International Journal of Modern Agriculture
ISSN: 2305-7246
Volume 21 Issue X, Month 2020

Crop production and land use inputs to global warming

Pavlo Lykhovyd *[1]

Institute of Irrigated Agriculture of NAAS

[1] pavel.likhovid@gmail.com

Abstract- Global warming is one of the main challenges of modern world. Climate change impacts greatly almost every sphere of human life and industrial activity with the strongest effect on nature-related sectors of the economy such as agriculture. Agriculture is a sphere of human activity, which is both the most effected and one of the effecting agents on global climate change. It is a common belief that agricultural production provides most emission of greenhouse gases resulting in rapid global climate change. However, this statement lacks evidence. The study presented in the paper is aimed to investigate the inputs of crop production, as a major branch of agriculture, to global greenhouse gases emission. Retrospective historical data provided by the Food and Agriculture Organization, the History Database of the Global Environment, and Climate Watch on the emissions and factors affecting them, including pesticides, fertilizers application, tractors use, agricultural land structure and forest areas, were implemented in the research. As a result, it was determined that crop production cannot be assumed as the leading force of greenhouse gases emission and global warming. Crop production inputs in global emission in 2010 were only 17.40%. There is a tendency to further decrease in greenhouse emission by crop production. However, when CO2 and CH4 emission tend to decrease, there is a threatening tendency to the increase in the volumes of N2O emissions from agricultural activities, mainly related to nitrogen fertilizers, pesticides, and tractors use. Also, there is a negative trend to further deforestation on the global scale, leading to the deterioration of global ecological balance and less absorption of greenhouse gases, thus resulting in the increased pace of global warming. Therefore, it is concluded that the main task of modern crop production is to keep up the pace for carbon emissions limitation and simultaneously take steps to eliminate the emission of N2O through the revision of mineral fertilizers (especially nitrogen) and pesticides application strategy and reduction of exhaust from tractors used in agriculture. Besides, afforestation is essential for the insurance of global ecological sustainability.

Keywords**:** Correlation**,** Forest area**,** Greenhouse gas**,** Emission**,** Sustainability**.**

I. INTRODUCTION

Global warming is one of the main concerns for sustainable development of agricultural sector and food security, especially in the regions that are initially vulnerable due to current unstable food supply and malnutrition (25). The studies on the dynamics of global air temperature change agree that we will unavoidably face gradual increase in the index in most areas of the Earth. The growth of air temperature is an undebatable fact, notwithstanding that there is no common opinion on the tempo of the raise. However, even the most optimistic scenario forecasts the increase by 0.3-1.7◦C (according to RCP2.6) until the end of the century if nearly zero emissions of greenhouse gases and no change in solar activity happen (23). Therefore, coping with the problems of global warming is one of the most relevant tasks for modern science and technology.

Agriculture is a branch of economy, which is the most sensitive to climate change. Dealing with natural ecosystems, its productivity and capability to ensure food security greatly depends on the adaptability of cultural species and technologies to changing environment. Most scientists agree that global climate change will reflect on the productivity of agricultural sector and will change the priorities and directions of development in crop production and animal husbandry (13, 22, 26). The territory of the whole Africa, Arab countries, India, and Southern America were expected as the main regions of crop yield deterioration in the older simulation models (1994-2010), while recent studies on the crop modeling in connection to climate change state that these territories could highly likely be accompanied by Australia, New Zealand, Far East, and Central America (25). Some countries (mainly located in North America, Northern Europe, and Central Asia) are expected to benefit from the global warming process, while the vast majority of the land areas will suffer from unstable crop production due to the water scarcity and weather instability and adverse climatic phenomena, which, accompanied by destructive anthropogenic activities, will lead to dramatical change in the whole look of the Earth's ecosystems (7, 9, 19). Besides, food security will be complicated due to the rapid increase in the global population (5).

At the same time, scientists claim that agriculture is to some extent to blame in the rapid global warming (10). It is believed that animal husbandry and intensive crop production are one of the major factors affecting climate through the impact on the quantities of greenhouse gases (GHG) in the atmosphere. It is believed that modern intensive cultivation technologies, especially those implementing highly energy consumptive machines, great amounts of fertilizers and pesticides, have a great share in the total GHG emissions, especially when accompanied by irrational land use and deforestation (1). Therefore, we see the global trend to cutting the number of livestock, transferring to organic farming and energy-saving technologies in the framework of climate-smart agriculture. However, the statement requires a proof because it is not clear whether agricultural inputs to the global GHG emissions are as great as it is believed and whether shifting to climate-smart, energy-saving, and organic farming practices would be really helpful.

The goal of this study is to determine the share of agricultural inputs into global GHG emission and establish the main sources of GHG emission from agricultural activities related to crop production.

II. Materials and Methods

The study based on the historical data of the Food and Agriculture Organization reports available for free at http://www.fao.org/faostat/en/#home and the reports by the History Database of the Global Environment available at http://themasites.pbl.nl/tridion/en/themasites/hyde/. The study embraced the data on the global application rates of pesticides (without differentiation, gross volume), nitrogen, phosphorus, potassium fertilizers, global areas under forests (3), agricultural land, arable land, and tractors use (numbers per 100 square kilometers). GHG (including CO_2, N_2O, CH_4) emission was estimated using the data provided by Climate Watch (https://www.climatewatchdata.org/data-explorer/historical-emissions). The data were generalized for the period of 1990-2010 years, and statistically processed by the means of linear correlation analysis (24) within Microsoft Excel 365 software. The analysis included the computation of linear Pearson's correlation coefficient (R), coefficient of determination (R^2), and the share of global crop production emissions in the total GHG emission in per cents (16). The trends in the studied agricultural indices and land use practices were determined using the procedure of Mann-Kendall and Sen's slope test at $p<0.05$, performed in the Real Statistics add-in for Microsoft Excel 365 (4).

III. Results

The results of the statistical data generalization of main agricultural indices, characterizing the intensity of agrotechnologies, are provided in the Table 1. The results of trend test testify that there are statistically significant trends to the increase in application of pesticides and of all kinds of fertilizers, together with a sharp increase in the tractors use, which is strongly related to modern technological progress and industrialization of agriculture. At the same time, there is no trend in the agricultural land areas (both total and arable) that testifies about the stability of land use. There is a positive tendency to decrease in the share of arable lands, which reflects the direction of comprehensive strategy to mitigation of adverse impacts of agricultural activities on environment. But at the same time there is a strong tendency to global deforestation, and this is one of the major concerns for environmental stability in future.

Global GHG emission are generalized in the Table 2. It is evident that global emission of all GHG, excepting N_2O, tend to increase. However, emission from crop production does not change. At the same time, there is a trend to increase in N_2O and CH_4 emission from crop production, and the situation with N_2O emission is critical because it demonstrates the growing trend not only in absolute volumes but also in the share in the global emission from all sources, while the share of other GHG emission from crop production in the total volume of emission decreases.

The analysis of GHG emission interconnection with land use and agricultural practices showed that the greatest impact on GHG emission is linked to the forest area: R^2 – 0.8281, 82.81% of determination (Table 3). Forests are the main regulators of CO_2 and CH_4 emission, while N_2O

emission remains out of their control. The slightest effect on the total GHG emission is observed for potassium fertilizers (R^2 – 0.0004, 0.04% of determination), while nitrogen fertilization provides the second after the forest area effect on the increase of total GHG emission with R^2 – 0.0256, 2.56% of determination. Nitrogen fertilization is the greatest driving force to the emission of N_2O (together with tractors in use – R^2 – 0.9604, 96.04% of determination) and CH_4 (R^2 – 0.8464, 84.64% of determination). The least affection on GHG emission among fertilizers is attributed to phosphorus fertilizers. The number of tractors in use occupies the second position in the inputs to CH_4 emission after fertilizers, while pesticides application is on the third place. Almost all crop production practices have slight (not higher than 26.01% of determination for fertilizers in general) effect on CO_2 emission. Land use peculiarities are also of little importance in GHG emission mitigation strategy. It is also interesting that almost all the studied factors have negative correlation with CO_2 emission, therefore, modern crop production cannot blame in CO_2 emission increase. Moreover, the use of tractors, application of pesticides and mineral fertilizers has negative correlation with total GHG emission, that is also a proof of groundless accusation of crop production in great inputs to global GHG emission and global warming.

IV. Discussion

The results of the study provide alternative look upon the problem of global warming and the role of crop production sector in the global climate change. Notwithstanding the fact the use of tractors and application rates of mineral fertilizers and pesticides increase under the relatively stable area of arable agricultural land, we see no increase in the total GHG emission from agriculture, while the global emission from all sources tends to grow. The share of crop production in total GHG emission and CO_2 plus CH_4 emission is gradually decreasing. Paustian et al. also stated that modern carbon sequestration technologies and efforts to deuce carbon emission from soils are efficient, but we must admit that this emission is only 3-6% of the total GHG emission, therefore this direction cannot be considered as a great force of GHG control and priority mitigation policy for combating global warming (18). The only concern is increasing emission of N_2O and, to some extent, of CH_4 gases from crop production sector. The major driving forces of N_2O emission in crop production are tractors, pesticides, and mineral fertilizers (especially nitrogen). That is why it is important to develop mitigation strategies oriented on the diminishment of negative environmental impacts of the use of these substances, and it is important to reduce exhaust of tractors, used in agriculture. N_2O emission are of the greatest concern also because of slight adsorption of this gas by forests, thus leading to enormous accumulation of it in the atmosphere. It is important to remember that in chase of carbon emission reduction some agricultural practices provide the increase in N_2O emission. For example, no-till practice, which is widely recognized as a carbon sequestration system of tillage, reduces carbon emission but at the same time on some types of soils it leads to significant increase in N_2O emission, thus resulting in the deterioration of GHG concentration in the atmosphere (21). However, this issue is not clarified yet because there is the evidence of positive affection on the GHG emission from the soil due to no-till practice (2). In our opinion, it depends greatly on the tools used for tillage and on the soil and weather conditions of the zone (20). Besides, it may depend on the crop and fertilization, as it is proved that soil respiration activity strongly depends not only on the depth of plowing, but also on the nutritious regime of soil and its meliorative state (15). However, this issue is of great importance because if CO_2 and CH_4 concentrations in the atmosphere could be managed not only through carbon sequestration and reduction of emissions by the industry, but also through afforestation as the forests are proved to be efficient absorbers of these GHG (14). Modern trend to deforestation and deterioration of forest quality is one of the greatest threats for global environmental stability and leads to significant shifts in biodiversity and climate patterns (6). Nowadays extraordinarily little attention is paid to save forests and promote afforestation, although this strategy could be one of the most efficient in facing the challenges of modern climatology (8, 17). Besides, afforestation provides a huge number of other positive effects, therefore, it is an efficient and simple instrument for total improvement of environment (11, 12). Current agricultural land use practices seem to be far from optimal, but in our opinion, they do not require urgent revision, especially considering the fact of gradual transfer to climate-smart technologies in agriculture, which are aimed to further decrease of CO_2 emission from crop production sector. The main goal of current land use is to keep the area of arable land on the ecologically safe level because the increase in arable land area means the increase in GHG emission and enhances the hazards for desertification. Another option should include the strategies for enhancement of the unit of arable land use through the implementation of thorough land use analysis and implementation of various patterns for land use transformation considering the most prospective directions both for economic and environmental benefits (27). The main directions for agriculture transformation to global warming mitigation policies should embrace revision of current strategies of pesticides and mineral (especially nitrogen) fertilizers use, which together with simultaneous afforestation and land use transformation could benefit to global environmental conditions and restrict rapid climate change.

V. CONCLUSION

According to the results of the study it is possible to draw following conclusions:

1) Crop production inputs to global GHG emission tend to decrease, and their share is 17.40% dated the end of 2010.

2) Crop production is a great factor of the increase in N_2O concentration in the atmosphere, having the share of emission up to 70.74% in 2010 with a tendency to further increase.

3) Deforestation is among the major reasons for CO_2 and CH_4 concentrations increase in the atmosphere. Afforestation will be helpful for the reduction of CO_2 concentrations in the atmosphere and will provide a number of additional benefits for global biodiversity and ecological sustainability.

4) The main task of modern crop production is to keep up the pace for carbon emissions limitation and simultaneously take steps to eliminate the emission of N2O through the revision of mineral fertilizers (especially nitrogen) and pesticides application strategy and reduction of exhaust from tractors used in agriculture.

REFERENCES

[1] Adger WN, Brown K. Land use and the causes of global warming. John Wiley & Sons. 1994.

[2] Chatskikh D, Olesen JE. Soil tillage enhanced CO2 and N2O emissions from loamy sand soil under spring barley. Soil and tillage Research. 2007; 97(1): 5–18.

[3] FAO and UNEP. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. 2020.

[4] Gocic M, Trajkovic S. Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. Global and Planetary Change. 2013; 100: 172–182.

[5] Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C. Food security: the challenge of feeding 9 billion people. Science. 2010; 327(5967): 812–818.

[6] Houghton RA, Byers B, Nassikas AA. A role for tropical forests in stabilizing atmospheric CO2. Nature Climate Change. 2015; 5(12): 1022–1023.

[7] Hughes TP, Kerry JT, Baird AH, Connolly SR, Dietzel A, Eakin CM, Heron SF, Hoey AS, Hoogenboom MO, Liu G, McWilliam MJ, Pears RJ, Pratchett MS, Skirving WJ, Stella JS, Torda G. Global warming transforms coral reef assemblages. Nature. 2018; 556(7702): 492–496.

[8] Islam SA, Rahman MM. Coastal afforestation in Bangladesh to combat climate change induced hazards. Journal of Science, Technology and Environment Informatics. 2015; 2(1): 13–25.

[9] Ito A, Reyer CP, Gädeke A, Ciais P, Chang J, Chen M, Francois L, Forrest M, Hickler T, Ostberg S, Sh, H, Thiery W, Tian H. Pronounced and unavoidable impacts of low-end global warming on northern high-latitude land ecosystems. Environmental Research Letters. 2020; 15(4): 044006.

[10] Javeed HMR, Iqbal N, Ali M, Masood N. Agriculture Contribution toward Global Warming. Climate Change and Plants: Biodiversity, Growth and Interactions, 1. 2021.

[11] Kamal A, Yingjie M, Ali A. Significance of billion tree tsunami afforestation project and legal developments in forest sector of Pakistan. International Journal of Law and Society. 2019; 1: 157.

[12] Korkanç SY. Effects of afforestation on soil organic carbon and other soil properties. Catena. 2014; 123: 62–69.

[13] Lal R. Integrating animal husbandry with crops and trees. Frontiers in Sustainable Food Systems. 2020; 4: 113.

[14] Lykhovyd PV. Role of forests in regulation of climate and crops productivity. Plant Archives. 2021; 21(S1): 731–735.

[15] Lykhovyd PV, Lavrenko SO. Influence of tillage and mineral fertilizers on soil biological activity under sweet corn crops. Ukrainian Journal of Ecology. 2017; 7(4): 18–24.

[16] Nagelkerke NJ. A note on a general definition of the coefficient of determination. Biometrika. 1991; 78(3): 691–692.

[17] Nilsson S, Schopfhauser W. The carbon-sequestration potential of a global afforestation program. Climatic Change. 1995; 30(3): 267–293.

[18] Paustian KAOJH, Andren O, Janzen HH, Lal R, Smith P, Tian G, Tiessen H, Van Noordwijk M, Woomer PL. Agricultural soils as a sink to mitigate CO2 emissions. Soil Use and Management. 1997; 13: 230–244.

[19] Prăvălie R. Major perturbations in the Earth's forest ecosystems. Possible implications for global warming. Earth-Science Reviews. 2018; 185: 544–571.

[20] Rochette P. No-till only increases N2O emissions in poorly-aerated soils. Soil and Tillage Research. 2008; 101(1-2): 97–100.

[21] Rochette P, Angers DA, Chantigny MH, Bertrand N. Nitrous oxide emissions respond differently to no-till in a loam and a heavy clay soil. Soil Science Society of America Journal. 2008; 72(5): 1363–1369.

[22] Rosenzweig C, Colls J. Global warming and agriculture. In Yields of farmed species: constraints and opportunities in the 21st century. Proceedings of a University of Nottingham Easter School Series, June 2004, Sutton Bonington, UK (pp. 143–165). Nottingham University Press. 2005.

[23] Stocker TF, Qin D, Plattner G-K, Alexander LV. Technical Summary. In: IPCC AR5 WG1 2013. pp. 33–115.

[24] Taylor R. Interpretation of the correlation coefficient: a basic review. Journal of Diagnostic Medical Sonography. 1990; 6(1): 35–39.

[25] Wheeler T, Von Braun J. Climate change impacts on global food security. Science. 2013; 341(6145): 508–513.

[26] Xue YN, Luan WX, Wang H, Yang YJ. Environmental and economic benefits of carbon emission reduction in animal husbandry via the circular economy: Case study of pig farming in Liaoning, China. Journal of Cleaner Production. 2019; 238: 117968.

[27] Yin G, Liu L, Jiang X. The sustainable arable land use pattern under the tradeoff of agricultural production, economic development, and ecological protection—an analysis of Dongting Lake basin, China. Environmental Science and Pollution Research. 2017; 24(32): 25329–25345.

TABLES

Table 1. Main agricultural indices for characterization of the intensity of agrotechnologies and land use practice (1990-2010)

Year	Pesticides application, Mt	Fertilizers application, Mt				Forest area, %	Land use			Tractors per 100 sq. km
		Nitrogen, Mt	Phosphorus, Mt	Potassium, Mt	Total, Mt		Agricultural land, Msq. km	Arable land, %	Arable land, MSq	
1990	2.29	77.18	35.97	24.68	137.83	31.62	40.67	10.86	4.42	2871.39
1991	2.26	75.63	35.24	23.73	134.60	31.57	40.78	10.89	4.44	2861.02
1992	2.32	73.66	31.19	20.49	125.34	31.62	46.81	10.82	5.06	2777.25
1993	2.39	72.39	28.96	19.13	120.48	31.57	47.29	10.83	5.12	2737.66
1994	2.54	72.43	29.57	20.05	122.05	31.51	47.51	10.81	5.14	2806.56
1995	2.69	78.36	30.66	20.66	129.68	31.46	47.56	10.80	5.14	2765.46
1996	2.79	82.59	31.10	20.89	134.58	31.40	47.66	10.74	5.12	2941.39
1997	2.92	81.32	33.29	22.58	137.19	31.33	47.87	10.77	5.16	2983.00
1998	2.98	82.81	33.31	22.04	138.16	31.28	48.01	10.80	5.19	3059.67
1999	3.09	84.92	33.29	22.10	140.31	31.22	48.05	10.80	5.19	3101.80
2000	3.06	80.79	32.43	21.69	134.91	31.17	48.11	10.77	5.18	3063.87
2001	3.03	82.18	33.07	22.59	137.84	31.14	48.08	10.75	5.17	3126.42
2002	3.07	82.59	34.55	26.62	143.76	31.10	47.96	10.71	5.14	3100.99
2003	3.16	86.58	36.99	28.41	151.98	31.07	47.82	10.76	5.15	3094.17
2004	3.34	89.02	38.59	30.83	158.44	31.03	47.92	10.78	5.17	3372.58
2005	3.42	89.45	38.82	29.60	157.87	31.00	47.93	10.82	5.19	3262.61
2006	3.46	91.96	39.78	30.45	162.19	30.97	47.82	10.75	5.14	3306.22
2007	3.75	96.08	41.68	33.45	171.21	30.95	47.80	10.74	5.13	3375.73
2008	3.79	95.57	37.62	32.21	165.40	30.92	47.76	10.76	5.14	3538.84
2009	3.71	97.64	38.36	28.38	164.38	30.90	47.64	10.74	5.12	3559.42
2010	3.96	100.79	42.95	33.21	176.95	30.87	47.62	10.70	5.10	3555.38
Trend	Yes ↑	Yes ↑	Yes ↑	Yes ↑	Yes ↑	Yes↓	No	Yes↓	No	Yes ↑

Table 2. Global greenhouse gases emission and the share of crop production inputs in it, billion tons (1990-2010)

Year	Global emission from all sources				Emission from crop production				Share of the crop production emission			
	CO_2	N_2O	CH_4	Total	CO_2	N_2O	CH_4	Total	CO_2	N_2O	CH_4	Total
1990	22.72	2.95	6.67	32.34	3.46	1.92	2.65	8.03	15.23%	65.02%	39.74%	24.83%
1991	23.19	2.91	6.71	32.81	3.46	1.90	2.65	8.01	14.92%	65.40%	39.50%	24.42%
1992	22.47	3.08	6.85	32.39	3.46	1.90	2.63	7.99	15.40%	61.77%	38.41%	24.67%
1993	22.72	2.85	6.50	32.07	3.46	1.88	2.62	7.96	15.23%	65.99%	40.29%	24.82%
1994	22.88	2.96	6.62	32.45	3.46	1.90	2.63	7.99	15.12%	64.30%	39.74%	24.62%
1995	23.37	2.98	6.56	32.91	3.46	1.93	2.64	8.03	14.80%	64.79%	40.26%	24.40%
1996	24.10	3.01	6.55	33.66	3.37	1.96	2.63	7.96	13.98%	65.07%	40.14%	23.65%
1997	24.24	3.24	7.21	34.69	4.04	1.95	2.62	8.61	16.67%	60.24%	36.33%	24.82%
1998	24.15	3.12	6.68	33.95	3.57	1.98	2.63	8.18	14.78%	63.44%	39.37%	24.09%
1999	24.46	2.96	6.50	33.92	3.34	2.00	2.65	7.99	13.66%	67.66%	40.75%	23.56%
2000	25.15	2.92	6.48	34.56	3.26	1.99	2.65	7.90	12.96%	68.13%	40.89%	22.86%
2001	25.37	2.79	6.59	34.74	3.58	2.01	2.65	8.24	14.11%	72.17%	40.20%	23.72%
2002	25.92	2.85	6.79	35.56	4.01	2.01	2.67	8.69	15.47%	70.53%	39.32%	24.44%
2003	27.17	2.84	6.83	36.84	3.82	2.02	2.68	8.52	14.06%	71.20%	39.23%	23.13%
2004	28.44	2.91	7.09	38.44	3.91	2.08	2.73	8.72	13.75%	71.55%	38.52%	22.69%
2005	29.40	2.97	7.28	39.64	3.84	2.09	2.76	8.69	13.06%	70.47%	37.93%	21.92%
2006	30.38	3.10	7.62	41.09	2.97	2.12	2.79	7.88	9.78%	68.39%	36.62%	19.18%
2007	31.28	3.26	7.70	42.24	2.69	2.17	2.82	7.68	8.60%	66.56%	36.64%	18.18%
2008	31.99	3.03	7.64	42.67	2.76	2.17	2.84	7.77	8.63%	71.57%	37.16%	18.21%
2009	31.53	3.07	7.78	42.38	2.89	2.18	2.84	7.91	9.17%	71.03%	36.53%	18.67%
2010	33.15	3.12	7.93	44.20	2.62	2.21	2.86	7.69	7.90%	70.74%	36.08%	17.40%
Trend	Yes ↑	No	Yes ↑	Yes ↑	No	Yes ↑	Yes ↑	No	Yes↓	Yes ↑	Yes↓	Yes↓

Table 3. Correlation analysis results for the evaluation of each factor's input in global greenhouse gases emission

Input source	Coefficient of Pearson's linear correlation (R)				Coefficient of determination (R^2)			
	CO_2	N_2O	CH_4	Total	CO_2	N_2O	CH_4	Total
Pesticides	-0.50	0.97	0.87	-0.10	0.2471	0.9455	0.7652	0.0096
Nitrogen	-0.56	0.98	0.92	-0.16	0.3132	0.9695	0.8474	0.0259
Phosphorus	-0.44	0.87	0.87	-0.06	0.1936	0.7539	0.7628	0.0035
Potassium	-0.42	0.90	0.90	-0.02	0.1757	0.8050	0.8186	0.0003
Fertilizers (in general)	-0.51	0.97	0.94	-0.10	0.2605	0.9339	0.8784	0.0101
Forest area	-0.92	-0.27	-0.76	-0.91	0.8544	0.0750	0.5797	0.8243
Agricultural land area	-0.02	0.38	0.20	0.14	0.0005	0.1450	0.0389	0.0198
Arable land area	0.01	0.34	0.16	0.15	0	0.1139	0.0251	0.0235
Tractors in use	-0.50	0.98	0.91	-0.10	0.2546	0.9558	0.8321	0.0093