Environmental pressures of different types of FADN farms in Poland

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Motivation

- Agriculture places a serious burden on the environment in the process of providing food and other products.
- It is the main source of **nitrate pollution** as well as the principal source of **ammonia pollution**. It is a major contributor to the **phosphate pollution** of surface waters (OECD, 2001)
- Releases large share of **greenhouse gases** (GHGs) into the atmosphere (IPCC, 2001a, WRI 2014).
- Agricultural Policy aims for decreasing of environmental pressure of agriculture

Research problem

- Quantification of environmental pressures resulting from agricultural production in different types of Polish FADN farms
- Determining the main factor influencing level of emissions in farm sector

Source and scope of the data

- Source of data: Polish FADN: sample from 2012 year
- Measures of environmental pressures (dependent variables):
  - GHG [kg CO_2/ha]
  - Nitrogen [kg N/ha]
  - Phosphorus [kg P_2O_5/ha]
- Analized factors (independent variables):
  - Type of farming
  - Soil quality index [0,05 –1,95 higher=better]
  - Agricultural land [ha]
  - Organic production system [1-yes, 0-no]
  - Intensity of production [GU*/ha]

*Grain unit (GU) has been proposed by [Woermann 1944] as an equivalent of nutritional value of 100 kg of barley.

Calculation of environmental pressures

Source of green house gases emission ($CO2$ equivalent):

- Production and application of fertilizers,
- Fossil fuels (heating and machinery),
- Electricity,
- Livestock emissions,

Nitrogen and phosphorus balances were calculated at the field level in line with OECD methodology

Methods

Multiple regression model:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \varepsilon_i$$

where: X1 – soil quality index, X2 – agricultural land, X3 – organic production system, X4 – intensity of production, εi – error term,

β_0*– intercept,* β_1*, . . . ,* β_4*– respective regression coefficients.*

Model estimation methods:

– weighted least squares, due to stratified sampling Horvitz–Thomson estimators were used

Classical multiple regression results
country level model

	Environmental pressures (estimates)		
	GHG emission kg CO_2/ha	N surplus kg N/ha	kg P surplus kg P_2O_5/ha
(Intercept)	763.201***	-12.099***	-3.63***
Soil quality index	-1070.617***	3.320.	6.428***
Agricultural land [ha]	-4.862***	-0.098***	-0.03***
Organic production system	-240.450**	-26.390***	-6.236***
Intensity of production [GU/ha]	51.248***	0.956***	0.679***
Adjusted R-squared	0.703	0.291	0.681

Significance codes: '***' p-value < 0.001; '**' < 0.01;'*'< 0.05; '.' < 0.1

*Grain unit [GU] has been proposed by [Woermann 1944] as an equivalent of nutritional value of 100kg of barley.

Weighted multiple regression

country level model

	Environmental pressures (estimates)		
	GHG emission kg CO_2/ha	N surplus kg N/ha	kg P surplus kg P_2O_5/ha
(Intercept)	153.749**	-7.526**	-2.356**
Soil quality index	-634.211***	7.788***	8.712***
Agricultural land [ha]	-6.746***	-0.054**	-0.041***
Organic production system	-107.188	-34.881***	-8.697***
Intensity of production [GU/ha]	53.666***	0.808***	0.644***
Adjusted R-squared	0.593	0.215	0.596

Significance codes: '***' p-value < 0.001; '**' < 0.01;'*'< 0.05; '.' < 0.1

*Grain unit [GU] has been proposed by [Woermann 1944] as an equivalent of nutritional value of 100kg of barley.

Type of farming
weighted mean of considered variables

Type of farming	GHG emission kg CO_2/ha	N surplus kg N/ha	P surplus kg P_2O_5/ha	Soil quality index	Agricul-tural land	Organic prod. system	Intensity of of production
Field crop (TF1)	1623	37.6	36.8	0.99	29.2	4.8%	46.8
Mixed crops (TF 6)	2165	40.2	33.8	0.89	12.8	18.2%	34.2
Cattle (TF4)	4574	33.9	43.8	0.60	18.8	11.7%	75.1
Pigs (TF51)	4591	147.2	90.6	0.81	22.7	0.3%	113.3
Mixed animals (TF7)	3438	51.5	46.1	0.64	13.4	3.9%	69.5
Mixed (TF8)	2272	39.6	38.5	0.78	15.3	5.0%	54.7

Weighted multiple regression for GHG emission

Type of farming	Soil quality index	Agricultural land	Organic prod. system	Intensity of production	Adjusted R^2
Field crop	82.671	-0.621.	-694.844***	14.537***	0.125
Mixed crops	-20.963	-17.231*	-1043.101**	43.923***	0.044
Cattle	-506.938***	-16.901***	-295.645*	70.232***	0.767
Pigs	-726.272***	-2.048	82.476	45.766***	0.947
Mixed animals	-119.935	-18.553***	-547.741***	56.88***	0.687
Mixed	-278.049***	-6.466***	-81.349	43.031***	0.450
All types	-634.211***	-6.746***	-107.188	53.666***	0.593

Significance codes: '***' p-value < 0.001; '**' < 0.01;'*'< 0.05; '.' < 0.1

GHG summary

- Even the pig farms are most intensive in terms of GU/ha further increase of production intensity result in highest increase of GHG emission in cattle farms.
- Increasing area of the farm tends to decrease of GHG otput, specially in farms with cattle (TF4 and TF7) – this might be result of distribution of fixed emissions (e.g. heating of buildings, electricity, part of fuel) on larger area of agricultural land.
- In most of farm types (except TF1) the GHG emission is lower on better soils. This might be explained by negative correlation between soil quality and stocking density.
- The models for farm types with animal production have much better description power regarding GHG emission.

Weighted multiple regression for nitrogen surplus

Type of farming	Soil quality index	Agricultural land	Organic prod. system	Intensity of production	Adjusted R^2
Field crop	36.666***	0.044.	-60.655***	-1.362***	0.164
Mixed crops	50.273***	-0.119	-39.555***	-0.715.	0.224
Cattle	16.562**	-0.163*	-34.489***	0.638***	0.241
Pigs	-34.155***	-0.186	-11.533	1.608***	0.771
Mixed animals	7.905	0.128	-34.811***	0.998***	0.312
Mixed	7.105*	0.036	-35.344***	0.359***	0.083
All types	7.788***	-0.054**	-34.881***	0.808***	0.215

Significance codes: '***' p-value < 0.001; '**' < 0.01;'*'< 0.05; '.' < 0.1

Nitrogen surplus summary

- Surplus of N is higher on better soils, specially in case of farms with plant production.
- Organic production methods contribute to much lower N surplus, specially in farms with plant production.
- Area of the farm has limited influence on N surplus.
- Increasing intensity of production leads to decrease N surplus in plant production farms.
- In farms with animals, increase of production intensity (higher stocking density) leads to higher N surplus, specially in pig farms.
- Descriptive power of models for N surplus is relatively low except pig farms.

Weighted multiple regression for phosphorus surplus

Type of farming	Soil quality index	Agricultural land	Organic prod. system	Intensity of production	Adjusted R^2
Field crop	11.595***	-0.026***	-13.737***	0.333***	0.202
Mixed crops	16.579***	-0.134*	-16.617***	0.435***	0.182
Cattle	4.729***	-0.109***	-6.575***	0.546***	0.631
Pigs	-4.418.	-0.028	-2.738	0.883***	0.930
Mixed animals	5.859***	-0.088*	-8.505***	0.666***	0.679
Mixed	7.981***	-0.032*	-9.137***	0.621***	0.472
All types	8.712***	-0.041***	-8.697***	0.644***	0.596

Significance codes: ‘***’ p-value < 0.001; ‘**’ < 0.01;‘*’< 0.05; ‘.’ < 0.1

Phosphorus surplus summary

- Surplus of P is higher on better soils except of pig farms.
- Farm area has limited impact on P surplus.
- Applying organic farming methods tends to decrease of P surplus, specially in farms with plant production.
- Increasing intensity of production causes increase od P surplus, particularly in farms with animals production.
- The modes for P surplus has relatively good description power for farm types with animal production.

Weighted multiple regression conventional v. organic

Production System	Soil quality index	Agricultural land	Intensity of production	Adjusted R^2
	GHG emission			
Conventional	-674.029***	-7.435***	54.346***	0.559
Organic	-401.921.	-6.018***	70.547***	0.709
	Nitrogen surplus			
Conventional	8.569***	-0.076**	0.722***	0.136
Organic	16.313**	0.015	-0.182	0.057
	Phosphorus surplus			
Conventional	8.803***	-0.058***	0.623***	0.531
Organic	6.391***	-0.013	0.464***	0.658

Significance codes: '***' p-value < 0.001; '**' < 0.01;'*'< 0.05; '.' < 0.1

Production systems summary

- Effect of soil quality on GHG emission is lower in organic farms. It might be result of weaker relation between soil quality and stocking density on organic farms.
- Increasing intensity of production in organic farms causes higher growth of GHG emission.
- Models for N surplus have very low descriptive power.
- Increasing intensity of production in organic farms generates lower nutrients surplus. It might be result of limitation in stocking density increase and fertilizers use on organic farms.

Conclusions

- The results of models estimated for particular farm types show also that environmental pressures and their drivers depend on farm production orientation.
- Results of all models show that with the increase of farm size environmental pressure measured per unit of land is decreasing in case of GHG, and has limited impact in case of N and P surplus.
- Unlike the size of farms, the increase of the production intensity results in a higher environmental load per hectare of land in most of farm types.
- The organic production system tends to have lower environmental pressure. However estimates of models built for organic farms shows that increase of production results in higher marginal emissions GHG than in conventional production system.