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## THE INFLUENCE OF AGRICULTURAL HOLDINGS ON THE NATURAL ENVIRONMENT

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### Summary

*Agriculture is the production field, which depends on the condition of the natural environment because it uses the natural processes of growth and reproduction of living organisms. The agriculture itself also affects the environment. The effects of this interaction, both positive and negative, are additionally shaped by the social, political, economic, technical and technological surroundings. The factors determining the agriculture's impact on a macro scale on the environment may, however, be brought down and subordinated to the main constituents, namely: the size of human population, demand for agricultural raw materials, the applied production technology (classical IPAT equation) and agro-climatic conditions. Based on the available forecasts and materials the potential directions and effects of constituents of the equation were analysed at the global level. However, establishing the environmental performance of a given agricultural holding and agriculture at the local level requires a different methodological approach. The article presents the method for measuring an agricultural holding's individual impact on the environment in the form of one indicator synthetic measure.*

**Key words:** *natural environment, agricultural holding, synthetic ratio, diagnostics features, IPAT equation*

**JEL:** *Q15, Q24, Q56, Q57, Q58.*

### Introduction

The issue corresponding to the protection of the natural environment, the depletion of natural resources, and the resultant threats of a local and global nature, are not only slogans popularised by certain groups of people (activists) searching for new political and social ideas. Forecast and prepared dramatic scenarios picturing the vision of global natural disaster effecting from human acts were causing and still cause the evolution of social values, not only in highly developed states, but also in those definitely poorer ones.

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The occurring change of the global climate in a manner not yet fully recognised, but potentially concealing serious dangers, focuses the social attention on all kinds of consequences of human impact on the environment, but will it be effective enough to change the human habits, needs and behaviours? But is it effective enough to cause a change in agricultural raw materials production systems into more environment friendly ones? What are the possibilities of reducing the negative impact and increasing the positive effect of agricultural activity on the environment and what role in this respect will be played by the surroundings of the agricultural holdings?

This article aimed at analysing on a macro scale the direction of changes as regards the main factors determining the mutual relationship between the environment and agricultural activity as one of the areas of human economic activity. The paper also presents a method enabling to measure the impact of a given agricultural holding on the natural environment in the form of one synthetic measure, which may be applied to establish its efficiency in this area and agricultural policy programming.

### The impact of agriculture on the natural environment – the theoretical aspect

The theoretical construction resulting from the public discussion among P. Ehrlich, J. Holdren and B. Commoner, often called as the IPAT equation, is a starting point for the establishment of relations between the natural environment and the functioning of human beings [Chertow, 2000]:

$$I = P \times A \times T \quad /1/$$

Where:

*I* – total impact of human activity on natural environment

*P* – population size,

*A* – affluence - global (or national) gross product per capita,

*T* – technology (impact of global or national) gross product unit on natural environment.

This was an attempt at a response on the epic questions about relations among people, economic development, technical and technological advancement, and the natural environment. In the search for a response on the impact of individual components of the model, many publications were prepared referring to different variants of this equation, where variables were differently developed and interpreted. One of them has become the basis for industrial ecology [Schulze, 2002, Fan et al., 2006, Dietz et al., 2007, Sachs, 2008, Mitchell, 2012].

The impact on the natural environment, as one of derivatives of human activity is the sum of all areas of their functioning. Therefore, index *I* may be de-aggregated and assumed as a determinant of, e.g., areas of the global (national) economy:

$$\Delta I = I_p + I_B + \dots + I_R \quad /2/$$

Where:

$\Delta I$  – total impact of human activity on natural environment,

$I_p$  – industrial impact,

$I_B$  – construction impact,

$I_R$  – impact of agriculture, etc.

Therefore, the question arises as to what are the possibilities of preventing the worsening of the natural environment, and what is the role of agriculture in this sphere? How can we influence agriculture in order to make it favourable for improvement rather than damaging the natural environment, and how can it contribute towards its competitiveness?

The impact of agriculture itself on the natural environment may be translated into the following formula:  $I_R = P_t \times F_t \times T_R \times K_t$  /3/

Where:

$I_R$  – impact of agriculture on natural environment,

$P_t$  – population size in period  $t$ ,

$F_t$  – value (quantity) of agricultural products manufactured calculated per person in period  $t$ ,

$T_R$  – average impact on natural environment of a unit of value (quantity) of agricultural raw materials manufactured,

$K_t$  – the impact of agriclimate in period  $t$ , being the component of  $I_R$ .

The identification and precise establishment of the impact of agriculture on the natural environment is a very difficult task, i.a. due to sectoral flows, but also to the wide spectrum of interdependencies. Because agriculture is not only the source of food, but there are also skins, fibres, raw materials for power and cosmetics purposes, etc. On the other hand, it utilises goods manufactured in different areas, i.a. it is a “consumer” of power carriers, mineral fertilisers, plant protection means, machines, building materials, etc. The process of manufacturing or obtaining these foods also has an impact on the natural environment, causing specific consequences [Pretty, 2008].

### **The factors determining the impact of agriculture on the natural environment**

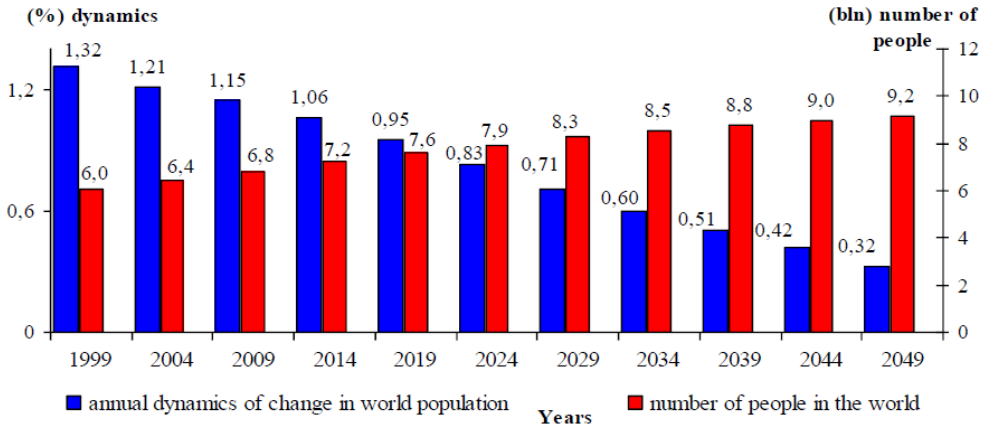
Changes in population on the global scale ( $P$ ) as the basic component of the equation /3/ show a constant increasing trend (Chart 1).

The dynamics of the increase in the population in the world are weakening, but due to the so-called base effect (the increment will exist at an increasing number of population) it is estimated that by the year 2050, the number of people around the world will increase by 2.3 billion people as compared to the year 2009, namely it will increase by nearly 34% [OECD, 2010].

Considering the changes in the population, an increase in the pressure on the part of agriculture towards the natural environment as a result of a growing demand for agricultural products on the global scale should be expected. According to expectations, this will provoke the doubling of the demand for food in 2050 as compared to the year 2000 [Bruinsma, 2009]. The increase in the number of inhabitants of the Globe will be accompanied also by higher utilisation of power carriers that according to forecasts will increase by 46% by 2030 as compared to the present level, and partially supplemented with raw materials of an agricultural origin. Increases in agricultural production will effect an increase in the utilisation of water for production purposes; as an optimistic variant, it

is forecast at 30% in 2030 [Institution, 2011]. However, the most serious challenge will undoubtedly be posed by the process of urbanising provoking pressure on the utilisation of land from production and agriculture to building purposes assigned for housing, as well as the construction of remaining, indispensable infrastructure, roads, airports, recreational areas, etc. [Smith et al., 2010].

**Chart 1.** The dynamics of change in the human population in years 1999-2049



Source: own work based on [OECD, 2010].

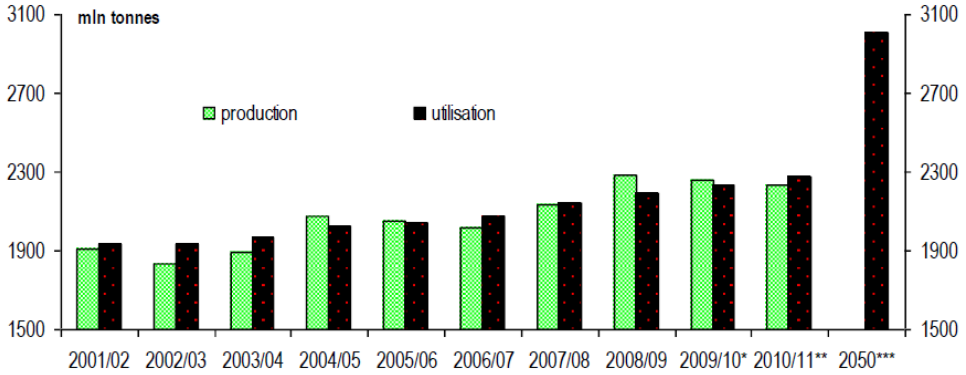
Under the new circumstances, agriculture will have to satisfy not only basic nutritive demands, but also demand resulting from higher aspirations and expectations towards improvements in existence in the states commonly defined as developing ones (increase in the consumption of food in these countries calculated per capita is expected to rise) and will have to compete for the above-mentioned resources with other areas of the world’s economy.

According to FAO forecasts, the process of increasing the level of fulfilment of nutritive needs on the global scale, calculated as number of calories consumed per capita in the whole predictive period (2007- 2050) will increase. Changes in the structure of diet caused by the higher consumption of animal origin products in developing and developed countries are also expected. Consequently, despite the use of agricultural raw materials for non-agricultural needs, in order to fulfil the nutritive needs of the increasing population and expectations on the structure of consumption, an increase in global agricultural production by 2050 is expected on the level of nearly 70% as compared to the years 2005-2007. The estimates show, i.a., that the total demand for cereals in 2050 will amount to over 3 billions tonnes annually, namely it will be increased by over 800 million tonnes as compared to the level from the economic year 2008/2009 (Chart 2). As far as meat is concerned, its consumption in the same period will be increased from 249 mln tonnes to 463 mln tonnes [Alexandratos, 2009].

The manner of the realisation of increases in global agricultural production is important from the perspective of the impact on the natural environment. Therefore, two basic methods in this respect are present. The process of the enlargement of the acreage of

crops for direct consumption by people and animals is one of them; the second refers to increases in expenditures and changes in plant production technology at the use of present surface of cropable land [Bruinsma, 2003].

**Chart 2.** The volume of production and utilisation of cereals in global scale



\* estimates, \*\* forecast, \*\*\* forecast omitting demand for power purposes

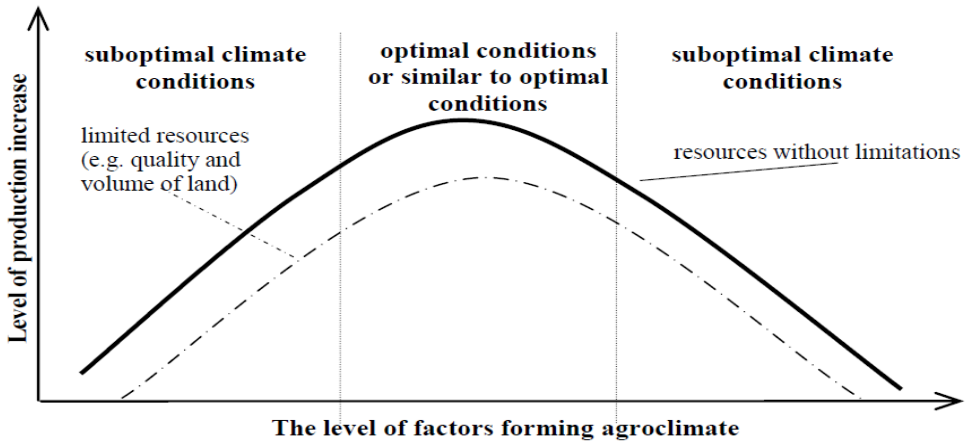
Source: prepared on the basis of [Alexandratos, 2009, FAO, 2010].

The increasing population is accompanied by changes in agricultural and climatic conditions, being the next important factor having an impact on the differentiating of both the production and environmental effects of agriculture. Agroclimate is composed of, e.g. the insolation of land, the content of carbon dioxide in the atmosphere, number of days of vegetation, humidity, interpreted as the quantity and frequency of precipitations, and, one of the crucial components, temperature. The increased intensity of particular elements along with the maintenance of proportions with different factors in the framework of their combination to some extent facilitates the achievement of higher yields and capacity for animal production, and, consequently, higher global production. A good example is the increase in the temperature and content of carbon dioxide that at the suitable humidification increases the photosynthesis process (stimulates it), and, in consequence, potential production output [Agrawala et al., 2010]. However, the excess of a limit point results in the opposite effect (become de-stimulators), e.g. the potential plant production yield and the level of animal production drops as a result of reactions to disadvantageous living conditions (Chart 3).

Climate changes observed nowadays and independent from causes of this phenomenon facilitate the predicting of significant increases in global temperatures until the end of the present century. The most frequent simulations show an increase in the average annual temperature from 2 to 4°C. For many places all over the world, it means significant excess in the limit of optimum climatic conditions for agricultural production, and entering the area of an increases agroclimatic barrier for growth in the production output [Mendelsohn, Dinar 2009]. Therefore, there is a risk that the pace of technological and technical progress in terms of improved possibilities for increasing production will not be able to level the disadvantageous impact of changes in climate conditions in order to fulfil global nutritive

needs, and maybe energetic ones. The limitation in the productivity of resources resulting from climate changes and insufficient natural capital (natural resources), especially agricultural land, may be an important barrier for the economic development of a given region of the world or a country. In these circumstances, conducting pro-environmental activities relying on the protection of agricultural land and its productive capacities, as well as the adjustment processes to the new agroclimate, social and economic conditions, seem to be important [Mitchell, 2012].

**Chart 3.** The impact of climate and its interactions with resources for increases in of agricultural production



Source: based on [Mendelsohn, Dinar, 2009].

The possibility of reversing the disadvantageous impact of agriculture on the natural environment should be then considered as lying in the betterment of technology and techniques of manufacturing. A change in the average impact of value (quantity) unit of manufactured agricultural raw materials on the natural environment seems to be the only currently-available tool facilitating an improvement in the mutual relations between agriculture and the natural environment [Alston et al., 2009, Sachs, 2008]. There is a possibility to invest in renewable natural resources (natural capital) aimed at the betterment of the condition of the environment. The cultivation of plants for green fertilisers (ploughing) is a good example of this type of investment. Cessation of harvesting plants results in an improvement in the humus content in soil, but also a decrease in the current quantity of agricultural raw materials assigned for consumption that, according to neoclassical theory, may be presented in the form of the equation [Pender, 1998.]:

$$C_t = (F(P_t, K_a, K_n) - p_a N_a - p_n N_n) / P_t \quad /4/$$

Where:

- $C_t$  – level of consumption of agricultural resources calculated per capita,
- $K_a$  – owned capital of anthropogenic origin,
- $K_n$  – owned natural capital,
- $N_a$  – expenditures on capital of anthropogenic origin,

$N_n$  – expenditures on natural capital,  
 $p_a$  – market price of anthropogenic capital unit,  
 $p_n$  – natural capital restoration coefficient,  
 $P_t$  – abundance of population in period  $t$ .

Investment in natural capital refers to that part of resources of the renewable type, e.g. those quantity or quality of which may be bettered. It should be remembered that expenditures on renewable capital do not cause their increase to an equal degree. In the example presented above, ploughing of green fertiliser brings organic mass to the soil, but this does not cause an increase in humus to the same quantity. As a result of processes occurring in the soil, part of organic fertiliser will be subordinated to mineralisation and is reduced to basic chemical compounds of the non-organic type, including carbon dioxide emitted into the atmosphere.

Investment in renewable natural resources will increase the productive options of future agriculture, although at the same time it will limit present consumption of agricultural raw materials ( $C_t$ ). The far-reaching investments of this type are therefore feasible under significant over-production of food and its availability. The non-renewable type, namely the one that cannot be restored after use, is differentiated in the framework of natural capital. The biodiversity of plants and animals and petroleum among raw materials is the most important element from the agriculture perspective.

Agricultural production depends on the utilisation of production resources, not only of natural kind (natural capital), but also of a type of anthropogenic origin. At least partial, mutual substitution of classical factors of production and natural capital is also possible, although sometimes with negative consequences for the environment. An example of this type of activity includes the limitation of the rotation of crops of plants through the simplification of rotation with a simultaneous increase in the chemicals applied – pesticides having a negative impact on, e.g. biodiversity, and a deterioration in water and soil quality. Another example includes specialisation of production through the elimination or significant limitation of organic fertilising through pulling out of animal production on a given farm on the fulfilment of the present demand of plants for nutritive components in the form of mineral fertilising only [Ruggeri, 2009].

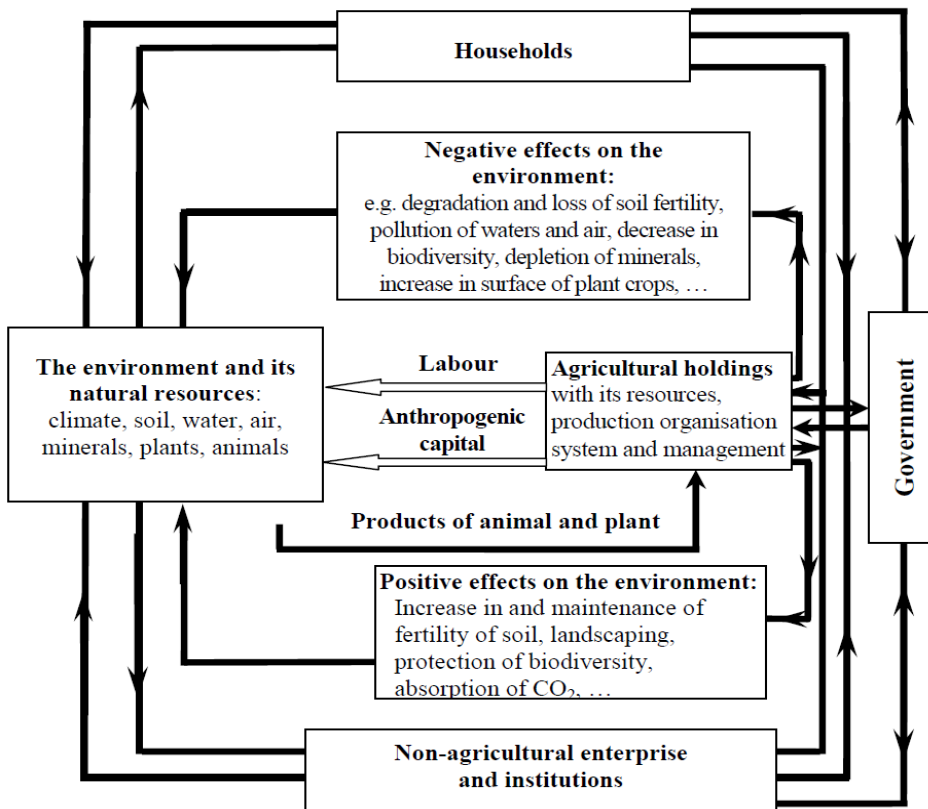
The specialisation of production is important not only from the perspective of needs and the grade of utilisation of property capital, but it also impacts on the organisation of labour, and the necessary range of knowledge and experience of employees. At the same time, the incorrect selection of cropable plants (a negative organic matter balance) leads to the lowering of the humus content in soil as a result of the advantage of the mineralisation process over humification. However, the negative results of this procedure for a household itself, contrary to productive, organisational, and financial effects, may be noticeable gradually and significantly delayed in time.

Not only do agricultural holdings interact with the natural environment, but they also function in a specific social, political, economic and technical environment (Chart 4). Therefore, survival interpreted as secured access to resources necessary for the existence of



agricultural holdings in the long-term perspective is the basic goal of activities conducted under changing external conditions. This goal is of the resource type, because it corresponds with the acquisition and maintenance of the relevant quantity of land, and the number of employees with adequate qualifications as well as tangible and current assets. It also has a financial aspect, most often identified with liquidity, namely financial security interpreted as the ability of the concurrent payment of obligations, and in holdings employing only the owners, securing their minimum level of consumption. The pressure of the environment, usually closely related, namely recipients, owners, suppliers regarding increases in the utilisation of resources (the correlation of quantity of foods obtained with expenditures from material and financial capital, as well as labour) may induce permanent neglect or periodic neglect of very negative, or generally negative, environmental effects. This is possible particularly in a crisis situation, when a holding is threatened with bankruptcy (legal entity holding), is faced with significant limitation of production resources, or the production and economic surplus generated is not sufficient for the basic living needs of owners and their families (small family farms) [Lichtenberg et al., 2010].

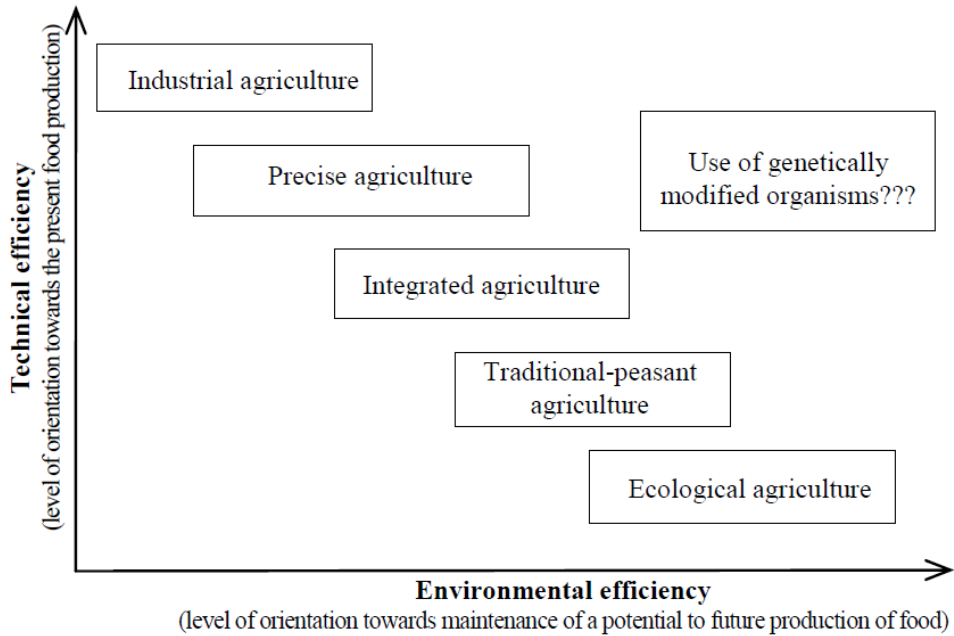
**Chart 4.** The interaction between agricultural holdings and the environment: political, economic, natural, technical and technological



Source: based on [Nigel, 2006, Kinzig et al., 2006, Runowski, Zietara, 2011].

The extent of the impact of agriculture on the natural environment is determined by the approved production system observed in agricultural holdings (Chart 5).

**Chart 5.** The productive and environmental efficiency of selected agricultural systems



Source: based on [Kerselaers et al., 2011].

Not all the negative effects of agricultural activity affect only the production potential of agriculture (these are local effects). The disadvantageous impact on the natural environment may be of a global or regional nature (the emission of carbon dioxide, ammonia, water pollution, etc.), and their effects are to a greater extent noticeable by other users of the natural environment, rather than agricultural holdings themselves. If so, we may deal with the classical shifting of the effects of activity in the form of pollution to third entities. Because most often the impact of agricultural holdings on the natural environment is of a non-market nature (neither positive nor negative effects are estimated in monetary units), their owners do not receive complete information on burden resulting from the negative impact of on ecosystem. Therefore, according to classical economic theory, they are not able to include them in the costs of activity. Then, we may observe the phenomenon of the partial or complete socialisation of the negative effects of their impact with the simultaneous improvement in the production and economic situation of a given entity. It is favoured by the social consent for the application of these practices (fear of loss of employment, nutritive self-sufficiency of the country, insufficient information, etc.), lack of negative or positive impulses from the state (legal regulations, financial instruments: penalties and charges, subsidies and budget subventions), and often— only knowledge and awareness of the effects of activities taken or neglect by owners and the administrators of such entities [Stiglitz, 2000, Zegar, 2007].

## **The practical measurement of the impact of agricultural holdings on the natural environment**

The quantification of the impact of agricultural holdings on the natural environment in the form of a single measure or coefficient is a difficult task considering the mentioned lack of unidirectionality of interdependencies, multi-faceted nature of the impact of both systems and their infiltration in different spheres of activity of analysed units and the environment.

There are different systems, coefficients, and ways of measuring the impact of agricultural holdings on the natural environment [Van der Werf, Petit, 2002, Goodlass et al., 2003, Kuosmanen, Kuosmanen, 2009, Mayer, 2008, Jan et al., 2012]. In our institute, since 2007 for this purpose we have applied, i.a., non-standard methods of multidimensional comparative analysis (MCA) facilitating a synthetic approach to complex phenomena described by many variables (diagnostic features). It refers to the multidimensional transformation of a space of selected diagnostics features describing a given phenomenon by one synthetic variable (measure). This facilitates the ordering of tested subjects in terms of the analysed phenomenon, namely the impact of the agricultural holding on the natural environment as given in this example, and through the simplification of this impact to one coefficient of a continuous nature.

A series of diagnostics features is selected under the rule stating that these should be based on the comparison and verification of application of adequate agricultural practices, largely reflect the impact of agricultural holdings on the ecosystem, and at the same time it should be founded on a well-documented source material. The following fragmentary indicators were used for the construction of a synthetic measure:

- biodiversity and correctness of crop rotation (point-based measure),
- balance of organic matter in soil expressed as the equivalent of the dry mass of manure (*dt1/ha*),
- share of permanent pastures used for production in the structure of agricultural land (%),
- balance of nitrogen and amount of oversized emissions or shortage of nitrogen as translated into a clear component (*dt1/ha*),
- anti-erosion protection expressed by share of surface of arable lands covered with vegetation in wintertime (%).

The biodiversity of plant production and the correctness of rotation is assessed as a pointwise-measure calculation based on the crops structure in a given calendar year, taking into account the number of individual plant groups cultivated by an agricultural farm, as well as the area these plants cover within the arable land. It has been assumed that an agricultural farm should grow plant species from at least three separate groups out of the following: cereal, fabaceae, oilseeds, root vegetables, poaceae grown on arable land, and other. The assumption has also been made that the cultivation of plants belonging to a given group should not take place more often than for two consecutive years. In the light of the above assumptions, in order for the rotation to be correct, and thus securing biodiversity,

the plant group cultivated on the largest area (predominant within the crop structure) may not exceed 60% of the cultivated arable land. Accordingly, the area of the plant group that has the second-largest proportion in the crop structure forms no less than 20% of the cultivated arable land, while the area of the remaining plant groups collectively forms at least 20% of total crops and plantings. Any deviations from these principles, consisting of a lower proportion of the respective plant groups, result in negative points, the number of which is equal to the actual observed values and the assumed limit values (60%, 20%, 20%). The calculation of the negative points rests on the assumption that 1% difference corresponds to one negative point.

The balance of the organic matter in the soil forms another variable used as the diagnostic feature for the assessment of the environmental impact of agricultural farms. It is estimated based on the crop structure and the stock volume of animals bred by an agricultural unit. The balance is prepared by comparing the loss of the organic matter resultant from the cultivation of plants that reduce the soil fertility and the increase attributable to the cultivation of plants contributing to the reproduction of the organic matter in the soil. The resultant difference was adjusted by the potential increase in organic matter achieved through infusing the soil with other organic fertilisers produced by the farm (straw, manure, cowpat, slurry). The balance was prepared using the reproduction and degradation ratios of the organic matter in soil relevant to the medium soil.

For the agricultural entities engaged in breeding animals, the number of animals was calculated into the volume of produced organic fertilisers, expressed as tonnes of dry manure mass. In addition, a balance of the demand for straw was prepared, whereby for the agricultural farms with an excess volume of straw, including stockless farms, the organic matter introduced, along with the incorporation of its surplus, was taken into account. At the same time, it was assumed that, with the nitrogen balance being below -5 kg/ha, the manure did not raise the humus pool in the soil. The assumption was also made that each organic fertilisation in excess of 10 tonnes of dry manure mass per hectare did not increase the humus pool in the soil as well.

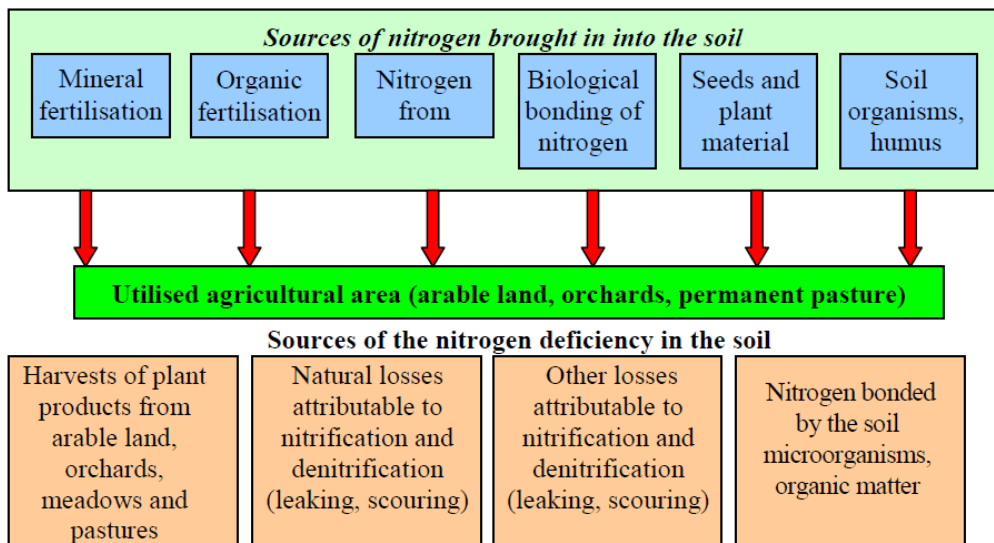
A positive balance of the organic matter is contributory to maintaining fertility, and, consequently, to the productivity of the agricultural soil. An increase in its value per hectare of the area of the arable land within an agricultural farm was incorporated as a stimulant variable for the synthetic environmental impact ratio of agricultural farms.

Permanent pasture plays an important role as the element with key implications for the environmental impact of agricultural farms, since it provides for a stronger protection of the soil, functions as a habitat and natural compensatory site, and also provides flood protection, while at the same time regulating the water balance, sequestering carbon dioxide and shaping the landscape. Permanent pasture in an agricultural farm is something of a “burden” on production and finances – the fact that it is continued to be maintained can be explained by the limited possibilities of the alternative utilisation of the land (terrain, hydrographic conditions). The fodder produced from it is usually of a much lower quality than that of the produce which could be potentially harvested, if the permanent pasture were used as arable

land. However, in order for the meadow and pasture ecosystems to exist, it is essential to pursue agricultural activity to suppress the plant succession. The proportion of the permanent pasture used in an agriculturally-appropriate manner is therefore a measure of the positive impact that an agricultural farm has on the environment. Hence, both the decision to change the way they are used through ploughing and to cease its utilisation and convert it into set-asides and brownfield land is unfavourable.

Nitrogen, and, more specifically, its inorganic compounds resulting from the processes related to agricultural activity, may be a source of significant water and air pollution. As a result of nitrogen conversion, such substances as methane, ammonia or nitric oxides are released to facilitate the greenhouse effect. When washed out of the water, nitrogen converts into various forms of nitrates and nitrites to form a significant source of environmental pollution. Nitrogen’s reactivity, as well as its diverse behaviour in natural circumstances, make its circulation more complex than is the case with the other fertiliser components, since nitrogen is also an essential component for plants used, i.e., to build proteins, nucleotides, alkaloids and chlorophyll. Given the fact that the major portion of this element typically is in organic form, it determines the soil fertility. When assessing the environmental impact of the agricultural farm in this respect, one should estimate the balance of this component as a reference point. For the purposes of the study in question, this feature was estimated for the farms based on the volume of the component brought in by each individual source (incoming factor) and the direction of its discharge – the outgoing factor (Chart 6).

**Chart 6.** Major components in the nitrogen (N) balance in the top layer of the utilised agricultural area



Source: based on [OECD, 2001].

Not only the surplus in nitrogen, but also its deficiency, has an adverse impact on plants and the metabolism of organic matter. The undesired effect is assumed to consist of losses arising from oversized nitrogen emission into the environment as part of the “other losses” (more than 5 kg per hectare) as well as the volume of its potential deficiency in plants (less than -5k per hectare).

For agricultural farms engaged in breeding animals, the nitrogen level provided with the organic fertilisation was estimated based on the assumed norms and their annual average status. Where the ceiling volume of the organic fertilisation was exceeded beyond the limit set out in the Nitrogen Directive, the total surplus was classified under “other losses”.

When preparing the balance of the nitrogen compounds, an equal amount of this component that reaches the soil with rainfall (17 kg per hectare yearly), as well as the amount of nitrogen from the atmosphere bonded by microorganisms living in symbiosis with the fabaceae, was taken into consideration (100 kg per hectare yearly). For the outcomings and the amount of nitrogen discharged by the soil microorganisms, the value was assumed at 10 kg per hectare yearly.

Anti-erosion protection, i.e. covering the arable land with vegetation in the winter period, is yet another feature taken into consideration for establishing the synthetic measure of the environmental impact of agricultural farms. The plant layer inhibits the degradation of the top layer – which is one of the most important soil layers – through the processes of lixiviation, entrainment and disintegration, as a result of the action of wind and flowing water. These processes depend on the weather and are particularly intensive when occurring in winter on bare soil. The best protection from this is therefore the highest-possible proportion of winter cereals grown as the main crop or the intermediate crop remaining on the field at that time. In the Poland has seen no progress in recent years in terms of reducing the area of arable land exposed to individual erosions. The devastating effect of wind continues to pose a significant threat to 27.6% of the area of utilised agricultural land, while water erosion has an adverse effect on 28.5% of the area of utilised agricultural and forest land, with gully erosion posing a risk to 17% of the utilised forest and agricultural land.

Due to the fact that the specific rates illustrated below have diverse denominators, they were subjected to normalisation through the zero-unitarisation method. For the majority of them (apart from the nitrogen balance), the following stimulant variable formula was applied [Diaz-Balteiro, Romero, 2004]:

$$Z_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Where:

$Z_i$  – normalised variable,

$X_i$  – variable before normalisation,

$X_{min}$  – for the organic matter balance, the minimum observed value, absolute

minimum for the biodiversity ratio (-80 points), for the proportion of permanent pasture (0%), for anti-erosion protection (0%),  
 $X_{max}$  –for the organic matter balance, the maximum value observed, the maximum absolute value for the biodiversity ratio (150 points), the proportion of permanent pasture (100%), the anti-erosion protection (100%).

The nitrogen balance is a destimulant variable with the veto threshold for the parameter within the -5 (kg/ha) do 5 (kg/ha ) range, and therefore requires not only to be normalised, but at the same time to be converted into the stimulant variable. To this end, the following formula has been applied:

$$Z_i = \begin{cases} \text{for } X_i < -5 \text{ kg} \times \text{ha}^{-1} & \frac{X_{max} - |X_i|}{X_{max} - X_{min}} \\ \text{for } X_i \in [-5 \text{ kg} \times \text{ha}^{-1}; 5 \text{ kg} \times \text{ha}^{-1}] & 1 \\ \text{for } X_i > 5 \text{ kg} \times \text{ha}^{-1} & \frac{X_{max} - X_i}{X_{max} - X_{min}} \end{cases}$$

With the following conditions met:  $X_{max} \neq X_{min}$  oraz  $X_{max} > |X_i|$ .

The synthetic ratio of the environmental impact of the agricultural farm ( $Ws$ ) has been calculated as the arithmetic mean:

$$Ws = \frac{100}{m} \sum_{j=1}^m Z_{ij} \quad i = 1, \dots, n, j = 1, \dots, m$$

Where:

- $Z_{ij}$  – Normalised value of the  $j$ -th feature and for the  $i$ -th facility
- $n$  – The number of the analysed facilities
- $m$  – The number of the adopted features

The synthetic ratio did not include the balance of the other macrocomponents such as phosphorus and potassium, despite the fact that the first might cause significant water pollution when discharged into it. As shown by the data provided by the OECD, however, agriculture in Poland is responsible for the emergence of this phenomenon only to a very limited extent, and agriculturally-generated phosphorus compounds do not burden the environment in a significant way [OECD, 2008]. What is more, phosphorus emission can emerge only within 25% of the utilised agricultural land in Poland, as only this percentage of the land shows a high proportion of this element in the soil. What can make for a serious problem in establishing the way phosphorous management influences environmental impact exerted by agricultural farms is the element’s mobility in the soil. A potential measurement of the emission would therefore entail specialist examination of water and soil.

The described method has one drawback in that it fails to take into account the impact of pesticide use, expressed, e.g. as an index of the active substances applied per one hectare. However, the expenditures on chemical agents used in agriculture make it impossible to assess the level of environmental burden in a reliable manner. A more extensive use of both agrochemicals and agents, which are more environment-friendly, i.e. are highly selective and their biodegradation process is faster, may result in increased expenditures, as their unit prices are understandably higher. A lower amount dedicated to this end does not necessarily mean less extensive use of agrochemicals. Agricultural farms with lower expenditures may utilise “cheaper agents”, discharging into the environment a higher volume of active substances or substances with a more adverse effect on the environment.

### **Summary and conclusions**

In order to improve the natural environmental impact of agriculture, it is essential to be persistent in seeking and implementing ecological innovations, i.e. techniques and technologies designed to reduce the adverse environmental impact of agriculture. To this end, both agricultural farms and the other entities involved in the food economy should undergo changes. To ensure that agriculture is more effective and efficient in striving to be environmentally friendly, it is essential to change the perception of the problem across the whole of society, not only at the local level, but also on a global scale.

In pursuing changes within the sphere of the natural environmental impact exerted by agricultural farms, one needs to launch joint initiatives and establish uniform norms or limitations to set a framework for the conditions under which the agricultural production ought to be pursued. Also, it is equally important to facilitate the transfer of knowledge as well as the new techniques and technologies to the developing countries, and to curb poverty among people engaging in agriculture, and also in those countries that are considered developed.

Both globally and for individual agricultural farms, one of the crucial factors to determine the way agriculture will develop in the future is the availability of agricultural land and the preservation of its fertility. To maintain the production capacity it is important that the government provides appropriate protection to the agricultural land through setting policies that regulate the way this production input is utilised and using economic tools to influence the market.

The presented method of measuring the impact of agricultural holding on the environment is a practical manner of expressing the phenomena by way of a synthetic measure. Despite its weakness and still model approach, it can be used to monitor the phenomena in practice and draw up rankings of agricultural holdings in respect to their environment friendliness. The manner of establishing the synthetic measure of environment friendliness presented in the article was targeted at measuring the capability of agricultural holdings to preserve the natural capital and hence the production potential in the future.



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