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SOCIO-ECONOMIC IMPLICATIONS OF FERTILIZERS USE IN AGRICULTURE - FOOD SECURITY AND SAFETY APPROACHES

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Abstract

The article analysis the relationship between the fertilizers use in agriculture and their effects on agricultural output and human health, in the global context of food security and safety and overpopulation. The research question is whether to use fertilizers to increase the agricultural output and ensure food security for a growing population or not, because chemical fertilizers are affecting food safety since they are transmitted through food to human body and they cause health problems. The aim of this paper is to assess the effects of the fertilizers use on human health, using the simple regression model. The main findings show that fertilizers use directly impacts human health. The relevance of the study lies in its capacity to inform people about the effects of the fertilizers use on human health, so they could make informed choices on the food they consume.

Key words: *food safety, food security, overpopulation, human health, sustainability*

INTRODUCTION

Nowadays, the relationships between food issues and other global emergencies become more complex in the context of overpopulation, climate change and resource scarcity. Food security and safety are ones of the world problems connected to other related problems [2]: demographic growth, poverty, energy, natural resources, environment, world trade and the monetary system.

Food security, as a global emergency, become a challenge in terms of population growth to 9 billion people expected to be the world inhabitants in 2050 [13]. In this context, agricultural output should increase by 70%, as reported by FAO [5]. Considering that the current agricultural areas are already under cultivation and the attempt to include more areas in agricultural system become a problem for the environment, the solution for increasing the agricultural production is to produce food in intensive systems, using chemical substances, such as fertilizers, in order to obtain higher yields [10].

The chemical substances used in agriculture are fertilizers, pesticides and veterinary medicine substances. They are used to grow yields and to ensure food security for a growing population, but they remain in food as residues, they affect food safety and, as such, human health. Thus, this paper investigates the effects of the fertilizers used in agriculture for obtaining higher agricultural outputs on human health, trying to answer the question whether to use fertilizers to increase yields and ensure food security or not, because chemical fertilizers are affecting food safety since they are transmitted through food to human body and they cause health issues.

Considering this, the research starts from the assumption that fertilizers use in agriculture is in between food security and safety. Ensuring food security and improved nutrition is the double-pronged goal of sustainable development, put forward at the 2030 Agenda for Sustainable Development of the United Nations [16]. While food security has been the topic of debate in numerous reports and scientific papers for many years, food safety has been less explored and analysed. As other author found [11], Romania is a country where macroeconomic indicators show that food security has been achieved, but it still battles with poverty, which leads to imbalanced diets, especially in rural areas.

Under this context, the use of chemical fertilizers is needed, in order to increase the agricultural output and to ensure food security. But fertilizers are transmitted through food into human body and cause health problems.

The objective of the research is to establish the direction and the intensity of the relationships between chemical fertilizers used in agriculture, agricultural output and human health. In pursuing this, statistical data for the three variables are analysed with simple regression model, using informatics programs. The data are retrieved from the FAO statistical databases and the National Institute of Statistic in Romania and they refer to the last fifteen years.

The amounts of chemicals administrated to agricultural crops need to rise in the future, in order to feed 9 million people, as expected to be in 2050. [5] FAO reported that the yearly cereal production will need to increase to about 3 billion tons, from 2.1 billion and meat production will need to increase by 200 million tons to achieve 470 million tons. This increase implies changes in agricultural technology, including fertilizers, pesticides and land uses [1].

The relationships between world emergencies are discussed in many papers: climate change affects food security, food safety and human health, overpopulation and over production putting pressure on natural resources and food security [8], [9]. Food Standard Authority from U.K. classifies the factors affecting food safety into three categories: the food microbiological content, the concentrations of chemical elements and the levels of radiation [7].

This piece of research focuses on the second factor, namely the presence of chemicals in food: fertilizers, pesticide and veterinary medicine residues, natural, environmental and process chemical contaminants, including particulate matter and polluted air. The abundance of pests and weeds, as a result of climate change, modifies the use of chemicals and fertilizers on crops [14]. These changes in technologies lead to higher quantities of chemicals administrated to crops and found, finally, in food [12].

Food can be contaminated by microbial pathogens, parasites, chemical contaminants and bio toxins. Studies [18] estimated that, worldwide, 600 million people fall ill after eating contaminated food and 420,000 die every year. In Romania, 1,694,876 cases of digestive diseases were reported in 2016 [15].

It is estimated that the amounts of chemical substances will raise, considering the need to produce more food for a growing population. They will be found, finally, in food products. These results of the research drive to the need of answering the questions whether there is a relationship between chemical substances used in agriculture, as a result of overpopulation needing more food, and human health? and if yes, what is its direction and intensity?

This paper starts from the hypotheses that H1: Fertilizers use increases agricultural output and ensure food security for a growing population and H2: Changes in fertilizers use as a result of overpopulation needing more food affects food safety and causes health problems.

H1 has been discussed in many papers [3], [4], and the results are obvious – the agricultural output increases as a result of fertilizers use. A report of the WHO [17] sustained that contaminated food causes more than 200 diseases – ranging from diarrhoea to cancers. In this study, digestive diseases are considered for explaining the effects of chemical residues in food to human health.

The paper is structured into four parts. After the introduction, including the problem statement and the research hypotheses, Section 2 presents the methodology and the data, while Section 3 analyses the results of the regression models. Finally, in Section 4, the results are discussed, the hypotheses are validated, and the conclusions are drawn.

MATERIALS AND METHODS

For validating the hypotheses expressed before, the relationships between variables corresponding to the use of fertilizers in

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agriculture, to the agricultural output and to human health are analysed.

The variables corresponding to the use of fertilizers in agriculture are the amounts of Nitrogenous (N fertilizers), Phosphorous (P fertilizers) and Potassium (K fertilizers) fertilizers administrated to crops in Romania, in the period 2002-2016. Figure 1 shows the dynamics of the fertilizers use in agriculture. Positive trends can be observed from 2006 to 2016. In 2016, the quantity of N fertilizers stabilized to 25.4 kg, the quantity of P fertilizers to 9.3 kg and the quantity of K fertilizers to 3.2 kg of active substance per hectare of agricultural land.

The variable corresponding to the agricultural output is the level of yields. The maize crop has been chosen, because it occupies the largest areas under cultivation in Romania (2.6 million hectares, out of 8.4 million hectares under cultivation). Its trend is oscillatory in the period under analysis, between 1.7 tons and 4.7 tons per hectare.

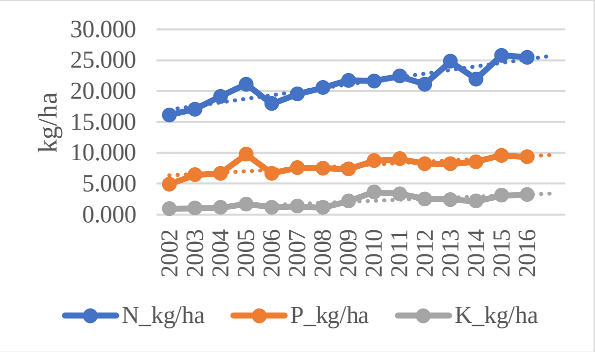

Fig. 1. Dynamics of fertilizers use in agriculture in Romania, 2002-2016 (kg active substance per hectare of agricultural land)
Source: FAOSTAT, 2019 [6].

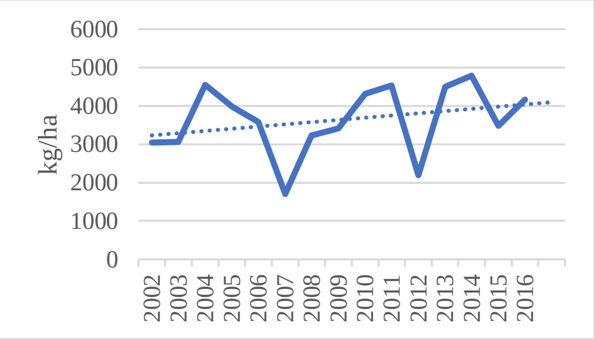

Fig. 2. Maize yield in Romania, 2002-2016 (kg/ha)
Source: FAOSTAT, 2019 [6].

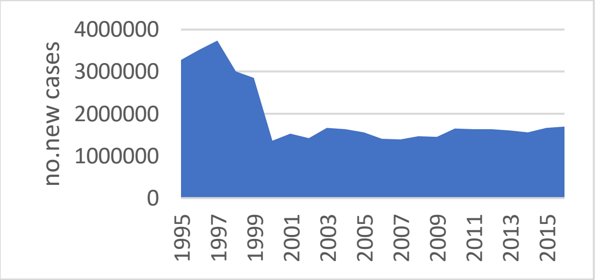

Fig. 3. New cases of digestive disease in Romania, 1995-2016
Source: National Institute of Statistics, Romania.

The variable corresponding to human health is the number of new cases of digestive diseases. Digestive diseases have been considered because it has been demonstrated in a report of the WHO [17] that chemical poisoning, including chemical fertilizers poisoning, may cause nausea, stomach cramps, vomiting, diarrhoea, weakness, headache, confusion, excessive sweating etc. all of these being symptoms of digestive diseases. Data on digestive diseases have been retrieved from the National Institute of Statistic of Romania database (Figure 3).

RESULTS AND DISCUSSIONS

Firstly, the variables are tested for normalization. The results for Digestive diseases are as follows: the mean ($\bar{x}$) registered a value of 1,564,091 new cases, the median (μ) registered 1,610,523 new cases, the maximum (max) registered 1,694,876 new cases, the minimum (min) registered 1,399,424 new cases. The Skewness value is -0.741, meaning that the sample is negatively skewed and strives towards left. The Kurtosis value is 1.6261 and it indicates a normal distribution. The probability is 0.41974, which is greater than 0.05, meaning that the null hypothesis of a normal distribution is accepted.

When testing the variable consumption of N fertilizers, the mean ($\bar{x}$) is 294,194 tons, the median (μ) is 296,055 tons, the maximum (max) is 357,352 tons, the minimum (min) 239,071 tons. The Skewness value of 0.256577 means the sample is positively skewed and strives towards right. The Kurtosis value is 2.1346, indicating a normal

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distribution. The probability of 0.7288, which is greater than 0.05, means that the null hypothesis of a normal distribution is accepted.

The results for the variable consumption of P fertilizers are as follows: the mean ($\bar{x}$) registered a value of 110,284 tons, the median (μ) registered 113,035 tons, the maximum (max) registered 138,137 tons, the minimum (min) registered 72,996 tons. The Skewness value is -0.2925, meaning that the sample is negatively skewed and strives towards left. The Kurtosis value is 2.4442, closed to the value of 3, and it indicates a normal distribution. The probability is 0.8158, which is greater than 0.05, meaning that the null hypothesis of a normal distribution is accepted.

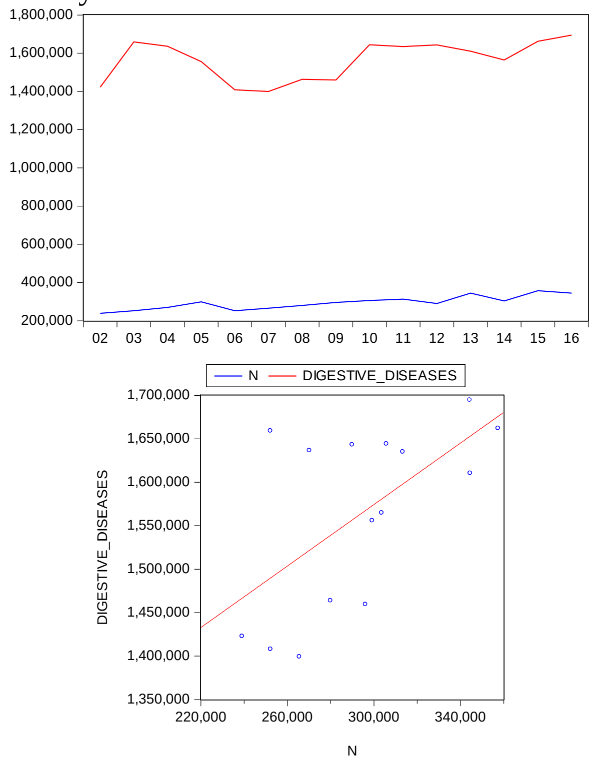
The test of normality for the variable consumption of K fertilizers retrieved the following results: the mean ($\bar{x}$) is 28,886 tons, the median (μ) is 29,606 tons, the maximum (max) is 51,500 tons, the minimum (min) 14,056 tons. The Skewness value of 0.35772 means the sample is positively skewed and strives towards right. The Kurtosis value is 2.1346, indicating a normal distribution. The probability of 1.73355, which is greater than 0.05, means that the null hypothesis of a normal distribution is accepted. As seen, all the variable tested have a normal distribution.

Secondly, the graphical rendering is tested, in order to have a better perspective over the variables. The graphs for the variables digestive diseases and the use of N fertilizers and the correlogram are presented in Figure 4. It can be noticed that the two variables have registered a likely trajectory. The current dataset has a positive trend, indicating a direct influence of N fertilizers use over the new cases of digestive diseases.

The graphs for the variables digestive diseases and the use of P fertilizers and the correlogram are presented in Figure 5. It can be noticed that the two variables have registered almost the same trajectory. The current dataset has an ascendant trend, indicating a direct influence of P fertilizers use over the new cases of digestive diseases.

The graphs for the variables digestive diseases and the use of K fertilizers and the correlogram are presented in Figure 6. It can be observed that the two variables have registered a likely trajectory. The current dataset has an ascendant trend, indicating a direct influence of K fertilizers use over the new cases of digestive diseases.

Thirdly, the stationarity of the variable is tested. The values of the variable new cases of digestive diseases have been tested using Dickey-Fuller test.



Date: 01/21/19 Time: 08:09
Sample: 2002 2016
Included observations: 15

Lag	AC	PAC	Q-Sta...	Prob
1	0.491	0.491	4.3978	0.036
2	0.388	0.193	7.3481	0.025
3	0.248	-0.00...	8.6587	0.034
4	0.230	0.077	9.8829	0.042
5	0.140	-0.02...	10.385	0.065
6	-0.01...	-0.16...	10.387	0.109
7	-0.23...	-0.30...	12.206	0.094
8	-0.22...	-0.03...	14.048	0.081
9	-0.34...	-0.18...	19.067	0.025
1...	-0.21...	0.106	21.498	0.018
1...	-0.24...	0.021	25.437	0.008
1...	-0.24...	-0.03...	30.556	0.002

Fig. 4. Correlations between new cases of digestive diseases and the use of N fertilizers
Source: results of the regression model.

The probability of t-statistics is 0.014, bellow 0.05 and the value of t-Statistic is over the three critical values, except 1% value, meaning that the data are stationary. When testing the values of the variable the use of N fertilizers, the probability of t-statistics is 0.0065, bellow 0.05 and the value of t-

Statistic is over the three critical values, meaning that the data are stationary. The values of the variable the use of P fertilizers are tested. The probability of t-statistics is 0.0326, bellow 0.05 and the value of t-Statistic is over the three critical values, except 1% value, meaning that the data are stationary. When testing the values of the variable the use of K fertilizers, the probability of t-statistics is 0.2000, over 0.05, showing a limit of the research.

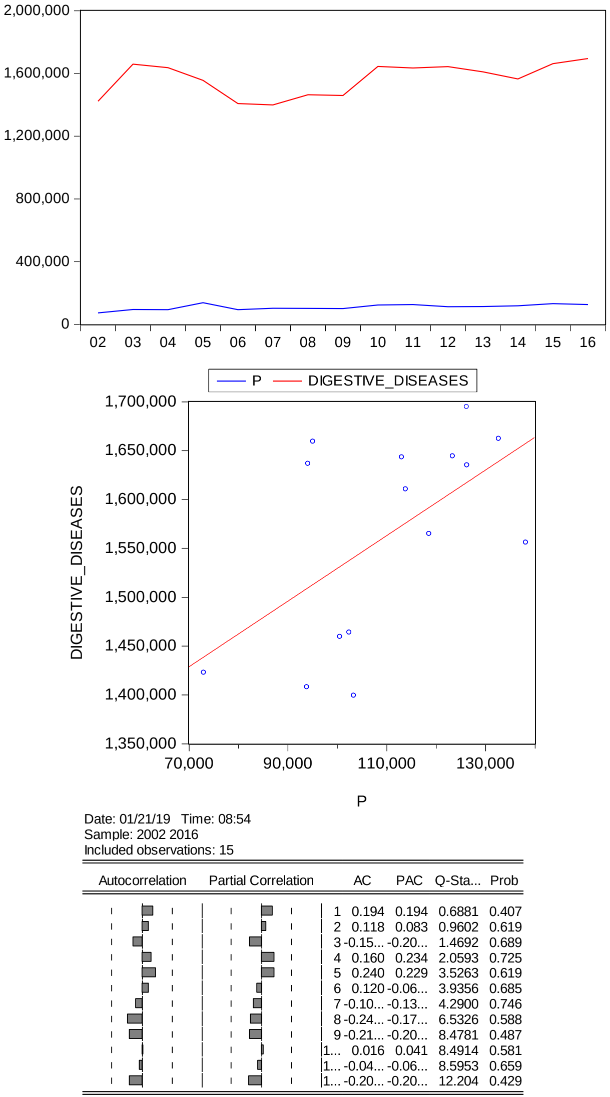


Fig. 5. Correlations between new cases of digestive diseases and the use of P fertilizers
Source: results of the regression model.

The fourth step is to test the causality between variables using the Granger Test. The probability of F-Statistic is 0.3553, higher than 0.05, meaning that there is no causality relation between the variable N fertilizers use and the variable new cases of digestive diseases. When testing the causality between the variable P fertilizers use and the variable new cases of digestive diseases, the probability of F-Statistic is 0.4041, indicating no causality between variables. Finally, when testing the causality between the variable K fertilizers and the variable new cases of digestive diseases, the probability of F-Statistic is 0.8421, meaning that there is no causality relation between variables. For the model's accuracy, there must not be any preexistent causality.

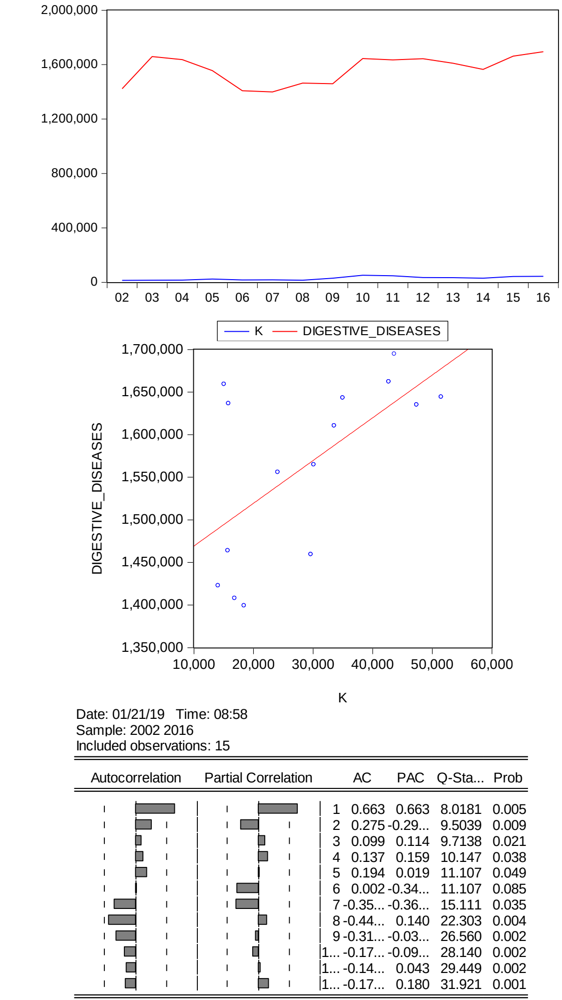


Fig. 6. Correlations between new cases of digestive diseases and the use of K fertilizers
Source: results of the regression model.

The following step is to set up the linear model of simple regression. The probability afferent of F-statistic test is 0.0173 for the variable N fertilizer use and 0.0001 for the constant which are below 0.05 resulting that the model is valid. The R-squared value is

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0.364, resulting the low capacity of the independent variable to explain the endogen variable. Durbin – Watson is 1.2844, closed to the value of 2, resulting that the errors are not correlated. The model explaining the relationship between digestive diseases and the use of N fertilizers is: digestive_diseases = 0.603*N, meaning that 1 unit change in the level of N fertilizers use will lead to 0.603 changes in the level of digestive diseases.

When analysing the variables P fertilizers use and the new cases of digestive diseases, the probability of F-statistic test is 0.0270 for the variable P fertilizers use and 0 for the constant, meaning that the model is valid. The value of R-squared is 0.323, resulting the low capacity of the independent variable to explain the dependent one. Durbin – Watson is 1.06, closed to the value of 2, resulting that the errors are not correlated. The model explaining the relationship between digestive diseases and the use of P fertilizers is: digestive_diseases = 0.569*P, which means that one-unit modification in the quantity of P fertilizers use leads to 0.569-unit modification in the number of digestive diseases.

When testing the variables K fertilizers use and the new cases of digestive diseases, the probability of F-statistic test is 0.0133 for the variable K fertilizers use and 0 for the constant, meaning that the model is valid. The value of R-squared is 0.386, resulting the low capacity of the independent variable to explain the dependent one. Durbin – Watson is 1.144, closed to the value of 2, resulting that the errors are not correlated. The model explaining the relationship between digestive diseases and the use of K fertilizers is: digestive_diseases =0.622*K, meaning that one unit change in the level of K fertilizers use will lead to 0.622 unit changes in the level of digestive diseases.

Finally, the model's validity is tested with the heteroscedasticity test, applied for residual values with the White Test probability. The value of the probabilities for F is 0.1155, for Chi-Square is 0.1037 and for the second Chi-square is 0.3288, all above 0.05, meaning that the errors are homoscedastic for the model showing the relationship between N fertilizers use and new cases of digestive diseases. The value of the probabilities for F is 0.3523, for Chi-Square is 0.3021 and for the second Chi-square is 0.6340, all above 0.05, meaning that the errors are homoscedastic for the model showing the relationship between P fertilizers use and new cases of digestive diseases. The value of the probabilities for F is 0.0695, for Chi-Square is 0.0678 and for the second Chi-square is 0.2035, all above 0.05, meaning that the errors are homoscedastic for the model showing the relationship between K fertilizers use and new cases of digestive diseases. The test for the residual values autocorrelation show that the Prob Chi-square is higher than 0.05, meaning that the residues are not correlated in time and the model is valid.

The forecasts for the following period of time (Figure 7) show that the new cases of digestive diseases fall as a result of N and P fertilizers changes, and they remain constant as a result of K fertilizers modification.

The forecasts for maize yields for the following years show that the yield is constant, as a result of N and P fertilizers changes and slightly rises as a result of K fertilizer variability (Figure 8).

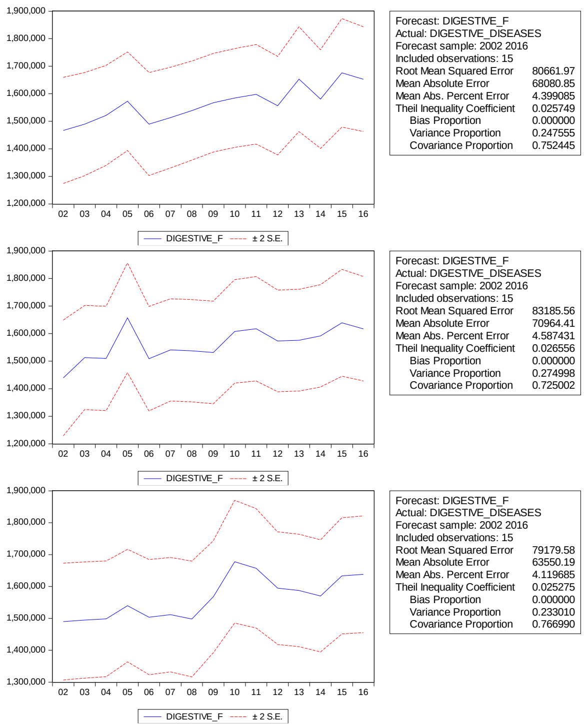

Fig. 7. Forecasts for new cases of digestive diseases, depending on the variability of N, P and K fertilizers' use

Source: results of the regression model.

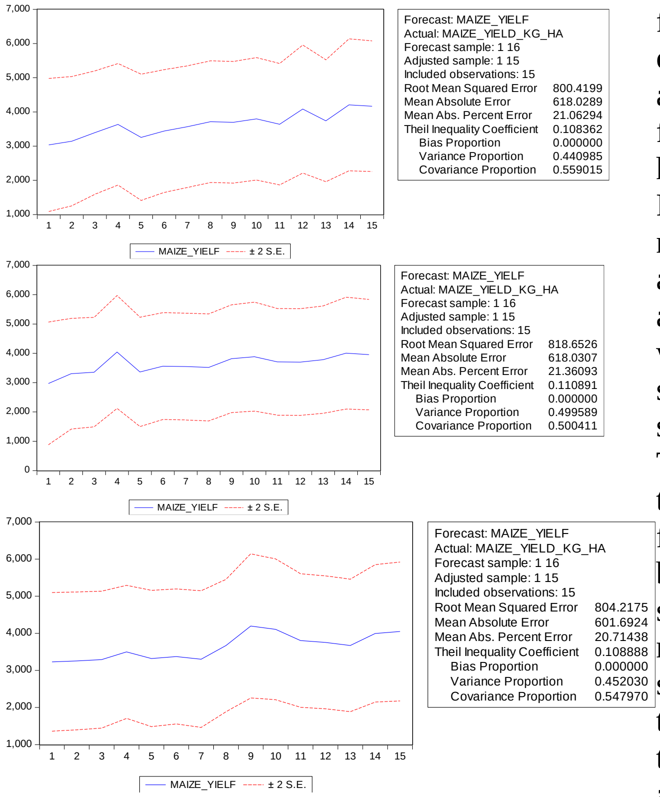

Fig. 8. Forecasts for maize yields, depending on the variability of N, P and K fertilizers' use
Source: results of the regression model.

CONCLUSIONS

Fertilizers use in agriculture impacts human health. The hypotheses of the research, arguing that H1: Fertilizers use increases agricultural output and ensure food security for a growing population and H2: Changes in fertilizers use as a result of overpopulation needing more food affects food safety and causes health problems are validated.

The results are sustained by other reports [17] arguing that diarrheal disease is the most common illness resulting from the consumption of contaminated food, affecting 550 million people to fall ill and 230,000 deaths every year. Moreover, the Food Standards Authority report in 2010 found that the presence of chemicals in food: fertilizers, insecticides, fungicides and herbicides, and veterinary medicine residues, natural, environmental and process chemical contaminants, is a factor affecting food safety.

Bearing in mind the need to increase the agricultural output by 70 percent until 2050, actions are needed to ensure food security so that every human being has access to adequate food. One solution to increase the agricultural output is to encourage and finance the agricultural research that should focus on finding solutions to increase yields without harming the environment or human health. Fertilizers management should be oriented to natural methods and materials, using lower amounts of chemical substances. Smart agriculture, with its machineries equipped with sensors that administrate chemical substances only if needed, could represent a solution for the future.

The relevance of the results lies in the fact that people can make informed choices on food they consume. In Romania this is even a bigger problem with the agricultural products sold on the fresh agricultural producers' markets, where the control of chemical substances administrated to crops are difficult to be done. Bearing in mind that the share of this market in total agricultural output sold on all markets is high, the issue of selling unsafe agricultural products grows in significance.

The research has its limitations. Not all digestive diseases are caused by contaminated food intake. There are other causes for digestive problems. We recommend that future research should consider only those cases of digestive diseases caused by food poisoning.

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