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# Forecasting $CO_2$ Emissions from Agriculture and Relationship with Some Variables in OECD Countries

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## 1. Introduction

The greenhouse effect is a most natural phenomenon. Its intensification has been noted for some time, which is evident in the observed increase in average global air and ocean temperatures. Despite the many voices of skeptics, human influence on these changes is more difficult to undermine. Besides the significant emissions from industry – mainly from burning fossil fuels, it is important also to consider the impact of agriculture and changes in land use.

According to the Food and Agriculture Organization (FAO), it is mainly the animal agriculture sector – which includes the production of feed crops, the manufacturing of fertilizer, and the shipment of meat, eggs, and milk—is responsible for 18% of all GHG emissions. Land use change and agricultural activities globally account for about 1/3 of the warming effect from increased GHG concentrations [3].

Farm animals and animal production facilities occupy 1/3 of the earth, and 2/3 of the available agricultural land [6].

Among the GHG, $CO_2$ is particularly important because it is produced in the largest quantities. $CO_2$ is released e.g. from the burning of fossil fuels, deforestation and other land-use changes that remove vegetative cover. The atmospheric concentration of $CO_2$ has risen nearly 25% in the past century. $CO_2$ emissions from agriculture are systematically growing (Fig. 1).

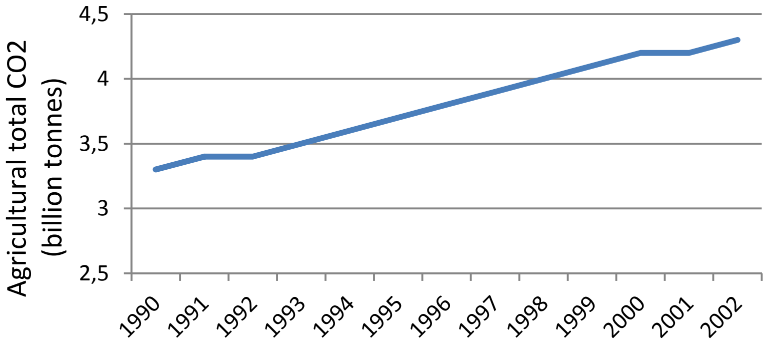


**Fig. 1**. Agricultural total $CO_2$ emission in OECD countries. Data source: [27]
**Rys. 1.** Rolnicze emisje $CO_2$ w krajach OECD

Croplands play an important role in the overall carbon budget. However, estimating the carbon balance is difficult because of the diversity of crops and farming systems, and strong influence in human management [25].

Previous analysis which examines the role of agricultural and forest sector carbon sequestration have generally been ignored [3, 21]. Until 1920 land use change was mainly an anthropogenic source of $CO_2$ emissions exceeding that of fossil fuels [8].

Energy is used directly in agriculture for a range of purposes, including operating vehicles and irrigation pumps, and controlling indoor temperatures of greenhouses, barns, and other farm buildings. Crop production requires a large amount of liquid fuel for field operations. Changes in the way of cultivation and production management are associated with energy consumption and $CO_2$ emissions from fossil fuel combustion. Energy consumption and emissions occur on-site from the operation of farm machinery and occur off-site from the manufacture and transport of cropland production inputs, such as pesticides, fertilizers, and agricultural lime [15]. Modern agriculture is accompanied by an increase in energy consumption.

Agricultural lands have the potential to mitigate fossil fuel emissions through production of dedicated bioenergy crops [1]. Land use change mainly depends on economics and legislation, but also by the availability of land. It is easy to see that the rapidly growing world population needs more land for agricultural crops. One way of acquiring them is intense deforestation, which further limits the absorption of harmful gases.

Deforestation for animal production accounts for 89.5% of all $CO_2$ livestock related emission and 34% of $CO_2$, $CH_4$, and $N_2O$ emissions. The forestry sector is currently responsible for 17.4% of GHG emissions [13].

The factors discussed above, are associated with $CO_2$ emissions from agriculture. In order to identify their relationship to the $CO_2$ emissions they were exploring by using data mining tools. The collected experimental or empirical data obtained previously in the direction of other research, can be used as a source of new and scientific valuable information that has not yet been used [23,24]. Data need methods to find the precious information that can complete the knowledge in the specific field. It does so algorithmic tools for data mining [7].

Data mining tools are often used in studies on the influence a variety factors on $CO_2$ emissions. Studying the interaction between $CO_2$ emission, arable production and forest land carried out in the work Terence and others [22]. In other analyzes, determined the correlation of $CO_2$ among others: energy consumption, Gross Domestic Product, manufacturing output and other [9] or investigated linkage $CO_2$ emissions from land use change, combustion of fossil fuels and population pressure on natural and terrestrial ecosystems [20]. Research on assessing the impact of factors responsible for $CO_2$ emissions in the agricultural sector, and future emissions are conducted in many scientific centers in the world [2, 10, 15, 16, 17, 18, 19, 25].

It is very important to be able to identify sources that are particularly intensively influencing $CO_2$ emissions, and reduce their share.

## 2. Materials and Methods

The aim of the study was to determine which variables and to what extent are the most significant for $CO_2$ emissions in OECD countries. Among the many factors which directly or indirectly are linked to $CO_2$ emissions from the agricultural sector, which was mentioned above, several were examined: pasture area, arable and permanent crop area, direct on-farm energy consumption, index of crop and livestock production and machinery use. The research was conducted globally in OECD countries and for chosen member countries. The tests were performed using analysis of variance ANOVA. Analysis of variance is used to study the effects of factors (independent variables) on the dependent variable. Results of F test (analysis of variance) provides information that the was observed impact of a factor on the dependent variable. ANOVA allowed the statistics value to be determined as a critical value from F-Snedecor distribution, for an assumed level of significance and number of degrees of freedom. Limit value of statistical significance was assumed at level $\alpha = 0.05$. As the dependent variable $CO_2$ emissions from agriculture was adopted and the qualitative variables were pasture area, arable and permanent crop area, direct on-farm energy consumption, index of crop and livestock production and machinery use, compiled for a 15 years period. Some information that carries a one-way analysis of variance Was used. The purpose of the ANOVA analysis was to gain of knowledge whether $CO_2$ emissions is different for different levels of the analyzed variables in individual years.

The study was conducted using the package R-Project version 2.10.0. Because in the case of data mining is preferred the use of more than one algorithm to solve the problem under consideration [24] a secondary objective of this study was to apply the artificial network. Neural networks were used mainly in terms of indications significant, affecting the $CO_2$ emissions variables and to forecast future scenario emissions from the agricultural sector.

Forecasts carried out based on ANNs Flexible Bayesian Models network performed globally for OECD countries. Recently ANNs techniques has become the focus of much attention, largely because of their wide range of applicability and the ease with which they can treat complicated problems even if the data are imprecise and noisy.

Before start of the forecasts data were standardized. Training set were consist of 15 cases and test set – 4096. It was used a network built of 6 variables in the input layer, 1 hidden layer consists of 682 neurons and output layer built from 1 neuron.

Obtained in the course of a learning network values indicate the network received the optimal conditions of the rate: the rejection impact of the value of 0.1 – for the acceptable limits of variation in the range 0.1–0.3, and the graphs of the control trajectory with value 0.352 – for limit values in the range 0.3–0.8.

A total of 257 different combinations were analyzed. Accepted for study variables oscillated around the actual data and with an allowance of up to ±10%. Therefore, to test the values were taken:

The impact of pasture area from 440 to 480 million hectares was assumed in modeling,

- Direct on-farm energy consumption is characterized by a gradual increase in the analyzed period. To modeling which examined the impact from the interval 1,100–2,400 Tonnes oil equivalent,
- The variable arable and permanent crop area between of 750–780 million hectares was established,
- Index of crop production in the intervals 40–120 and Index of livestock production – from 70 to 115 was adopted,
- Number of agricultural machinery is approximately constant and equals 371,500. To estimation values in the range 355,000 – 385,000 units was assumed.

Statistical data came from FAO and the OECD databases [26, 27]. To estimate the Flexible Bayesian Models on Neural Networks version 2004-11-10 was used [14].

## 3. Results and Discussion

ANOVA shows very highly statistically significant analyzed variables (except machinery use) for all OECD countries globally. The diversity of OECD member countries including topographical factors, agricultural potential, quantity of population, social and economic structure, strategic regional location and many other factors, cause, that in different regions, the other variables with varying intensity determine the size of this issue.

Exemplary result generated by program R is given in Figure 2.

The analysis indicated that, in many cases the quantity of $CO_2$ differs for different values of the k level. Significant results of ANOVA test (statistic F) indicates that this factor has an effect on the dependent variable, which means that the different values of the factor (in particular years) change the value of the dependent variable – have an impact on the value of this variable ($CO_2$ emissions). The significance for individual variables is indicated by "Signif. codes" and the obtained results for all countries are attached in Table 1. A high variables relationship of $CO_2$ emissions was obtained for instance in New Zealand (with the exception of the arable and permanent crop area) or for Spain.

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Analysis of Variance Table

Response: TotalCO2
                          Df     Sum Sq    Mean Sq  F value    Pr(>F)    
Pasture.area               1 1.3319e+16 1.3319e+16 866.2967 1.924e-09 ***
Energy.consump.            1 2.5116e+15 2.5116e+15 163.3587 1.324e-06 ***
Index.of.crop.prod.        1 1.8365e+15 1.8365e+15 119.4498 4.356e-06 ***
Index.of.livestock.prod.   1 1.1768e+15 1.1768e+15  76.5400 2.281e-05 ***
Machinery.use              1 1.1041e+13 1.1041e+13   0.7181    0.4214    
Crop.area                  1 5.0533e+13 5.0533e+13   3.2868    0.1074    
Residuals                  8 1.2300e+14 1.5375e+13                       
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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**Fig. 2.** ANOVA result generated by program R for total OECD countries; Signif. codes: 0 '***' and 0.001 '**' – high statistical significance, 0.01 '*' – statistical significance, 0.05 '.'– boundary value of statistical significance, 0.1 ' ' and 1 – insignificant value

**Rys. 2.** Wyniki analizy ANOVA generowane w programie R dla wszystkich krajów OECD; Signif. codes: 0 '***' oraz 0.001 '**'– wysoce istotne statystycznie, 0.01 '*'– istotne statystycznie, 0.05 '.'– granica istotności statystycznej, 0.1 ' ' oraz 1 – wartości nieistotne statystycznie

It should be noted that in Poland and France only one factor pointed to a relationship with the tested variable, other proved to be statistically insignificant. In Poland it is mainly the industrial and energy sector, where emissions from the energy sector accounts for 96.2% of $CO_2$ emissions, and industrial processes – 3.6% [12]. In France, $CO_2$ emissions come mainly from transport and households. Norway is a country with near zero emissions of $CO_2$. Norway declares even, that by 2030 they completely limited $CO_2$ emissions. It can therefore be concluded that other factors, which in these studies were not considered, affect the tested variable with a much higher intensity.

The most important observed modeling results showed (as in the analysis of ANOVA) a highly significant association between the size of pasture area and $CO_2$ emissions. Negative correlation between the variables was observed. With the increase of pastures area, $CO_2$ emissions decrease (Fig. 3).

**Table 1.** The results of analysis of variance for all studied countries
**Tabela 1.** Wyniki badań analizy wariancji dla wszystkich badanych krajów

| Country | Pasture area | Arable and permanent crop area | Energy consumption | Index of crop production | Index of livestock production | Machinery use |
|---|---|---|---|---|---|---|
| **OECD** | *** | *** | *** | *** | *** | |
| France | ** | | | | | . |
| Greece | *** | *** | | | | *** |
| Germany | *** | | ** | . | * | |
| Iceland | * | *** | | * | | |
| Italy | | *** | | | | *** |
| Japan | | *** | * | ** | | |
| New Zealand | *** | | *** | *** | *** | *** |
| Norway | *** | . | | | | |
| Poland | | * | | | | |
| Spain | ** | *** | ** | * | ** | |
| Turkey | | *** | *** | ** | ** | |
| USA | *** | *** | | . | . | |

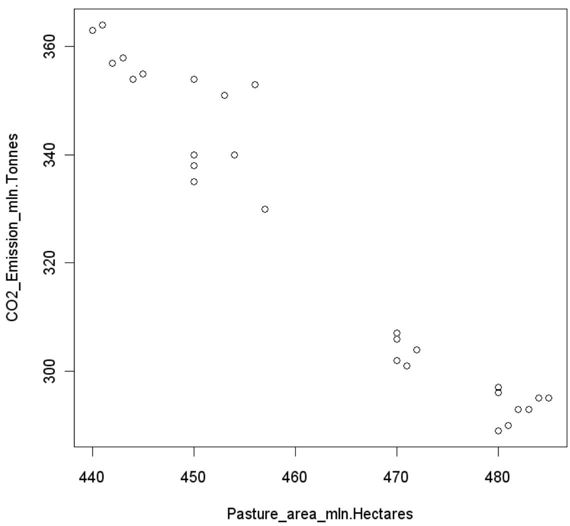


**Fig. 3.** Scatterplot for mean values of $CO_2$ emission and Pastures area
**Rys. 3**. Wykres rozrzutu dla wielkości emisji $CO_2$ i areału pastwisk

The highest projected emissions were obtained by gradually increasing all of the analyzed variables and with a pastures area drop. The lowest emission was characterized at the highest values of pasture area, with visible influence of variable arable and permanent crop area (with a decrease of arable area – a decrease in $CO_2$ emissions was noted). Because of the large number of results (4112 responses) it was more important relationships presented on the Figure 4.

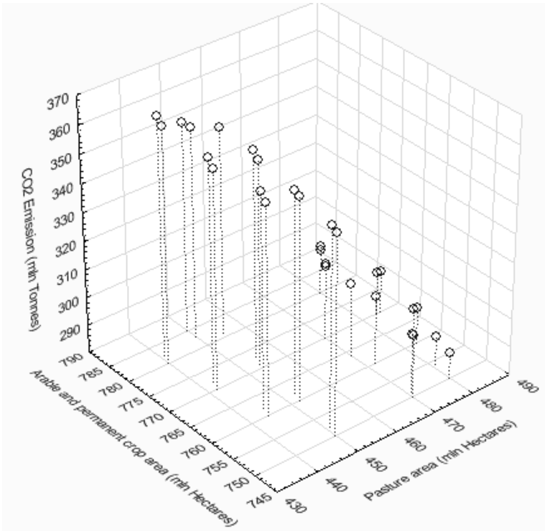


**Fig 4**. Relationship between pasture area, crop area and $CO_2$ emission
**Rys. 4.** Zależność pomiędzy wielkością areału pastwisk, upraw a emisją $CO_2$

A very important role for $CO_2$ emissions from the agriculture sector for pasture areas and arable and permanent crop area was indicated.

## 4. Conclusion

The use of two different methods employed in data mining allowed an indication of the factors significantly associated with agricultural $CO_2$ emissions. ANOVA by changing the value of the factor (in this case, the values of the variables in individual years), in many cases it is linked to the size of $CO_2$ emissions. The results are different for different countries, wherein the variables pastures and arable and permanent crop areas are significant in almost all the analyzed countries.

Neural networks also indicated as very highly statistically significant variables in OECD countries globally – pastures and arable and permanent crop area. According to some scientist a change of land use for arable land, may lead to the release and increase of $CO_2$ emissions [5]. As show Dphil et al. [4] land use change with a high content of soil organic matter (SOM) (e.g. forests, grass) in to a low SOM (e.g. arable land) cause the release of carbon. As a result, more arable land conducts an increase in $CO_2$ emissions.

Methods conducive to climate protection are the conversion of arable land to grassland and pastures and intensification reduction.

There is no universally applicable list of practices that allows for the reduction of emissions. Practices must be evaluated separately for each region, agricultural systems based on climate, social setting, and historical patterns of land use.

In these trials statistical tools and ANN proved to be helpful in indicating highly significant factors connected with $CO_2$ emissions, in practice they are to be treated with special concern.

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# Prognozowanie rolniczych emisji $CO_2$ i związek z wybranymi zmiennymi w krajach OECD

## Streszczenie

Dzięki sztucznym sieciom neuronowym możliwie jest rozwiązywanie specyficznych problemów, z którymi zmagają się tradycyjne techniki obliczeniowe. Sieci neuronowe mogą być stosowane tam, gdzie występują problemy z przetwarzaniem i analizą danych, ich przewidywaniem, klasyfikacją i kontrolą. Podjęte badanie wskazują, które czynniki sektora rolnego krajów Organizacji Współpracy Gospodarczej i Rozwoju (OECD) są powiązane z emisjami $CO_2$. Badania oparto na analizie wariancji ANOVA z wykorzystaniem pakietu statystycznego R. Ewentualne spodziewane emisje $CO_2$ prognozowano z wykorzystaniem sieci neuronowych (SSN) Flexible Bayesian Models on Neural Networks. Prognozy umożliwiły identyfikację czynników szczególnie istotnych. Badanie wykazały znaczący wpływ na wielkość emisji $CO_2$ wielkości areałów pastwisk oraz gruntów ornych i stałych powierzchni upraw.