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CLIIMATE CHANGE AND LIVESTOCK PRODUCTION

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Abstract. The assessment of the climate change impact on livestock sector was made based on projections of changes in temperature received by regionalization of global experiments the most reliable for the Republic of Moldova (RoM) CMIP6 22 GCMs introduced by three Socio-Economic Pathways (SSPs): SSP1-2.6, SSP2-4.5, and SSP5-8.5, and projections of changes in productivity of main cereal crops (winter wheat and grain corn). To assess the livestock production vulnerability to climate change by categories, it was used the empirical-statistical approach, linking fluctuations of livestock production to climate conditions during the 1981-2010 observed time period. Using the multiple regression equations relationship in the livestock production variability by categories with projections of changes in temperature and productivity of main cereal crops, there were calculated the future projections of livestock production changes in the RoM (%/20 years) by 2040, 2060 and 2100, relative to 2000-2019 reference time period.

Key-words: climate change, impact, livestock, production

Introduction. Climate change are increase heat stress in livestock and affect productivity [1-4]. Under SSP5-8.5 scenario to mid-century, land suitability for livestock production will decrease because of increased heat stress prevalence in mid and lower latitudes [5].

Most domestic livestock have comfort zones in the range 10-30°C, depending on species and breed [6]. At higher temperatures, animals eat 3–5% less per additional degree of temperature, reducing their productivity and fertility. Heat stress suppresses the immune and endocrine system, enhancing susceptibility of the animal to disease [1]. Heat effects on productivity have been summarised for pigs [7], sheep and goats [8], and cattle [9]. The direct effects of higher temperatures on the smaller ruminants (sheep and goats) are relatively muted, compared with large ruminants; goats are better able to cope with multiple stressors than sheep [8].

The purpose of our study was to (i) examine the historical observed trends in livestock production by categories during three observation periods: a) 1965-1990, b) 1991-2020), c) 2000-2022, based on livestock production statistical data at the RoM's agricultural enterprises of various categories, and (ii) calculate possible projections of future changes in livestock production by categories for 2021-2040, 2041–2060 and 2081–2100 time periods, based on the projected changes in summer temperatures and main cereal crops yield, received from CMIP6 multi-model ensemble of 22 GCMs introduced by three Socio-Economic Pathways (SSPs): SSP1-2.6, SSP2-4.5, and SSP5-8.5. The milk, eggs, wool, beef, pork, mutton and poultry production were considered in this study in order to analyze the livestock production specific interactions between the changing climate and future feed-grain availability.

Data and methods. The assessment of the climate change impact on livestock sector was made based on projections of changes in temperature received by regionalization of global experiments the most reliable in the Republic of Moldova CMIP6 22 GCMs introduced by three Socio-Economic Pathways (SSPs): SSP1-2.6, SSP2-4.5, and SSP5-8.5 and projections of changes in productivity of main cereal crops (*winter wheat and grain corn*) in the RoM, [4].

To assess the livestock production vulnerability to climate change by categories, it was used the empirical-statistical approach, linking fluctuations of livestock production to climate conditions during the 1981-2010 observed time period. The temperature and crop predictor variables were selected in conformity with step-by-step regression analysis, taking into account their contribution to livestock production by categories, and consecutive analysis of all possible combinations, with the purpose to find the most reliable model [10].

Using the multiple regression equations relationship in the livestock production variability by categories with projections of changes in temperature and productivity of main cereal crops, there were calculated the future projections of livestock production changes in the RoM (%/20 years) for the near term by 2040 (2021–2040), mid-term by 2060 (2041–2060), and long term by 2100 (2081–2100), according to CMIP6 Ensemble of 22 GCMs introduced by three Socio-Economic Pathways (SSPs): SSP1-2.6, SSP2-4.5 and SSP5-8.5, relative to reference time period (2000-2019).

Results and discussions. The linear trends of variability in production of main livestock products at all categories of producers in the RoM for years 1965-1990 have been characterized by a sustainable increase of the livestock production: by 355.2 kt per decade for milk; by 311 million pieces per decade for eggs; by 33.2 kt per decade for pork; by 26.9 kt per decade for beef; and by 20.3 kt per decade for poultry. Negative trend was observed only for wool production, by 173.4 t per decade, (**Table 1; Figure 1**).

Livestock production increased significantly due to the implementation of intensive technologies of animal growing in the 1981-1990 time periods, achieving the maximum average annual level: for milk – 1359.22 kt; eggs – 1051.2 million pieces; wool – 2761.9 tons; pork – 147.4 kt; beef– 94.3 kt; and poultry – 55.4 kt.

Table 1. Linear trends of livestock production and their statistical significance (p-value) for three observation time periods (1965-1990, 1991-2020 and 2000-2022) in the RoM

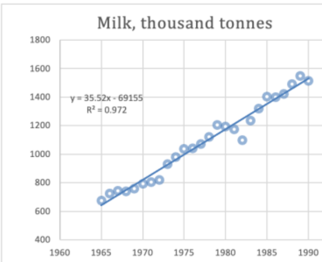
Li vestock product ion	*1965-1990*		*1991-2020*		*2000-2022*	
	ren d	*- valu e*	*ren d*	*- valu e*	*ren d*	*- valu e*
M ilk, kt	5.5 2	**.000 0**	19. 12	**.000 0**	14. 82	**.000 0**
E ggs, ml pieces	1.1 1	**.000 0**	1.5 1	.554 6	0.9 3	.608 5
W ool, t	17. 34	**.037 8**	38. 37	**.000 0**	30. 37	**.000 0**
B eef, kt	.69 3	**.000 0**	3.2 2	**.000 0**	0.7 9	**.000 0**
P						

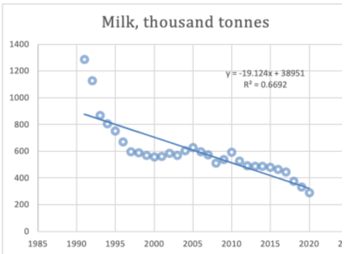
Li vestock product ion	***1965-1990***		***1991-2020***		***2000-2022***	
	ren d	***- valu e***	***ren d***	***- valu e***	***ren d***	***- valu e***
ork, kt	.32 0	**.000 0**	0.6 9	.256 8	1.6 1	**.000 0**
M utton, kt	.00 9	.577 6	0.2 2	**.000 0**	0.1 4	**.000 0**
P oultry, kt	.02 9	**.000 0**	1.2 0	**.000 2**	1.8 4	**.000 0**

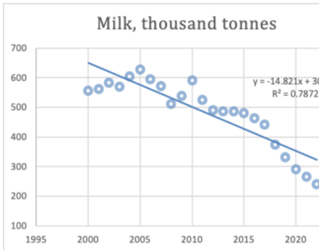
Note: Bold is used to mark statistically significant values.

Then, in the forthcoming decades (1991-2020) there was a tendency for sharp decrease in livestock production: by 191.2 kt per decade for milk, by 383.7 tons per decade for wool, by 32.2 kt per decade for beef, and by 2.2 kt per decade for mutton and goat, at the same time was been observed a slight increase by 12 kt per decade for poultry.

The greatest decrease in the annual average livestock production was observed in the 2001 – 2010 years: for milk – 600.4 kt; wool – 2071.1 tons; pork – 45.4 kt; beef – 14.2 kt; mutton – 2.4 kt and in the 1991-2000 years for eggs – 583.9 million pieces; and poultry – 23.9 kt, (**Table 1**; **Figure 1**).







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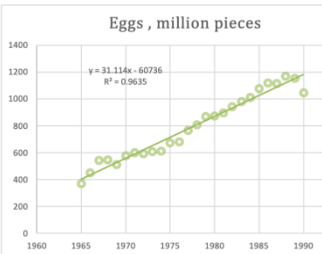

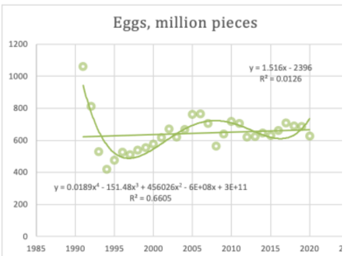

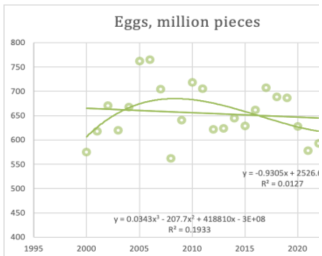

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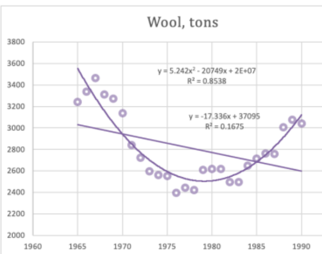

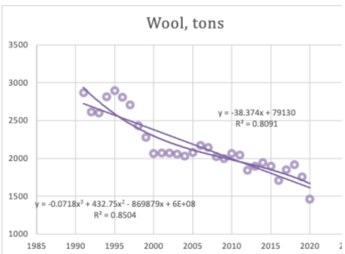

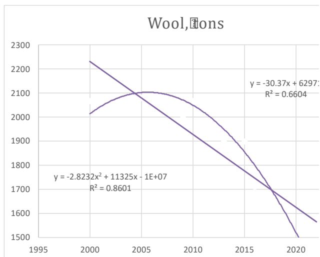

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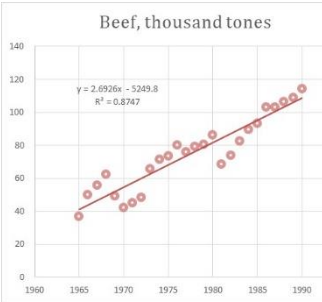

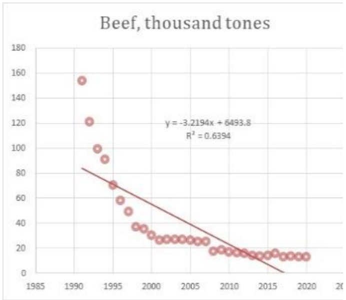

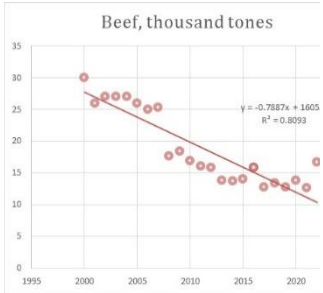

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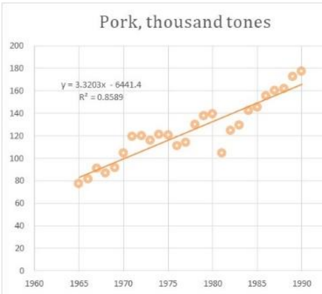

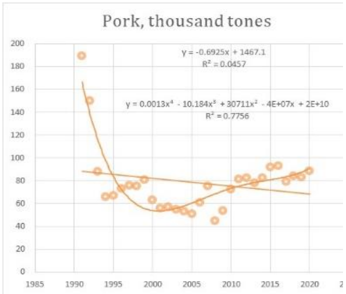

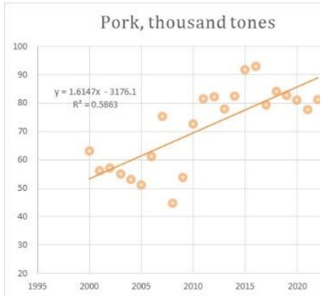

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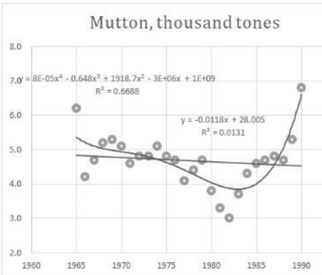

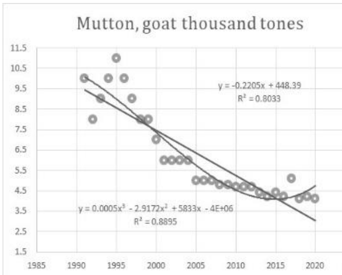

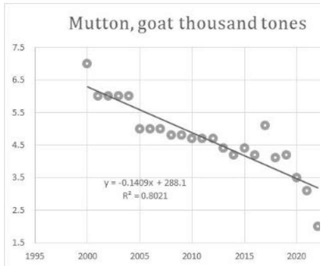

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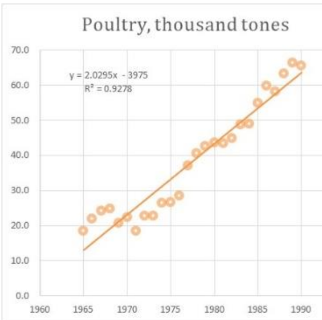
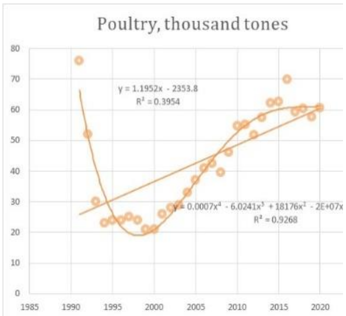
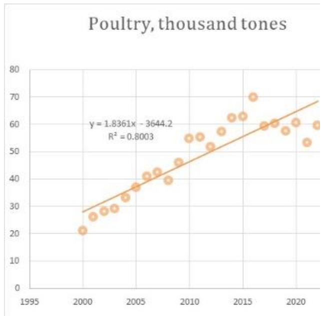






A) B) C)

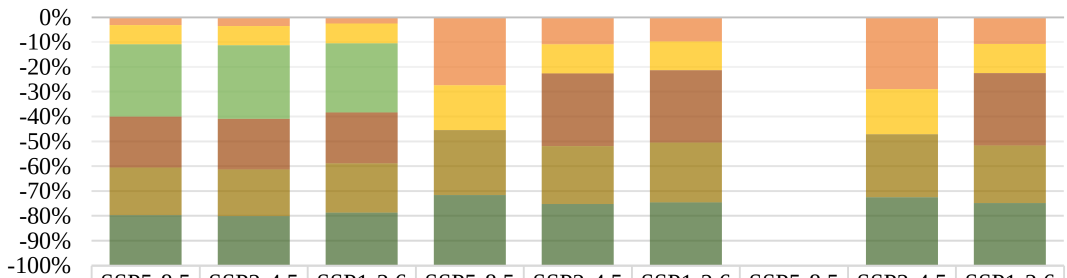
Figure 1: Livestock production variability trends and their coefficients of determination (R^2) for three observation periods: A) 1965-1990, B) 1991-2020), C) 2000-2022 in the RoM

However, in the last years (2000-2022) there was observed a tendency for statistically significant increase in some livestock production: by 16.1 kt per decade for pork, and by 18.4 kt per decade for poultry (**Table 1**; **Figure 1**).

Recent studies project the considerable increases in the number of "extreme stress" days per year for cattle, chicken, goat, pig and sheep populations with SSP5-8.5 scenario, and lower with SSP1-2.6, [3-5].

Pigs are projected to be particularly affected in the mid-latitudes of Europe, East Asia, and North America [11], estimated that global warming of 1.5°C and 2°C may exceed limits for normal thermo-regulation of livestock animals and result in persistent heat stress for animals [3]. However projected impacts on poultry and pigs will be lower due to temperature control in large parts of Europe, but greater in SEU where open systems prevail, [12].

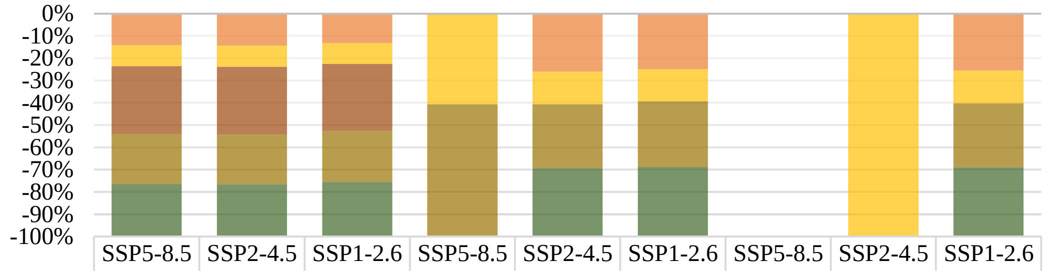
The possible projections in the livestock production (*milk, eggs, beef, pork, mutton and poultry)*, due to future climate changes in the RoM, have been considered for two alternative scenarios: (1) assuming increase in summer average temperature (Jun, Jul and Aug) and no decrease in the future cereal crops yield – optimistic scenario (**Figure 2A**); and (2) considering increase in summer average temperature (Jun, Jul and Aug) and possible decrease in the yield of the main cereal crops (winter wheat and grain maize) – pessimistic scenario (**Figure 2B**).



	SSP5-8.5	SSP2-4.5	SSP1-2.6	SSP5-8.5	SSP2-4.5	SSP1-2.6	SSP5-8.5	SSP2-4.5	SSP1-2.6
	2021-2040			2041-2060			2081-2100		
Poultry	-52	-52	-52	-71	-57	-56		-74	-58
Mutton	-49	-49	-48	-65	-54	-53		-68	-53
Pork	-52	-53	-50		-68	-64			-67
Beef	-74	-78	-68						
Eggs	-20	-20	-19	-45	-27	-25		-49	-27
Milk	-8	-9	-6	-69	-25	-21		-77	-25

Milk Eggs Beef Pork Mutton Poultry

(A)



	2021-2040			2041-2060			2081-2100		
	SSP5-8.5	SSP2-4.5	SSP1-2.6	SSP5-8.5	SSP2-4.5	SSP1-2.6	SSP5-8.5	SSP2-4.5	SSP1-2.6
Poultry	-65	-66	-64		-73	-71			-73
Mutton	-62	-62	-60	-87	-69	-67			-68
Pork	-84	-85	-79						
Beef									
Eggs	-26	-27	-25	-59	-35	-33		-64	-35
Milk	-39	-40	-35		-62	-57			-60

(B)

Figure 2. Projections of future changes in livestock production in the RoM (%/20 years) as compared to 2000-2019 reference period: (A) Optimistic scenario – without changes in the yield of main cereal crops (winter wheat and grain maize); (B) Pessimistic scenario – considering projections of changes in the yield of main cereal crops.

The analysis of the obtained results revealed that due to the impact of the main climate and crop predictors variables in the RoM by 2040 the milk production could decrease from 6 per cent (SSP1-2.6) to 8 per cent (SSP5-8.5), (optimistic scenario), and/or from 35 per cent (SSP1-2.6) to 39 per cent (SSP5-8.5), (pessimistic scenario).The maximum values of milk production decrease may be reached by 2100, from 25 per cent (SSP1-2.6) to 77 per cent (SSP2-4.5) (optimistic scenario), and/or by 60 per cent (SSP1-2.6) (pessimistic scenario).

Due to dramatic changes in climatic conditions and high drop in cereal crop productivity in the RoM, by the end of the XXI century, the milk production will be impossible under optimistic scenario (SSP5-8.5), and/or pessimistic scenario (SSP2- 4.5).

The eggs production by 2040 could decrease from 19 per cent (SSP1-2.6) to 20 per cent (SSP5-8.5), (optimistic scenario), and/or from 25 per cent (SSP1-2.6) to 26 per cent (SSP5- 8.5), (pessimistic scenario). The maximum values of eggs production decrease could be reached by 2100, from 27 per cent (SSP1-2.6) to 49 per cent (SSP2-4.5) (optimistic scenario), and/or from 35 per cent (SSP1-2.6) to 64 per cent (SSP2-4.5) (pessimistic scenario).

Without implementing of adaptation measures due to changes in climatic conditions and high drop in main cereal crop productivity in the RoM by the end of the XXI century, the eggs production will be impossible according to SSP5-8.5, or be economically not cost effective in case of SSP2-4.5 scenarios.

The beef production in the RoM is and will be in the future the most vulnerable to climate change, under all three assessed SSPs scenarios, already by 2040, is expected a severe decrease in productivity from 68 per cent (SSP1-2.6) to 74 per cent (SSP5-8.5) (optimistic scenario), as compared to 2000-2019 reference period. By 2060, and 2100, under all three assessed SSPs scenarios, a strong decreasing trend will persist in beef production and lead to situation when beef breeding will be economically not cost-effective, and/or even impossible due to climate change, increase in summer average temperature, drought conditions, deterioration of pasture conditions, and high drop in cereal crop productivity, **Figure 2A, B**.

In case the predicted climate change occurs, the current beef production potential can be maintained only in case of implementation of adaptation measures for heat stress regulation and if supplemental feed is offered; this factor would reduce significantly the economic efficiency of cattle production and may have an impact on beef quality as well.

Due climate change and decrease in cereal crop productivity, the pork production in the RoM already by 2040 may decrease from 50 per cent (SSP1-2.6) to 53 per cent (SSP2-4.5), (optimistic scenario), and respectively from 79 per cent (SSP1-2.6) to 85 per cent (SSP2-4.5), (pessimistic scenario). In case the predicted climate change occurs, by the end of the century the current pork production potential can be maintained only in case of implementation of adaptation measures for heat stress regulation and if supplemental feed is offered; this factor would reduce significantly the economic efficiency of pork production and may have an impact on pork quality as well.

For mutton production by 2040, a strong decrease in the productivity is expected, from 48 per cent (SSP1-2.6) to 49 per cent (SSP5-8.5), (optimistic scenario), and/or from 60 per cent (SSP1-2.6) to 62 per cent (SSP5-8.5), (pessimistic scenario). The maximum values of mutton production decrease may be reached by 2100, from 53 per cent (SSP1-2.6) to 68 per cent (SSP2-4.5), (optimistic scenario), and/or by 68 per cent (SSP1-2.6) (pessimistic scenario).

In case the predicted climate change occurs, by the end of the century the sheep breeding will be economically not cost-effective, and/or even impossible due to climate change, increase in summer average temperature, drought conditions, deterioration of pasture conditions, and high drop in cereal crop productivity, especially under pessimistic scenario in the RoM.

The poultry production already by 2040 could decrease by 52 per cent (optimistic scenario), and/ or from 64 per cent (SSP1-2.6) to 66 per cent (SSP2-4.5), (pessimistic scenario). The maximum values of poultry production decrease could be reached by 2100, from 58 per cent (SSP1-2.6) to 74 per cent (SSP2- 4.5) (optimistic scenario), and/or by 73 per cent (SSP1-2.6) (pessimistic scenario). Furthermore, by the end of the century, according to the both optimistic and pessimistic scenario, i.e., by considering the projected changes in summer temperature and decreasing trends in yield of the main cereal crops, the poultry breeding will be economically not cost-effective, or even impossible in the future climate conditions of the RoM, **Figure 2A, B**.

Conclusions. The temperature effect of future climate change on domestic animals in RoM will be to reduce livestock production. Climate change is forecast to reduce livestock production - milk, eggs, beef, pork, mutton and poultry. As noted above, possible decrease in the yield of the main cereal crops (winter wheat and grain maize) can further reduce livestock production by categories.

It is anticipated that the heat-stress effect on livestock would be experienced gradually over time that led to livestock production will be economically not cost-effective, or even impossible in the future climate conditions of the RoM without of implementation of adaptation measures for heat stress regulation and if supplemental feed is offered.

Now adaptation practices for livestock systems on European farms commonly focus on controlling cooling, shade provision and management of feeding times, [13].

Response options to insufficient amount and quality of fodder include changing feeding strategies [14], feed additives [15], relocating livestock linked to improved pasture management, organic farming, [16].

Effective agricultural policy is needed to increase the climate-resilience of livestock production, as well as introduction of financial adaptation measures that include simplifying procedures for obtaining subsidies, insurance premiums and credits rates that will allow adoption of climate friendly agro-ecological systems in the RoM.

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Bibliography.

1. Das, R. et al., 2016: *Impact of heat stress on health and performance of dairy animals: a review.* Vet World, 9(3), 260-268.
2. Godde, C. M. et al., 2021: *Impacts of climate change on the livestock food supply chain; a review of the evidence.* Glob Food Sec, 28, 100488, doi:10.1016/j.gfs.2020.100488.
3. Bezner Kerr, R., et al., 2022: *Food, Fibre, and Other Ecosystem Products. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 713–906, doi:10.1017/9781009325844.007.
4. Taranu, L., et al., 2023: *Climate Change Impacts, Risks and Vulnerabilities in the Republic of Moldova: Observed Trends and Future Projections.* Chișinau, 367 p. ISBN 978-9975-81-141-5.
5. Thornton, P. K., et al., 2021: *Increases in extreme heat stress in domesticated livestock species during the twenty-first century.* Global Change Biol., doi:10.1111/gcb.15825.
6. Nardone, A., et al., 2006: *Climatic Effects on Productive Traits in Livestock.* Vet. Res. Commun., 30(S1), 75-81.
7. da Fonseca de Oliveira, A. C. et al., 2019: *Impacts on performance of growing-finishing pigs under heat stress conditions: a meta-analysis.* Vet. Res. Commun., 43(1), 37-43, doi:10.1007/s11259-018-9741- 1.
8. Sejian, V. et al., 2018: *Review: Adaptation of animals to heat stress.* Animal, 12(s2), s431-s444, doi:10.1017/S1751731118001945.
9. Herbut, P., et al., 2019: *The Physiological and Productivity Effects of Heat Stress in Cattle: A Review.* Annals of Animal Science, 19(3), 579-593, doi:10.2478/aoas- 2019-0011.
10. Ţaranu L. 2014: *An Assessment of Climate Change Impact on the Republic of Moldova's Agriculture Sector: A Research Study Complementing the Vulnerability and Adaptation Chapter of the Third National Communication of the Republic of Moldova under the United Nations Framework Convention on Climate Change*. Ed.: V. Scorpan, M. Ţăranu; Climate Change Office, Min. of Environment, UNEP, Ch.: "Tipografia Centrala", 260 p.
11. Lallo, C. H. O. et al., 2018: *Characterizing heat stress on livestock using the temperature humidity index (THI) prospects for a warmer Caribbean.* Reg. Environ. Change, 18(8), 2329-2340, doi:10.1007/ s10113-018-1359-x.
12. Bednar-Friedl, B., et al., 2022: *Europe. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1817–1927, doi:10.1017/9781009325844.015.

13. Gauly, M. et al., 2013: *Future consequences and challenges for dairy cow production systems arising from climate change in Central Europe – a review.* Animal, 7(5), 843-859, doi:10.1017/S1751731112002352.
14. Kaufman, J. D., et al., 2017: *Lowering rumen-degradable protein-maintained energy-corrected milk yield and improved nitrogen-use efficiency in multiparous lactating dairy cows exposed to heat stress.* Journal of Dairy Science, 100(10), 8132-8145, doi:10.3168/jds.2017-13026.
15. Ghizzi, L. G. et al., 2018: *Effects of functional oils on ruminal fermentation, rectal temperature, and performance of dairy cows under high temperature humidity index environment.* Animal Feed Science and Technology, 246 (October), 158-166.
16. EEA, 2019: *Climate change adaptation in the agriculture sector in Europe.* (04/2019), doi:10.2800/537