Applying machine intelligence method to analyzing the impact of agri-environmental subsidy schemes on the eco-efficiency

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Introduction

The concept of agricultural eco-efficiency is one standpoint that may summarize the economic and environmental factors of agriculture when we aim to produce more high-quality products while reducing the use of land, water, energy, labor and capital resources.

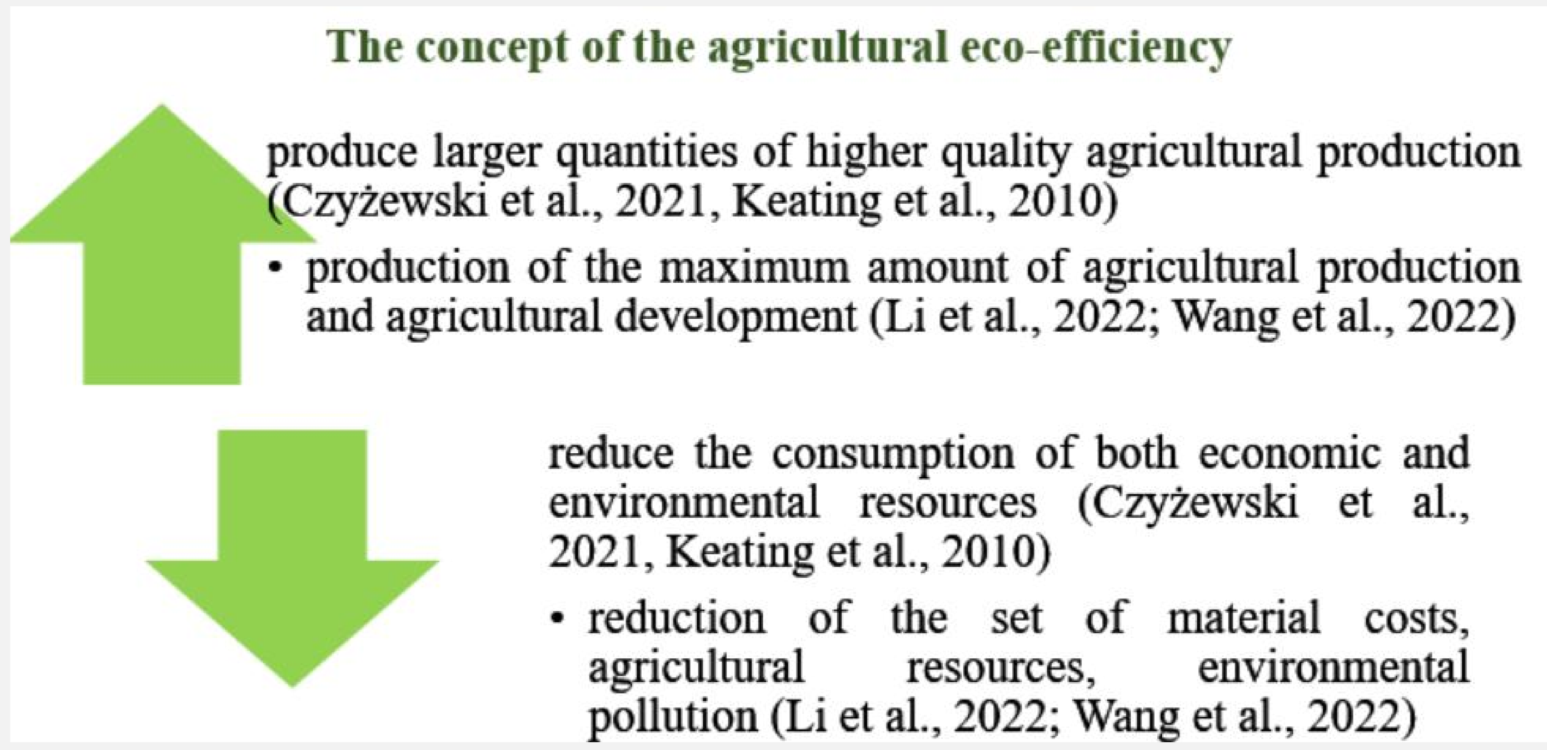
Agri-environmental subsidies (AES) are described as a key agricultural policy tool used to promote environmentally friendly farming, environmental innovation, and maintenance of soil quality. In general, AES supports activities that will reduce environmental issues arising from the agricultural activities through monetary compensation for farmers. Previous studies are more directed to quantifying environmental results of AES application while the empirical evidence on the combined environmental and economic impact of the AES schemes is limited.

This research will consider detailed econometric analysis of AES and other selected determinant factors‘ impact on agricultural eco-efficiency (AEE) of EU crop farms. AES contribution to the climate change mitigation goals set by European Green Deal could be increased by their improved monitoring and impact evaluation.

Research aim - to analyze the impact of agri-environmental subsidy (AES) schemes on the eco-efficiency of EU crop farms by applying machine intelligence methods, in particular the neural networks, and to compare our results to the ones obtained by multiple regression.

Research objectives:

- ✓ to explore the concept of the agricultural eco-efficiency and select the appropriate determinants of the eco-efficiency.
- ✓ to evaluate the agricultural eco-efficiency of EU crop farms by applying DEA approach.
- ✓ to assess the impact of AES and other selected factors on the eco-efficiency of EU crop farms by applying (i) multiple regression and (ii) neural network methods.
- ✓ to compare the results of regression analysis to those of the neural networks.

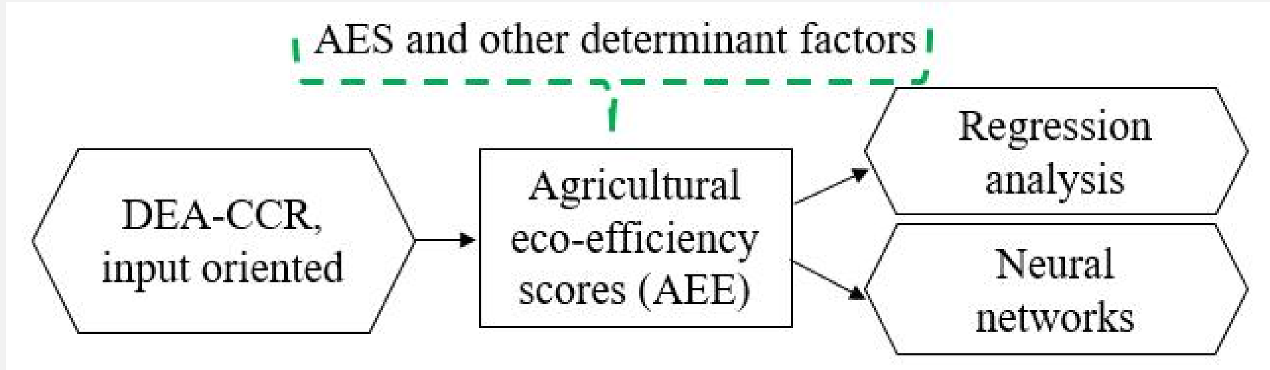


Methodology

General research question: to analyze the impact of AES on the eco-efficiency of EU crop farms over the period 2017 – 2021.

Research methods: descriptive statistics of our data; DEA-CCR used in estimating eco-efficiency score (with Rstudio); multiple linear regression and Multilayer Perceptron (MLP) neural network approach to assessing the impact of our determinants (using SPSS™).

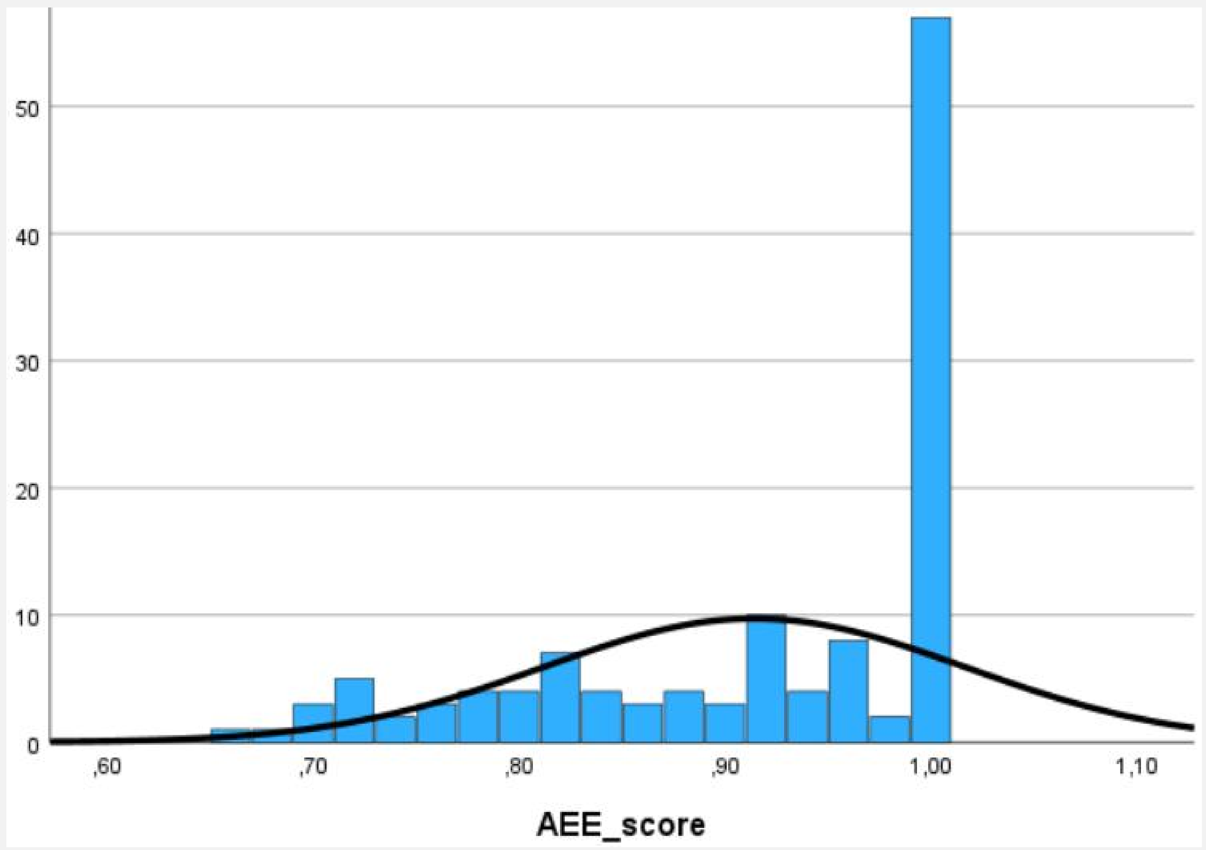
Research data – aggregated FADN data of 25 EU countries field crop farms (excluding Malta and Romania), in the years from 2017 to 2021.



Results

Descriptive statistics revealed extreme values of the variables and therefore they were standardised, and Malta was deleted as an outlier. Romania also excluded because of the missing nitrogen data that was used in AEE score determination with DEA. Two-stage analysis was implemented. At the first stage the AEE scores of farms were computed by using DEA-CCR (N=125), AEE score mean=0,914.

Distribution of AEE scores of EU crop farms through the period is presented in the histogram.



Country	5y_mean
AT	0,99
BE	1
BG	0,89
CY	0,93
CZ	0,73
DE	0,91
DK	1
EE	0,92
EL	0,96
ES	1
FI	0,87
FR	0,84
HR	0,78
HU	0,90
IE	1
IT	0,98
LT	0,84
LU	0,92
LV	0,80
NL	1
PL	0,91
PT	1
SE	0,99
SI	0,95
SK	0,73

The AEE scores of the 5 years‘ averages were calculated and assigned to each country. Then, the countries were classified into efficiency groups belonging either above the mean group (high eco-efficiency and fully eco-efficient) or below the mean (medium and low eco-efficiency). High and fully eco-efficient group (N=14) included mainly initial EU countries while the most recent EU members (joined EU since 2004) where engaged in medium and low eco-efficiency group.

Results

At the second stage the multiple regression analysis was applied first to determine the impact of AES and other selected factors on the AEE score of EU crop farms. The variance of AEE scores explained by regression model was R^2=0.415. The farm economic size, fixed assets (EUR) per utilized agriculture area (ha), AES (EUR) per utilized agriculture area (ha) and belonging to the group of the old or new EU member state were found to be significant predictors.

For also finding possible hidden patterns in the AEE scores, the neural networks were also applied. Values of the factors were standardized because of the extreme outliers. Our neural network model was distinctly better with R^2=0.691.

	Importance	Normalized importance
Economic size	0.227	100.0 %
Fixed assets / hour	0.153	67.3 %
AES / UAA	0.136	60.0 %
Fixed assets / UAA	0.134	59.2 %
Subsid. investm./UAA	0.113	49.7 %
Old/ new EU MS	0.091	39.9 %
Rent land ha/UAA	0.085	37.6 %
Debtratio	0.061	26.8 %

The average *Economic size* of the farm seems to be the most important variable affecting the AEE score. The importances of the other variables are determined by comparing them to the most significant one.

Main conclusions

- Analysis of the concept of agriculture eco-efficiency revealed the most important variables used in its assessment. On the basis of this analysis, a database of input and output variables was created including polluting output (GHG) as well for calculating AEE score.
- DEA-CCR approach was used in assessing EU crop farms AEE score. The mean of AEE score 0.914 demonstrates quite high eco-efficiency level of the crop farms, although almost half of the farms could be classified to be as medium and low eco-efficient. Hence, there is possibility for resource saving with keeping the same output of the production.
- Both regression analysis and neural networks indicated the AES impact to be significant and important on eco-efficiency level of the farms, although it was not the most important factor. Economic features of the farms, such as economic size and capital intensity, prevailed.
- Regression analysis explained less than half of the variance of AEE scores, and this may be due to extreme values in the data as well as the outliers. Thus, the neural network approach by using transformed values of the variables seems a better resolution and may be applied to the AEE score prediction instead.

If it is a part of the project, please put here the information and logo