Economic and mathematical modelling of ecosystems` territorial sustainability

L. Horoshkova *(Zaporizhzhia National University, Bila Tserkva Institute for continuous professional education),* ***Ie. Khlobystov*** *(National university of "Kyiv-Mohyla academy"),* ***L. Kapranova*** *(Priazovskyi state technical university),* ***D. Tarasenko*** *(Donetsk State University of Management),* ***A. Horbovyy*** *(University of State Fiscal Service of Ukraine)*

SUMMARY

The study is relevant, because nowadays the growth of anthropogenic loads and air pollution require special attention to the modelling of determinants of pollutant emissions` dynamics
Economic and statistical modelling of pollutant emissions` mass and growth rates during 1991 - 2017 applying statistical indicators of relative and cumulative frequency has been made in the article. The following substances have been studied: sulfur dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide. Statistical indicators of relative and cumulative frequency have been used when modelling. It has been taken into consideration in the model that values of emissions during the studied period are marginal ones, which do not pose a threat to the environment in the country. It has been proposed to consider the reliability degree equal to half of the confidence interval for the general arithmetic average growth rate of emissions and their growth rates as the limits of Ukrainian ecosystem`s sustainable development. The obtained results have been tested by the estimation based on the confidence interval for the mean.
The study results can be used to predict environmental pollution parameters in Ukraine, which will not cause an environmental disaster.

Introduction

The atmosphere plays essential role in global, regional and local transporting of pollutants and environmental pollution. Growing anthropogenic load caused by the accumulation of harmful impurities affecting air pollution, slows down the process of atmosphere`s natural self-cleaning. Today, global effects of air pollution exist, i.e. accumulation of greenhouse gases and ozone depletion. Thus, the issue of the determinants of air pollution dynamics modelling in Ukraine needs to be solved.

Method

In the analysis, general-scientific methods (analysis and synthesis, induction and deduction) and special methods of phenomena and processes analysis (abstraction, econometric and econometric-mathematical modelling) have been used.

Results

The qualitative composition of atmospheric air directly depends on the anthropogenic loads on the air. Atmospheric pollutant emissions in Ukraine both by stationary and mobile sources generally tend to decrease (except for 2012). However, in 2016 there was acceleration in growth rates of pollutant emissions, except nitrogen dioxide (Fig. 1).

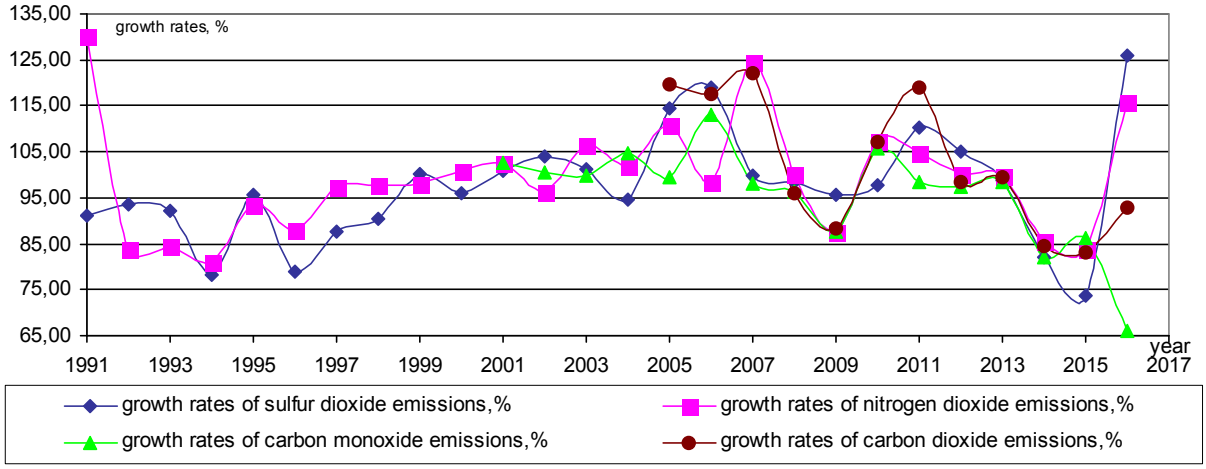

Figure 1 *Dynamics of growth rates of pollutant emissions during 1991 – 2016*

Economic and statistical modelling of the dynamics of pollutant emissions` determinants in Ukraine for the following substances: sulfur dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide have been made. Data on the sum of emissions during 1991 - 2017 and their growth rates have been used. The model is to determine the safe limits of changes in emissions and their growth rates. The approach is explained by the fact that during the studied period emissions fluctuated within certain limits, but the environmental disaster did not happen. These data can be used as a guide for the target (expected) emission values (minimum emission degree) and critical ones (maximum emission degree).

Economic and statistical modelling was made based on statistical indicators of relative and cumulative frequency. These data according to mathematical statistics are the sample of each substance emissions` values. A positive number that indicates how many times a variant happens within the data is called a frequency.

Relative frequencies (the variant frequency ratio to the sample) are often used instead of frequency values, called ratios. Relative frequencies indicate how often certain pollutant emissions were received during the studied period.

We assume that emission values most frequently met during the studied period are the marginal emissions that do not pose a threat to the national environmental situation.

On the other hand, the limits can be estimated by the confidence interval for mean values. For the accepted 0.95 confidence level presented in most studies, the confidence interval for mean values will be determined using Microsoft Excel (Service, Data Analysis, Descriptive Statistics).

Thus, we propose the reliability degree equal to half of the confidence interval for the general arithmetic mean of pollutant emissions` growth rate. It is considered as the limits of present ecosystem sustainable development.
Let us make calculations in two ways and compare them.
The calculation results are shown in Fig. 2 - 5.

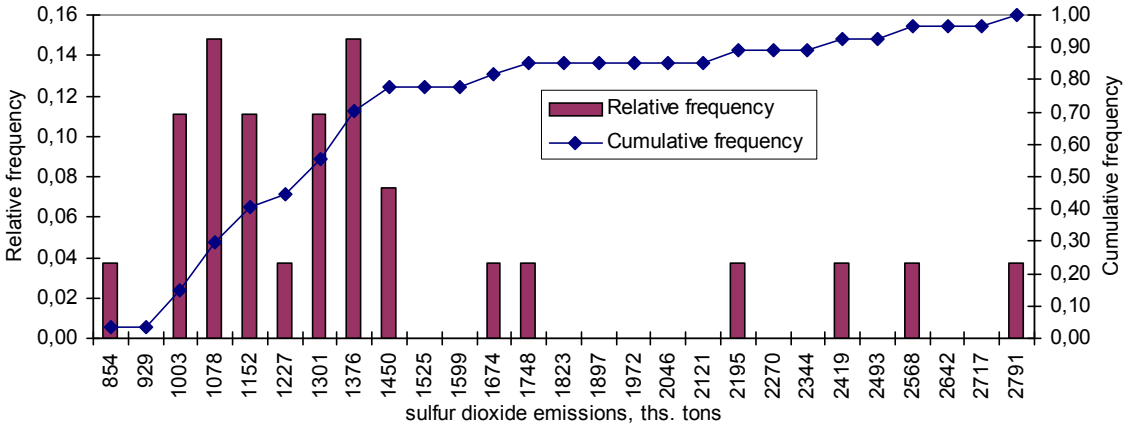

Figure 2 *Relative and cumulative frequencies of sulfur dioxide emissions during 1991-2016*

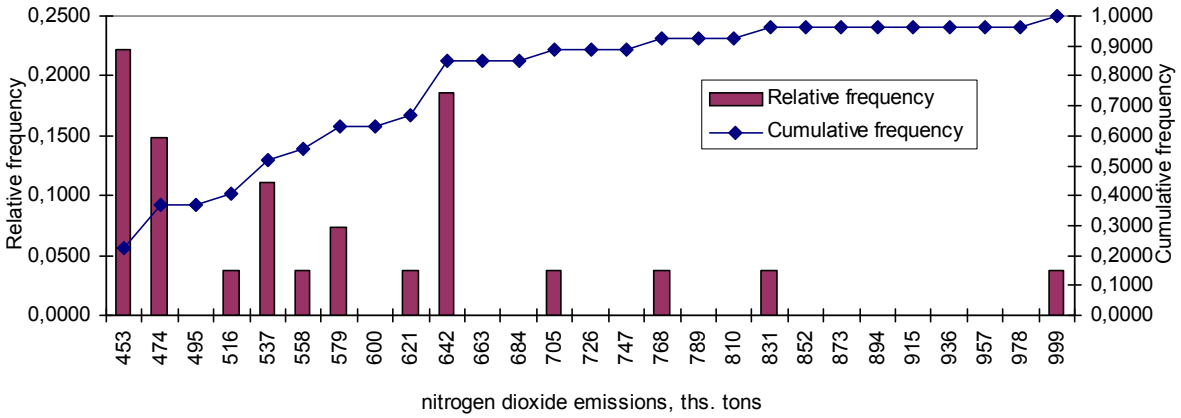

Figure 3 *Relative and cumulative frequencies of nitrogen dioxide emissions during 1991-2016*

Fig. 2 demonstrates the following masses of sulfur dioxide emissions: 1077,5 and 1375,5 thousand tons as optimal values. That is, these values do not pose a threat to the ecosystem`s sustainability.
When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable emissions of 1397,6 ± 200,0689 thousand tons.
Fig. 3 illustrates the following masses of nitrogen dioxide emissions: 453 and 642 thousand tons as optimal values. These values do not threaten the ecosystem`s sustainability.
When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable emissions of 568,6852 ± 53,2569 thousand tons.
Fig. 4 shows the following masses of carbon monoxide emissions: 2871,2 and 2975,8 thousand tons as optimal. That is, these values do not pose a threat to the ecosystem`s sustainability.
The second method application allows to obtain the following results: 0.95 confidence level provide the limits of allowable emissions of 2763,62 ± 257,0544 thousand tons.
Fig. 5 illustrates the following masses of 132,2; 156,2 and 236,2 million tons as optimal values. That is, these values do not pose a threat to the ecosystem`s sustainability.
The second method application gives the following results: 0.95 confidence level provide the limits of allowable emissions of 181,68 ± 21,9718 million tons.

Similarly, the optimal values of growth rates of pollutant emissions have been estimated. It has been found out that for sulfur dioxide they are 96.0%. This means that emissions` growth rate`s slowdown at 4% per year will strengthen ecosystem`s sustainability. When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable changes of sulfur dioxide emissions growth rates of 97,28 ± 5,0356%.

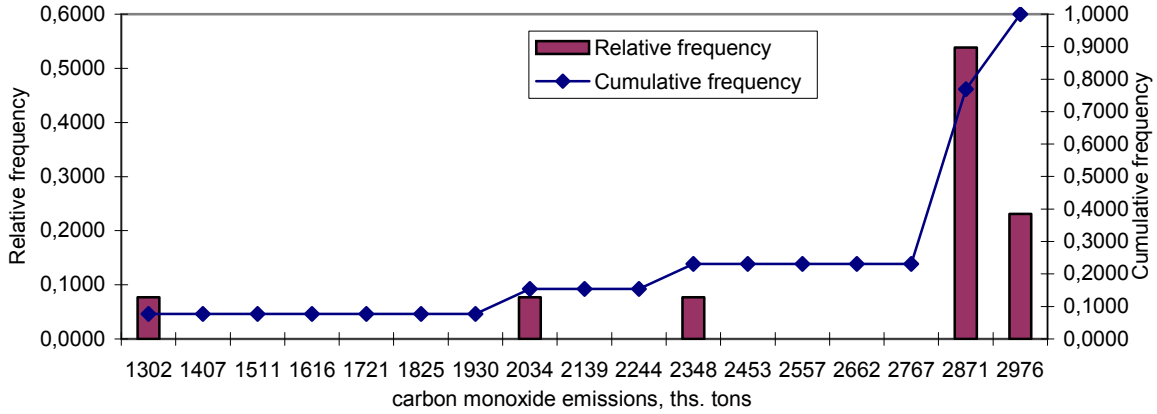

Figure 4 *Relative and cumulative frequencies of carbon monoxide emissions during 1996-2016*

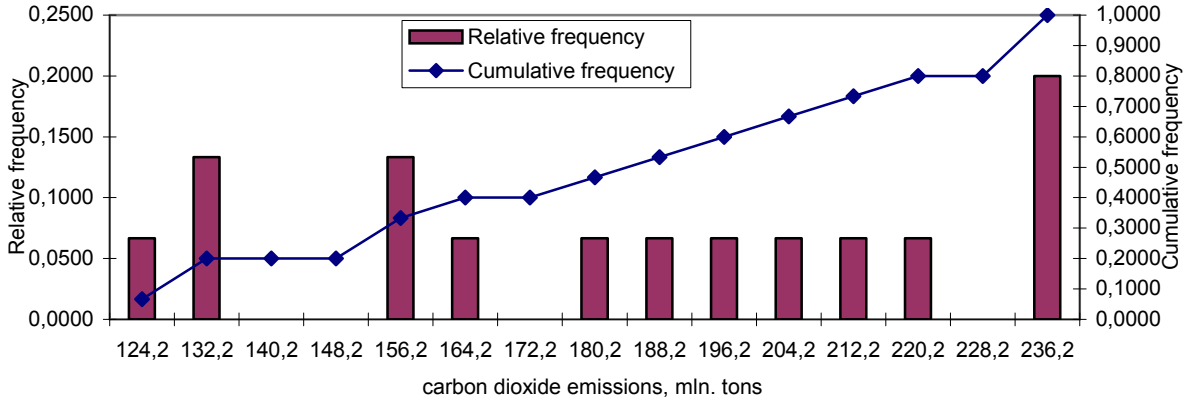

Figure 5 *Relative and cumulative frequencies of carbon dioxide emissions during 2000-2018*

It has been proved that the following growth rates of nitrogen dioxide emissions can be considered as optimal values: 85.6 and 101.6%. That is, these values that do not pose a threat to the ecosystem`s sustainability. Slowing down the emissions` growth rate at 14.4% per year will strengthen the ecosystem`s sustainability. When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable changes of nitrogen dioxide emissions` growth rate at 99,28 ± 4,9249%.

The growth rate of carbon monoxide emissions was an average101.24%. This indicates that, unfortunately, there was no steady emission growth slowdown during 1991-2017, i.e. there was lack of conditions for strengthening the ecosystem`s sustainability.

The second method application provide the following results: 0.95 confidence level provide the limits of allowable changes in the growth rate of carbon monoxide emissions at 96,05 ± 5,8762%. To strengthen the ecosystem`s sustainability, the decline of emissions` growth rate at 5% or more should be achieved.

The following growth rates of carbon dioxide emissions can be considered as allowable values: 85,97 and 120,97%. That is, these values that do not threaten the ecosystem`s sustainability. The ecosystem`s sustainability strengthening could be achieved due to the emissions` growth rate at 14.1% or more downtrend.

The second method allows to obtain the following results: 0.95 confidence level provide the limits of allowable changes in the growth rate of carbon dioxide emissions at 100,82 ± 8,9367%.
The studies of the uncertainty function for identification of hazardous states of atmospheric pollution vector in Ukraine are promising for pollution assessment (Pospelov et al., 2012). The studies of the magnetic properties of soils in Ukraine are promising for pollution assessment (Menshov and Sukhorada, 2010; Menshov et al., 2012).

Conclusions

Economic and statistical modelling of totals and rates of growth of pollutant emissions during 1991 - 2017 has been made applying statistical indicators of relative and cumulative frequency for the following substances: sulfur dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide. In the process of modelling, statistical indicators of relative and cumulative frequency have been used. The model takes into account that the values of emissions that were most often achieved during the studied period are the limits of emissions that do not pose a threat to the environmental situation in the country. It has been proposed to consider the reliability degree equal to half of the confidence interval for the general arithmetic mean of pollutant emissions growth rate as the limits of Ukrainian environmental system`s sustainable development. The obtained results have been verified by the estimation using the confidence interval for the mean values. It has been found out that the optimal values of sulfur dioxide emissions are from 1077,5 and 1375,5 thousand tons. The emission limit values will be 1397,6 ± 200,0689 thousand tons. Optimal values of nitrogen dioxide emissions are 453 and 642 thousand tons. The emission limit values will be 568,6852 ± 53,2569 thousand tons. Optimal values of carbon monoxide emissions are 2871,2 and 2975,8 thousand tons. The emission limit values will be 2763,62 ± 257,0544 thousand tons. Optimal values of carbon dioxide emissions are132,2; 156,2 and 236,2 million tons. The emission limit values will be 181,68 ± 21,9718 million tons. The optimal growth rates of sulfur dioxide emissions are 96,0%. The limits of the allowable change in sulfur dioxide emissions growth rate will be 97,28 ± 5,0356%. Optimal values of nitrogen dioxide emissions growth rates are 85,6 and 101,6%. That is, these values do not pose a threat to the ecosystem`s sustainability. Emissions` growth rate slow down at 14.4% per year will help to strengthen ecosystem`s sustainability. The limits of the allowable change in nitrogen dioxide emissions growth rate will be 99,28 ± 4,9249%. It has been revealed that carbon monoxide emissions` growth rate was an average 101.24%, i.e. during 1991-2017 the emission growth was in steady slowdown, that is there were no prerequisites for ecosystem`s sustainability strengthening. It will be possible to strengthen the ecosystem`s sustainability, if the emissions` growth rate slows down by 5% or more. The following growth rates of carbon dioxide emissions can be considered as allowable: 85,97 and 120,97%. That is, these values do not threaten the ecosystem`s sustainability. Ecosystem`s sustainability could be strengthened as a result of emission growth rate retard at 14.1% or more. The limits of the allowable change in carbon dioxide emissions` growth rate will be 100,82 ± 8,9367%. The study results could be used to forecast the parameters of environmental pollution in Ukraine, which will not lead to the environmental disaster.

References

Pospelov, B., Rybka, E., Meleshchenko, R., Krainiukov, O., Harbuz, S., Bezuhla, Y., Morozov, I., Kuruch, A., Saliyenko, O., Vasylchenko, R. [2012]. Use of uncertainty function for identification of hazardous states of atmospheric pollution vector. *Eastern-European Journal of Enterprise Technologies. Ecology*, 2, 10(104), 6-12.

Menshov, O., Sukhorada, A., Homenko, R., Kruglov, O. [2012]. Ultradetailed Environmental Magnetic Investigations in Ukraine. *Near Surface Geoscience 2012-18th European Meeting of Environmental and Engineering Geophysics, European Association of Geoscientists & Engineers*, 306.

Menshov, O., Sukhorada, A. [2010]. Magnetic properties of Ukraine soils and their informational content. *72nd EAGE Conference and Exhibition-Workshops and Fieldtrips, European Association of Geoscientists & Engineers.*