Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 25, No. (3) : 2023 : 439-447

ISSN-0972-3005

DOI No.: http://doi.org/10.53550/AJMBES.2023.v25i03.009

FACTORS INFLUENCING MILK PRODUCTION: AN EXPLORATORY STUDY OF KEY DRIVERS AND TRENDS

ALOK K. WANKAR[1*], SANDEEP N. RINDHE[*2], PRAKASH M. KEKAN[3], ALOK MISHRA[4], NANDKUMAR S. DOIJAD[5] AND AKHILESH SHEWALE[6]

[1,3]Department of Veterinary Physiology, College of Veterinary & Animal Sciences, (MAFSU), Parbhani 431 401 M.S., India
[2]Livestock Product Technology, College of Veterinary & Animal Sciences, (MAFSU), Parbhani 431402 M.S., India
[4]Department of Animal Husbandry and Dairy, BRD PG College, Deoria, UP, India
[5]National Institute of Pharmaceutical Education and Research (NIPER), Department of Pharmaceutical, Hyderabad 500 037, Telangana, India
[6]Department of Periodontology, Swargiya Dadasaheb Kalmegh, Smruti Dental College and Hospital, Nagpur 441 110, M.S., India

(Received 24 February, 2023; Accepted 12 April, 2023)

***Key words** : Milk production, Global warming, Dairy enterprise, Milk, Transiting dairying*

Abstract– In recent years, global warming associated climate change has led to sustained economic losses in US$ $ billions to dairy sector, globally. It is estimated that by 2050's the United States dairy industry alone will suffer more than $1.7 billion loss. As human dependency on animal products for nutrition is increasing, the urgency to maximize production is even greater. With the booming human population, there's additional constraint on available natural resources. High yielding animals are already under tremendous pressure making them more susceptible to adverse climatic conditions. When exposed to heat stress or lack of adequate nutrition livestock substantially decrease milk, meat or egg production. While, most of the researchers attempted to evaluate the impact of heat stress or other factors at a regional level, the impact of global warming, its interactions with other variables transiting dairying are yet to be clearly comprehended on a global scale. So, this exploratory study evaluated the effect of climate change, other key drivers and their interaction on milk production. Our results from hierarchical regression analyses have revealed that, environmental temperature, land availability and milk yield were the key factors influencing the milk production and dairy enterprise in turn.

INTRODUCTION

The United Nations (UN) has predicted a booming increase in human population by the year 2067 (UN 2017), and the demand for livestock products is also expected to double by 2050 (Rojas-Downing *et al.*, 2017). In the future, the demand for dairy products is expected to grow as, Food and Agricultural Organization (FAO) recommends daily consumption of dairy products for optimum health and nutrition (Speckmann *et al.,* 1981). Currently, agriculture and animal husbandry employs more than 1.3 billion people globally and contribute 40% of world GDP (Hurst *et al*., 2005).

Environmental temperatures have already increased by 1.5 °C and there are predictions of future increases between 0.3 to 4.8 °C by the end of the 21st century (IPCC, 2018). The impact of global warming will be direct as well as indirect on animal production systems, crop yield, soil fertility, pasture availability, water quality and quantity, vectors, pathogens, and parasites (Reynolds *et al.,* 2010).

Over the years, our understanding of the effects of heat stress on animal welfare, health, production and economics has grown immensely (Martinsohn *et al.,* 2012; Collier *et al.,* 2017; Wankar *et al.,* 2021). Animals exposed to heat stress show compromised growth, poor performance and milk yield (Mishra 2021; Wankar *et al.,* 2021). Numerous prediction models (AIM/CGE, DNE21+, ENVLinkages, GCAM,

([1]Assistant Prof., [2]Assistant Prof., [3]Prof., [4]Senior Research Fellow, [5]Scientist, [6]Faculty)

IMAGE, MESSAGE-GLOBIOM, POLES, REMIND) revealed deleterious consequences of global warming on the dairy sector as well as natural ecosystems, resulting in loss of billion of US $ (Mauger *et al.,* 2015; Harmsen *et al.,* 2019).

The dairy sector, to be sustainable and profitable here onwards, must upscale production and automation, improve animal potential, curb carbon footprint and greenhouse gas emissions (GHG's), respectively. A systematic comprehension of the environmental impact, livestock population, milk yield, natural resources, the gross domestic product (GDP) and GHG, etc. on dairying, is much needed today. So, scaling on the background, this paper will explore some correlations between total milk production with other variables like arable land, temperature and milk yield. Also, some futuristic trends for dairy enterprise will be explored.

MATERIALS AND METHODS

Data mining

Data for average temperature, cattle population, milk production, arable land, gross domestic product (GDP) and methane production for different continents, during the period 1961's to 2017's, was sourced from the FAOSTAT website (FAOSTAT 2020), and predictions were made for the two years, i.e., 2050's and 2100's. For forecasting, the Microsoft office excel FORECAST.ETS function, were used (Windows 16). Milk yield was only forecasted for the next 20 years, i.e., 2030's and 2040's, respectively, using the same program.

Statistical analysis

Data from the past, i.e., from 1971's to 2017's (n=46), were selected for multiple regression analysis using SPSS statistical software (SPSS 19.0). All the variables were checked for assumptions of normality, linearity, homoscedasticity, and multi-collinearity (Coakes, 2005) and finally three independent variables were selected for the regression analysis (arable land, temperature, and milk yield). Thereafter, a two-stage hierarchical regression model was constructed with total milk production as a dependent variable and at stage one, arable land and temperature were the main predictors, while milk yield was entered at stage two.

RESULTS

Africa

The hierarchical multiple regression revealed that at stage one [F (2, 44) = 78.80, P <.001, R^2 = .78], arable land and temperature contributed significantly and accounted for 85 % variance (Table 1). However, addition of milk yield didn't contribute significantly to the model ΔF (1, 43) = .51, P < .47, ΔR^2 = .002, at stage two.

It can be seen from the figures, that the Africa might be 2 to 3.5°C hotter by 2050's and 2100's, respectively (Figure 1). The total cattle population appears to grow, but the increase in milk production and milk yield seems negligible (Figures 2-4). Both GDP might and methane emission will increase by the end of the 21st century in Africa (Figures 5-6).

Americas

From Table 2, it can be seen that at stage one [F (1, 45) = 98.53, P < .001, R^2 = .68], temperature contributed significantly to the model accounting to 68 % of the variation. Similarly, milk yield resulted in 20 % variance at stage two (ΔF (1, 44) = 78.08, P < .001, ΔR^2 = .20).

In past, till the start of 20th century, the temperature in America only grew by 0.7°, but thereafter an increase of 3.5 °C was noted by the year

Table 1. Hierarchical regression analysis for Africa: milk production

Variable	B	β	t	sr²	*R*	*R²*	*Adjusted R²*	*ΔR²*
Stage 1					.92	.85	.84	.85
Arable land	180.86	.47	4.81***	.07				
Temperature	11774277.99	.49	5.03***	.08				
Stage 2					.92	.85	.84	.00
Arable land	185.65	.48	4.84***	.07				
Temperature	11956639.52	.50	5.05***	.08				
Milk yield	-4040.71	-.04	-.71	-.08				

Note: n=46, **p* <.05, ***p* <.01, ****p*<.001,
Stage 1 constant=-19154871.40, *Stage 2* constant=-12192903.74

2100 (Figure 1). A steady growth rate for cattle population, milk production, milk yield and a negative trend for the GDP can be seen from the Figures 2-5. Also, methane emissions might increase 2-3 times by the mid to end of the 21st century in the Americas (Figure 6).

Asia

At stage one, both arable land and temperature affected the regression model significantly, [F (2, 44) = 67.39, P < .001, R^2= .75] and accounted for 75 % total observed variance (Table 3). Further, milk yield at stage two accounted for an additional 24 % of the variance (P < .001).

In Asia, average environmental temperatures might rise up to 3.5 °C by end of 21st century (Figure 1). Both the cattle population and milk production appears to grow, simultaneously, still, there's no

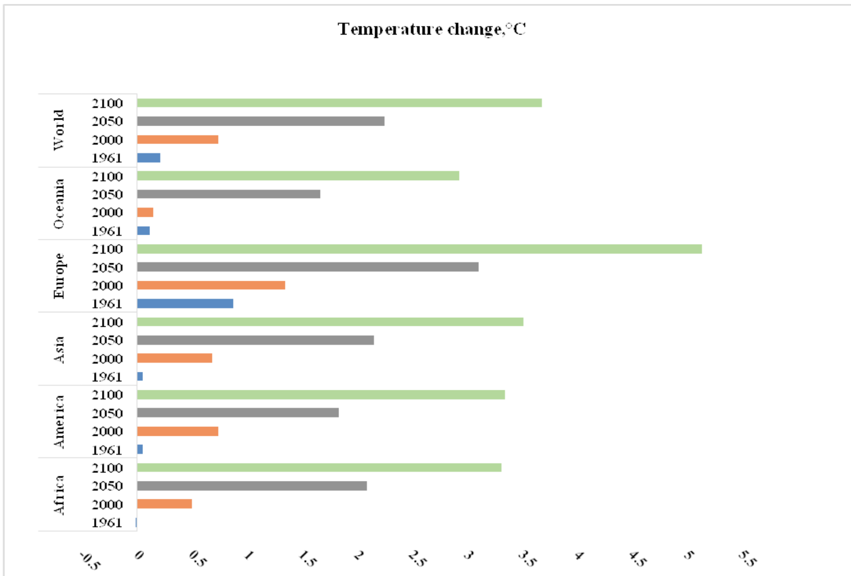

Fig. 1. Ambient temperature change over the continents

Table 2. Hierarchical regression analysis for Americas: milk production

Variable	B	β	t	sr²	R	R^2	Adjusted R^2	ΔR^2
Stage 1					.82	.68	.68	.68
Temperature	50775437.28	.82	9.92***	.68				
Stage 2					.94	.88	.88	.20
Temperature	21311931.59	.34	4.67***	.05				
Milk yield	6517.24	.65	8.83***	.20				

Note: n=46, *p <.05, **p <.01, ***p<.001, variable arable land didn't met all the regression assumptions, hence not included for America
Stage 1 constant=102418101.59, *Stage 2* constant=-34744083.60

Table 3. Hierarchical regression analysis for Asia: milk production

Variable	B	β	t	sr²	R	R^2	Adjusted R^2	ΔR^2
Stage 1					.86	.75	.74	.75
Arable land	564.83	.18	1.85	.01				
Temperature	127180376.60	.74	7.65***	.32				
Stage 2					.99	.99	.99	.24
Arable land	-159.72	-.05	-3.05**	-.07				
Temperature	3322119.39	.01	.82	.00				
Milk yield	55077.51	1.01	40.68***	.24				

Note: n=46, *p <.05, **p <.01, ***p<.001,
Stage 1 constant=-189593486.008, *Stage 2* constant=-60938454.956

notable increase for milk (Figures 2-4). A robust negative trend with time is seen for gross domestic product, while average methane emission might, double by the turn of 21st century (Figures 5-6).

Europe

For model one, [F (2, 44) = 78.80, P < .001, R^2 = .78], both temperature and arable land accounted for significant 78 % change. While at stage two [ΔF (1, 43) = 15.46, P < .001, ΔR^2 = .05], milk yield added another 5 % variance (Table 4).

Drastic changes in ambient temperature are evident for Europe (Figure 1), as high 5°C. It is interesting that to note that, while milk yield and milk production show an increasing trend, the cattle population will decline (Figures 2-4). The forecast show a decreasing pattern for both GDP and methane emission (Figures 5-6).

Oceania

It was evident from Table 5 that, arable land and temperature had significant impact at stage one [F

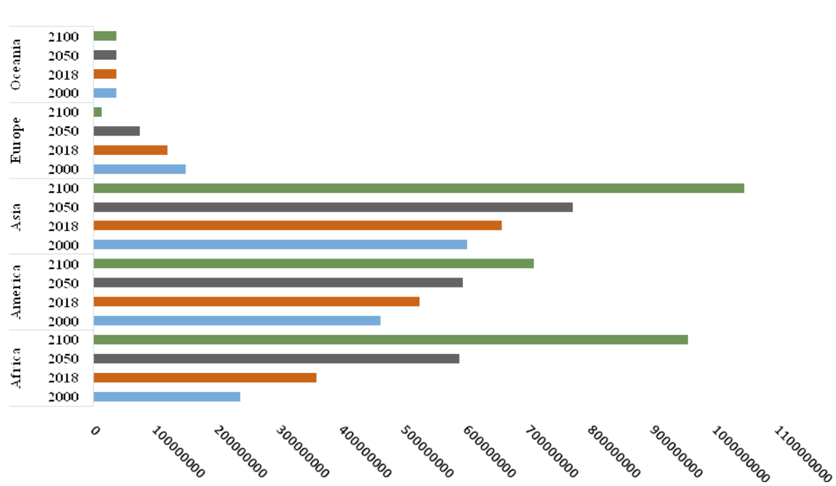

Fig. 2. Dairy cattle population for different continents

Table 4. Hierarchical regression analysis for Europe: milk production

Variable	B	β	t	sr^2	*R*	R^2	*Adjusted* R^2	ΔR^2
Stage 1					.88	.78	.77	.78
Arable land	751.83	1.01	9.59***	.45				
Temperature	6549993.09	.18	1.78	.01				
Stage 2					.91	.83	.82	.05
Arable land	921.00	1.24	11.44***	.48				
Temperature	1010633.13	.02	.29	.00				
Milk yield	3318.32	.43	3.93***	.05				

Note: n=46, *p <.05, **p <.01, ***p<.001,
Stage 1 constant=-7691183.20, *Stage 2* constant=-130162234.36

Table 5. Hierarchical regression analysis for Oceania: milk production

Variable	B	β	t	sr^2	*R*	R^2	*Adjusted* R^2	ΔR^2
Stage 1					.79	.62	.60	.62
Arable land	897.54	.62	5.75***	.04				
Temperature	4234527.94	.25	2.36*	.28				
Stage 2					.90	.82	.81	.02
Arable land	214.36	.14	1.47	.00				
Temperature	281826.78	.01	.20	.00				
Milk yield	861.01	.77	7.03***	.19				

Note: n=46, *p <.05, **p <.01, ***p<.001,
Stage 1 constant=-3817600.49, *Stage 2* constant=-16887874.27

(2, 44) = 36.86, $P < .001$, $R^2 = .62$] and resulted in 62 % variance. Similarly, the addition of milk yield at stage two [ΔF (1, 43) = 49.43, P< .001, $\Delta R^2 = .20$] resulted in another 20 % of change.

In Oceania, temperatures rise by over 3.5 °C are seen (Figure 1). Although the cattle population doesn't show any notable growth, total milk production and milk yield show a positive growth trend (Figure 2-4). Total methane emissions seem to rise, while GDP shows a negative growth rate (Figures 5 and 6).

DISCUSSION

Our findings indicate that arable land and temperature appears to be significant predictors for total milk produced, while milk yield/animal significantly adds to the prediction model. Earlier, Smith *et al*. (1968) had demonstrated the effect of environmental variables and their correlations with milk yield. Currently, 70 % of total arable land is utilized for the livestock sector and feed production (FAO 2009). The multiple regression analyses have been previously used with success, for forecasting milk yield (Dongre *et al.*, 2012). Additionally, the impact of and heat stress on milk production, milk yield, and milk components is thoroughly studied (Wheelock *et al.*, 2010; Bernabucci *et al.*, 2015; Mishra, 2021; Wankar *et al.*, 2021). The findings of present research are thus corroborated by previous works, confirming arable land and environmental temperatures as the major factors influencing the dairy sector (Dongre *et al.*, 2012; Wankar *et al.*, 2021)

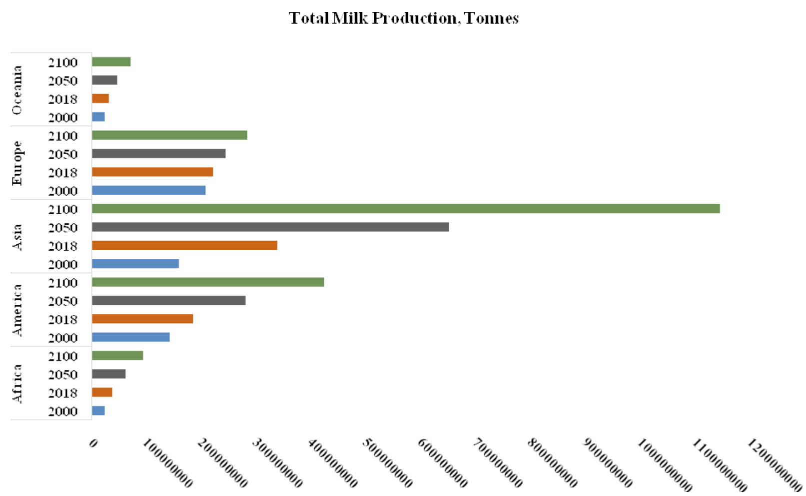

Fig. 3. Continent wise milk production

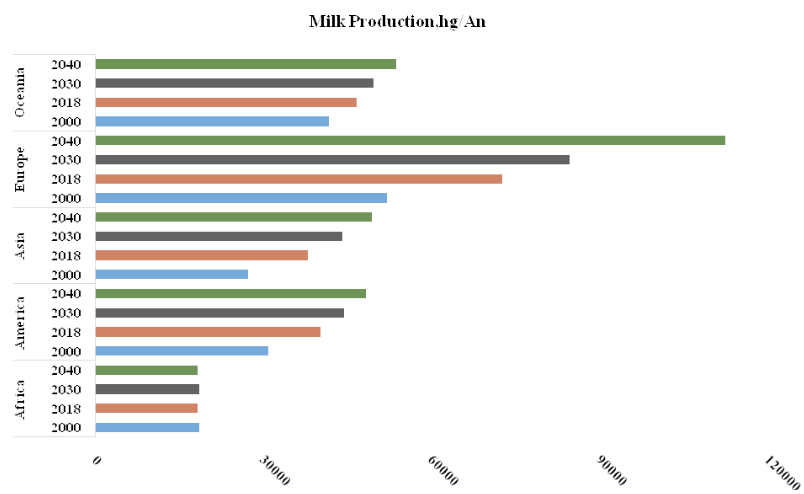

Fig. 4. Milk yield/animal for different continents

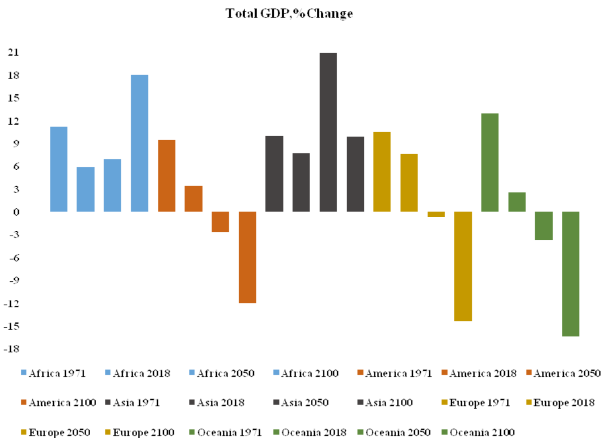

Fig. 5. Average GDP transition for continents

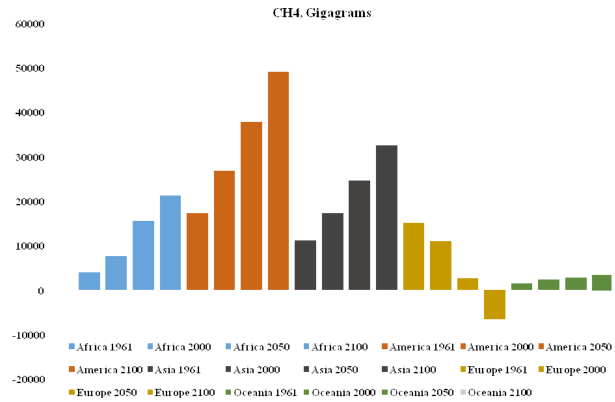

Fig. 6. Average methane emission over different continents

Dairy sector: Africa

Reports suggest that as the environmental temperature rise here, rearing beef cattle or goats increases while dairy animals drops (Seo and Mendelsohn, 2006). Dairy sector in Africa is mainly unorganized and dependant on environmental conditions, making it susceptible to adverse climate changes (Griffin, 2012; Nkondze *et al.*, 2013).

Despite dependability on environmental conditions, the milk production in Africa increased by 3.6 % p.a, during the years 2005-2015, making Africa one of the fasters developing dairy nations (FAO and GDP 2018). Africa is a continent with rich untapped natural resources and production intensification, automation, dairy breeds with low methane output will be pertinent for dairy enterprises, in future.

Dairy sector: Americas

In Americas and the heat stress associated economic losses sustained by the dairy sector are escalating with time; $ 897-1,500 million (St-Pierre *et al.*, 2003), $ 800 million (Ziggers 2012), $1.2 billion (Key *et al.*, 2014), respectively. Further, predictions models estimate decline in milk production by 1.4 kg/day and 1.9 kg/day and losses of $1.7 billion and $2.2 billion by the years 2050's and 2080's, respectively (Mauger *et al.*, 2015).

During, 2009–2018 dairy cattle decreased by nearly one % and so did the farms by an alarming 31 %, but total milk production still increased by 13 %, owed mainly to superior dairy breeds (Census of Agriculture, 2017; Kilgannon and Eid, 2018). Considering the American scenario, with time introduction of climate-resilient dairy breeds, reduction in GHG's and a transition from intensive to semi-intensive or pasture system will be more productive for sustainability (Crosson *et al.*, 2011; O'Brien *et al.*, 2012).

Dairy sector: Asia

In Asia 87 % dairy farms are not intensive but are either small or mixed types, making the dairy enterprise more dependent and susceptible to climatic variations (Nagayets, 2005; Devendra *et al.* 2010). However, Asia still witnessed an 11 % growth in cattle population during the period, 2005 to 2015, resulting in 4.5 % growth in the dairy sector in the last decade (FAO and GDP, 2018).

Majority of milk comes from developing Asiatic nations (> 75 %) but, less milk yield than American or European cows, is currently the major constraint here (Kaur and Arora, 1982; Tailor and Nagda, 2005). Agriculture and animal husbandry employs, nearly 60 % of the population here, contributing more than 25 % to the GDP and the expansion of dairy can be limitless, as most of the cattle breeds are very well adapted and are naturally thermotolerant (Devendra, 2012).

Dairy sector: Europe

European nations have always been major exporter of milk and milk products and the abolishment of the milk quota system since 2015 opened trading opportunities for all E.U. nations, alike (EUROSTAT 2015). But, the effect of global warming is much more evident in Europe and there's an increase in both length and intensity of summer days, profoundly affecting the pasture-based dairy husbandry and agriculture sector (Gauly *et al.*, 2012).

Although the, high yielding European cattle are well adapted to cold environmental conditions, the transitional climate change and global warming might be a major performance constraint in future (Collier *et al*., 2017). Further it is predicted that, both the major and minor dairy nations of EU will have to bear sustained economic losses attributed to global warming (IPCC, 2014, Bórawski *et al.,* 2020).

Dairy sector: Oceania

Australia and New Zealand are the two leading global exporters of milk and milk products and the dairy enterprise here is, organised extensively (pasture-based) and intensively. Australian agency, Commonwealth Scientific and Industrial Research Organization (CSIRO) has already predicted heat stress associated losses between 35-85 liters and 85-330 liters, by the years 2025's and 2050's, respectively, for dairy sector (Hennessy *et al.,* 2016).

Similarly, dairy enterprise in New Zealand, accounting for more than 25% of national exports (MAF, 2008; MPI, 2014) will also be negatively impacted due to global warming phenomenon (Osei-Amponsah *et al.,* 2020). Decline in total milk production between 2.8 to 4.3 %, cutting down the revenue exports is expected due to poor animal performance under climate change (Baisden *et al*., 2010; Kalaugher, 2013).

Final considerations and conclusion

The impact of global warming might be diversified over different continents, and E.U., Americas, and Oceania, having high production cattle breeds and adapted to cold conditions will be more susceptible. On the other hand tropical regions like Africa and Asia, harboring thermotolerant cattle breeds can become world leaders and exporters, replacing E.U., Australia, New Zealand, and the Americas soon, if the production potential is maximized.

On a continental scale, nations with superior well adapted dairy stock, abundant natural resources and friendly trade policies will rise as dairy giants, under climate change scenario. Our research identified potent drivers like environmental temperature, arable land and milk yield which influence the milk production. In future, these variables can be focused upon for maximizing milk production for a sustainable, clean and profitable dairy enterprise.

ACKNOWLEDGEMENTS

Authors declare sincere acknowledgment to FAOSTAT for their open access policy

Authors' contributions AKW and SNR conceptualized the research; PMK and AM conducted the literature search, analysis of data; AKW and NSD prepared of drafts; AKW and AS did editing and finalization of manuscript.

Compliance with ethical standards Not required

Conflict of interest The authors declare that they have no conflict of interest

Data Availability The data can be accessed at FAOSTAT.com

REFERENCES

Baisden, W.T., Keller, E.D., Timar, L., Smeaton, D., Clark, A.J., Ausseil, A., Power, W. and Zhang, W. 2010. New Zealand's Pasture Production in 2020 & 2050. GNS Science Consultancy Report, 2010/154, 65

Bernabucci, U., Basiricò, L., Morera, P., Dipasquale, D., Vitali, A., Piccioli Cappelli, F. and Calamari, L. 2015. Effect of summer season on milk protein fractions in Holstein cows. *Journal of Dairy Science*. 98: 1815–1827. doi:10.3168/jds.2014-8788

Bórawski, P., Pawlewicz, A., Parzonko, A., Harper, J.K. and Holden, L. 2020. Factors Shaping Cow's Milk Production in the E.U. *Sustainability.* 12: 420 https://doi.org/10.3390/su12010420

Census of Agriculture, 2017. Census Publications-Ranking of Market Value of Ag Products Sold, New York. https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Rankings_of_Market_Value/New_York/index.php

Coakes, S. 2005. SPSS: Analysis without Anguish. 1st ed. Milton, Qld.: Wiley Australia

Collier, R.J., Renquist, B.J. and Xiao, Y. 2017. A 100-year review: stress physiology including heat stress. *Journal of Dairy Science.* 100: 10367–10380. doi:10.3168/jds.2017-13676

Crosson, P., Shalloo, L., O'Brien, D., Laniganc, G.J., Foley, P.A., Bol, T.M. and Kenny, D.A. 2011. A review of whole farm systems models of greenhouse gas emissions from beef & dairy cattle production systems. *Animal Feed Science and Technology*. 166: 29–45. http://dx.doi. org/10.1016/j.anifeedsci.2011.04.001

Devendra, C., Swanapoel, F.J.C., Strobel, A. and van Rooyen, 2010. Implications and innovative strategies for enhancing th future contribution of livestock', In : *The Role of Livestock in Developing Communities: Enhancing Multifunctionality,* eds F.J. Swanapoe, A. Strobel and M. Shibonisao, University of Free State, Bloemfontein, S. Africa.

Devendra, C. 2012. Climate Change Threats and Effects: Challenges for Agriculture & Food Security. ASM Series on Climate Change. Academy of Sciences Malaysia.

Dongre, V.B., Gandhi, R.S., Singh, A. and Ruhil, A.P. 2012. Comparative efficiency of artificial neural networks

& multiple linear regression analysis for prediction of first lactation 305-day milk yield in Sahiwal cattle. *Livestock Science.* 147(1–3): 192–197.

EUROSTAT, 2015. Archive: Milk & Milk Products—30 Years of Quotas. https://ec.europa.eu/eurostat/statisticsexplained/index.php/Archive:Milk_&milk_products_-_30_years_of_quotas

FAO & GDP, 2018. Climate Change & the Global Dairy Cattle Sector-The Role of the Dairy Sector in a Low-Carbon Future; Food & Agriculture Organization of the United Nations & Global Dairy Platform Inc.: Rome, Rome, Italy, 2018. Available online: http://www.fao.org/3/CA2929EN/ca2929en.pdf

FAO (Food and Agriculture Organization), 2009. The state of food & agriculture. Livestock in balance. FAO, Rome.

FAOSTAT, 2020. Agricultural production database. Food & Agricultural Organization. http://www.apps.fao.org

Gauly, M., Bollwein, H., Breves, G., Bru Gemann, K., Da Nicke, S., Das, G., Demeler, J., Hansen, H., Isselstein, J., Ko Nig, S., Loho lter, M., Martinsohn, M. and Meyer, U. 2012. Future consequences & challenges for dairy cow production systems arising from climate change in Central Europe – a review. *Animals.* 1 – 17. doi:10.1017/S1751731112002352

Griffin, J. 2012. The Impact of Climate Change on South Africa. Climate Emergency Institute http://www.climateemergencyinstitute.com

Harmsen, M., Van Vauren, D.P., Bodirsky, B.L., Chateau, J., Durr-Lasserve, O., Drouet, L., Fricko, O. and Fujimori, S. 2019. The role of methane in future climate strategies: mitigation potentials and climate impact. *Climate Change.* https:/doi.org/10/1007/s10584-019-02437-2.

Hennessy, K., Clarke, J., Erwin, T., Wilson, L. and Heady, C. 2016. Climate change impacts on Australia's dairy regions. CSIRO Oceans & Atmosphere, Melbourne, Australia

Hurst, P., Termine, P. and Karl, M. 2005. Agricultural workers and their contribution to sustainable agriculture and rural development. FAO, Rome ftp://ftp.fao.org/docrep/fao/008/af164e/af164e00.pdf

IPCC (Intergovernmental Panel on Climate Change), 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II & III to the Fifth Assessment Report of the IPCC, Geneva, Switzerland, 151

IPCC (Intergovernmental Panel on Climate Change), 2018. 2018- special report: global warming of 1.5 ˚C & Climate change synthesis report

Kalaugher, E., Bornman, J.F., Clark, A. and Beukes, P. 2013. An integrated biophysical and socio-economic framework for analysis of climate change adaptation strategies: The case of a New Zealand dairy farming system. *Environmental Modelling and Software.* 39: 176-187

Kaur, H. and Arora, S.P. 1982. Influence of level of nutrition & season on the oestrus cycle rhythm & on fertility in buffaloes. *Journal of Tropical Agriculture.* 59(4),274–278

Key, N., Sneeringer, S. and Marquardt, D. 2014. Climate change, heat stress and U.S. dairy production. A Report Summary from the Economic Research Service, United States Department of Agriculture. http://www.ers.usda.gov/ media/1679930/err175.pdf

Kilgannon, C. and Eid, K. 2018. When the Death of a Family Farm Leads to Suicide. The New York Times, 19 March 2018

MAF (Ministry of Agriculture and Forestry), 2008. Situation & Outlook for New Zeal& Agriculture & Forestry (August 2008). http://www.maf.govt.nz/mafnet/rural-nz/statistics-&-forecasts/sonzaf/2008/page- 19.htm

Martinsohn, M., Hansen, H., von Thünen-Institut, J.H. and Braunschweig, 2012. The Impact of Climate Change on the Economics of Dairy Farming – a Review and Evaluation. *German Journal of Agricultural Economics*. 61(2): 80-95.

Mauger, G., Bauman, Y., Nennich, T. and Salathé, E. 2015. Impacts of Climate Change on Milk Production in the United States. *The Professional Geographer.* 121-131.

Mishra, S.R. 2021. Thermoregulatory responses in riverine buffaloes against heat stress: An updated review. *Journal of Thermal Biology*. 96: 102844. https://doi.org/10.1016/j.jtherbio.2021.102844.

MPI (Ministry for Primary Industries), 2014. Situation & Outlook for Primary Industries 2014. Ministry for Primary Industries, Wellington

Nagayets, O. 2005. Small farms: current status & key trends. In: *Proceedings, Future of Small Farms*, International Food Policy Research Institute, Washington, D.C., USA

Nkondze, M.S., Masuku, M.B. and Manyatsi, A.M. 2013. The Impact of Climate Change on Livestock Production in Swazil land. The case of Mpolonjeni Area Development Programme. *Journal of Agricultural Studies*. 2(1): 1-15

O'Brien, D., Shalloo, L., Patton, J., Buckley, F., Grainger, C. and Wallace, M. 2012. A life cycle assessment of seasonal grass-based and confinement dairy farms. *Agricultural Systems.* 107: 33–46.

Osei-Amponsah, R., Dunshea, F.R., Leury, B.J., Cheng, L., Cullen, B., Joy, A., Abhijith, A., Zhang, M.H. and Chauhan, S.S. 2020. Heat Stress Impacts on Lactating Cows Grazing Australian Summer Pastures on an Automatic Robotic Dairy. *Animals.* 10(869): 1-12. doi:10.3390/ani10050869.

Reynolds, C., Crompton, L. and Mills, J. 2010. Livestock and climate change impacts in the developing world. *Outlook on Agriculture.* 39(4): 245–248

Rojas-Downing, M., Melissa, A., Nejadhashemi, P., Harrigan, T. and Woznicki, S.A. 2017. Climate Change and Livestock: Impacts, Adaptation, and Mitigation. *Climate Risk Management*. 16: 145-63. https://doi.org/10.1016/j.crm.2017.02.001

Seo, S.N. and 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 & Policy in Africa, University of Pretoria.

Speckmann, E.W., Brink, M. and McBean, L.D. 1981. Dairy foods in nutrition & health. *Journal of Dairy Science.* 64(6): 1008-101.6

St. Pierre, N.R., Cobanov, B. and Schnitkey, G. 2003. Economic losses from heat stress by U.S. livestock industries. *Journal of Dairy Science*. 86: (E Suppl.) https://doi.org/10.3168/jds.S0022-0302 (03)74040-5

Tailor, S.P. and Nagda, R.K. 2005. Conception rate in buffaloes maintained under subhumid climate of Rajasthan. *Indian Journal of Dairy Science*. 58(1): 69–70

United Nations, 2017. Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision. https://esa.un.org/unpd/wpp/Download/St&ard/Populations.

Wankar, A.K., Rindhe, S.N. and Doijad, N.S. 2021. Review-Heat stress in dairy animals and current milk production trends, economics, and future perspectives: the global scenario. *Tropical Animal Health & Production.* 53: 70. DOI: 10.1007/s11250-020-02541-x

Wheelock, J.B., Rhoads, R.P., Vanbaale, M.J., Saers, S. R. and Baumgard, L.H. 2010. Effects of heat stress on energetic metabolism in lactating holstein cows. *Journal of Dairy Science*. 93: 644–655. doi:10.3168/jds.2009-2295

Ziggers, D. 2012. Heat stress in dairy cows review. *All About Feed. Net.* 20: 26-27.