe stress will experience a reduction in milk productivity of about 10 to 25% and also a decline in their reproductive performance. The decline in milk production and reproduction responses to effects of projected heat stress will increase markedly under very severe stress. The projections of future climate on heat stress on dairy cattle suggests that climate change will have direct impact on the dairy industry by affecting the intensity and frequency of cattle heat stress and hence, will adversely affect both the milk production and reproduction. Potential cow deaths may also occur especially in the northern periphery. A number of studies by Mader and Davis (2004); Parsons et al. (2001) and Thornton et al. (2008) reported on declines in the levels of feed intake due to high temperature further exacerbating decline in milk yield. This will more likely be pronounced in the tropics. Increased energy deficits will lead to a reduction in cow fertility, fitness and longevity (King et al., 2005).

Conclusion

The management implications of livestock under heat stress might involve adoption of measures to minimize the effects on production. These measure range from low, moderate to high cost adaptation measures. For example, low cost measure might be reducing overcrowding and maximizing shade, moderate cost include use of sprinklers for cooling and improving ventilation and high cost measures include construction of new building design and installation of thermo controlled air conditioning (Wolfe et al., 2008).

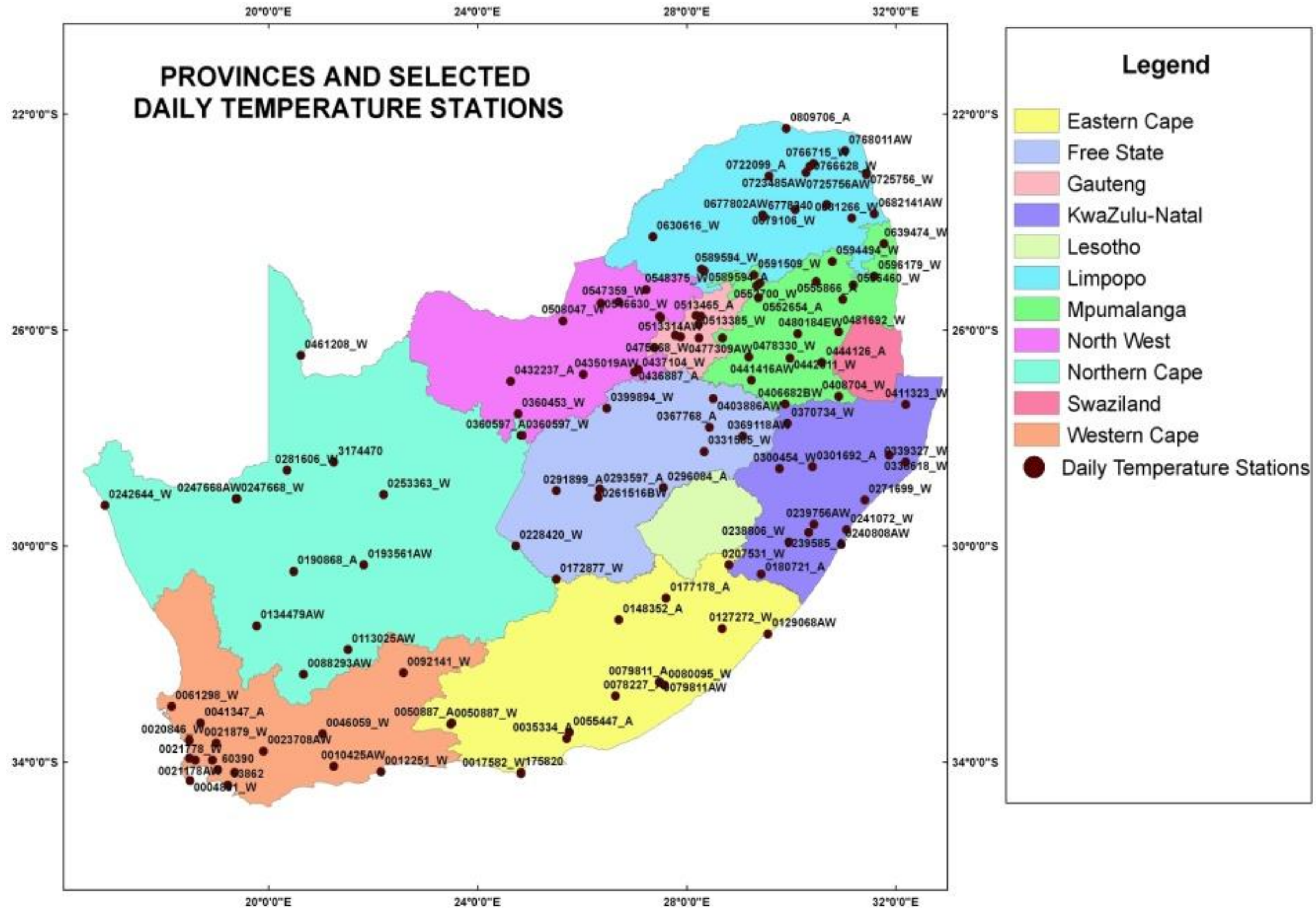

Figure 1. Study area's provinces and climate stations.

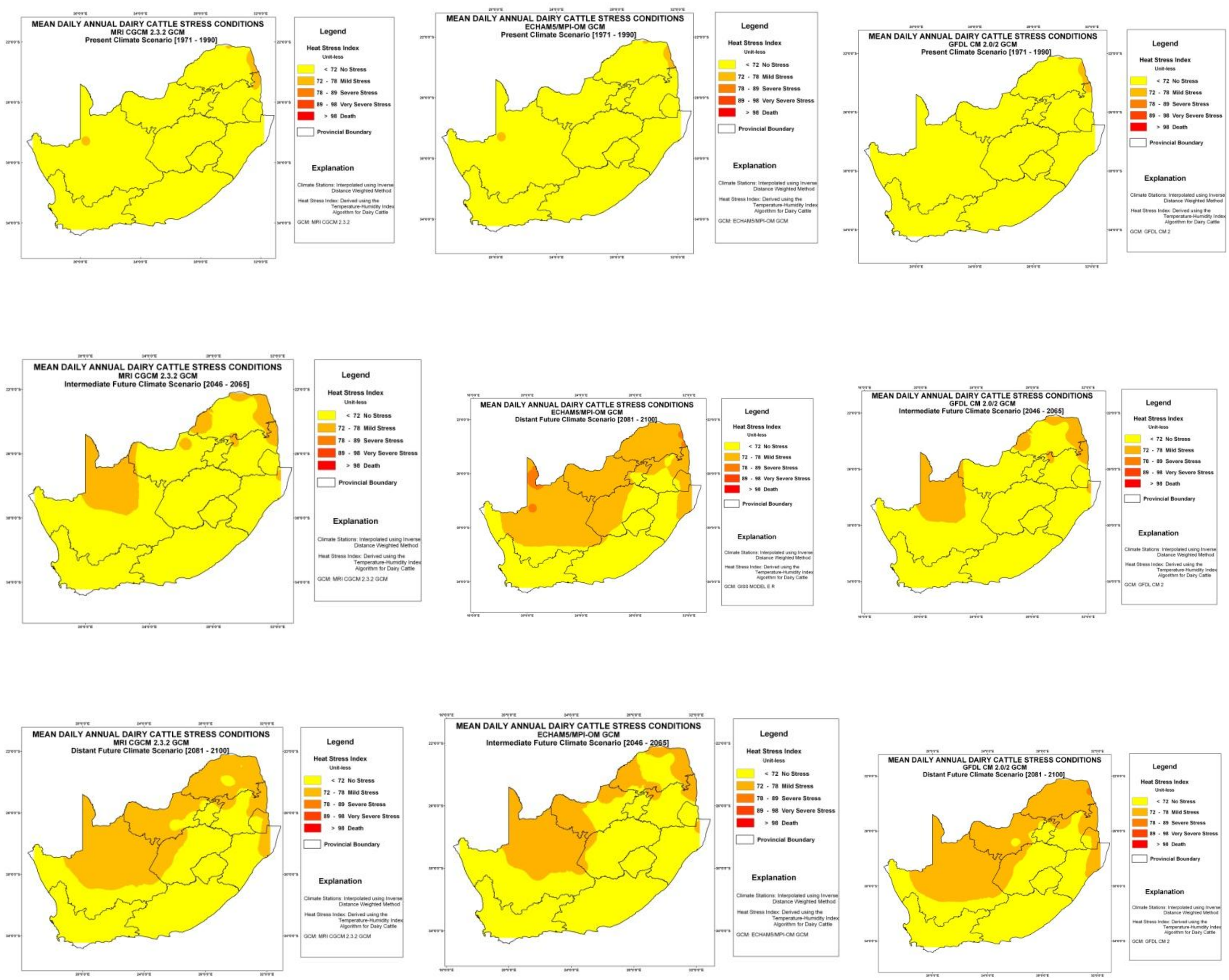

Figure 2. Mean annual thermal heat stress for dairy cattle for present climate conditions derived from MRI-CGCM2.3.2, ECHAM5/MPI-OM and GFDL-CM2.0/2.

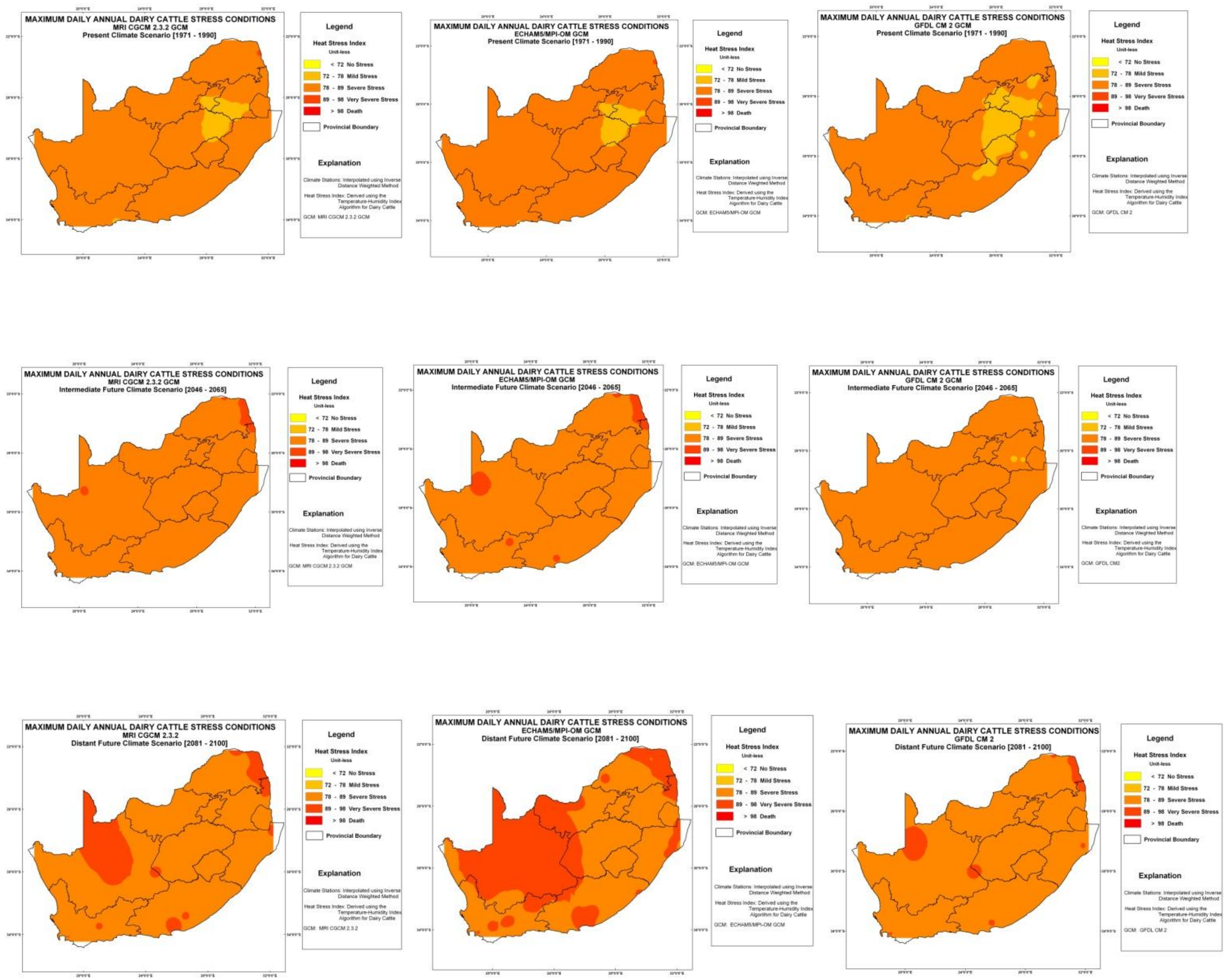

Figure 3. Maximum annual thermal heat stress for dairy cattle for present climate conditions derived from MRI-CGCM2.3.2, ECHAM5/MPI-OM and GFDL-CM2.0/2.

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REFERENCES

Chase LE (2006). Climate change impacts on dairy cattle. Fact sheet, Climate Change and Agriculture: Promoting Practical and Profitable Responses. Online at http://climateandfarming.org/pdfs/FactSheets/III.3Cattle.pdf.

DoA (2007). Department of Agriculture. Trends in the Agricultural Sector 2007. National Department of Agriculture, Pretoria, RSA.

Hahn GL (1999). Dynamic responses of cattle to thermal heat loads. J. Anim. Sci.77:10-20IPCC (Intergovermental Panel on Climate Change). 2007. Technical Paper on Climate Change and Water. Working Goup II. Cambridge University Press, Cambridge, UK. [Internet]. Available from: http:// www.ipcc.ch/meetings/session21. Accessed 22 August, 2008

King JM, Parsons DJ, Turnpenny JR, Nyangaga J, Bakari P, Wathes CM (2005). Ceiling to milk yield on Kenya smallholdings requires rethink of dairy development policy. British Society of Animal Science Annual Conference,York.

Klinedinst PL, Wilhite DA, Hahn GL, Hubbard KG (1993). The potential effects of climate change on summer season dairy cattle milk production and reproduction. Clim. Change, 23: 21-36.

Mader TL (2003). Environmental stress in confined beef cattle. J. Anim. Sci., 81 (suppl. 2): 110-119

Mader TL, Davis MS (2004). Effect of management strategies on reducing heat stress of feedlot cattle: feed and water intake. J. Anim. Sci., 82: 3077-3087.

Parsons DJ, Armstrong AC, Turnpenny JR, Matthews AM, Cooper K and Clark JA (2001). Integrated models of livestock systems for climate change studies.1. Grazing systems. Glob. Change Biol., 7: 93-112.

Thornton PK, van de Steeg J, Notenbaert A, Herrero M (2008). The livestock-climate poverty nexus: A discussion paper on ILRI research in relation to climate change. Discussion Paper No. 11. ILRI, PO Box 30709, Nairobi 00100, Kenya. p. 76.

Seo S, Mendelsohn R (2006). The impact of climate change on livestock management in Africa: A structural Ricardian analysis. CEEPA Discussion Paper No. 23, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

St. Pierre NR, Cobanov B, Schnitkey G (2003). Economic losses from heat stress by U.S. livestock industries. J. Dairy Sci., 86(Suppl): 52–77

Wolfe, DW, Ziska, L, Petzoldt C, Seaman A, Chase L, Hayhoe K (2008). Projected change in climate thresholds in the Northeastern U.S.: implications for crops, pests, livestock, and farmers. Mitig. Adapt Strat. Glob. Change, 13: 555–575.

Yousef MK (1985). Stress Physiology in Livestock. CRC Press, Boca. pp. 3-7