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POLLINATION VALUE AS AN ECOSYSTEM SERVICE

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ABSTRACT: The objective of this study is to present the issues associated with insect pollination as an environmental service. Moreover, it presents the methods of estimating the value of pollination and the results of the research into that value.
Research indicates a significant value of pollination – between 153 and 167 billion dollars in the world. Depending on the estimation method, the value of plant pollination by insects may vary. The differences reach as much as several dozen percent. The discrepancies result from different understanding of the term "value", and in the case of cultivated plants – from significant diversification of the data on the impact of pollination on the crops (available in the subject literature). The literature is dominated by research in determining the value of pollination for cultivated plants. The research into the economic value of pollination for maintaining biodiversity is conducted at a very small scale.

KEY WORDS: pollination, value, ecosystem service, pollination value estimation methods

Introduction

The use of natural resources by people has been the subject of interest of multiple scientific disciplines. It is addressed by representatives of natural, social and economic sciences. The directions of the research in that scope are often associated with interdisciplinary issues on the borderline of sciences, such as assessments of the ecosystems' reactions to being used by people, specification of the needs of various social groups associated with using the natural resources, analysis of the awareness among the society of the relationships between people and nature, optimization of the landscape structure from the point of view of social needs and recommendations of sustainable development, etc. (see Solon, 2008). One of the main directions of research in that field is considered to be the monetary valuation of the respective services provided by nature (Solon, 2008) which is addressed by environmental economy.

Ecosystem services may be perceived and assessed from two points of view, i.e. biological-ecological and social-economic. In the former case, a service is any natural process, due to which people obtain high quality of the natural foundations for their life and development. In turn, from the socioeconomic point of view, an environmental service is significant for management processes (Poskrobko, 2010).

The ecosystem services are difficult to estimate, among others because of the direct, but also indirect, impact on people's lives. The difficulty is additionally exacerbated by the fact that those services have many functions. In turn, the diversity of the ecosystem services make it impossible, or at least difficult, to develop one universal method of specifying their monetary value.

This study attempts to characterize one of the ecosystem services, i.e. pollination. Apart from characterization of pollination, the objective of this study is to demonstrate its functions and to present and assess the methods of estimating the value of pollination. The assessment was made on the basis of subject literature as well as the results of other authors' research. Moreover, the study includes a review of the results of the research into pollination value.

Ecosystem services – division, value and need for valuation

Ecosystems and biological diversity provide people with multiple goods and services. Ecosystem services accompany people in every activity. The literature contains many definitions of the term ecosystem services, both in Polish (Michałowski, 2011; Poskrobko, 2010; Solon, 2008; Żylicz, 2017), and

foreign (Constanza et al., 1997; MEA, 2005) literature. The differences are visible in the attitude to that issue, but also in the use of synonyms of the terms, i.e. the Polish word świadczenia (or *usługi* (services)) of the ecosystem (or of the environment), but the researchers do not share one opinion in that regard.

As indicated above, the ecosystem and its services affect every person. Constanza and his colleagues (1997) listed 17 key ecosystem services, associated with practically every area of our lives. Further research was aimed at grouping the ecosystem services. Kośmicki (2005) listed the following types of environmental services:

- raw material, production and transformation services;
- regulation and disposal services;
- preparation to anthropogenic use services;
- information services.

Each type of services includes between several and more than a dozen types of ecosystem services. The first type includes the services associated with production of oxygen, water, food, fodder, fertilizers, medical supplies, biochemical substances, raw materials for the industry and construction, goods for households and development of a gene pool reserve. The regulation and disposal services includes the highest number of ecosystem services. These include, among others, regulation of energy balances, water flows and climate, protection against harmful space radiations, consumption of solar energy, regulation of biological control mechanisms, maintenance of soil richness, collection and recycling of organic substances, food elements and anthropogenic wastes, cleaning and retention of waters and supplementation of underground waters, maintenance of biological biodiversity and living space for organisms, and stabilization of ecosystems. In turn, the preparation to anthropogenic use services included the following types of services: use of energy, residence, cultivation, tourism and recreation. Information services were divided into the services associated with: esthetics of nature, obtaining of models for incentives and remuneration, models for learning processes, assigning of sense and socialization models, historical and scientific information, as well as storage of the genetic pool reserve (Kośmicki, 2005).

Similarly, four groups of ecosystem services were listed by C. Hanson and his team (2012), who indicated the following types of environmental services (Hanson et al., 2012):

- supply – associated with obtaining products from ecosystems, e.g. food, biological materials, drinking water, biomass, biochemical or with preserving genetic resources;

- control – associated with the benefits obtained from managing the ecosystems and the natural processes taking place within them, i.e. maintenance of quality of air and water, control of the climate, water flows, limitation of water and wind erosion, maintenance of soil quality, control of pollution, biological control, limitation of the prevalence of diseases and extreme phenomena, pollination;
- cultural – consisting in the intangible benefits from the ecosystems, including educational, ethical and spiritual values, benefits from tourism, recreation and inspiration;
- support – being the natural processes assisting the other services provided by ecosystems – which include the services associated with primary production (production of matter as a result of photosynthesis and assimilation), flow of elements and water and development of natural habitats for the organisms that support the capacity of ecosystems to maintain balance of the environment.

The division into groups of environmental services facilitates the specification of their significance for people and their hierarchization. This, in turn, may facilitate their valuation, because people often do not incur costs associated with benefiting from ecosystem services and so do not perceive them as economic goods, but as natural goods which do not require recovery or protection (Graczyk, 2010). This may cause excessive use of those services, which may lead to excessive hardship for the environment.

According to the researchers dealing with the theory of environmental and natural resource economy, the need to research the environmental services results from the following premises (Michałowski, 2008):

- the environmental services constitute one of the fundaments of the concept of permanent and sustainable development;
- they are based on complex natural mechanisms which are often impossible to replace by technology;
- people's activities destroy natural ecosystems, thus deteriorating environmental services;
- the quality of environmental services is limited by short-term economic benefits.

These premises indicate the significance of environmental services in development of the economy, and the fact that it is improbable, and often impossible, to replace them by technologies – people simply depend on the environment. This, in turn, directly indicates the value of the ecosystem services and the need to notice the conditions which need to be taken into account when considering the economic properties of ecosystem services, i.e. (Graczyk, 2010):

- understanding of the ecological functions of an ecosystem, which result in development of environmental goods and services,
- identification of the direct and indirect impact of the ecosystem services on the management process, i.e. their ecological and economic impact,
- quantitative specification of the economic costs and benefits of ecosystem benefits,
- specification of the value and manner of distribution of ecosystem services among beneficiaries.

It is not easy to estimate ecosystem services. It requires extensive knowledge, not only in economy, but also in natural or social sciences. That is why there exists a number of limitations and conditions for entering and using ecosystem services in the economic balance. Becla, Czaja and Zielińska (2013) specify the following:

- cognitive conditions and barriers – the need to possess the knowledge on the given services and the scope of its prevalence;
- information conditions – the need to possess certain information on the service;
- institutional and legal conditions – lack of or limited possibility to apply the solutions proposed in business practice;
- economic and accounting conditions – limited possibility to apply the methods of service valorization or absence of such methods;
- axiological conditions – acceptance of natural environmental services as economic values or lack thereof.

The difficulties with determining the total value of ecosystem services are also connected with the difficulty with specifying the respective components of that value, i.e. the use and non-use value. The use value may be divided into direct and indirect use value. In turn, non-use value is divided into the value of existence and of inheritance. A detailed division and description of those values was presented, among others, by Żylicz (2013, 2017).

Pollination as an environmental service

Pollination is necessary for obtaining seeds, and so lack thereof would mean disappearance of the flora from our planet. In terms of the origin of the pollen, plants are classified as autogamous or allogamous. Autogamous plants use for pollination the pollen from the same flower or from a different flower of the same plant, while allogamous plants use the pollen from another plant of the same species. However, in the case of autogamous plants, pollination with the pollen from another flower results in better seeds and yields. In the case of allogamous plants, for pollination they need an external factor,

such as wind, water or animals. Of animals, it is insects that play a dominant role in that regard. In Poland, almost 80% species of allogamous plants are pollinated by insects and over 20% by wind. Among pollinating animals, western honey bee (Apis mellifera) is responsible for ca. 90-95% of insect pollinations (Jabłoński, 1997; Jabłoński, 1998; Kołtowski, Jabłoński, 2008). Apart from western honey bees, it is also bumblebees and solitary bees that play a relatively important role in plant pollination. In our climate zone, plants are also pollinated by flies, butterflies, beetles, thrips and bugs.

However, it is western honey bee that plays the most important role in insect pollination. It participation in plant pollination is increasing due to the following factors (Majewski, 2011):

- decreasing number of wild pollinators in the natural environment,
- large areas of croplands which make the access for wild pollinating insects difficult,
- pollution of the natural environment,
- improper use of plant protection products and other chemicals in farming,
- reduction in non-production areas.

These factors result in limitation of the population of pollinators in the natural environment, but also cause losses in bee keeping, e.g. through poisoning with plant protection products.

The advantage of western honey bees over other pollinators also results from the fact that that species is kept by people in large numbers. In a bee family, a significant number of specimens overwinter and, in early spring, they are ready to pollinate the plants. The populations of other insects are small in spring because, for example in the case of bumblebees, it is only a pregnant female that overwinters. Another advantage of western honey bees is that they may be transported to pollinate the crops. They may also be encouraged to pollinate the given plant species. These insects demonstrate the so-called flower fidelity, i.e. the tendency to visit the plants of one species during one flight, which increases the chances for correct pollination of plants. Western honey bees visit flowers during the whole period of their blossoming, collecting nectar and pollen (Skowronek, 2001).

In terms of classification of the ecosystem services, pollination belongs to control services, as a natural process occurring in ecosystems. Pollination also plays an important role in the group of supply services, because that process is necessary for obtaining food and it impacts the genetic resources. The other groups listed by Hanson and others (2012) may also cover the role of pollination. This indicates that the classification of environmental services presented by the above-mentioned authors, is blurred. However, the classification presented by Kośmicki (2005) is also blurred. It is not a weakness of

those classifications, but just confirms the complexity of the impact of environmental services on our lives.

Pollination by insects, especially honey bees, as an environmental service, provides people with multiple direct and indirect benefits. The main one that is relatively easy to estimate, is the benefit associated with obtaining food. In the case of insect-pollinated plants, that element is necessary for obtaining crops, or to increase and quantity and quality of crops. In the case of western honey bees, the benefit associated with pollination is the possibility to produce bee products. It is the possibility to obtain such products, in particular honey, that people started to keep bees. These products are eaten by people, but are also used in medicine or cosmetology. Another advantage of pollination is biodiversity. A total absence of pollinators would cause such changes in the environment as elimination of species of allogamous plants. In turn, the extinction of one species of pollinators might result in extinction of certain plant species. Such a situation may occur when, as a result of the process of coevolution, the given plant species may only be pollinated by the given species of pollinator.

The indirect benefits of pollination are mainly due to pollinators. With the example of western honey bees, two main advantages may be demonstrated: a) the insects are eaten by other animals, and in some human societies, bee larvae are eaten by people; b) bees may also play the role of a bioindicator, because that common species may reach practically any place and it accumulates pollution in its body, thus demonstrating the quality of the natural environment.

Pollination Valuation Methods

As a rule, valuation of the environment or of its respective elements, is not easy. Among others, it results from the fact that it delivers public goods without market prices. Environmental economy lists the following groups of methods (Navrud, Pruckner, 1997):

- market price methods,
- methods of avoidance and recovery cost,
- methods of valuation of non-market goods,

The first two groups are relatively obvious, because they are based on objective information. Controversies may result from the valuation of non-market goods which results from lack of market prices of those goods, and thus from the specific approach to their valuation, which may be difficult and controversial.

In turn, Żylicz (2013), in the cases of appearance of ecosystem services being public goods, indicates the possibility to estimate them using direct or

indirect techniques. The direct methods include reference to hypothetical markets, in which you may buy or sell the given goods. The value of a service may be determined by asking how much would the people be willing to pay for it (willingness to pay – WTP) or how much they would want for such goods (willingness to accept – WTA). In turn, in indirect techniques, economic value is obtained by checking the so-called replacement markets, where the goods that are complementary to our goods, are purchased and sold.

Specification of the value of pollination results from the function it plays and from whether the plants are cultivated or wild. In the case of occurrence of market prices for leasing pollinating insects (western honey bee) or for purchasing insects for crop pollination (bumblebees, solitary bees), the value of pollination may be determined on the basis of market prices. The value of pollination in the case of agricultural crops is often determined in combination with the size and value of the given production. That valuation may also use cost-based methods, such as the replacement cost method. It is much more difficult to estimate the pollination of wild plants (maintenance of biodiversity). The WTP or WTA methods may be applied here, but their credibility would be low.

The literature of pollination valuation is dominated by publications regarding agricultural production. The characteristics and assessment of the methods of valuation of the pollination service was presented by Mburu et al. (2006), Breeze et al. (2016) and Majewski (2016b).

Pollination value – results of world and Polish research

The economic value of the global ecosystem services is huge and rising. Their value (stated in fixed prices from 2007) for the year 1995 was estimated at USD 46 billion (46×10^{12}), and for 2011, taking into account the changes in the area of the respective ecosystems, at USD 125 trillion (Constanza et al., 2014). That value exceeds the world GDP, which demonstrates the role of those services. The economic value of pollination only constituted less than 0.4% of the value of services of all the ecosystems (ca. USD 167 billion: in 1995). However, the study lacks specific information on the manner of determining that value, which makes it difficult to compare it with other results.

The literature concerning pollination value is dominated by the publications associated with that value from the point of view of agriculture (including vegetable raising, gardening and horticulture). In the world, about 35% of food production depends on insect pollination. The plants pollinated by

animals provide people with ca. 74% of the global production of fats and 35-65% of vitamin E (Klein et al., 2007). About 22.6% of agricultural production in developing countries and 14.7% in developed countries, depends on insect pollination, and those levels are rising. Since 1961, the area of insect-pollinated plants in the world has risen by over 300% (Aizen et al., 2008).

The value of cultivated plant pollination in the world was estimated at USD 153 billion (Gallai et al., 2009). The order of magnitude is the same as in the research of Constanza et al. (1997, 2014), which may suggest that those researchers underestimated the value of pollination of wild plants. Gallai et al. (2009) estimated the value of pollination in Europe for ca. USD 22 billion, i.e. 15% of the total value.

If we compare the results of the estimated value of cultivated plant pollination in the European Union, prepared by Gallai et al. (2009) as well as Leonhardt et al. (2013), we will find that the obtained results are not significantly different (EUR 14.2 and 14.6 billion, respectively). This may indicate lack of subjectivity in the methods used.

In turn, according to the research conducted for the USA, the value of cultivated plant pollination, taking into account the value of fruits, vegetables and plants obtained from pollination, increased in that country from USD 9.3 billion in 1989 to USD 14.6 billion in 2000 (Morse, Calderone, 2000).

In Poland, the research into the value of pollination was only associated with cultivated plants. The value of insect pollination of the 19 most important insect-pollinated plants was estimated at ca. EUR 720 million, on the basis of the data from 2004 (Zych, Jakubiec, 2006). In turn, for 2012, that value for the main cultivated insect-pollinated plants, i.e. rapeseed and agrimony, orchards, fruit bushes and permanent plantations, was specified at over EUR 825 million, and for 2015 – almost EUR 1.8 billion (Majewski, 2014, 2016b). The difference mainly results from the fact that the 2015 estimation took into account more insect-pollinated plants. If we assumed the same plants, the value specified for 2015 would be higher by less than EUR 400 million than the pollination value estimated for 2012. On the other hand, the values obtained were impacted by the market prices of the agricultural products generated with the use of pollination, which prices are characterized by a high degree of variation, which also affects the values obtained, because the estimation was based on the method of production value obtained due to pollinators.

By analyzing 27 studies estimating the value of pollination, almost half of them were based on the method of value of production obtained due to pollinators (dependence ratio). In seven cases, yield analysis was used to determine that value. Other methods, such as replacement costs or consumer surplus, were applied to a small degree (Hanley et al., 2015). The methods most

frequently used for estimating the value of pollination may only be applied to cultivated plants. To determine the value of pollination of wild plants, we should apply more advanced methods which have not been applied in the analyzed publications.

As indicated, the pollination value estimation method affects the results obtained. This is proven by the research of Majewski (2016a) who determined the value of pollination of apple orchards in Poland using three methods (value of production, value of production obtained with pollination, and replacement cost). Depending on the method applied, the differences in value were almost 50%, with values from over PLN 1.5 billion for the method of valuation of the production obtained due to pollination to over PLN 2.2 billion for the method of replacement costs (Majewski, 2016a). The results obtained depend both on the method applied and on the assumptions made in the research (specification of the impact of pollinators on the value of production, specification of the average salary, etc.). A change in assumptions may sometimes change the results, and thus the conclusions drawn from them, beyond recognition.

Conclusion

Ecosystem services are estimated higher than the world GDP, which shows that the environment plays the main role in people's lives. Pollination constitutes a small share of those services (less than 0.4%). Despite that, the global economic value of pollination, as an environmental services, is counted in billions of dollars, and, as of now, would be impossible to substitute.

It is not easy to determine the economic value of pollination or of other ecosystem services, because it is difficult to determine all the effects of that service. It is relatively easy to estimate the value of pollination of cultivated plants, on the basis of the increase in the size and quality of production. However, in this case it should be mentioned that pollination is not the only and sufficient phenomenon. It only increases the production potential of plants, while other activities are to make use of that potential. The problem with estimating the value of cultivated plant pollination is the determination of the degree, to which pollination has increased the size and quality of crops. It is much more difficult to specify the value of pollination as a service that allows to maintain biodiversity. It is a complex issue, because insects are elements of the environment, and apart pollination, they also produce food, but also constitute food for other animals, and make soils richer.

The literature is dominated by the publications on the value of pollination of cultivated crops, which may also indicate better recognition of that issue than in the case of the impact of insects on biodiversity. The methods

applied in the studies were usually based on the crops obtained due to pollination. The replacement cost method has been applied relatively seldom. In the age of threats to the natural environment and dying out of pollinating insects, that method might prove useful in demonstrating the significance of those insects. Especially that, at the current level of technology development, it would be impossible to replace insects with machines (although research is pending), and the only replacement method is manual pollination by people.

It seems that the research into valuation of pollination is developing. The impact of pollinating insects on crops has been specified for most cultivated plants. The main challenge before the researchers is specification of the economic value of pollination for maintenance of biodiversity.

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