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ENVIRONMENTAL ASPECTS OF SUSTAINABLE AGRICULTURE

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A b s t r a c t

Agricultural policy in the European Union at Community level, as well as in the member states, increasingly emphasises the issue of sustainable agriculture. The pursuit of climate neutrality requires a reduction in emissions from agricultural sources. Above all, it is necessary to fully exploit the potential of agricultural and forestry areas to increase carbon sequestration in biomass and soil, optimise systems for the storage, transport and use of livestock manure, and significantly improve energy efficiency and increase the share of renewable energy in plant and livestock production. Rural areas, and in particular agriculture, are also seen as one of the main and important sources of pollution and eutrophication of water. Determining the correct way to assess the degree of sustainability of farms requires objective and feasible to determine measures and indicators of socio-economic-environmental sustainability and a lot of analysis, methodological and practical research. To date, no uniform set of sustainability indicators has been developed and their selection depends on data availability.

Keywords: climate change, farms, environmental sustainability

1. INTRODUCTION

Sustainable agriculture is an alternative to the industrial model. Agricultural sustainability is linked to the concept of economic order and economic

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sustainability [1]. Economic governance consists of productive, environmental and social governance. Among the various definitions of sustainability of production, social and environmental order for the agricultural sphere, the sense of sustainability is well illustrated by the description according to Vereijken [2]. He defines production order as ensuring the stable production of sufficient food of the desired quality and at socially acceptable prices. Social order is the provision of an income for farmers comparable to that of other occupational groups while maintaining as much agricultural employment as possible. Environmental governance, he defines as ensuring the protection of soil, water, air and agricultural landscape, and the welfare of livestock. Sustainable agriculture is not the same as the concept of organic or ecological agriculture. What sustainable and organic farming have in common is a concern for soil, water and air protection and a concern for other environmental resources. However, they differ in their approach to agricultural inputs, as organic farming is based on the complete abandonment of chemical plant protection products and artificial fertilisation. The economic, environmental and social dimensions of sustainable agriculture are to some extent complementary. A prosperous and efficient agriculture is able to invest in environmentally friendly production activities, and environmentally friendly production and low prices for agricultural products are beneficial from a society-wide point of view [3].

The European Green Deal assumes that the European Union will transform itself into a modern, resource-efficient and competitive economy that improves the quality of life of the Union's citizens while playing a leading role in the global fight against climate change. The key components of the European Green Deal (COM/2019/640 final) [4] (Fig. 1) include the objectives of environmental sustainability in EU agriculture.

Poland is fulfilling its obligations on agricultural sustainability under four EU Regulations of 2013. (OJ 2013: L347/549; L347/608; L347/671; L347/865) [5], *the Water Framework Directive* (Directive 2000/60/EC) [6], the *Nitrates Directive* (Directive 91/676 EEC) [7], the *Biodiversity Strategy* 2011 and 2020 (COM/2011/244 final; COM/2020/ 380 final) [8]. As a complement to the EU documents, the *Strategy for Responsible Development* to 2020 (with an perspective to 2030) of 14 February 2017 was introduced in Poland. (M.P.2017.260) [9], *Strategy for Sustainable Development of Rural Areas, Agriculture and Fisheries* 2030 of 15.10.2019. (M.P.2017.1150) [10] and the *National Environmental Policy 2030 - Development Strategy in the area of environment and water management* of 9.08.2019. (M.P.2019.794) [11].

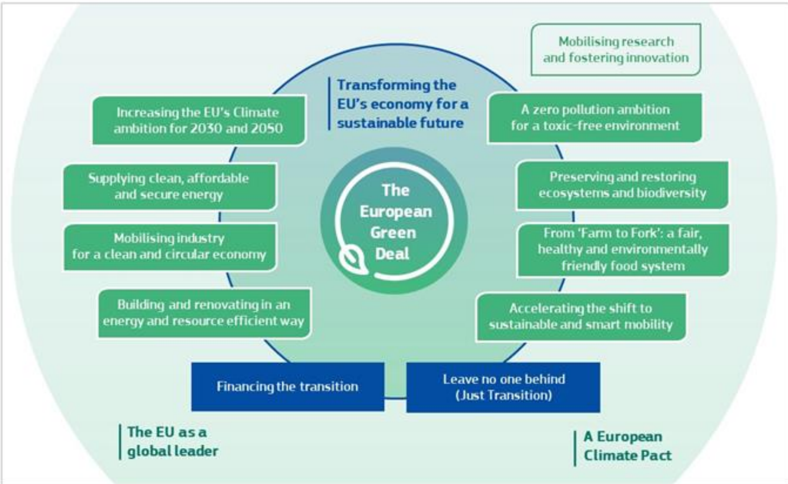

Fig. 1. Key components of the European Green Deal (COM/2019/640 final) [4]

All of these documents draw attention to the need for sustainable development of agriculture and rural areas by, inter alia, reducing greenhouse gas emissions, protecting water and soils, circular economy of waste management.

2. GREENHOUSE GAS AND AMONIUM EMISSIONS

On the one hand, agriculture plays an important and positive role in mitigating climate change: thanks to the photosynthetic process of plants, which capture carbon dioxide from the atmosphere, and properly managed soils store it. However, agriculture (forestry and fisheries) is also responsible for greenhouse gas emissions (GHG). According to the IPCC report [12] on the impact of land use on climate change, the Agriculture, Forestry and Other Land Use (AFOLU) sector accounts for 23% of global anthropogenic GHG emissions. EU agriculture accounts for 12.72% (476,965 $MtCO_{2e}$, 2021 data) of all EU GHG emissions, 70% of which come from livestock farming - agriculture is only overtaken by industry, the energy sector and housing. This sector recorded a 1% decrease in GHG emissions compared to 2020 [13].

Agricultural practices are associated with two types of greenhouse gases in particular:

– methane (CH_4) - from livestock digestive processes, faecal management and rice cultivation;

– Nitrous oxide (N_2O) - derived from agricultural soils fertilised with nitrogenous fertilisers of organic and mineral origin and from manure management.

In the case of CO_2, it is omitted from consideration, believing that the value of emissions is comparable to the ability of crops to absorb it [12].

Table 1 summarises Poland's greenhouse gas emissions expressed in CO_{2e} for the base year and 2020 and their changes by major source category. All source categories recorded a decrease in emissions compared to the base year. The largest decrease in GHG emissions was recorded in the categories: Waste and Agriculture (by 48.2% and 31.6% respectively). In agriculture, such a significant decrease in emissions was due to structural and economic changes after 1989, including a decrease in livestock and crop production (e.g. there was a decrease in the cattle population between 1988 and 2020 from over 10 million head to about 6 million head, sheep from over 4 million head to about 288,000 head) [14].

Table 1. Greenhouse gas emissions in Poland expressed in CO_{2e} for the base year and 2020 and their changes by major source category [14]

Lp.	Categories	Total [kt eq. CO_2]		(2020 - base)/ base [%]
		Base year	2020	
	SUM (with category 4)	560,104.68	355,061.91	-36.61
	TOTAL (excluding category 4)	579,450.00	376,038.46	-35.10
1	Energy	476,158.99	305,335.93	-35.88
2	Industrial processes and product use	31,265.87	25,074.07	-19.80
3	**Agriculture**	**50,186.43**	**34,314.52**	**-31.63**
4	Land use, land use change and forestry	-19,345.32	-20,976.55	8.43
5	Waste	21,838.71	11,313.94	-48.19

Category 4 Land use, land use change and forestry/LULUCF

In 2020, total GHG emissions from Polish agriculture amounted to 9.1% of the country's total anthropogenic emissions. The largest share of total GHG emissions (expressed in CO_{2e}) (excluding the Land Use, Land Use Change and Forestry/LULUCF sector) was accounted for by the energy sector (approximately 81.2%), and within this sector, fuel combustion processes (75.5%).

Polish agriculture is primarily a source of nitrous oxide emissions (N_2O) and accounts for 81.8% of total anthropogenic emissions of this gas. As for the total nitrous oxide emissions from agriculture, 68.9% came from land use (nitrogen fertilisation) and 12.9% originated from animal manure management [14].

Methane emissions (CH_4) from agriculture in 2020 represent 31.9% of emissions from all domestic sources. Emissions from the enteric fermentation subcategory were the dominant source of emissions in the agriculture category with a share of about 29.1% in methane emissions. In Polish agriculture, the main source of methane emissions is enteric fermentation (89.5%) and animal faeces management (10.3%). It should be added that emissions from enteric fermentation of dairy cows are the most significant, accounting for 58.9% of total emissions from this source. Methane emissions from livestock manure management are projected to increase up to 2040, driven by the likely further increase in the poultry population and the growing proportion of barn-free systems for cattle, particularly dairy cows and pigs. It is estimated that by 2040, total cattle populations will remain at current levels, but sheep, goat and horse populations will decline [15]. Some opportunities to reduce the increase in emissions from this source by 2040 are mainly due to technological advances in how livestock manure is managed [14].

In total GHG emissions from agriculture, calculated in carbon dioxide equivalent (CO_{2e}), the main sources of emissions in 2020 were agricultural soils (45.9%) and enteric fermentation (34.3%) (Table 2) [14].

Table 2. Emissions of the main greenhouse gases from 2019 to 2020 in the agriculture category [14]

Emission source categories	CO_2 [kt]		CH_4 [kt]		N_2O [kt]	
	2019	2020	2019	2020	2019	2020
AGRICULTURE	1,122.67	1,458.75	556.38	566.66	59.6	62.72
A. Intestinal fermentation	-	-	508.02	516.66	-	-
B. Animal faeces	-	-	47.44	48.89	9.39	9.86
D. Agricultural soils	-	-	-	-	50.18	52.82
F. Incineration of vegetable waste	-	-	0.92	1.11	0.04	0.04
G. Liming	541.35	836.3	-	-	-	-
H. Use of urea	411.41	431.33	-	-	-	-
I. Other fertilisers	169.91	191.13	-	-	-	-

In addition to methane, one of the main gaseous air pollutants from agricultural production is ammonia. It is estimated that in the European Union, agriculture is responsible for over 92% of emissions of this gas, while in Poland this value reaches 94%. The largest part of ammonia emissions is connected with animal faeces - 78%, and the remaining 22% of emissions is connected with the use of mineral nitrogen fertilisers [13].

Ammonia is an inorganic compound of nitrogen and hydrogen, which is formed in animal faeces by bacterial and enzymatic hydrolysis processes of protein substances, including amino acids, amides, urea and uric acid. The formation of ammonia in agricultural production depends on a number of factors, among which are: the nitrogen content of the animal's diet, the way the animals are kept, the way manure is stored, the type of fertiliser used, as well as the dose and technique of application and atmospheric conditions [16]. The most important negative environmental impacts of ammonia include eutrophication of aquatic ecosystems and acidification of soils.

An additional problem causing air emissions due to climate change is the increase in agricultural fires. The direct causes of the increase in fires in numbers as well as in area are extreme meteorological conditions: the occurrence of warm and snowless winters (resulting in a prolongation of the danger period in the past considered non-flammable), climate warming, rainfall deficiency, drought, as well as human irresponsibility (grass burning in meadows, roadside ditches and wastelands). In 2021- 2,938 fires in agricultural crops, meadows and stubble and 9,362 fires in wasteland were recorded, covering an area of 3,086 ha and 1,986 ha, respectively [17].

3. WATER POLLUTION AND SOIL DEGRADATION

The Helsinki Convention, signed by all countries bordering the Baltic Sea (Denmark, Germany, Sweden, Estonia, Finland, Latvia, Lithuania, Poland and Russia), imposes an obligation to reduce pollution of the Baltic Sea introduced through rivers and their intakes, discharges from canal and pipeline outlets, dumping at sea and pollution from ship operations, as well as from the atmospheric air [18]. The most serious threats generated by agriculture are considered to be the unused biogenic nitrogen and phosphorus compounds in agricultural production, which can leak into groundwater and open water and, in the case of nitrogen, volatilise into the atmosphere. Among the Baltic States, Poland has the largest area of arable land (188,101 km^2). Due to the fact that Poland is located in the catchment area of the Baltic Sea, all biogenic polluted waters flow into marine waters. Statistical data collected by HELCOM indicate that 56% of nitrogen and 49% of phosphorus discharged into surface waters of the Polish part of the Baltic Sea catchment area comes from area sources primarily from agriculture [19].

The use of fertilisers is the main yield-forming factor that determines the development of agricultural production and, at the same time, influences the degree of risk of water pollution. According to the Act of 10 July 2007 on Fertilisers and Fertilisation (Journal of Laws 2007 No. 147, item 1033) [20], fertilisers are "products intended to provide plants with nutrients and increase soil

fertility or increase the fertility of fishponds, which are mineral fertilisers, natural fertilisers, organic fertilisers and organic-mineral fertilisers".
Among the countries in the Baltic Sea catchment area, the highest consumption of nitrogen and phosphate fertilisers in 2020 was in Germany (approx. 1,372 thousand tonnes) and Poland (approx. 1,034 thousand tonnes), while the lowest consumption was in Estonia (approx. 41 thousand tonnes) and Latvia (approx. 84 thousand tonnes) [17].

As indicated by CSO data [21], the consumption of nitrogen fertilisers (in pure N) in Poland in 2019/20 amounted to 1.0 million tonnes and was higher than in the two previous years by 3.9 and 19.9%, respectively. Per hectare of agricultural land, 69.1 kg of nitrogen fertilisers were used in 2019/2020, compared to 67.7 kg the year before and 48.4 kg in the 1999/2000 marketing year. In the case of phosphate fertilisers, their use in 2019/2020 stood at 0.4 million tonnes (in pure component - P_2O_5). This represents an increase compared to previous years of 4.4% and 20.8% respectively. Per ha of agricultural land, 24.0 kg of phosphate fertilisers were used in 2019/2020, 23.4 kg the year before and 16.7 kg in the 1999/2000 marketing year.

Nitrogen and phosphorus balances, as agri-environmental indicators, are an important source of information on the environmental impact of agriculture. The average gross nitrogen balance per ha of agricultural land increased from 41.1 kg in 1998-2000 to 48.3 kg in 2018-2020, a figure well below the required 70 kg per ha of agricultural land [21].

In agricultural cultivation, the possibility of fulfilling the principles of a circular economy with environmental sustainability is important and possible through the use of, among other things, natural fertilisers. The group of natural fertilisers according to the cited law includes manure, liquid manure and slurry. Manure is a fertiliser consisting of the faeces and urine of livestock with the addition of bedding. If no bedding is used in the rearing and the faeces themselves are flushed with water, then we are dealing with liquid manure. Slurry, on the other hand, is the fermented urine of the livestock. The amount of manure produced on a farm depends on a number of factors. Among the most important of these is livestock density. In scientific research, as well as for the purposes of agricultural practice, the amount of manure arising and its agricultural value are based on the so-called large livestock unit (LU) based on a body weight of 500 kg, which corresponds to a dairy cow [22, 23].

Livestock manure is the primary natural fertiliser. Its highest use in Poland was recorded in the 2009/2010 year (61 kg per 1 ha of agricultural land). In subsequent years, manure consumption remained at around 40 kg per ha of agricultural land. In the 2019/2020 year, it was almost 35 kg per ha of agricultural land, which means that it decreased by almost 5 kg per ha of agricultural land compared to the 2018/2019 year. The reduction in the method of fertilisation using manure may be due to the decrease in cattle and pig breeding on farms and thus the decrease in the production of this manure [17].

In addition to groundwater and surface water pollution resulting from improper use and storage of fertilisers, there may be soil and water contamination from residues of chemical plant protection products. Pollution from improper wastewater management on farms is also a major threat: lack of treatment of wastewater before it is discharged into water or the ground, as well as the formation of leachate from leaking septic tanks.

The protection of waters against pollution caused by nitrates from agricultural sources has been regulated by the so-called Nitrates Directive. The Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) [7] recognises nitrates from agricultural sources as the main cause of pollution from diffuse sources affecting water.

According to the 'Programme of measures to reduce water pollution by nitrates from agricultural sources and to prevent further pollution (Journal of Laws 2018, item 1339) [24], a manure storage area should be understood as tanks for liquid manure, a slab with a leachate tank and an installation for draining leachate from the slab into the tank, or another storage area for manure or bird manure. In addition, the "Programme of measures..." [24] sets out the conditions for the application of fertilisers when they are prone to leaching into groundwater or washing into surface water, the timing of the application of manure on agricultural land and the need for fertiliser programmes.

Alongside quality protection is water quantity protection, i.e. economical water use by agriculture. Direct water consumption in Polish agriculture, for domestic purposes, watering animals and irrigating plants, is relatively small and does not exceed 10% of the total amount of water consumed by all branches of the economy. This is related to the relatively small area of agricultural land equipped with irrigation devices (less than 1% of agricultural land) and improper operation of drainage systems [25]. The rationalisation of water use in agriculture requires the adaptation of the overall crop structure and cultivation method in order to make the most efficient use of water resources in the soil, as well as the reduction of water take-off by evaporation [26]. Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse [27] encourages a circular economy approach to water reuse in agriculture.

Another problem of modern agriculture also related to the availability of water resources is the progressive degradation of soils.

In 2021, agricultural and forest land occupied 90% of Poland's area. Arable land accounted for approximately 60%, forests and woodland 30%, and other land 10%. Of the agricultural area, arable land accounted for 72%, permanent grassland

20%, orchards about 1%. In 2021, the area of arable land decreased by 23,000 hectares (0.1%) compared to the previous year. There was an increase in the area of forest and wooded and shrub land by about 7 thousand ha (0.1%), the area of built-up and urbanised land by about 28 thousand ha (1.5%) and the area of land under water by about 3 thousand ha (0.4%) [17].

Loss of soil organic matter is one of the biggest and growing problems in modern agriculture. Increasing dry spells and low-snow winters cause soil drying and humus mineralisation. Salinisation significantly reduces soil quality and plant cover. Due to the destruction of soil structure, saline and sodic soils are much more easily eroded by water and wind. When land degradation occurs in arid, semi-arid and moderately wet areas, then the phenomenon is called desertification. Salinity leads to the effects of desertification, which are loss of soil fertility, destruction of soil structure, soil compaction and soil crusting [28].

However, agricultural management can encourage biodiversity and the restoration of soil organic matter through organised tools and techniques (e.g. mulching or the use of catch crops). The preservation of soil humus resources is important not only for maintaining the productive functions of soils, but also for the role of soils in sequestering (fixing) carbon dioxide from the atmosphere, contributing to the reduction of the greenhouse effect. Intensive use of soils in monocultures destroys soil structure, leads to excessive aeration of habitats and mineralisation of humus and the release of large amounts of carbon dioxide into the atmosphere [29].

4. WASTE MANAGEMENT

Rural areas generate not only manure, municipal waste, but also waste associated with agricultural activities. Municipal waste does not include waste from manufacturing, agriculture, forestry, fisheries, septic tanks, sewage networks and sewage treatment plants, including sewage sludge, end-of-life vehicles and construction and demolition waste [28]. Pursuant to Article 2 of the Waste Act of 27 April 2001 (Journal of Laws No. 62, item 628, as amended) [30], the provisions of the Act do not apply, inter alia, to animal excrement, manure, liquid manure and slurry intended for agricultural use in the manner and under the conditions specified in the regulations on fertilisers and fertilisation.

Waste generated by agricultural activities, apart from animal faeces, includes: plant protection products and their packaging, out-of-date plant protection products, fertiliser bags, string, foil, agro-fibre, crates, tractor, trailer and other agricultural machine tyres, used engine oils, batteries and accumulators, asbestos products, chemicals used on the farm, dead animals and veterinary waste, crop residues should be handed over under individual agreements with entities managing them and holding the relevant permits. According to the regulation on the waste catalogue [31], hazardous waste on the farm includes: toxic and very toxic plant protection products, out-of-date products and packaging; used oils; oil filters; asbestos and asbestos-containing insulation and construction products, batteries and accumulators, chemicals, wood preservatives; waste from veterinary examination, diagnosis, treatment and prevention, fallen and slaughtered animals and waste animal tissue with hazardous properties. These wastes must be dealt with in accordance with the rules specified for the relevant hazardous waste group.

5. CRITERIA FOR ASSESSING THE ENVIRONMENTAL SUSTAINABILITY OF FARMS AND AGRICULTURE

Adopting the concept of sustainability of agricultural development, based on the coexistence and interaction of the three orders: economic, environmental and social, it is possible to establish a set of yardsticks that form the basis for monitoring trends of change and describe the interdependencies taking place in these spheres. The differences in the set of sustainability indicators at the farm level and the country as a whole are significant. While at the farm level environmental indicators are of primary importance, at higher levels (local, regional, national, global) indicators relating to economic and social structures become more important [32].

Determining the correct way to assess the degree of sustainability of farms requires objective and identifiable measures and indicators of socio-economic-environmental sustainability and a great deal of analysis, methodological and practical research. To date, no uniform set of sustainability indicators has been developed and their selection depends on data availability. Attempts to agree internationally on a core list of sustainability indicators have not been successful in establishing a baseline for monitoring global change, nor in developing universally acceptable proposals for assessing agricultural sustainability [33].

One solution is to use the Farm Accountancy Data Network (FADN) accounting database. FADN is a European system for the collection of accountancy data from farms, the formal development of which began in 1965. FADN accounting, although mainly focused on organizational and economic issues, can be used for ecological-economic evaluation of farms, as it is the only source of microeconomic data, obtained on the basis of the same accounting principles in all EU member states. One of the indicators of eco-economic efficiency is the efficiency of input use. It determines the economic efficiency of the agricultural pressure on the environment. From both an ecological and an economic point of view, it is a negative phenomenon that there is no economic effect when the pressure is exerted on the environment. In this respect, agricultural types including grain animals score worst. Much better results are obtained by agricultural types with ruminants: grazing animals and dairy cows [34,35].

On the basis of FADN and CSO data, the following parameters can be adopted to determine the sustainability of the agricultural production process in terms of meeting environmental requirements, according to the guidelines of the study *Sustainability of Polish agriculture in the context of public statistics* [33]:

– share of cereals in the arable land sowing structure - not exceeding 66%; Cereals are the basic group of crops cultivated in Poland. Information on the share of cereals in the sowing of arable land is a statistical indicator indicating the environmental friendliness of agricultural production. Correct crop rotation is one of the requirements for participation in agri-environmental programmes.

– the number of crop groups cultivated on the farm - of at least 3; This number is indicative of the respect of plant selection and succession, which ensures the reduction of the development of agrophage populations, reduction of weed infestation and reduction of nitrogen losses. To qualify as a sustainable farm, it is necessary to grow at least three groups of crops out of six: cereals, legumes, root crops, oilseeds, grasses on arable land and others.

– an index of winter vegetation cover of arable land (IPGR) - of at least 33% (recommended value 50%);
IPGR is expressed by the ratio of the area under winter crops, perennial crops and intercrops to the total area of arable land. Maintaining vegetation on arable land between two main crop yields prevents water pollution and erosion. Covering the soil with vegetation during the winter period prevents the negative effects of climatic factors on the soil, such as precipitation and wind.

– a stocking density of all animals kept on the farm not exceeding 2 livestock units per hectare of farmland; The livestock stocking rate indicates the intensity of organisation on farms. It is assumed that the acceptable stocking rate should not exceed 2 livestock units (LU) per hectare of agricultural land. Each EU country is obliged to determine the equivalent of 170 kg of nitrogen expressed in livestock units. In Poland, 1.5 livestock units (LU) has been adopted as the equivalent. By using livestock manure in fertilisation and thus enriching the soil organic matter reserves, the positive impact of livestock production on the natural environment is marked. Highly intensive livestock production can cause potential threats to the ecosystem (e.g. methane and ammonia emissions, groundwater pollution).

– the balance of organic matter in the soil; the humus content of the soil strongly influences the quality and level of yield of crops. The rationale for implementing correct agricultural practices is to at least prevent the degradation of soil organic matter and ultimately to increase soil fertility. The balance of soil organic matter depends on the choice of crop species and their share in the crop structure, as well as the amount of organic fertiliser applied. Sustained negative balance over a period of several years can result in soil degradation, loss of soil fertility and productivity. Another negative effect of degradation is the release of large quantities of mineral nutrients, including nitrogen, leading to groundwater and surface water pollution.

– the fertiliser balance of the main macronutrients in the soil (nitrogen, phosphorus, potassium); Providing cultivated plants with the right amount of nutrients is a prerequisite for obtaining high yields, thus utilising the plants' production potential. Incorrect fertilisation adversely affects the profitability of production (high fertiliser costs), as well as posing serious risks to human, animal and environmental health. Fertilisation should balance the nutritional needs of plants, but at the same time must not create excessive macro-element reserves in the soil.

The assessment of agricultural sustainability (at a macro scale) diverges from farm sustainability. The core set of agricultural sustainability assessment includes 58 indicators divided into groups (the number of indicators per group is given in brackets) [30]:

a. Economic indicators
   - Agricultural production (9)
   - Inputs to agricultural production activities (6)
   - Agricultural income (3)
b. Environmental indicators
   - Land use and landscape conservation (10)
   - Soil use and conservation (12)
   - Water resources, use and protection (3)
   - Air pollution and protection, waste (3)
c. Social indicators
   - Resources and economic activity of the agricultural population (3)
   - Farm family income, poverty and social exclusion (6)
   - Education, health and social care (3).

From the point of view of the global environmental assessment, agricultural activities using natural resources have at the same time a significant impact on its condition. Of key importance is the interdependence between practices and the ways in which land, water and air resources are used and managed. In terms of environmental indicators, the parameter group on *land use and landscape protection* focuses on assessing changes in land use structure, sowing structure and agricultural area associated with environmentally friendly agricultural production techniques and technologies. The group of indicators of land *use and soil conservation* includes an assessment of mainly areas dependent on human activity. The degree of land use is characterised by changes in the area of set-aside and fallow land on arable land, the area of devastated and degraded land and the actions taken to restore their use value through appropriate reclamation, land reclamation and irrigation. The numerical values of these indicators are mainly derived from the respective practices of fertilisation of agricultural land and the use of plant protection products (pesticides). The proposed indicators therefore include data on the use of mineral and chemical fertilisers, organic fertilisers (manure, liquid manure and slurry) and lime fertilisers. Another area of environmental impact of agriculture is related to *water resources, use and protection*. The assessment of these issues relates to the extent to which rural areas are piped and channelled, the use of water resources by agriculture, as well as the impact of agriculture on the state of water purity and the use of irrigation systems. In terms of *air pollution and protection,* methane emissions, correlated mainly with the size of livestock farming, nitrous oxide emissions, associated with the intensity of soil fertilisation, are of particular importance. Agricultural activities are also the main source of ammonia emissions. Agricultural activities also contribute to carbon dioxide emissions through increased energy consumption and the degree of mechanisation. At the same time, part of CO_2 emissions are absorbed by vegetation. In statistics, carbon dioxide emissions are reported as net emissions, i.e. including emissions and removals from the combined sector "Land Use Change and Forestry", a numerical determination of the contribution of agriculture is therefore not possible [14].

6. CONCLUSIONS

The transformation towards the development of a sustainable agriculture model in Poland is inevitable. However, as shown in the study *Perspectives of sustainable agriculture in Poland - Socio-political analysis* (2019) [36] in the aspect of assessment of the environmental pillar, farmers have a general, superficial awareness of the negative impact of agricultural practices on the environment, and the current situation in agriculture is determined primarily by economic conditions. Consequently, the environmental standards and requirements in force are often not complied with by farmers. The lack of a uniform system and criteria for assessing the sustainability of agriculture and farms is also not conducive to the idea of development.

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