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## **ROLE OF ECO-INNOVATIONS IN AGRICULTURAL DEVELOPMENT**

### *ROLA EKOINNOWACJI W ROZWOJU ROLNICTWA*

**Key words:** agricultural innovation, eco-innovation, sustainable development, progress, competitiveness

*Słowa kluczowe:* innowacje w rolnictwie, ekoinnowacje, zrównoważony rozwój, postęp, konkurencyjność

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**Abstract.** Though the issue of eco-innovation is a new category in economic sciences, it is seen by farmers as a way to attain competitive advantage in the global market more and more often. The main determinants of implementation of eco-innovation in the economy are the formal and legal regulations and market factors. The primary purpose of eco-innovation is to reduce negative environmental impact of agricultural activity and to produce food that is good for people. The aim of this article is to present the issue of eco-innovation and to indicate strengths and weaknesses as well as opportunities and threats for agriculture that result from their implementation.

### **Introduction**

Adjusting contemporary agriculture to bidding legal regulations and to consumer requirements forces farmers to apply innovative solutions. The EU countries see the need to protect the environment to an increasing extent. This is reflected by the premises of the Common Agricultural Policy 2014-2020. Consumer awareness is also significantly increasing, and they demand that farmers produce organic food.

While striving for better use of the existing potential of land, labour or capital, farmers look for an opportunity to attain competitive advantage through innovation and greening. Innovation may provide agriculture with an opportunity for sustainable economic growth and improve rural livelihoods with regard to its social and economic aspect.

Numerous authors attempted at explaining the significance of innovation. This concept is approached through numerous factors, both macro- and microeconomic [Matusiak 2011]. Innovation may be defined in two ways: as a process, and as a result [Kujawiński 2012, p. 13]. It may be seen as introduction of new ideas, systems, strategies, programmes, devices, processes, products or services that are novel to an organisation [Damanpour 1992, p. 375-402]. Donatella Cavagnoli, on the other hand [2011, p. 111] understands innovation as a process of creative use of knowledge, transformation of an organisation's own knowledge or knowledge from external sources into new products, services, or processes.

Due to the specific nature of agriculture, innovations in this field must take account of seasonality of production cycles and the dependence of economic and productive results on natural phenomena and uncertainty related to market disruptions. Józef Ryznar [1995, p. 70] recognises any new ideas and concepts whose purpose is to improve production processes, farm- and homestead-related procedures and any device that facilitates works or makes it more efficient, and any product of human activity, behavioural patterns or values that have not been present in the country or on a farm before as innovations.

The aim of this article is to present the issue of eco-innovations and indicate strengths and weaknesses as well as opportunities and threats for agriculture that result from their implementation.

## Eco-innovations in agriculture

It is necessary to educate the society, including agricultural producers, so that they develop environmental awareness and environmental responsibility. The development of the country, including agriculture, should follow the principle of sustainable development, which means that it should be based on environmentally friendly development. Attainment of the objectives of sustainable agriculture requires increasing its innovativeness, but also establishing a link between innovative solutions and environmental protection. According to Halina Kałuża and Agnieszka Ginter [2015, p. 172], there is a need for eco-innovative solutions in agricultural product production process that would make it possible to reduce the use of natural capital and create eco-innovations by disseminating new technologies and techniques. It also depends on farmers' own ability to use knowledge in practice and their openness to new production technologies and techniques.

Eco-innovations are a relatively new category in economic sciences. The term was coined by combining words 'ecology' and 'innovation' in order to extend the concept of innovation by including relations between organisms and their environment. As is the case of other innovations, the essence of eco-innovation is to ensure competitive advantage while simultaneously minimising negative environmental impact. From the economic perspective, eco-innovations make it possible to make profit due to their pro-environmental nature. Such profit may be earned because of the possibility to demand a higher price for products due to their environmental friendliness and the reduction in cost due to more efficient use of resources [Andersen 2010].

One of the earliest attempt to define eco-innovations was made by Claude Fussler and Peter James [1996], who described it as innovations that bring profits both to entrepreneurs and consumers while simultaneously reducing the environmental impact. As shown by studies by Minna Kanerva et al. [2009], eco-innovation in the simplest and broadest sense should be seen as any innovation that weakens negative impact of economic processes on the environment and limit environmental damage. On the other hand, Arthur Little [2005] defines sustainable innovation process as creation of new market space for products and services by pointing to the social expectations concerning sustainability of the economy and environmental protection.

There are two schools of economic thought interested in the issue of eco-innovation: the neoclassical: the neoclassical school and the evolutionary school. The neoclassical research focuses on assessing the instruments of environmental policy. Absorption of innovation is seen as an economic decision based on the cost-benefit relationship. What is stressed is the significance of the mechanisms that stimulate measures aimed at limiting pollution. On the other hand, the goal of the research by the economists of the evolutionary school is to find factors that influence decisions concerning innovation. In the light of the evolutionary theory, eco-innovation should be seen as other technological changes. Their absorption is an endogenous process stimulated by economic factors, technical capacity, and socio-organisational relations. Eco-innovations should compete with the existing production processes and products [Leszczyńska 2011].

In the European Commission's Competitiveness and Innovation Framework Programme (CIP) 2007-2013, eco-innovation is defined as any form of innovation that aims at or results in significant and visible progress towards sustainable development through reduction in negative environmental impact, improved resilience to environmental pressure, or more efficient and responsible use of natural resources. According to the sustainable development concept, the aim of eco-innovation is to strive to eliminate harmful environmental impact, and if it is impossible, to significantly limit it. As a EU Member State, Poland also implements the Europe 2020 whose primary objectives include sustainable development, and thus support for economy that uses resources more efficiently, is more environmentally friendly, and competitive.

While defining eco-innovation, we may divide it into categories according to OECD (Organisation for Economic Co-operation and Development) recommendations. The first type of eco-innovation concerns reduction in negative environmental impact of enterprises, which may be achieved by reduced resource and energy consumption and use of soil, e.g. by preserving biodiversity and landscape. Another type of eco-innovation is related to recognition and monitoring of

environmental problems, such as potable water purification and treatment, prevention of soil erosion, desertification, and deforestation. The third type means introduction of products and services with reduced environmental impact [OECD 2005]. Most academics see creation of eco-innovation as reduction in and not elimination of negative environmental impact because it is commonly believed that each new change leads to some environmental pressure [Dangelico, Pontrandolfo 2010].

Eco-innovation may also be referred to as the key element of 'green' knowledge-based economy. It contributes to increase in efficiency of the economy due to reduction in material and energy consumption per production unit by using solutions developed in a process that requires intellectual input. Due to eco-innovation, the material input used in the process is replaced by knowledge. Eco-innovation should result in limiting the externalities (external costs) and negative environmental impact, which affects human health and quality of life. Thus, eco-innovation creates a bridge between the sustainable development strategy (included in the EU environment policy) and the EU development goals by 2020 which include growth that is:

- smart (i.e. development of knowledge- and innovation-based economy),
- sustainable,
- socially inclusive (strengthening of the economy that is characterised by high employment and economic, social or territorial cohesion) [Kanerva et al. 2009].

Features of eco-innovation: reduction in environmental pressure (decrease in emissions of pollutants, increase in resource productivity, including energy efficiency), environmental benefit compared to an alternative solution, benefit for the entrepreneur, intentionality (conscious action), systemic approach, reference to the product/service life cycle, social effect, positive effect on the environment regardless of the aim of innovation, systemic change, consumer benefits.

### **Eco-innovation in the domestic economy**

One of the basic measures of eco-innovation is the Eco-Innovation Scoreboard. The indicator takes into account the entire economy of a specific country, both all branches of industry and agriculture. Its purpose is to analyse eco-innovation level, and it is based on such indicators as:

- input (government environment and energy R&D spendings, number of scientists, green investments),
- activities (enterprises that implement eco-innovation with regard to energy and material efficiency and those that hold an ISO 14001 certificate),
- output (patents, publications, information on eco-innovation in the media),
- environmental effects (efficiency of raw material, energy and water consumption, emissions),
- socio-environmental effects (export of eco-innovative products) [Grodzicka-Kozak, Wojtach 2013].

Polish economy has been second-to-last among the 27 EU countries since 2010. The eco-innovation indicator for Poland is three times lower than for Finland, Sweden, Germany, or Denmark, and two times lower than the EU average. In four years, its level dropped for most countries. However, it is not a good sign for Polish economy than only Bulgaria had a lower eco-innovation indicator in 2013. This is caused by the low level of spendings on research and development (R&D). In Poland, the percentage of GDP spent on research and development was 0.87%, while the average for the entire European Union exceeded 2%. The expenditure was highest in Finland – 3.32% and Sweden – 3.21%, which hold the highest positions in the Eco-Innovation Scoreboard. Percentage of GDP spent on R&D is even higher in the case of the economies of Japan (3.38%) and South Korea (4.04%) [EUROSTAT 2016].

One of indicators, which influence the level of innovation of a specific state, is its research potential. In Poland, there are currently 137 public higher education institutions, 92 sectoral research institutes and 69 units of the Polish Academy of Sciences. At least 113 faculties of 36 state higher education institutions enjoy scientific potential with respect to R&D activity in the field of environmental technologies and eco-innovations. Furthermore, 30 clusters represent such potential, but – in thematic terms – clusters, which operate in the field of energy from renewable sources in a broad sense, are dominant. Agriculture-oriented clusters are, inter alia, as follows:

- the “Kuyavian-Pomeranian Branch of the EKOLAND Association of Organic Food Producers” Cluster whose main objective is to organise an organic farming system in Poland based on the following programme: production criteria – farm inspection – product attestation. It will contribute to the development of organic agricultural production in a sustainable manner.
- the “Organic Food Valley” Cluster oriented towards building an Eastern supra-regional cooperation platform for the development and promotion of organic food products in the territory of Poland.

The implementation of eco-innovations in various sectors of the economy, including agriculture, is facilitated by eco-friendly policy provided for in the “Europe 2020” strategy. In Poland, these issues are supported under a programme, entitled “Environment, agriculture and forestry” – Biostrateg, run by the National Centre for Research and Development. The budget available to support the programme, which stimulates the Polish economy’s innovation and competitiveness growth in 2014-2015, was PLN 500 million.

### **SWOT analysis for eco-innovation in agriculture**

SWOT presents analysis for eco-innovation implemented in Polish agriculture by indicating strengths and weaknesses of such innovations as well as opportunities and threats related to them.

- strengths: positive impact on the environment and health of the society, support by the eu, higher direct payments, adjustment to consumer expectations, reinforcement of scientific and technological basis, local initiatives that may transform into a strong trend for promoting eco-innovation;
- weaknesses: high implementation cost, low awareness of farmers, who fail to notice environmental concerns to a sufficient extent, insufficient assistance by the state, low development spendings, insufficient cooperation between research units and farmers lack of qualified and experienced advisors;
- opportunities: increasing social awareness of food- and health-related issues, increasingly more restrictive environmental law, UE 2014-2020 financial perspective with the emphasis on eco-innovation, new consumer behaviour trends, e.g. the pro-health trend, European economy focused on environmentally friendly solutions, growing consumer interest in products that provide added value opportunity to attain competitive advantage on the market;
- threats: changes to the economic situation in the country (economic crisis), farmers opposing implementation of innovations due to the risk related to changes to the production profile, insufficient knowledge of products classified as organic food in the society, necessity to feed continuously growing population, competition by non-EU countries.

The issue of eco-innovation in agriculture is a complex one. In spite of the increasing social awareness, the majority of consumers continue to make decisions based on price. One of the main barriers for the development of eco-innovation in Polish agriculture is the high implementation cost. On the other hand, there is an opportunity resulting from the EU’s approach, which is oriented towards support for organic farming.

### **Examples of eco-innovations in agriculture**

Eco-innovations in agriculture and the food economy are defined slightly differently than traditional industrial eco-innovations. The reason therefor is mainly the dependence of agriculture on natural conditions and climate. Eco-innovations in agriculture are not only new technologies, products, processes or services that can contribute to environmental protection or a more efficient use of resources. They are very often well-known and proven solutions improved based on the latest knowledge from various fields of science.

An adverse impact of agriculture on the environment can be reduced by sound waste management as one of the main priorities of EU environmental policy which are laid down and implemented in accordance with action programmes. Agriculture is one of sectors of the economy which produces the most greenhouse gases on a global scale (13.5%), in Poland (9%). Agricultural greenhouse gases are carbon dioxide, methane and nitrous oxide. It is worth noting that the balance of CO<sub>2</sub> sequestration in the soil is mostly determined by applying basic principles of proper agricultural technology and crop rotation. However, emissions of nitrous oxide from the soil are influenced, in addition to

proper agricultural technology, by the level of fertilisation with mineral nitrogen and compound fertilisers and the application of basic principles of mineral and organic fertilisation, taking into account nutritional requirements of plants as well as fertilisation needs of the soil and its pH. Moreover, agricultural technology offers great potential for eco-innovations. The application of reduced tillage, including direct sowing, is to improve soil fertility at lower cost without an adverse impact on crop yields. These systems protect the soil against water and wind erosion and improve its sorption capacity. Increased biological soil activity contributes to increasing the mineralisation of humus and accelerates the percolation of water into the soil profile and reduces its unproductive losses.

Farms have great potential for replacing conventional fuels by using renewable energy sources or waste energy. The total production of energy from RESs on farms in the European Union in 2008 amounted to approx. 12 million tonnes of oil equivalent (Mtoe), including 8 Mtoe of electricity and nearly 4 Mtoe of heat [Institute for Renewable Energy 2011]. In contrast, the estimated EU production of energy from RESs in agriculture in 2020 will be from approx. 36 Mtoe of electricity up to 62 Mtoe. Heat production will increase to over 6 Mtoe.

Polish farms apply RES microinstallations. The development of autonomous individual energy systems is driven by the development of energy storage which can significantly reduce costs. Energy from photovoltaic cells or wind turbines can be stored by using lithium batteries, capacitors or in the form of compressed air, hydrogen, methane, heat. U.S. experts' research reveals that storage prices will fall so low in the next few years that households in the U.S. will start disconnecting from the energy grid even before the middle of the next decade. Own electricity will not only be cheaper, but will also contribute to improving individual energy security [www. blog.rmi.org/blog, 2016].

Biogas plants are one way of managing agricultural waste. Eco-innovations are about technological, product and organisational innovations. Technological changes are focused on the selection of appropriate substrates which allow for obtaining biogas with an increased concentration of methane, accelerate fermentation, enable a better use of feedstocks or better parameters of the fermentation process. Furthermore, a preferment, which is a residue from the fermentation process, may be used as a fertiliser with usable nitrogen compounds for plants. Research on biogas plants in Poland is carried out in numerous centres, both public and private. Poland's largest biogas laboratory is located in the Ecotechnology Laboratory of the Poznań University of Life Sciences. An additional advantage of constructing a biogas plant for a farmer is a related possibility of production diversification into food and energy production.

Another way of managing waste is vermicomposting, i.e. the process of modifying the process of biodegradable waste composting by which earthworms are used to convert organic matter into an organic fertiliser or plant conditioners. Current research aims at developing a technology model so that an appropriately selected mix of different waste and technology regime control allow for obtaining compost with certain characteristics, suitable for safe use and remediation. The research is carried out in the Institute of Water Supply and Environmental Protection of the Cracow University of Technology. In particular, its aim is to analyse the content of nitrogen, phosphorus, the amount of dry organic matter in and pH of vermicompost.

Moreover, biofuels should be increasingly used in agricultural production. At present, new technologies are being developed to produce third- and fourth-generation biofuels. Third-generation biofuels are produced by using the same plants as in the second generation (energy crops, organic waste substances), but raw materials are modified at the stage of cultivation by using molecular biological techniques. Nevertheless, fourth-generation biofuels, which are produced from plants with genetically improved CO<sub>2</sub> assimilation during cultivation, are the future of fuels.

Examples of eco-innovations in agriculture are projects funded under the Horizon 2020 programme of the EU, the purpose of which is to support projects related to agriculture and forestry:

- the ENERMETER project is aimed at creating a modern sensor in order to obtain high-resolution images within the entire vineyard area which will improve the quality of the final product by enabling the production system to be continuously monitored and will reduce environmental pollution related to the rational use of pesticides;

- the CT project which enables remote diagnostics of plants on site, monitoring and comprehensive decision support. The aim of the project is to create a system of small, easily installable, compact and inexpensive precision sensors delivering easy-to-understand information to the farmer;
- the GALNIMBUS project funded under Horizon 2020, the purpose of which is to improve irrigation-water use efficiency up to 30% by developing irrigation controllers able to perfectly match irrigation doses to plant needs. The system is to use the analysis of real-time data from the field (soil moisture, solar radiation, pH, plant stress, etc.) to assess the state of crops and readjust irrigation doses by analysing weather forecasts.

A globally unique greenhouse construction technology was developed in the Poznań University of Life Sciences. The eco-innovativeness of the solutions applied consists in using foam-filled walls and a climate control system. With construction costs higher by no more than 20% (compared to traditional solutions), the solution proposed by Poznań scientists makes it possible to reduce both CO<sub>2</sub> emissions to the atmosphere by 95% and water consumption for vegetable production by 80%. At the same time, it is recommended to use a biogas plant in the system to replace any other heat sources. The use of buffer tanks to store heat to heat the greenhouse at night is another solution for reducing greenhouse operating costs when heat is not provided by the lamps.

A good example of eco-innovations in greenhouse production is the use of LED (Light-Emitting Diode) technology as supplementary plant lighting. This solution makes it possible to reduce energy consumption by up to 50% compared to conventional technologies. At the same time, such technologies offer long life, resistance to vibration and humidity, high energy efficiency, fast response, the optimal adjustment of the colour spectrum of light. This solution allows for achieving maximum plant productivity and 15-30% higher production, depending on whether a one- or two-level system is used.

### Summary and conclusions

1. The above reflection on eco-innovation in agriculture make it possible to formulate a number of conclusions.
2. In the nearest future, eco-innovation will be one of the ways to achieve competitive advantage.
3. Farmers who fail to see the environmental aspects will fail to cope with high competition level in the EU.
4. Farmers should knowingly use EU funds allocated to support for eco-innovation.
5. Increasing consumer awareness results in growing pressure on agriculture and requires production of organic foodstuffs.
6. Social awareness of the need to implement pro-environmental solutions in agriculture and other branches of economy.
7. Without state aid it will be impossible to implement eco-innovation in agriculture due to high cost.

Properly directed development of Polish agriculture may live up to global challenges while maintaining good agricultural productions standards, efficient use of resources, and responsible use of the environment. Therefore, it is appropriate to strive to build durable competitive advantage and development potential of agriculture based on innovation and eco-innovation.

Poland is characterised by high intellectual potential in the field of eco-innovativeness, but also by poor R&D cooperation and a low propensity to introduce eco-innovations. Without comprehensive support from state institutions, reversing this trend seems to be impossible.

Issues of reducing greenhouse gas emissions in agriculture should be considered not only in terms of technology, but also should take into account the necessity to maintain food security. The pressure of the necessity to feed the growing population will have a significant impact on the level of intensity of using natural resources and the introduction of environmentally friendly solutions in agriculture.

In spite of great progress of EU agriculture towards sustainable development and environmental protection, it seems that agriculture will face the issue of satisfying increased demand for food and simultaneous conservation of natural resourcesm particularlry soil and water, if eco-innovation is not implemented to a large extent.

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### Streszczenie

Celem artykułu jest przedstawienie zagadnienia ekoinnowacji oraz wskazanie silnych i słabych stron oraz szans i zagrożeń dla rolnictwa z ich wprowadzania. Mimo że zagadnienie ekoinnowacji jest nową kategorią w naukach ekonomicznych, to staje się coraz częściej dostrzegane przez rolników jako sposób na uzyskanie przewagi konkurencyjnej na globalnym rynku. Główne determinanty wdrażania innowacji ekologicznych w gospodarce to regulacje formalno-prawne oraz czynniki o charakterze rynkowym. Celem innowacji ekologicznych jest przede wszystkim zmniejszenie negatywnych skutków działalności rolniczej na środowisko naturalne, jak również produkcja żywności przyjaznej dla ludzi.

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