ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Artificial Croplands and Natural Biosystems in the Conditions of Climatic Changes: Possible Problems and Ways of their Solving in the South Steppe Zone of Ukraine.

Raisa Anatoliivna Vozhehova[1], Serhii Vasylovych Kokovikhin[1], Pavlo Volodymyrovych Lykhovyd[1]*, Serhii Hervasovych Vozhehov[2], and Antonina Viktorivna Drobitko[3].

[1]Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, Kherson, Naddniprianske, 73483, Ukraine.
[2]Institute of Rice of the National Academy of Agrarian Sciences of Ukraine, village Antonovka, Skadovsk district, Kherson region, 75705, Ukraine.
[3]Mykolaiv National Agrarian University, Mykolaiv, Heorhiia Honhadze Street 9, 54020, Ukraine.

ABSTRACT

The goal of our study was to determine possible consequences and trends of the climatic changes in the South Steppe zone of Ukraine. We used perennial meteorological data from Kherson regional hydro-meteorological station and international meteorological indexes for assessment of the climate processes. The evapotranspiration in the region in the period from 2005 to 2016 averaged to 4.3 mm/ha per day. We determined that evapotranspiration increase under the progressive air temperatures rise cannot be covered at the expense of natural humidification, although rainfall amounts are tending to increase too. The moisture deficit reached the maximum value of 680 mm/ha per season in 2014. Regression models of the climatic processes of the zone showed stable trend to increase of dryness (from 462 mm/ha of the moisture deficit in 2005 to 502 mm/ha in 2016, correspondingly). Global warming will effect not only on the artificial croplands, but it threatens sustainability of the natural biosystems, especially, natural grasslands and forests. Climatic changes in Kherson region should be taken into account while planning sustainable crop production and maintaining biosystems diversity in the region. Application of the modern irrigation methods of the artificial croplands and pastures are the priority direction of agricultural production in the zone.

Keywords: global warming, climatic changes, agricultural production, evapotranspiration, rainfall, temperature.

***Corresponding author**

INTRODUCTION

Climatic changes are unavoidable. Presently we are facing the challenges of global warming. Mainly it is manifested, and associated in minds of most of people, with progressive increase in air temperatures. As a matter of fact, this opinion is quite sensible: scientists from all over the world are stating about increase of the average global temperature [46, 49]. But global warming is not limited to only temperature increase. Its effects on the environment are much more various and comprehensive [45]. It also effects precipitation amounts and their distribution in time and place; it has led to melting of the glaciers, changing directions of the streams, displacement of climatic zones, etc. According to agronomic research, global warming is highly likely to affect agricultural production sustainability [6, 24]. A number of scientific studies show that without proper adaptation, climatic changes will be a hard challenge for agricultural production, particularly, in non-irrigated conditions of the arid and semi-arid zones [48]. Rational adaptation measures can help to reduce susceptibility of agriculture [15, 54, 59]. Of course, the adaptation will require lots of connected with it expenses [20, 44]. But all in all climatic changes will lead to running down the economics of agricultural production, requiring investments in keeping on the artificial and natural biosystems sustainability [38]. Especially, taking into account that fact that water demand is expected to be increased not only for needs of agricultural production, but for urban needs too. And this increase is estimated at 80% to 2050, that might be really crucial [22]. It was predicted that temperature increase of 1-3°C over the nearest decades can lead to increase of the global potential evapotranspiration up to 75-225 mm per year, while precipitation amounts are likely to run down to 4-5% [29]. Recent studies stated about increasing of drought periods longevity in the Eastern Africa, which is traced back to the climatic changes in the region [34]. Drought periods will become more frequent and common phenomenon over the continent in the XXI century [43]. Other studies state about temperature increases that might have significant impact on the crop yields [3, 32, 51], especially, in Africa [55]. At the same time, this awful prognosis is not considered convincing enough by all the scientific society. Some studies established that water resources supply is not likely to decline with climatic changes [21]. In opinion of some scientists, no crucial harm to agricultural production sustainability is expected due to the global warming [39]. Particularly, at the irrigated croplands [11, 12, 13]. We agree with the statement that climatic changes impact on the agricultural systems in particular and biosystems in general should be studied differently at the irrigated and non-irrigated lands, and in the different climatic zones of our planet [27, 50]. So, the goal of our study was to determine possible effects of the modern climatic changes on the crop production sustainability in Kherson region both at the irrigated and non-irrigated lands, assess possible negative effects on biosystems in general, and suggest some ways of solving the problems, which may occur, particularly, by the application of modern irrigation methods.

MATERIALS AND METHODS

The long-term meteorological data were gathered at Kherson Regional Hydro-meteorological Center (geographical coordinates: latitude 46°38′24′′N, longitude 32°36′52′′E, altitude 41 m). Calculation of the effectivwe rainfall amounts was conducted with accordance to the US Bureau of Reclamation [8]. Hydro-thermal coefficient was estimated by using the formula 1 [40]:

$$HTC = \frac{10 \times R}{t} \quad (1)$$

where HTC is the hydrothermal coefficient value, units; *R* is the rainfall amounts within the period, mm; *t* is the sum of positive temperatures above 10°C.

Evapotranspiration was calculated by the Penman-Monteith methodology [62]. To avoid handling of the enormous calculations, all the computations were carried out within the CROPWAT 8.0 software application [57]. Moisture deficit was assessed by the disparity between the evapotranspiration and the effective rainfall amounts.

Standard deviation of the average annual meteorological indexes was calculated by using the formula 2 [23, 33]:

(2)

$$SD = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \overline{x})^2}{N-1}}$$

where *SD* is the standard deviation; $x_1, ..., x_n$ are the observed values of the average annual meteorological inexes; *N* is the number of observations.

The coefficient of variation of the average annual meteorological indexes was calculated by using the formula 3 [18]:

$$CV = \frac{SD}{\overline{x}} \quad (3)$$

where *CV* is the coefficient of variation; *SD* is the standard deviation; $\overline{x}$ is the mean value of the water quality criterion.

The linear regression trend lines were built by using the common calculation methods within the LibreOffice Calc 6 software application analysis tools [14, 41, 52].

The coefficient of determination was calculated by using the formula 4 [10, 19]:

$$R^2 = 1 - \frac{V(y|x)}{V(y)} \quad (4)$$

where $V(y|x)$ is the dispersion of the dependent argument.

RESULTS AND DISCUSSION

The results of the study state about an evident and considerable changes in climate patterns of Kherson region. It was also established that these changes had appeared far long ago. Figure 1 demonstrates highly reliable (the coefficient of determination R^2 is 0.82) tendency to increase in the rainfall amounts. The tendency had appeared in the XIX century, and it is going on nowadays. But it is weaker now than it used to be in the above-mentioned period. This fact can be proved by the meteorological data obtained in the period from 2005 to 2016 at the Kherson regional hydro-meteorological station (Figure 2). The coefficient of determination is many times lower (R^2 is only 0.15 vs. 0.82), although the tendency remains quite recognizable and definite. We also determined that rainfall amounts, both gross and effective, are highly variable indexes: the coefficient of variation (*CV*) was high enough and averaged to 27.5% and 21.9%, correspondingly (Table 1).

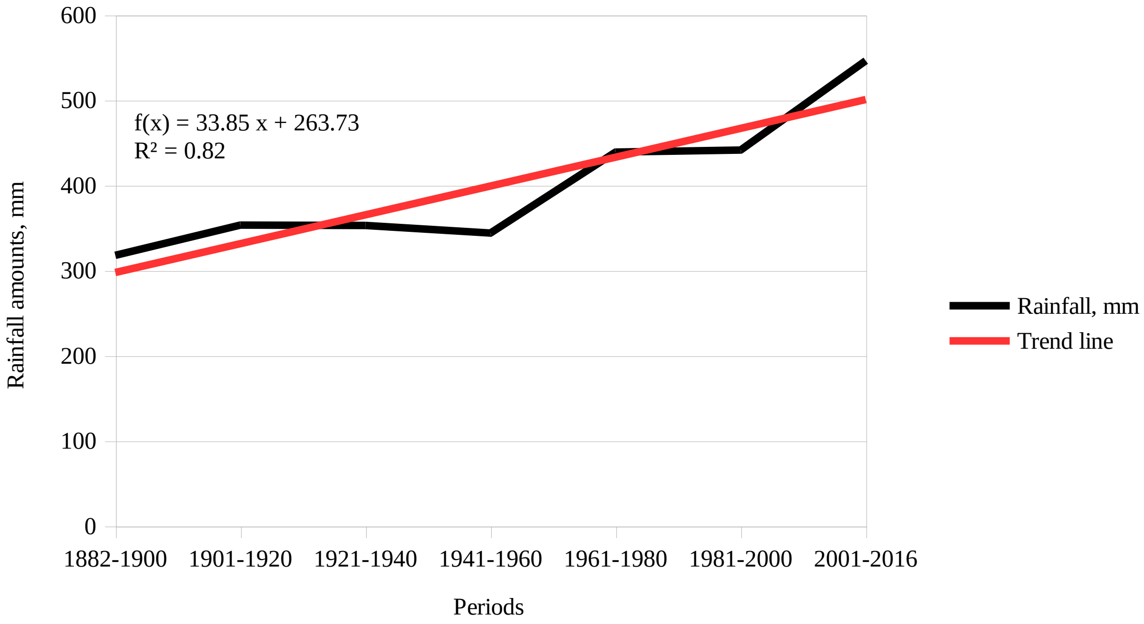

Figure 1: Average annual rainfall amounts during the last 134 years (from 1882 to 2016)

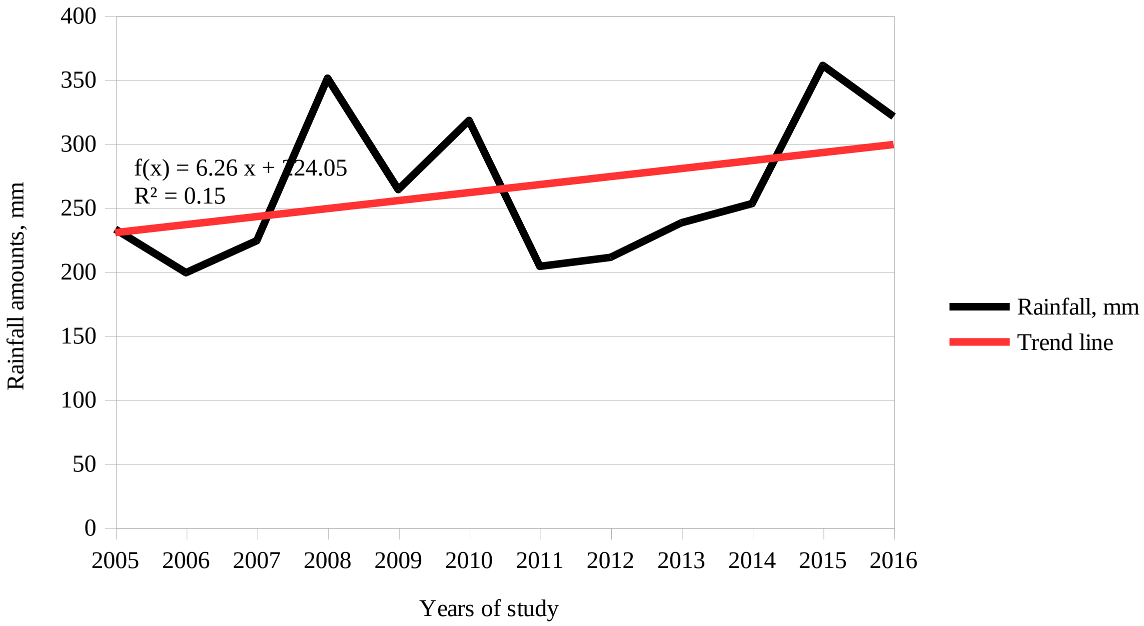

Figure 2: Average annual effective rainfall amounts expressed in mm/ha for the studied period from April to September of 2005-2016

The amounts of the effective rainfall increase from year to year during the last twelve years and reached their maximum of 361 mm/ha in 2015 (Table 1). But sum of the positive temperatures above 10°C is also considerably increasing (Table 1, Figure 3).

Table 1: Average annual meteorological indexes for the studied period (April - September of 2005-2016)

Indexes	Years												Mean value	CV, %	SD
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016			
Rainfall, mm/ha	259	221	249	439	293	397	227	235	264	316	451	401	313	27.5	86.1
Effective rainfall, mm/ha	233	199	224	351	264	318	204	211	238	253	361	321	265	21.9	58.1
Sum of temperatures above 10°C	3496	3283	3482	3286	3353	3539	3327	3858	3534	3570	3476	3574	3482	4.6	160.2
Hydro-thermal coefficient, units	0.74	0.68	0.72	1.34	0.87	1.12	0.68	0.61	0.75	0.88	1.30	1.12	0.90	28.3	0.25
Relative air humidity, %	63.7	64.3	59.4	67.0	59.5	65.8	62.6	60.1	61.7	60.0	65.1	66.0	62.9	4.4	2.8
Evapotranspiration, mm/ha (per day)	3.8	4.0	4.5	3.9	4.3	4.0	4.1	4.2	4.3	5.1	4.6	4.5	4.3	8.5	0.4
Evapotranspiration, mm/ha (total)	695	732	823	714	787	732	750	767	787	933	842	823	782	8.5	66.2
Moisture deficit, mm/ha	462	533	599	363	523	414	546	556	549	680	481	502	517	16.1	83.0

ISSN: 0975-8585

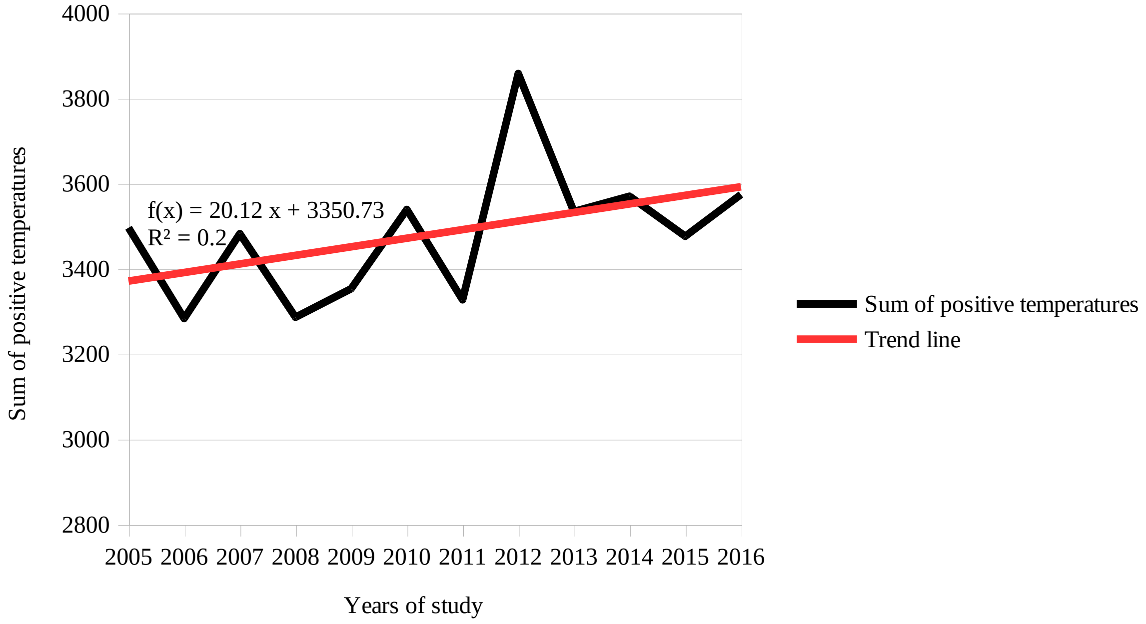

Figure 3: Average annual sum of positive temperatures (above 10°C) for the studied period from April to September of 2005-2016

And increase of the latter climate index seems to be much more influential than of the precipitation amounts. The fact is that moisture deficit during the last twelve years shows tendency to growth in spite of more humidification with greater rainfall amounts.

The calculations have proved previous statement, and figure 4 reflects the above-mentioned fact. So, natural humidification is still incapable to provide sufficient moisture level, required for sustainable and effective cultivation of the major crops in the region without artificial irrigation. And it is considered that further climatic changes will only strengthen the tendency to drought increase.

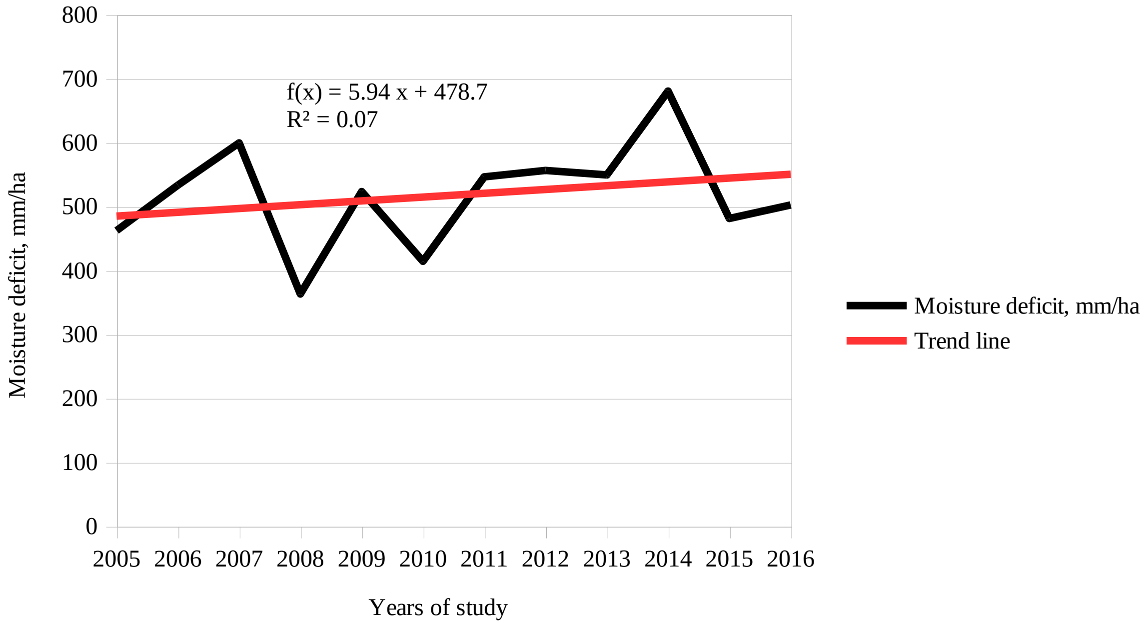

Figure 4: Average annual moisture deficit expressed in mm/ha for the studied period from April to September of 2005-2016

It should be mentioned that additionally we have calculated the values of the hydro-thermal coefficient (HTC). This methodology of the humidification level assessment is an old one and was widely used in the USSR. The HTC values obtained through the calculations demonstrated absolutely opposite tendencies to the above: they are growing up and this fact says about improvement of the humidification conditions in the region (Figure 5). But we have to say that HTC cannot be considered as a reliable index any more. It takes into account a limited number of meteorological factors (only temperature and rainfall amounts), when evapotranspiration calculated by the Penman-Monteith method figures on a number of the additional important indexes, for example, wind speed, solar radiation, vapor pressure, etc. [1]. Besides, variability of the index is very high (*CV* is 28.3%), so it is unstable enough to be considered trustworthy (Table 1). So, all the changes in climate, in our opinion, must be estimated by using the modern methodology of calculations, which has been provided by FAO.

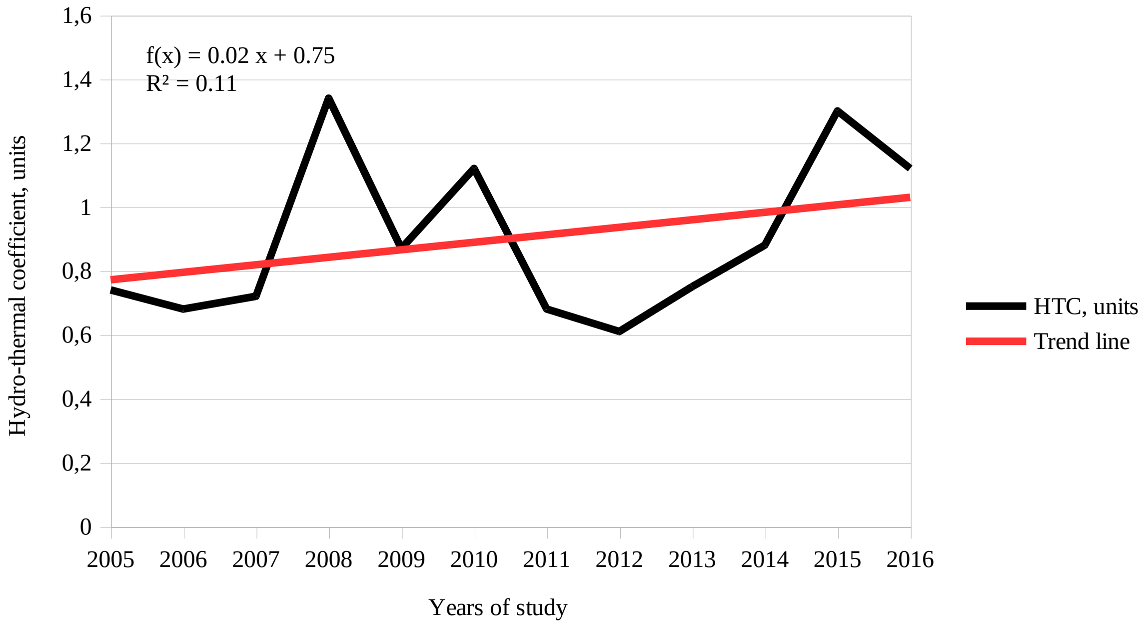

Figure 5: Average annual hydro-thermal coefficient values for the studied period from April to September of 2005-2016

Climatic changes concerning to the global warming are established in different parts of the world. For example, temperature increase of 1.8°C was recorded in Nepal for the period of 1975-2006 [37]; Australia warmed of about 0.8°C during the last century [26]; forest fires occurrence is projected to be increased in Canada due to the global warming of 25-75% by the end of the XXI century [61]; changes in monsoon flow and pattern of precipitation are highly likely to be effected by the modern climate trends in India [7]; air temperatures are anticipated to be increased up to 2-3°C by 2065 in Pakistan [25]; climate and environmental conditions are being changed by the global warming in China [47]. All the studies devoted to the subject determined an evident tendency to climatic changes in Ukraine. It was stated that these changes are leading to significant warming of climate, which has increased the annual air temperature by 0.6±0.2°C per 100 years on the background of insignificant increase in the annual precipitation amounts by 5-7% per 100 years. And in the Steppe zone of Ukraine air temperature increase to 2070 is estimated even higher. It is projected to be about 1.61-1.65°C. This fact causes strong tendency to evapotranspiration increase in the zone, which is also proved by our investigations and other researches [42]. Climatic changes are expected to have an effect on water resources, especially, in Southern and Eastern regions of the country. It should also be mentioned, that water scarcity growth can cause additional problems under the global warming conditions, particularly, in use of the irrigation water with limited suitability, as it is in the Inhulets irrigation system of Kherson region [30, 36]. Climatic changes can lead to appearance of the unexpected hindrances in agricultural production [4, 5]. Correlating results of our study with previously conducted scientific investigations in this field we can see that most of the domestic scientists are convinced in aggravation of agricultural production in connection with global warming, even to the level of desertification of some areas [4, 5, 35]. But some foreign authors do not agree with the above-mentioned. There is a number of studies trying to convince us in benefits of the climatic changes for Ukrainian, Romanian, Moldavian, Hungarian and Bulgarian agricultural production. They state that the only restriction to growth of agricultural production can be improper irrigation [2]. Some scientists forecast an increase in export of agricultural products in Ukraine and Russia[9, 17]. So, this question is quite disputable. But all the studies state, and ours is not an exception, that climatic changes of the global warming are coming and we have to take steps to deal with their challenges. Besides, we have mainly focused our researches on the agricultural sector reactions to the climatic changes. But it is obvious, that observed tendencies, which are leading to increase of severity in drought conditions, will have negative effect on the natural biosystems of the South Steppe zone, especially, on Askania-Nova natural park and Oleshkivskii pine forest. We see that fire incidents in the forest in the hot summer time of the year become more and more frequent from year to year. And a tendency to biodiversity changes has been recently established in the Carpathians forest ecosystem too [28], so the problem is not common only in the South of Ukraine. Also, everyone should understand significance of the global warming impact on human health and life conditions (particularly, of weak and old people, who suffer from various chronic diseases), wild nature (both flora and fauna) and natural biosystems and landscapes in general [31, 56, 60].

CONCLUSIONS

Climatic changes are unavoidable. It is evident that mankind should take steps to survive and keep on food support on the proper level in the modern conditions of global warming, which causes great impact on the agricultural systems functioning first. Our study has proved the fact of considerable moisture deficit increase, particularly, in the South Steppe zone of Ukraine. Growing moisture deficit is one of the most important limiting factors of sustainable crop production in the region. So, it requires scientifically based solving in the nearest future. We suggest introduction of drought-tolerant crops, viz., grain sorghum, safflower, millet, chickpea, etc., at the non-irrigated lands as possible alternative for some crops with high requirements to water supply, for example, corn. And concerning to irrigated agriculture we suggest introduction of the modern water-saving irrigation methods (drip, subsurface irrigation, micro-sprinkler irrigation, etc.) as but one way to provide stable and high yields of the major crops and to prevent further water scarcity in the region. Besides, we are calling for taking necessary steps for preservation of the current biodiversity in the region and saving our environment from possible negative effects of the global warming. A special care should be taken to protect rare and most susceptible to dryness and heat species of animals and plants. Besides, we should take steps for preventing desertification of the region and saving natural forests.

REFERENCES

[1] Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration-Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome, 300(9), D05109, 1998.

[2] Bär R, Rouholahnejad E, Rahman K, Abbaspour KC, Lehmann A. Climate change and agricultural water resources: A vulnerability assessment of the Black Sea catchment. Environ Sci Policy 2015; 46: 57-69.

[3] Battisti DS, Naylor RL. Historical warnings of future food insecurity with unprecedented seasonal heat. Science 2009; 323: 240-244.

[4] Boychenko S, Voloshchuk V, Movchan Y, Serdjuchenko N, Tkachenko V, Tyshchenko O, Savchenko S. Features of climate change on Ukraine: scenarios, consequences for nature and agroecosystems. Proceedings of the National aviation university 2016; 4: 96-113.

[5] Boychenko S, Voloshchuk V, Tkachenko V. Features of climate change on Ukraine: scenarios, consequences and adaptation. Proceedings of the Seventh World Congress Aviation in the XXI-st Century. Safety in Aviation and Space Technologies 2016; 5.4: 82-86

[6] Chang JH. Climate and agriculture: an ecological survey. Routledge. Taylor & Francis, London, 2017.

[7] Dash SK., Hunt JCR. Variability of climate change in India. Curr Sci 2007; 93(6): 782-788.

[8] Dastane NG. Effective rainfall. FAO irrigation and drainage paper 25. Food and Agriculture Organization of the United Nations, Rome, 1978.

[9] Deppermann A, Balkovič J, Bundle SC, Di Fulvio F, Havlik P, Leclère D, Lesiv M, Prishchepov AV, Schepaschenko D. Increasing crop production in Russia and Ukraine - regional and global impacts from intensification and recultivation. Environ Res Lett 2018; 13(2): 025008.

[10] Devore JL. Probability and Statistics for Engineering and the Sciences. Cengage learning, Boston, 2011.

[11] Dinar A, Campbell MB, Zilberman D. Adoption of improved irrigation and drainage reduction technologies under limiting environmental conditions. Environmental and Resource Economics 1992; 2(4): 373-398.

[12] Dinar A, Yaron D. Influence of quality and scarcity of inputs on the adoption of modern irrigation technologies. Western J Agric Economics 1990; 15(2): 224-233.

[13] Dinar A, Zilberman D. The economics of resource-conservation, pollution-reduction technology selection: the case of irrigation water. Resour Energ 1991; 13(4): 323-348.

[14] Draper NR, Smith H. Applied regression analysis. John Wiley & Sons, New York City, 2014.

[15] Easterling WE, Crosson PR, Rosenberg NJ, McKenney MS, Katz LA, Lemon KM. Agricultural impacts of and responses to climate change in the Missouri-Iowa-NebraskaKansas region. Clim Change 1993; 24(1-2): 23-62.

[16] Erickson B, Nosanchuk T. Understanding Data. Milton Keynes, Open University Press, Toronto, 1979.

[17] Ermolieva T, Yermoliev Y, Atoyev KL, Golodnikov OM, Gorbachuk VM, Kiriljuk VS, Knopov PS. Development of Robust Land-use Decisions in Eastern Europe under Technology, Climate, and System Change: The Case of Ukraine. Systems Analysis 2015 - A Conference in Celebration of Howard Raiffa, 11 -13 November 2015.
[18] Everitt B, Skrondal A. The Cambridge dictionary of statistics (Vol. 106). Cambridge: Cambridge University Press, 2002.
[19] Ezekiel M, Fox KA. Methods of correlation and regression analysis. Wiley, New York, 1967.
[20] Fankhauser S. The potential costs of climate change adaptation. Adapting to Climate Change: An International Perspective, Springer, New York, 1996, pp. 80-96.
[21] Fleischer A, Lichtman I, Mendelsohn R. Climate change, irrigation, and Israeli agriculture: Will warming be harmful? Ecol Econ 2008; 65(3): 508-515.
[22] Flörke M, Schneider C, McDonald RI. Water competition between cities and agriculture driven by climate change and urban growth. Nature Sustainability 2018; 1: 51.
[23] Furness RW, Bryant DM. Effect of wind on field metabolic rates of breeding northern fulmars. Ecology 1996; 77(4): 1181-1188.
[24] Gitay H, Brown S, Easterling W. Ecosystems and their goods and services. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 235-342.
[25] Gorst A, Groom B, Dehlavi A. Crop productivity and adaptation to climate change in Pakistan. Grantham Research Institute on Climate Change and the Environment Working paper, 2015, pp. 189.
[26] Hughes L. Climate change and Australia: trends, projections and impacts. Austral Ecology; 28(4): 423-443.
[27] Jablonski LM, Wang X, Curtis PS. Plant reproduction under elevated CO_2 conditions: a meta-analysis of reports on 79 crop and wild species. New Phytologist 2002; 156(1): 9-26.
[28] Kruhlov I, Thom D, Chaskovskyy O, Keeton WS, Scheller RM. Future forest landscapes of the Carpathians: vegetation and carbon dynamics under climate change. Reg Environ Change 2018; 18(5): 1555-1567.
[29] Le Houérou HN. Climate change, drought and desertification. J Arid Environ 1996; 34(2): 133-185.
[30] Likhovid PV. Analysis of the Ingulets irrigation water quality by agronomical criteria. Success of Modern Science and Education 2015; 5: 10-12.
[31] Lindner M, Maroschek M, Netherer S, Kremer A, Barbati A, Garcia-Gonzalo J, Seidl R, Delzon S, Corona P, Kolstrom M, Lexer MJ, Marchetti M. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecol Manag 2010; 259(4): 698-709.
[32] Lobell DB, Banziger M, Magorokosho C, Vivek B. Nonlinear heat effects on African maize as evidenced by historical yield trials. Nat Clim Chang 2011; 1: 42-45.
[33] Logan M. Biostatistical design and analysis using R: a practical guide. John Wiley & Sons, New York City, 2011.
[34] Lott FC, Christidis N, Stott PA. Can the 2011 East African drought be attributed to human-induced climate change? Geophys Res Lett 2013; 40(6): 1177-1181.
[35] Lykhovyd PV. Global warming inputs in local climate changes of the Kherson region: current state and forecast of the air temperature. Ukr J Ecology 2018; 8(2): 39-41.
[36] Lykhovyd PV, Kozlenko YV. Assessment and forecast of water quality in the River Ingulets irrigation system. Ukr J Ecol 2018; 8(1): 350-355.
[37] Malla G. Climate change and its impact on Nepalese agriculture. J Agric Environ 2009; 9: 62-71.
[38] Mendelsohn R. Climate-change damages. Economics and Policy Issues in Climate Change. Resources for the Future, Washington, D.C., 1998.
[39] Mendelsohn R, Dinar A. Climate, water, and agriculture. Land Econ 2003; 79(3): 328-341.
[40] Meshherskaja AV, Blazhevich VG, Zhitorchuk JV. Hydrothermal coefficient and its connection with crops yields. Works of GGO 1978; 400: 133-148.
[41] Montgomery DC, Peck EA, Vining GG. Introduction to linear regression analysis (Vol. 821). John Wiley & Sons, New York City, 2012.
[42] Müller D, Jungandreas A, Koch F, Schierhorn F. Impact of Climate Change on Wheat Production in Ukraine. Agricultural Policy Report. Kyiv, 2016.
[43] Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P. Africa. Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel of climate change. Cambridge: Cambridge University Press, 2014, pp. 1199-1265.
[44] Nordhaus WD. To slow or not to slow: The economics of the greenhouse effect. The Econ J 1991; 101: 920-937.
[45] Parry ML, Carter TR. An assessment of the effects of climatic change on agriculture. Clim Chang 1989; 15: 95-116.
[46] Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature 2005; 438(7066): 310-317.
[47] Qin D, Ding Y, Mu M. Climate and environmental change in China: 1951–2012. Springer, Berlin, 2015.

[48] Rosenzweig C, Parry ML. Potential impact of climate change on world food supply. Nature 1994; 367: 133-138.
[49] Schär C, Vidale PL, Lüthi D, Frei C, Häberli C, Liniger MA, Appenzeller C. The role of increasing temperature variability in European summer heatwaves. Nature 2004; 427(6972): 332-336.
[50] Schlenker W, Hanemann WM, Fisher AC. Will US agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. Am Econ Rev 2005; 95(1): 395-406.
[51] Schlenker W, Lobell DB. Robust negative impacts of climate change on African agriculture. Environ Res Lett 2010; 5(1): 01410.
[52] Seber GA, Lee AJ. Linear regression analysis (Vol. 936). John Wiley & Sons, New York City, 2012.
[53] Smit B, Skinner MW. Adaptation options in agriculture to climate change: a typology. Mitig Adapt Strat Gl 2002; 7(1): 85-114.
[54] Smith JB. Using a decision matrix to assess climate change adaptation. Adapting to Climate Change: An international Perspective. Springer, New York, 1996, pp. 68-79.
[55] Sonwa DJ, Dieye A, El Mzouri EH, Majule A, Mugabe FT, Omolo N, Brooks N. Drivers of climate risk in African agriculture. Climate and Development 2107; 9(5): 383-398.
[56] Stone R. If the mercury soars, so may health hazards. Science 1995; 267(5200): 957-959.
[57] Swennenhuis J. CROPWAT 8.0. Water Resources Development and Management Service of FAO: Italy, Rome, 2009.
[58] Weisberg S. Applied linear regression (Vol. 528). John Wiley & Sons, New York City, 2005.
[59] Wheaton EE, McIver DC. A framework and key questions for adapting to climate variability and change. Mitig Adapt Strat Gl 1999; 4: 215-225.
[60] Williams AP, Allen CD, Macalady AK, Griffin D, Woodhouse CA, Meko DM, Swetnam TW, Rauscher SA, Seager R, Grissino-Mayer HD, Dean JS, Cook ER, Gangodagamage C, Cai M, McDowell NG. Temperature as a potent driver of regional forest drought stress and tree mortality. Natur Clim Chang 2013; 3: 292.
[61] Wotton BM, Nock CA, Flannigan MD. Forest fire occurrence and climate change in Canada. Int J Wildland Fire 2010; 19(3): 253-271.
[62] Zotarelli L, Dukes MD, Romero CC, Migliaccio KW, Morgan KT. Step by step calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method). Institute of Food and Agricultural Sciences. University of Florida, 2010.