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Spatial differentiation of particulates emission resulting from agricultural production in Poland

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Abstract: The article presents the spatial differentiation of particulates emission resulting from agricultural production in Poland. Some indicators of emission have been verified and adjusted to the Polish conditions. The paper estimates PM2.5 (particulate matter, aerodynamic diameter less than 2.5 μm) and PM10 (particulate matter, aerodynamic diameter less than 10 μm) emission resulting from agricultural production and agricultural soil. The findings of the research conducted by the Institute of Ecology of Industrial Areas in Katowice in cooperation with the Institute for Chemical Processing of Coal in Zabrze were the main source of those alterations. Data concerning particular sources of emission also come from the information provided by the Central Statistical Office in Warsaw, the Bank of Local Data 2017. The estimation of PM2.5 and PM10 emission was conducted based on the structure of sources of emission resulting from agriculture contained in "EMEP/EEA Emission Inventory Guidebook" in accordance with the Tier 2 method.

Keywords: agricultural soil; emission; particulate matter (PM); plant production

Man's agricultural activity particularly interfering in the natural environment, is not neutral for the surrounding. Starting with the increase in aeolian processes and pollen intoxication from fields, through composting and emission of organic matter decomposition products and animal farming, agriculture is a significant source of air pollution. In addition, modern mechanised agriculture emits pollutants produced by agricultural vehicles and machines and the heating of buildings. Plant cultivation is the main source of particulates from agriculture as its share in PM10 (particulate matter, aerodynamic diameter less than 10 μm) emission is 89.1% and PM2.5 (particulate matter, aerodynamic diameter less than 2.5 μm) is 97.8% (WIOS 2018). In agriculture, particulates are created practically in the course of every activity, including field operations, soil cultivation, mineral fertilisation, haying, and other works (Arslan and Aybek 2012).

Agricultural operations such as cultivation, planting, nurture, fertilisation, mowing, cutting, baling, and manure or compost spreading may result in pollutants emission (Roman and Konieczna 2015). It takes place in the course of agricultural activities, machines driving on the fields or the work of the machinery engines (Roman et al. 2018). Weather conditions such as drought or wind may constitute additional reasons for emission. As a result, in case of such circumstances, it is recommended to limit particular operations in the area and adjust them to the existing atmospheric conditions (Cetin et al. 2017).

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The application of the recommendations contributes to the decrease in the amount of particulates in the air resulting from the limitation of vehicle movement and the work of engines.

In Poland's Informative Inventory Report 2017 (KOBIZE 2017), there is information about the volume of emission in the atmosphere. The emission estimate in Poland concerns sulphur dioxide, nitrogen oxides, ammonia, carbon monoxide, particulates (PM2.5, PM10 and TSP (TSP – total suspended particles), non-methane volatile organic compounds (NMVOC), heavy metals (HMs) and permanent organic pollutants (POP), including dioxins and furans (PCDD/F), HCB (hexachlorobenzene), PCB (polychlorinated biphenyls) and PAH (polynuclear aromatic hydrocarbons) (Hutchings et al. 2016). In the case of pollutants emitted from transport, their source is close to the earth, and as a result, they have an impact on the emission rate concerning the areas located close to roads. The characteristic features of pollution originating from transport include a relatively high level of fuel combustion products concentration (carbon monoxide, nitrogen oxides, volatile hydrocarbons, suspended particulates), pollution concentration along transportation roads, and varied intensity of their occurrence connected with the type of traffic in different parts of the day and season.

The emission of particulates from agriculture mainly takes place as a result of field operations: soil cultivation and harvesting. The additional sources include fertilisation, pollen, field burning, transporting crops and animal farming (e.g. during fodder preparation and feeding animals, and bedding and cleaning sheds). The theoretical volume of PM2.5 emissions from agricultural sources by type of source is presented in Table 1 (KOBIZE 2017).

Table 1. Volume of PM2.5 emission – basic data

SNAP nomenclature and code	Emission of PM2.5 (Mg)	
	2014	2015
Total	125 515.0	124 562.5
10. Agriculture	486.3	548.5
11. Other sources of emission and absorption of pollutants*	255.1	512.3

*the category of forest fires, as a natural source, is not taken into account in the total value; PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm; SNAP – Selected Nomenclature for Air Pollution

Source: KOBIZE (2017)

METHODOLOGY

The methodology of emission balances estimation assumes to provide the transparent and completely comparable results consistent with the guidelines of the EMEP reporting nomenclature. Emissions from agricultural production should be calculated in accordance with the EMEP/EEA Guidebook methods (European Monitoring and Evaluation Programme/European Environment Agency), and with at least the Tier 2 or above (detailed) methodology usage. It is acceptable to use other scientifically developed emission assessment methods if they are more appropriate than the standard methods from EMEP/EEA Guidebook (European Commission 2013).

In accordance with the recommendations EMEP/EEA (2016), the Tier 1, Tier 2 and Tier 3 methods are used to estimate the level of pollution, taking into account the given emission factors (EF). Depending on the source of emission, the choice of the approach should be done based on the recommendations in the EMEP/EEA Guidebook (EMEP/EEA 2016).

Tier 1 method

One of the four main sources of emission from agricultural production and agricultural land is soil cultivation and harvesting (PM), the share of which exceeds 80% of the total (CEIP 2015). In accordance with the EMEP/EEA (2016) recommendations, the Tier 2 method was used for estimating PM2.5 ($E_{pollutant}$) emission from agricultural production [Nomenclature for Reporting (NFR) 3.D category – plant production and agricultural soil]. In the course of calculating the emission of pollutants from agricultural production, the basic approach is the use of the Tier 1 method with presumed (average) values of emission factors (EF). In accordance with the Tier 1 method, in order to determine the volume of pollution, the general Equation (1) is used.

$$E_{pollutant} = AR_{area} \times EF_{pollutant} \quad (1)$$

where: $E_{pollutant}$ – the amount of pollution emitted (kg/year); AR_{area} – cultivation area (ha); $EF_{pollutant}$ – emission factor (kg/ha × year).

The value of AR_{area} characterises the acreage of agricultural land that includes all arable land, pastures and meadows. The value of the emission indicator for NFR 3.D category (agricultural production and agricultural soil) is presented in Table 2.

https://doi.org/10.17221/337/2018-AGRICECON

Table 2. Emission rate for NFR 3.D category (plant production and agricultural soil)

Pollution	Value (kg/ha)	Confidence interval (95%)		Reference
		lower	upper	
PM10 from combine harvesting, taking into account grain moisture during harvesting	4.10–6.90	–	–	Batel (1976)
PM10 from combine harvesting	3.30–5.80	–	–	WRAP (2006)
PM10 soil cultivation	0.10	–	–	RAINS (2018)
PM10 soil cultivation	0.06–0.30	–	–	Wathes et al. (2002)
PM10 soil cultivation	0.28–0.48	–	–	Hinz (2002)
PM10 from agricultural operations (NFR 3.Dc)	1.56	0.78	7.80	Van der Hoek and Hinz (2007)
PM2.5 from agricultural operations (NFR 3.Dc)	0.06	0.03	0.30	Van der Hoek and Hinz (2007)
TSP (NFR 3.Dc)	1.56	0.78	7.80	Van der Hoek and Hinz (2007)

PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm; PM10 – particulate matter, aerodynamic diameter less than 10 μm; NFR – Nomenclature for Reporting

Source: Hutchings et al. (2016)

The level of pollution estimated with the use of the above indicators does not cover the emission from fertilisers, pesticides or meadow grasses (e.g. hay). The level of emission resulted mainly from the combine harvesting and soil cultivation. The measurements in California [4.2 kg/ha – National Emission Inventory (NEI) method and 5.2 kg/ha – California Air Resources Board (CARB) method] showed a much higher volume of emission. This results from climate and soil-related factors in the area. It should be remembered that temperature and humidity have an impact on the measurement. Similar results were obtained in Brandenburg (Germany) in 2006, where as a result of climate conditions (hot and dry air), an increase in the emission was recognised in comparison with former years. The indicator of emission ($EF_{pollutant}$) corresponding to PM10, PM2.5 and PM1 (particulate matter, aerodynamic diameter less than 1 μm) in field operations is presented in Table 3.

Imprecision in measuring the above-presented emission indicators may result from a small number of experimental measurements. Presumed indicators of emission from agricultural crops and the type of harvest are presented in Table 4.

The values calculated characterise the level of emission measured in direct proximity of trac-

Table 3. $EF_{pollutant}$ for PM10, PM2.5 and PM1 in field operations

Activity	PM10 (kg/ha)	PM2.5 (kg/ha)	PM1 (kg/ha)
Harrowing (tooth harrow)	0.82	0.29	< 1
Harrowing (disc harrow)	1.37	0.12	0.03
Cultivation	1.86	0.06	0.02
Ploughing	1.20	0.05	0.01

$EF_{pollutant}$ – indicator of emission; PM10 – particulate matter, aerodynamic diameter less than 10 μm; PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm; PM1 – particulate matter, aerodynamic diameter less than 1 μm

Source: Hutchings et al. (2016)

Table 4. $EF_{pollutant}$ (EF_{PM}) PM for agricultural plant breeding

Plant	Soil cultivation (kg/ha)	Harvesting (kg/ha)	Cleaning (kg/ha)	Drying (kg/ha)
Wheat	0.25	4.9	0.19	0.56
Rye	0.25	3.7	0.16	0.37
Barley	0.25	4.1	0.16	0.43
Oat	0.25	6.2	0.25	0.66

$EF_{pollutant}$ – indicator of emission; PM – particulate matter; EF_{PM} – emission rate in the operation and cultivation

Source: Van der Hoek and Hinz (2007)

https://doi.org/10.17221/337/2018-AGRICECON

Table 5. Tier 2 method for agricultural plant cultivation PM10 (humid climate)

Plant	Soil cultivation (kg/ha)	Harvesting (kg/ha)	Cleaning (kg/ha)	Drying (kg/ha)
Wheat	0.25	0.49	0.19	0.56
Rye	0.25	0.37	0.16	0.37
Barley	0.25	0.41	0.16	0.43
Oat	0.25	0.62	0.25	0.66
Other crops	0.25	–	–	–
Grass*	0.25	0.25	–	–

*including hay; PM10 – particulate matter, aerodynamic diameter less than 10 μm

Source: Van der Hoek and Hinz (2007)

tors and machines used in the course of field operations. Most of the indicators are based on the work of Van der Hoek and Hinz (2007), and their volumes were averaged and referred to the level of PM emission per hectare for the need of calculation.

Tier 2 method

The Tier 2 method determines the technological approach with the use of the factors of EF emission. The emission of particulates may be calculated by multiplying the cultivated field area by the EF and a multiple of emission. The equation describing the emission of PM10 or PM2.5 is presented as Equation (2).

$$E_{PM} = \sum_{i=1}^{I} \sum_{n=0}^{N_{i,k}} EF_{PM_{i,k}} \times A_i \times n \qquad (2)$$

where: E_{PM} – emission of PM10 or PM2.5 from the plant cultivation (kg/year); I – number of crops kinds; A_i – acreage of the given (and this) plant cultivation per year (ha); k – type of operation; $N_{i,k}$ – number of operations within this plant cultivation per year; $EF_{PM_{i,k}}$ – emission rate in this operation and cultivation (kg/ha); n – the initial value of the index.

The calculations should refer to the given climate and farm acreage, which are parameters typical of a particular country. It should be remembered that part of the emission also occurs in the area close to the place of cultivation. Tables 5–8 present the value of EF indicators in the dry climate (the Mediterranean) and humid climate (all the other types).

Table 6. Tier 2 method for agricultural pant cultivation PM10 (dry climate)

Plant	Soil cultivation (kg/ha)	Harvesting (kg/ha)	Cleaning (kg/ha)
Wheat	2.25	2.45	0.19
Rye	2.25	1.85	0.16
Barley	2.25	2.05	0.16
Oat	2.25	3.10	0.25
Other crops	2.25	2.45	0.19
Grass*	2.25	1.25	–

*including hay; PM10 – particulate matter, aerodynamic diameter less than 10 μm

Source: Van der Hoek and Hinz (2007)

Table 7. Tier 2 method for agricultural plant cultivation PM2.5 (humid climate)

Plant	Soil cultivation (kg/ha)	Harvesting (kg/ha)	Cleaning (kg/ha)	Drying (kg/ha)
Wheat	0.015	0.020	0.009	0.168
Rye	0.015	0.015	0.008	0.111
Barley	0.015	0.016	0.008	0.129
Oat	0.015	0.025	0.0125	0.198
Other crops	0.015	–	–	–
Grass*	0.015	0.01	–	–

*including hay; PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm

Source: Van der Hoek and Hinz (2007)

https://doi.org/10.17221/337/2018-AGRICECON

Table 8. Tier 2 method for agricultural plant cultivation PM2.5 (dry climate)

Plant	Soil cultivation (kg/ha)	Harvesting (kg/ha)	Cleaning (kg/ha)	Drying (kg/ha)
Wheat	0.12	0.098	0.0095	0
Rye	0.12	0.074	0.0080	0
Barley	0.12	0.082	0.0080	0
Oat	0.12	0.125	0.0125	0
Other crops	0.12	–	–	–
Grass*	0.12	0.050	0.000	0

*including hay; PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm

Source: Van der Hoek and Hinz (2007)

Tier 3 method

The Tier 3 method is a more precise tool in comparison with Tier 1 and Tier 2. The authors used the Tier 2 method because of the lack of detailed data allowing for the use of the Tier 3 method.

RESEARCH FINDINGS

The emission of particulates from agricultural production and soil mainly results from field operations (soil cultivation or harvesting), fertilisation, cultivated plants' pollen, and transport of crops. The emission depends on the climate conditions, especially the moisture of soil and field surface. Table 9 presents the volume of PM2.5 emission from agricultural production and soil.

Calculations do not take into consideration the emission from farm vehicles moving along dirt roads and the fuel used because the data were taken into account in the group 1.A (NFR). The calculation does not take into consideration the dust and other small particles blown from the soil because the emission does not directly result from agricultural operations and is considered to be natural. The sources that should be taken into account within NFR 3.D are described in Table 10.

The value of PM2.5 emission from agricultural operations (NFR 3.Dc) (Cultivation and transport of crops on the farm) accounts for 0.06 kg/ha (Van der Hoek and Hinz 2007; Hutchings et al. 2016). The estimated indicator does not include emission from fertilisers, pesticides or products from grassland (e.g. hay).

Table 9. Volume of PM2.5 emission from agricultural production and soil

PM2.5 emission	Percentage (%)	Volume (Gg/a)
Total	100	1 220.0
Agricultural production and soil	1	13.0

PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm

Source: CEIP (2015)

Table 10. Area of analysed emission by NFR code

NFR	Name	Source definition	Emission indicators
3.Dc	plant cultivation and crops transport on the farm	source of emission has been created in the course of plant cultivation and storing (e.g. grain) on a given farm and delivered from another place (e.g. fertilisers and fodder for livestock)	80% of PM emission in 3D* category results from soil cultivation and crop harvesting; the values of PM do not include emission from fertilisers, pesticides or from grassland (e.g. the production of hay)
3.Dd	plant cultivation and storing outside a farm and transport of unprocessed agricultural products	cultivation and storing outside a farm and transport of unprocessed agricultural products	all types of emission from this source should be taken into account; there is no methodology for calculation

*emission from animal husbandry is calculated within NFR 3.B (manure management); NFR – Nomenclature for Reporting

Source: Hutchings et al. (2016)

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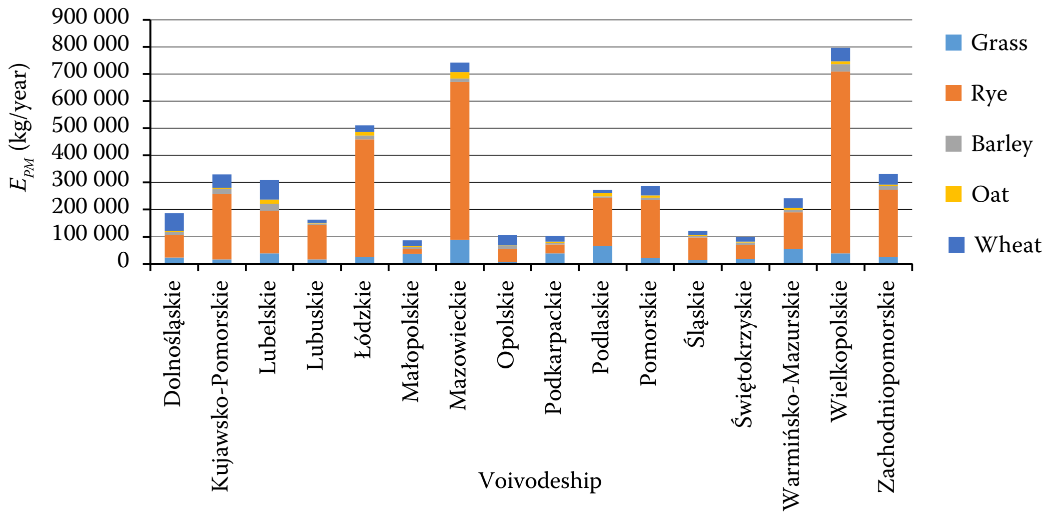

Figure 1. PM2.5 emission from agricultural production by types of crops in Poland

E_{PM} – emission of PM10 or PM2.5 from the plant cultivation; PM – particulate matter

Source: authors' own calculations based on data provided by the BDL (2018)

The value of emission results mainly from combine harvesting and soil cultivation.

In the course of calculation, the level of pollution by PM2.5 and PM10 was analysed. For the calculation of PM2.5 emission in a year, the Equation (1) was used ($E_{pollutant} = AR_{area} \times EF_{pollutant}$). The level of PM2.5 and PM10 pollution is presented in Figures 1–2.

For comparison, the characteristic emission of particulates was specified as a quotient of the sum of pollution from particular types of plant cultivation and the acreage of the voivodeship (an administrative subdivision of Poland). This allowed for the presentation of the value of a unit of pollution on the surface of a field. The estimation of the value of a unit of PM2.5 pollution in particular voivodeships is presented in Figure 3, and the value of PM10 pollution is presented in Figure 4.

The highest PM2.5 pollution unit occurs in Łódzkie and Wielkopolskie Voivodeships, where agricultural

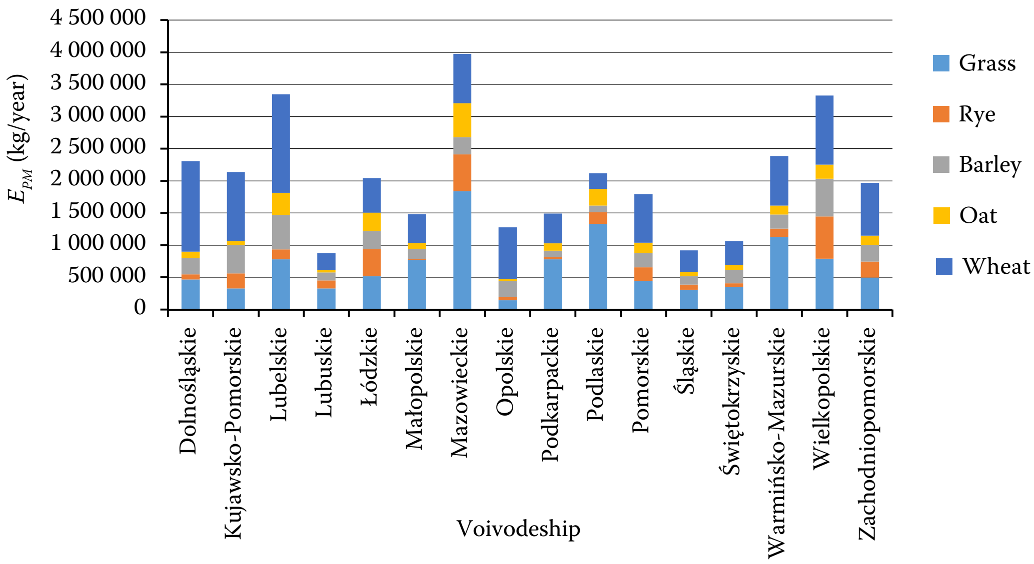

Figure 2. PM10 emission from agricultural production by types of crops in Poland

E_{PM} – emission of PM10 or PM2.5 from the plant cultivation; PM – particulate matter

Source: authors' own calculations based on data provided by the BDL (2018)

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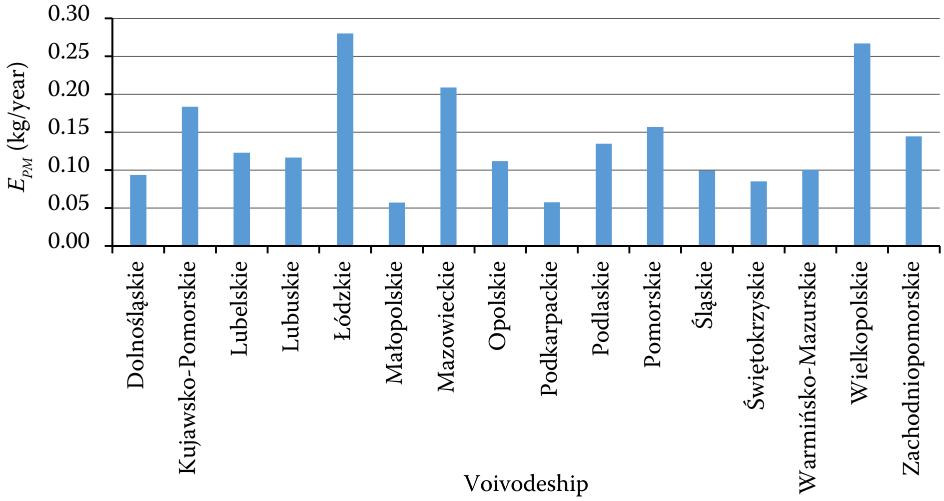

Figure 3. Level of PM2.5 pollution unit in Poland

E_{PM} – emission of PM10 or PM2.5 from the plant cultivation; PM – particulate matter

Source: authors' own calculations based on data provided by the BDL (2018)

operations during rye cultivation had the most significant influence. The level of PM2.5 pollution in those voivodeships exceeded the unit value of 0.25 kg/ha. The highest PM10 pollution unit was recorded in Lubelskie and Opolskie Voivodeships, where the increased intensity of work was recorded during the cultivation of rye. The level of PM10 was close to 1.3 kg/ha. The obtained value was subject to statistical analysis, which is presented in Table 11 for PM2.5 and in Table 12 for PM10.

The distribution of statistical features is presented in diagrams, indicating the mean, the mean standard error and the mean standard deviation for PM2.5 and PM10 pollution. The values typical of the level of PM2.5 pollution are presented in Figure 5, and of the level of PM10 pollution in Figure 6.

Figures 5–6 allow for the estimation of the influence of the technologies applied in cultivation on the PM2.5 and PM10 pollution levels. In the case of PM2.5 pollution, the highest emission unit occurs during the rye

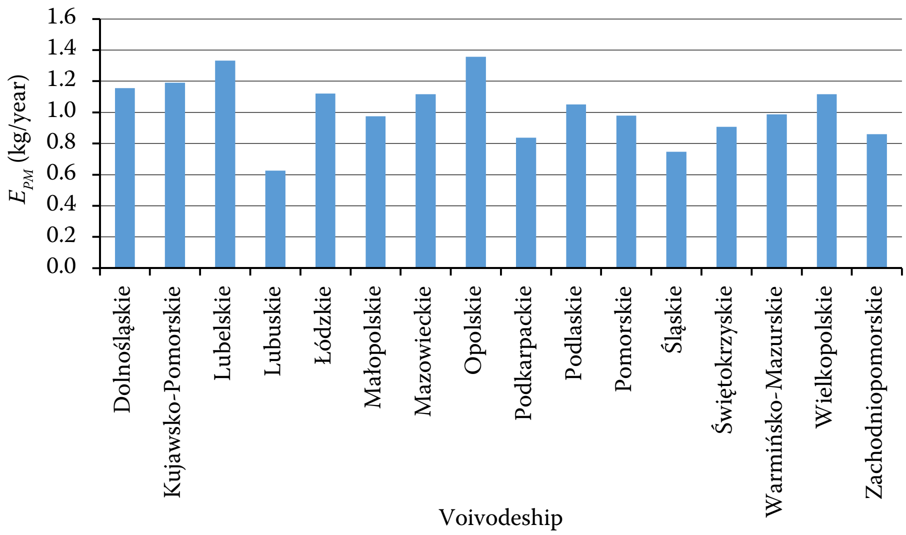

Figure 4. Level of PM10 pollution unit in Poland

E_{PM} – emission of PM10 or PM2.5 from the plant cultivation; PM – particulate matter

Source: authors' own calculations based on data provided by the BDL (2018)

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Table 11. Results of the descriptive statistical analysis of PM2.5

Plant	Average (kg/ha)	Min (kg/ha)	Max (kg/ha)	Std. variation (kg/ha)	Sum (kg/ha)
Grass	0.015977	0.007440	0.032103	0.007005	0.255635
Rye	0.094849	0.011268	0.238645	0.067352	1.517580
Barley	0.006419	0.002436	0.012492	0.003080	0.102705
Oat	0.003535	0.001292	0.007036	0.001870	0.056556
Wheat	0.017953	0.005647	0.039769	0.009401	0.287255

PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm

Source: authors' own research

Table 12. Results of the descriptive statistical analysis of PM10

Plant	Average (kg/ha)	Min (kg/ha)	Max (kg/ha)	Std. variation (kg/ha)	Sum (kg/ha)
Grass	0.328942	0.153181	0.660949	0.144230	5.263074
Rye	0.093058	0.011055	0.234138	0.066080	1.488920
Barley	0.136329	0.051736	0.265315	0.065414	2.181259
Oat	0.078183	0.028605	0.155736	0.041439	1.250922
Wheat	0.385901	0.121374	0.854806	0.202073	6.174412

PM10 – particulate matter, aerodynamic diameter less than 10 μm

Source: authors' own research

cultivation. The cultivation of grasses, wheat, barley or oat was a technology with much lower emission. In the case of PM10 emission, the level of pollution may be divided into two groups taking into account

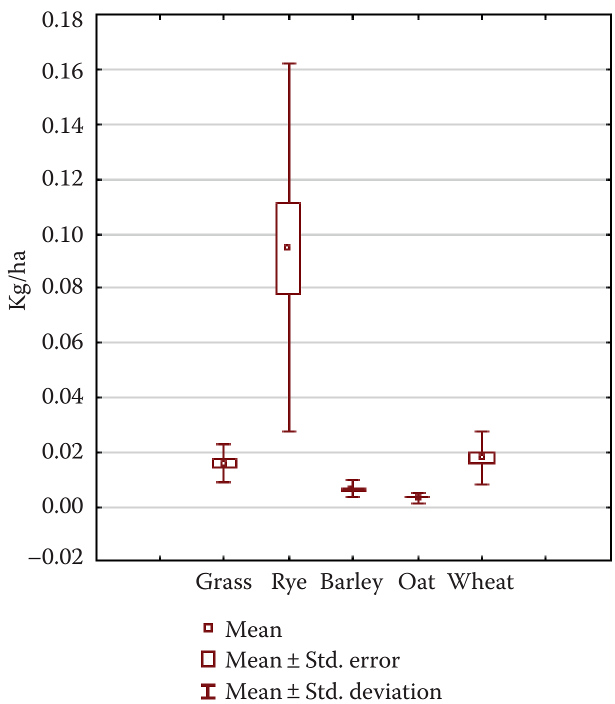

Figure 5. Value characterising the level of PM2.5 pollution

PM2.5 – particulate matter, aerodynamic diameter less than 2.5 μm
Source: authors' own calculations

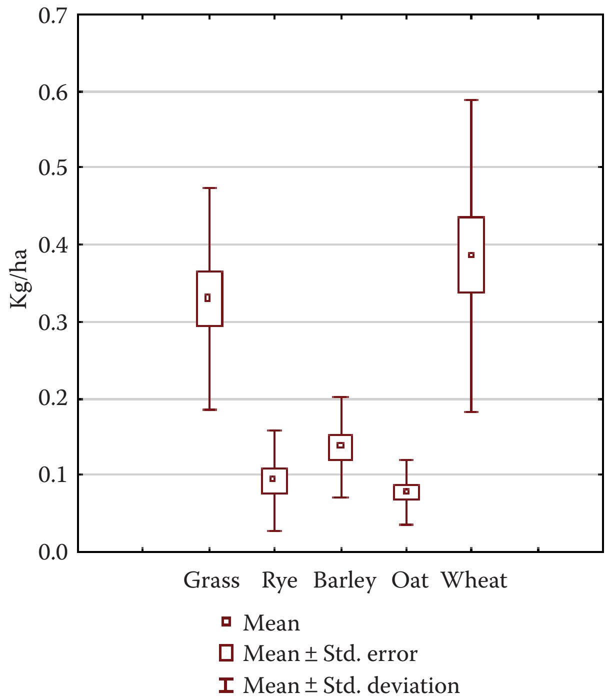

Figure 6. Values characterising the level of PM10 pollution

PM10 – particulate matter, aerodynamic diameter less than 10 μm
Source: authors' own calculations

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the emission unit for a given technology. The cultivation of grass and wheat constitutes the most invasive technologies in comparison to the cultivation of rye, barley and oat.

CONCLUSION

Based on the findings of statistical research, it can be concluded that the choice of technology has a considerable impact on the PM2.5 and PM10 pollution unit. In the case of the PM2.5 pollution, the cultivation of rye turned out to be the most invasive technology as its mean value accounted for 0.067352 kg/ha. In the case of the PM10 pollution, the cultivation of grass and wheat turned out to be the most invasive technology as its mean value accounted for 0.144230 and 0.202073 kg/ha, respectively. It is probably connected with the use of agricultural machines and tools used for the operations, which influence the level of pollution.

Operations on agricultural lands, such as cultivation, planting, weeding, fertilisation, harvesting, mowing, cutting, baling, and manure or compost spreading, cause raising dust, i.e. air pollution. In addition, this pollution can be increased by emission from machine engines. Decreasing the number of operations reduces the amount of dust produced in the area of given plant production, e.g. the limitation of vehicle movement makes it possible to limit soil abrasion or its decay and results in the decrease in the direct pollutant emission and limitation of engine exhaust. Additional improvements can result from modification and adjustment of cultivation operations, precise fertilisation, the reduction of soil cultivation systems, exchange or modernisation of internal combustion engine machines (technological development) and combining cultivation operations.

The legal regulations of the European Union regarding air quality and purity have been recorded in the Directive 2008/50/EC (2008). As a result of agricultural activity, the exceeding of air quality standards is forcing to adopt alternative pro-ecological solutions at the local and national level, ultimately reducing the emission of dust to the atmosphere. Some countries prepared a document that calls for the use of the described appropriate agricultural practices. According to the recommendations, it is appropriate to combine operations during a single pass of the machine (e.g. application of fertiliser during sowing) with the limitation of agricultural tools during the field cultivation. The other example of proper agricultural practises is to limit the travel speed during the field cultivation, and performing these activities when the soil is adequately moist (Sakirkin et al. 2012).

The pollution of PM2.5 emission from agriculture in the European Union accounts for about 15%, and emission of PM10 around 22%. According to estimation, there is some potential for a gradual pollution reduction by implementing and enforcing European law restrictions. Restrictions should apply to all agricultural waste, because, according to estimation, they cause a 75% increase of PM2.5 in the agricultural sector. It was determined that the application of all remedies in the agricultural sector would result in a reduction of PM2.5 dust emissions by 5%. However, due to many existing barriers, the existing implementation and enforcement of law restrictions are not effective enough. Therefore, in the future, the relevant authorities should work on them.

REFERENCES

Arslan S., Aybek A. (2012): Particulate matter exposure in agriculture. In: Haryanto B. (ed.): Air Pollution – A Comprehensive Perspective. IntechOpen. Available at https://www.intechopen.com/books/air-pollution-a-comprehensive-perspective/particulate-matter-exposure-in-agriculture

Batel W. (1976): Staubemission, Staubimmission und Staubbekämpfung beim Mähdrescher. Grundl, LandtechnikBd, 26: 205–248.

BDL (2018): Statistics Poland – BDL. Available at https://bdl.stat.gov.pl/BDL/dane/podgrup/teryt (accessed Jan 13, 2018).

CEIP (2015): Officially reported emission data. The Convention on Long-range Transboundary Air Pollution Centre on Emission Inventories and Projections. CEIP. Available at http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/reported_emissiondata/ (accessed Sept 1, 2016).

Cetin M., Sevik H., Isinkaralar K. (2017): Changes in the particulate matter and CO_2 concentrations based on the time and weather conditions: the case of Kastamonu. Oxidation Communications, 40: 477–485.

Directive 2008/50/EC (2008): Directive of the European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe. Official Journal of the European Union, L152: 1–44.

European Commission (2013): Directive of the European Parliament and of the Council on the Reduction of National Emissions of Certain Atmospheric Pollution and the Amendment of Directive 2003/35 / EC, Bruksela 18.12.2013 r. COM (2013), 920 final. ANNEXES, 1–6: 11.

EMEP/EEA (2016): Air Pollutant Emission Inventory Guidebook. European Environment Agency, Louxemburg.

https://doi.org/10.17221/337/2018-AGRICECON

Hinz T. (2002): PM in and from agriculture – introduction and overview. In: Hinz T., Rönnpagel B., Linke S. (eds): Particulate Matter in and from Agriculture. Special Issue 235, Landbauforschung Völkenrode: 1–6.

Hutchings N., Webb J., Amon B. (2016): EMEP/EEA Emission Inventory Guidebook 2013. 3.D Crop Production and Agricultural Soils: 1–41. Available at https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/4-agriculture/3-d-crop-production-and/view (accessed Jan 13, 2018).

KOBIZE (2017): Poland's Informative Inventory Report 2017. Submission under the UN ECE Convention on Long-range Transboundary Air Pollution and the Directive (EU) 2016/2284. Warsaw: 1–51.

RAINS (2018): Regional Air Pollution Information and Simulation. RAINS.

Roman K.K., Konieczna A. (2015): Evaluation of a different fertilisation in technology of corn for silage, sugar beet and meadow grasses production and their impact on the environment in Poland. African Journal of Agricultural Research, 10: 1351–1358.

Roman M., Roman M., Roman K. (2018): The forecast of economic processes of selected agricultural products in the development of bioenergy and agritourism activity in Poland. In: Jedlička P., Marešová P., Soukal I. (eds): Double-Blind Peer-Reviewed Proceedings Part II of the International Scientific Conference Hradec Economic Days. University of Hradec Kralove, Hradec Kralove, Jan 30–31, 2018: 247–248.

Sakirkin S.L.P., Maghirang R., Amosson S., Auvermann B.W. (2012): Air, dust emissions from cattle feeding operations. Part 1 of 2: Sources, factors, and characteristics. Dust Emissions, Education in Animal Agriculture, January 2012: 1–12.

Van Der Hoek K., Hinz T. (2007): Particulate matter emissions from arable production – a guide for UNECE emission inventories'. Landbauforschung Völkenrode, 308: 15–19.

Wathes C.M., Phillips V.R., Sneath R.W., Brush S., ApSimon H.M. (2002): Atmospheric emissions of particulates (PM10) from agriculture in the United Kingdom. ASAE Annual Meeting, Paper number 024217. American Society of Agricultural and Biological Engineers. Available at http://elibrary.asabe.org/abstract.asp?aid=10582&redir=[confid=cil2002]&redirType=techpapers.asp&dabs=Y (accessed Sept 26, 2016).

WIOS (2018): Powietrze. WIOS. Available at http://www.wios.lodz.pl/files/docs/r15xiiixpowietrze.pdf (accessed Jan 20, 2018).

WRAP (2006): Countess environmental, fugitive dust handbook, prepared for the Western Governors' Association. Countess Environmental, Westlake Village, CA: 1–10.

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