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ECONOMICS AND ENVIRONMENT

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PROBLEMY TEORETYCZNE I METODYCZNE

Jerzy **ŚLESZYŃSKI**

THE PRINCIPLES OF SUSTAINABILITY

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ZASADY TRWAŁOŚCI GOSPODAROWANIA

STRESZCZENIE: Celem artykułu jest przedstawienie i zinterpretowanie, a następnie rozwinięcie zasad trwałości gospodarowania, których autorem jest angielski ekonomista David Pearce. W artykule skupiono uwagę na następujących czterech zasadach: słabej, wrażliwej, silnej i restrykcyjnej trwałości gospodarowania; będących zarazem swoistymi zasadami trwałego rozwoju. Na publikacje Pearce'a i wspomniane zasady powołuje się wielu naukowców, również w Polsce, jednak dołączane komentarze często niefortunnie odbiegają od oryginalnej wersji zasadniczych wskazówek Pearce'a, które zostały wyprowadzone wprost z teoretycznych założeń ekonomii środowiska i zasobów naturalnych.

SŁOWA KLUCZOWE: trwały rozwój, trwałość kapitału

Introduction

The correct translation of the term sustainable development, from English into Polish, must take into account the obvious fact that this concept of development, from the very beginning, has been focused on continuation, vitality and adaptation. And above all, this concept is associated with the existence which is successfully sustained over the passage of time. The best Polish translation would be "trwały rozwój", without making any reference to weighting or balancing. Of course, because sustainable development is a kind of genuine development it must have a complex structure. Therefore, sustainable development is centered not only on environmental sustainability but also and simultaneously on sustainability of economic development and on sustainability of social structures. In the papers written by David Pearce original nomenclature was applied in a form of four principles dealing with: weak sustainability, sensitive sustainability, strong sustainability and restrictive sustainability. All these categories of sustainability are closely linked with the problem of constant capital, with the issue of substitution between different types of capital, and also with the characteristics of exhaustible resources that are rightly divided into renewable resources and non-renewable resources[1].

The right understanding of the principles of sustainable management indicates, on the one hand, the necessity of substituting irreversibly declining non-renewable resources, and on the other hand, emphasizes the opportunity (as shown by C.W. Clark this chance can be rejected for economic reason[2]) for rational and sustainable management of renewable resources[3]. Of key importance in the long run is the rate at which a process of replacing non-renewable resources by renewable resources may be effectively exercised. Another and particularly difficult problem is how to define boundaries and rules for the safe replacement of natural capital by a man-made capital.

1 D.W. Pearce, R.K. Turner, *Economics of Natural Resources and the Environment*, Hemel Hempstead 1990.

2 For arithmetic comparison C.W. Clark linked the net present value of the infinite sum of annual sustainable revenues to the value of the amount proceeded from invested total liquidation of the resource when the biomass gives its greatest growth. The conclusion was rather sad: sustainable benefits from a resource that renews very slowly may be less profitable than its one-time liquidation, if there is $g<r$ (where "g" is the rate of natural growth of the resource and "r" stays for the prevailing discount rate).

3 C.W. Clark, *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, New York 1976.

The emergence of new ideas related to sustainability management is the response to the negative changes that have occurred in the human life conditions from the crucial moment when the industrial revolution has started the overexploitation of environmental goods and natural resources. This process has ultimately led after only two centuries to the scarcity of natural resources while reducing simultaneously their quality. Environmental degradation in economic terms was a result of human activities, which did not protect the life-supporting ecological infrastructure and the entire biosphere. In particular, the exploitation of the most useful natural resources was guided by the criterion of short-term profit maximization and did not take into account sustainability of natural capital. This neglect justifies the present need for meaningful and urgent interest in the principles of working and effective sustainable management.

Sustainable resource management

The sustainable management should be understood as maintaining of the available capital, thus, not reducing the managed capital in subsequent periods of use. Let the starting point for further discussion in this paper be a simple equation showing that the total capital, which we have (K), is the sum of the capital produced by man (KH), human and social capital (KS) and natural capital (KN): K = KH + KS + KN. In this article the relationship that combines the resources forming KH and KN is a major concern.

The natural capital definition used to be as follows: the whole natural environment as a source of goods and universal means of production, which are not produced by man. Natural capital is composed of very diversified resources useful for all human beings. Natural capital are all biotic and non-biotic components of the Earth: all that is on its surface or in its interior (including soil, air, water). These resources provide people with the stream of useful goods and services. Some of them are taken directly from the nature and some of them are consumed indirectly. This stream can be renewable or non-renewable, depending on the characteristics of the resource contributing to the natural capital.

The sustainable management should support sustainable development and this means the adoption of such a course of action by which it is possible to receive revenues/benefits from the environment for a long time. It is worth recalling that the income is defined as sustainable as it was formulated by Hicks[4]. The income is the stream of payments, which does not erode its base (the capital is not consumed) and is not merely a change in the form of assets. Thus, the benefit that comes with the loss of environmental capital should not

4 J.R. Hicks, *Value and Capital*, Oxford 1946.

be considered as income. Consumption of natural capital without its reproduction should be interpreted as liquidation, and thus as the opposite effect to accumulation.

There is a quite substantial economic bibliography on the analysis of sustainable management of natural resources. The solution to the problem appears in these works which indicate conditions that must be met to make the long-term economic development possible which inevitably depends on natural resources[5]. However, the neoclassical Hotelling rule in its basic version is inadequate for sustainable management, because it only supports the strategy to maximize the net benefit from non-renewable resources. It indicates the optimal path of economic resource exploitation program at a given discount rate and the known benefits and costs of obtaining this resource. Sustainable management paradigm is not represented here at all and, thus, the total depletion of any resource is just one possible option among the other scenarios of its exploitation.

The seminal economic research has been actually undertaken on the desired optimum size of investment in the acquisition of new resources, which should take into account the costs arising from the increasing scarcity of resources being under exploitation[6]. Neoclassical analysis has led to the description of some important relationship between the rate of consumption of non-renewable resources and increasing ability of the economy to perform sustainable exploitation based on renewable resources. Hartwick formulated his model which showed that the condition for long-term economic growth is to invest rents from the used non-renewable resources in their substitutes what should guarantee a permanent reproduction of consumed capital. Conclusion derived implicitly from the Hartwick model could be extremely optimistic: the appropriate level of substitution of non-renewable resources by renewable resources would guarantee to maintain the current level of prosperity or even increase it, and all this in an infinite time horizon!

Economists, however, have a tendency to a rather instrumental adaptation of the diversity and specificity of the natural conditions, on which the economy depends, into their analyses. Natural capital should not be limited to the already exploited and production-oriented resources, but also have to take into consideration the overall biological conditions that ensure the proper functioning of

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5 R.M. Solow, *The Economics of Resources or the resources of Economics*, "American Economic Review" 1974 no. 64, p. 1–14; J.M. Hartwick, *Intergenerational Equity and the Investing of Rents from Exhaustible Resources*, "American Economic Review" 1977 no. 67, p. 972–974; J.M. Hartwick, *Substitution among Exhaustible Resources and Intergenerational Equity*, Working Papers 294, Kingston, Ont. Canada, 1978; Solow R.M., *On the Intertemporal Allocation of Natural Resources*, "Scandinavian Journal of Economics" 1986 no. 88, p. 141–149.

6 M. Common, C. Perrings, *Towards an Ecological Economics of Sustainability*, "Ecological Economics" 1992 no. 6, p. 7–34.

the biosphere. Therefore, an important addition to economic models are theoretical considerations on stability and resilience of ecosystems and the entire biosphere. Ecological economics seeks to recognize this problem and proposed, for instance, the theory of adaptive management of natural resources[7].

It is perfectly right that natural capital should be clearly distinguished from other forms of capital, and above all from capital produced by man[8]. The difference between them is fundamental, because only natural capital was the indispensable condition for the appearance, duration and evolutionary development of life on Earth, and now natural capital determines the duration, development and survival of human civilization. The benefits derived from natural capital for the most part of them do not exist on the market. This is why ecological services were overlooked by academic economics for a long time. As a result, imperfect policy led in the past and still leads to the overuse of natural resources and their increasingly reduced availability. In just two centuries natural capital became a limiting factor for the economic development to a greater extent than the capital produced by man. At the same time natural environment of high-quality advanced to the basket of goods sought after and desired by consumers with a sufficiently high level of income.

Principles of sustainability by Pearce

The concept of constant capital assets can be analyzed and capital durability can be graded theoretically. Such an approach implies the acceptance of distinctive typology of sustainability principles. There are more or less strict rules for capital preservation exemplified in Pearce's writings[9]. Typology proposed by Pearce used to be reduced in the literature to a very simple dualism: the principle of weak sustainability versus the principle of strong sustainability. Such a contrast opposition impoverishes interpretation and is the cause of many misunderstandings. Next in this paper four principles proposed by Pearce will be discussed in detail[10].

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7 C.S. Holling, *Resilience and Stability of Ecological Systems*, "Annual Review of Ecology and Systematics" 1973 no. 4, p. 1–23; C.S. Holling, *The Resilience of Terrestrial Ecosystems: Local Surprise and Global Change*, in: C.W. Clark, R.E. Munn (eds), *Sustainable Development of the Biosphere*, Cambridge 1986, p. 292–317.

8 N.O. Martins, *Ecosystems, strong and the classical circular economy*, "Ecological Economics" 2016 no. 129, p. 32–39; J. Śleszyński, *Ekonomia a nieodwracalne zmiany w środowisku naturalnym*, "Prace Ekonomiczne Uniwersytety Ekonomicznego we Wrocławiu" 2016, Wrocław, in print.

9 D. Pearce (ed.), *Blueprint 3: Measuring Sustainable Development*, London 1993.

10 J. Śleszyński, *Ekonomiczne problemy ochrony środowiska*, Warszawa 2000.

The principle of weak sustainability requires the constant size of the total capital (K) regardless of its structure. Because the total capital consists of natural capital, capital produced by man, social and human capital, it is assumed that different types of capital are perfect substitutes. At least within the limits of the current level of knowledge, activity and available resources at any given time. This assumption implies that losses in natural capital can be easily compensated, for example, using new technology and manufactured goods. This is perfectly in line with the neoclassical modeling and with its orthodox assumption about perfect substitution. However, while the lack of wood to a large extent can be mitigated by the production of plastic, it would be difficult to believe in ensuring adequate "surrogates" for the ecosystem role of certain species that went extinct through men's fault or for the hard-working insects pollinating flowering plants.

The principle of sensitive sustainability states that, in addition to maintaining the total volume of capital (K) constant, the relationship between certain resources within the total capital cannot be violated. In particular, the volume of certain resources belonging to natural capital should never be reduced. This is the result of ecological observation that the man-made capital and natural capital can be substituted, but only in very specific and rather narrow limits. For example, the proper functioning of the biosphere and numerous ecosystems creates an objective requirement that certain components of natural capital (KN_k k=1,..,K; $KN=KN_1+KN_2+...+KN_K$) should be always present in the biosphere, moreover, that they should occur in proper proportions. Sensitive ecosystem may indeed require that some of its components are always in place in a particular abundance and/or have a defined share in the biotope or in the biomass. Because we do not know enough about the ecological boundaries and critical values of the natural capital, the most practical behaviour would be a careful management of natural resources just to avoid overexploitation and above all to avoid unwanted irreversible losses[11].

The principle of strong sustainability requires keeping the total amount of capital (K) constant, accompanied by keeping the amounts of the different types of capital constant, each one separately: KH, KS, KP. This is the result of the assumption that natural capital and capital produced by man are not substitutable for each other, but only complementary. This implies a practical conclusion that the loss of some kind of capital should be offset by growth in the same type of capital, provided that it can be another resource but belonging to the same type of capital. Such a phenomenon has long been observed in the case of tools and equipment manufactured by man. Nobody is reproducing consumed man-made capital without economic reflection. Technological innovations make it possible that productive capital Anno Domini

11 J. Śleszyński, *Ekonomia a nieodwracalne…*, op. cit.

2016 is clearly different from the components of productive capital from the interwar period. To some extent, this phenomenon also applies to natural capital and energy resources. Energy carriers are changing and only the twentieth century saw the dominance of oil, which took up a position occupied so far by other fossil fuels. It should be emphasized that the strong sustainability poses a significant limitation: used portion of natural capital cannot be replaced by any investment in capital produced by man.

The principle of restrictive sustainability demands maintaining constant the total amount of capital (K) and calls for the prohibition of any depletion of the highlighted resources (KH_i k=1, ..., I; KS_j k=1, ..., J; KN_k k=1, ..., K) included in the three distinguished types of capital: KH, KS, KP. In accordance with this principle the non-renewable resources, belonging to natural capital (KN), could not be exploited at all, because the method of their reconstruction does not exist. However, in the case of a specific renewable resource, in accordance with the principle of restrictive sustainability consumption, it is acceptable. Still, only this part that in the future can be counterbalanced by the resource growth and, therefore, will not reduce the resource belonging to the natural capital, should be consumed. In other words, consumption cannot affect the ability of the resource to renew in subsequent periods, and thus to provide the opportunity of similar benefits (sustainable yield) in the future.

It is justified to anticipate that in the near future economic development will have to change fundamentally because of its obvious limitations associated with the use of disappearing non-renewable resources and the poor ecological conditions of renewable resources. Using the concepts introduced by Pearce someone can describe the problem and suggest that a new paradigms consistent with the paradigm of sustainable development should be based on the adoption of principles of sensitive or strong sustainability, and also, in some cases, principles of restrictive sustainability in the management of renewable resources. In the management of natural resources sometimes we are willing to substitute one type of the resource for the other, for instance this occurs in the case of fishing. However, this replacing has certain limits, because when we intensify cod fishing we still don’t want to lose the population of cod completely so after a while we allow this resource to renew by intensifying the exploitation of another resource like herring. In turn, the conservation of threatened species and protected areas is a good example where the application of the principle of restrictive sustainability makes sense. For example, we will never be able to replace coral reefs in the biosphere and coral reefs are essential in the shaping of global ocean environment also the global climate.

The principle of weak sustainability and to some extent the principle of sensitive sustainability are the right way of dealing with non-renewable resources. Non-renewable resources, by definition, irrevocably disappear following their acquisition and consumption. Scientific and technological progress allowed the transition from one type of non-renewable resource to another. This tactic was successful in the case of mineral deposits and much less in the case of fossil fuels. However, in the near future, we should expect serious problems with the application of this principle with respect to the Rare Earth Metals and Minerals (Rare Earth Metals/Minerals). Such rare resources like scandium, lanthanum, cerium or yttrium are non-renewable, while terribly needed in most electronic devices. In addition, there are only traces of them in the Earth's crust and about 90% of the raw material is now in the hands of China. The economic practice of substitution will be extremely difficult, because these are elements with unique properties and China's monopoly will additionally hamper any strategy to find substitutes among other and equally scarce elements.

The presented logical and coherent interpretation of sustainable management should eliminate from public discussion and literature such statements like, for example: a) "the principle of strong sustainability and certainly the principle of restrictive sustainability are unrealistic and can not ever be implemented in practice", b) "the principle of weak sustainability is not connected with the problem of substitution", c) "the principle of strong and weak sustainability can be used regardless of whether the analyzed resources are renewable or non-renewable", etc. These and similar statements exist in the circulation of information and at first glance seem to be intriguing and polemical. However, confronted with the precise interpretation of the typology given by Pearce, they simply turn out to be untrue.

A necessary addition to the theoretical considerations on sustainable management is mentioning of the fact that the management takes place within the limits of the ecosystems, which are not static but undergo evolutionary changes in response to changing environmental conditions. Single cells, organisms, populations, social and economic systems, the biosphere as a whole – all these objects on their level of organization of life are not eternal. They are characterized by a certain but determinable "life expectancy" which is given to them evolutionarily and that usually is sufficient to develop an appropriate response to all changes taking place in the environment. Too short lifespan, equally in the case of a body as in a socio-economic system, does not allow for finding satisfactory adaptive response. On the other hand, too long lifespan also becomes lethal because of the increasing weakening of the system which leads to a loss of its viability and critically limiting its adaptability.

Talking about sustainability in biological and economic terms should not be construed as an improvement of the definition, but as an encouragement and an incentive to predict the future and attempt to find the best response to the challenges of the future[12]. Significant and real importance should be attached to the recognition of characteristics of the resources making the total capital. This knowledge is necessary for an appropriate application of the principles of sustainable management and providing specific answers to the questions: what is the capital we would like to keep constant and what we can effectively and meaningfully substitute, what is the time horizon preferred for such sustainability, how to supervise and monitor the process of adaptation? In addition to predicting and planning sustainability, methodology for adaptive thinking is needed to elaborate an appropriate reaction to dynamic changes in the relationship between man and its natural environment[13].

The continuation of human civilization will depend both on random and determined environmental factors, and first of all on the success of properly designed adaptive man-made processes. In this context managing the precautionary principle but also determining allowable safe limits of intervention in the environment, and avoiding irreversible and dangerous changes in the environment are increasingly important[14]. Only on a such firm foundation sustainable management of natural resources and sustainability of our socio-economic system can be safely built.

Conlusions

The close relationship of environmental conditions and the economy emphasizes three simple recommendations of sustainable development proposed in the beginning of Nineties[15]:

1. In order to reduce the scale of the use of environmental resources, reduce the material flow in the economy and increase the efficiency of used resources that are really necessary for us.

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12 R. Costanza, B.C. Patten, *Defining and predicting sustainability*, “Ecological Economics“ 1995 no. 15, p. 193–196.

13 L.H. Gunderson, C.S. Holling, S.S. Light (eds), *Barriers and bridges to the renewal of ecosystems and institutions*, Columbia University Press, New York 1995; D. Reed (ed.), *Structural Adjustment, the Environment, and Sustainable Development*, Earthscan, London 1996.

14 C.W. Clark, F.H. Clarke, G.R. Munro, The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment, “Econometrica” 1979 vol. 47, pp. 25–47; J. Śleszyński, *Ekonomia a nieodwracalne…,* op. cit.

15 H.E. Daly, *Sustainable Development: From Concept and Theory to Operational Principles*, “Population and Development Review” 1990 no. 16, Supplement: Resources, Environment, and Population: Present Knowledge, Future Options, p. 25–43.

2. Renewable resources should be used in accordance with the principle of sustainable revenue. It means that in the case of living organisms operation should be limited to their growth and do not exceed the limit guaranteeing their restoration. In the case of pollutants released into the environment their quantity should not exceed the capacity of natural ecosystems to assimilate these pollutants.
3. Non-renewable resources should be used in such a way that the available natural capital would not undergo reduction, which means that in the long-term the present consumption of non-renewable resources should be gradually replaced by their renewable substitutes.

Truly, the concept of sustainable development is anthropocentric, since it is aimed at improving the living conditions of the human population. However, it also contains a conservative component, because it takes into account the need to ensure appropriate conditions for the functioning of nature and, in particular, for the continued supply of resources and services aimed at sustaining life. Seen from this perspective, sustainable development must be understood as a consensual strategy to improve the quality of life within the limits set by the resistance to human pressure of the most important ecosystems forming the biosphere and within the barriers to the development set by the availability of natural resources[16].

The principles of sustainability are only a typology of management methods that take into account the possibilities and limitations of the substitution process. Substitution, which in this scheme is a specification that relates primarily to natural capital and man-made capital. In that context, the lack of substitution between resources belonging to different types of capital is considered. Alternatively, the substitution of all resources regardless of which type of capital they are is allowed. Certainly, the inclusion of considerations on human and social capital would make whole theoretical reasoning more difficult and unclear. Therefore, it should be noted that the principles discussed here facilitate the description of reality, but it is neither comprehensive nor perfect.

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16 This way of understanding and interpreting sustainable development is also present in the Polish economic literature. At this point it is worth mentioning, just for example, several works that relate to the general concept of sustainable development or relate to the system of indicators to measure sustainability: T. Borys, *Indicators for Sustainable Development – Polish Experiences*, Warszawa-Białystok 2005; A. Graczyk (ed.), *Teoria i praktyka zrównoważonego rozwoju*, Białystok-Wrocław 2007; T. Żylicz, *Sustainability Indicators: An Economists's View*, in: T. Hak, B. Moldan, A.L. Dahl (eds), *Sustainability Indicators. A Scientific Assessment*, Washington D.C. 2007, p. 97–105; B. Fiedor, *Trwały rozwój a koncepcja społecznej gospodarki rynkowej*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu", in: *Kształtowanie zrównoważonego rozwoju w reakcji na kryzys globalny*, no. 225, Wrocław 2011, p. 13–29; J. Śleszyński, *Synthetic sustainable development indicators: Past experience and guidelines*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" 2013 no. 308, p. 144–164.

Nevertheless, in-depth study of the theory and practice of sustainable development and management can only benefit from principles of sustainability but cannot be limited to them. Certainly, ecological economics needs a strong and effective rejection of too optimistic neoclassical assumption of perfect substitution. Moreover, a soft return to certain themes of classical economics talking about the circular economy would be justified and expected[17].

It seems that the fundamental value of the discussed typology of the principles of sustainable management is their focus on two issues. Firstly, they clearly indicate the problem of major defects in the assumption of perfect substitution between factors of production. Continuation of such an assumption in relation to the decisive part of all natural resources is not only wrong but also dangerous. Secondly, the principles help to consider and highlight the differences between non-renewable resources and renewable resources. What's more, the principles can become a stimulus for reflection and research related to discovery of the real limits of substitution with respect to the key components of natural capital. In particular, the principle of sensitive sustainability demands application of specific and empirically developed limits of intervention in the environment. Such limits should concern the sustainability of the important and often essential components of the biosphere.

Literature

Borys T., *Indicators for Sustainable Development – Polish Experiences*, Warszawa-Białystok 2005

Clark C.W., *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, New York 1976

Clark C.W., Clarke F.H., Munro G.R., *The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment*, "Econometrica" 1979 no. 47, p. 25–47

Common M., Perrings C., *Towards an Ecological Economics of Sustainability*, "Ecological Economics" 1992 no. 6, p. 7–34

Costanza R., Patten B.C., *Defining and predicting sustainability*, "Ecological Economics" 1995 no. 15, p. 193–196

Daly H.E., *Sustainable Development: From Concept and Theory to Operational Principles*, "Population and Development Review" 1990 no. 16, Supplement: Resources, Environment, and Population: Present Knowledge, Future Options, p. 25–43

Fiedor B., Trwały rozwój a koncepcja społecznej gospodarki rynkowej, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu", in: Kształtowanie zrównoważonego rozwoju w reakcji na kryzys globalny, no. 225, Wrocław 2011, p. 13–29

Graczyk A. (ed.), *Teoria i praktyka zrównoważonego rozwoju*, Białystok-Wrocław 2007

Gunderson L.H., Holling C.S., Light S.S. (eds), *Barriers and bridges to the renewal of ecosystems and institutions*, New York 1995

17 D.W. Pearce, R.K. Turner, op. cit.; N.O. Martins, op. cit.

Hartwick J.M., *Intergenerational Equity and the Investing of Rents from Exhaustible Resources*, "American Economic Review" 1977 no. 67, p. 972–974

Hartwick J.M., *Substitution among Exhaustible Resources and Intergenerational Equity*, Working Papers 294, Kingston, Ont., Canada, 1978

Hicks J.R., *Value and Capital*, Oxford 1946

Holling C.S., *Resilience and Stability of Ecological Systems*, "Annual Review of Ecology and Systematics" 1973 no. 4, p. 1–23

Holling C.S., *The Resilience of Terrestrial Ecosystems: Local Surprise and Global Change*, in: C.W. Clark, R.E. Munn (eds), *Sustainable Development of the Biosphere*, Cambridge 1986, p. 292–317

Martins N.O., *Ecosystems, strong and the classical circular economy*, "Ecological Economics" 2016 no. 129, p. 32–39

Pearce D. (ed.), *Blueprint 3: Measuring Sustainable Development*, London 1993

Pearce D.W., Turner R.K., *Economics of Natural Resources and the Environment*, Hemel Hempstead 1990

Reed D. (ed.), *Structural Adjustment, the Environment, and Sustainable Development*, London 1996

Solow R.M., *The Economics of Resources or the resources of Economics*, "American Economic Review" 1974 no. 64, p. 1–14

Solow R.M., *On the Intertemporal Allocation of Natural Resources*, "Scandinavian Journal of Economics" 1986 no. 88, p. 141–149

Śleszyński J., *Ekonomiczne problemy ochrony środowiska*, Warszawa 2000

Śleszyński J., *Synthetic sustainable development indicators: Past experience and guidelines*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" 2013 no. 308, p. 144–164

Śleszyński J., *Ekonomia a nieodwracalne zmiany w środowisku naturalnym*, "Prace Ekonomiczne Uniwersytety Ekonomicznego we Wrocławiu" 2016, Wrocław, in print

Żylicz T., *Sustainability Indicators: An Economists's View*, in: T. Hak, B. Moldan, A.L. Dahl (eds), *Sustainability Indicators. A Scientific Assessment*, Washington D.C. 2007, p. 97–105

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ECOSYSTEM SERVICES IN POSTGLACIAL LANDSCAPE – BASIC ASSUMPTIONS AND RESEARCH METHODOLOGY

Prof. Marek **Degórski,** PhD • Prof. Ewa **Roo-Zielińska,** PhD • Bożenna **Grabińska,** PhD • Anna **Kowalska,** PhD • Prof. Jerzy **Solon,** PhD • Andrzej **Affek,** PhD • Bogusława **Kruczkowska,** PhD • Jacek **Wolski,** PhD • Ewa **Kołaczkowska,** PhD • Edyta **Regulska,** PhD • Izabela **Zawiska,** PhD – *Polish Academy of Sciences, Poland*

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ŚWIADCZENIA EKOSYSTEMOWE W KRAJOBRAZIE MŁODOGLACJALNYM. PODSTAWOWE ZAŁOŻENIA I METODA BADAŃ

STRESZCZENIE: W artykule przedstawiono założenia teoretyczne i metodologię badań projektu finansowanego przez Narodowe Centrum Nauki (2012/07/B/ST10/04344) zatytułowanego "Świadczenia ekosystemowe w krajobrazie młodoglacjalnym – ocena zasobów, zagrożeń i wykorzystania". Celem projektu jest zastosowanie koncepcji usług ekosystemowych do oceny wartości potencjałowej środowiska przyrodniczego i kulturowego w dostarczaniu ES w trzech gminach (Nowinka, Giby, Suwałki), położonych na obszarze młodoglacjalnym.

SŁOWA KLUCZOWE: potencjał ekosystemów, identyfikacja i ocena usług ekosystemowych, preferencje społeczne, typy ekosystemów, tematyczne mapy usług ekosystemowych

Introduction

The use of natural resources and potential of environment has long been of interest to both scientists and practitioners, primarily related to the spatial management and planning. The concept of ecosystem services, treated as a synthetic approach in the evaluation of environmental potential and resources is in line with such research direction and dates back to the mid-sixties of the twentieth century[1]. However, the development of research referring to the concept of ecosystem services advanced considerably in the last decade of last century. At the time, the fundamental works for further research and development of ES concept were published[2]. Such rapid increase in interest of ecosystem services caused a growing number of publications, which exceeded the 1000 papers per year at the end of the first decade this century, on a global scale.

Nevertheless, the hypotheses presented by most authors were poorly documented and justified as they concentrated only on selected groups of ecosystem services, viewed in various spatial or temporal scales and frequently, in a rather general manner. It resulted in a large number of case stud-

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1 R.T. King, *Wildlife and man,* "Conservationist" 1966 no. 20(6), p. 8–11; D.R. Helliwell, *Valuation of wildlife resources*, "Regional Studies" 1969 no. 3, p. 41–49; R. Hueting, *Functions of nature: should nature be quantified*?, in: R. Hueting (ed.), *What is nature worth to us?* A collection of articles 1967–1970, (in Dutch) 1970; E.P. Odum, H.T. Odum, *Natural areas as necessary components of man's total environment,* Transactions of the 37th North American Wildlife and Natural Resources Conference, March 12–15, Washington D.C., 1972 no. 37, p. 178–189.

2 G. Bingham et al., *Issues in ecosystem valuation: improving information for decision making*, "Ecological Economics" 1995 no. 14, p. 73–90; R. Costanza et al., *The value of the world's ecosystem services and natural capital,* "Nature" 1997 no. 387, p. 253–260; G.C. Daily (ed.), *Nature's services: societal dependence on natural ecosystems*, Washington D.C. 1997, p. 334; G.C. Daily, P.A. Matson, *Ecosystem services: From theory to implementation*, "Proceedings of the National Academy of Sciences of the United States of America. PNAS" 2008 no. 105(28), p. 9455–9456; R.S. de Groot, *Functions of nature: evaluation of nature in environmental planning, management and decision making*, Amsterdam 1992, 315 pp.; R. Haines-Young, M. Potschin, *Methodology for defining and assessing ecosystem services,* Nottingham 2009, 94 pp.; K.E. Limburg, C. Folke, *The ecology of ecosystem services: introduction to the special issue*, "Ecological Economics" 1999 no. 29, p. 179–182; MEA, *Ecosystems and Human Well-being: Current State and Trends*, vol. 1, Findings of the Condition and Trends, Working Group of the Millennium Ecosystem Assessment, Washington, Covelo, London 2005, p. 917; D. Pimentel et al., *Economic and Environmental Benefits of Biodiversity*, "BioScience" 1997 no. 47(11), p. 747–757; K.J. Wallace, *Classification of ecosystem services: Problems and solutions*, "Biological Conservation" 2007 no. 139, p. 235–246; M.A. Wilson, S.R. Carpenter, *Economic valuation of freshwater ecosystem services in the United States: 1971–1997,* "Ecological Applications" 1999 no. 9, p. 772–783.

ies. The biggest problem concerned ES terminology and methodology, which contributes to deprecation of the flagship concept[3]. In recent years, attempts have been made to organize both the terminology and methodology of ES research[4], what has enabled to understand easily the meaning of the ES concept and to optimize research methods.

Nonetheless, to date, there has been rather a small number of scientific papers which verified in a comprehensive manner the methodological assumptions of the ES concept as a conglomerate of material and non-material benefits derived by human from natural environment and cultural heritage. Such scientific approach to ES concept has been adopted and implemented in the project "Ecosystem services in young glacial landscape – assessment of resources, threats and use" supported by National Science Centre (2012/07/B/ST10/04344), carried out in Institute of Geography and Spatial Organization, Polish Academy of Sciences since 2012. This article presents the project objectives, assumptions and research methodology.

Theoretical background of the project

In the project, we adopted the potential approach to ES, assuming that it is not always possible to determine the actual ES flows. The ecosystem services were considered in an interrelated triangle involving:

- local community and its preferences;
- individual ecosystems viewed as the service suppliers;
- the whole landscape with land use types and their functions.

In this context, the main scientific objectives of the project were as follows:

- to identify, quantify, order and rank ecosystem services;

3 M. Degórski, J. Solon, *Ecosystem services as a factor strengthening regional development trajectory,* "Economics and Environment" 2014 no. 4(51), p. 48–57.

4 EEA Annual report 2013 and Environmental statement 2014. *Air quality in Europe – 2013 report EEA,* European Environment Agency, Kopenhagen, Denmark, Report No 9/2013. 112 pp.; J. Maes et al., *Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments Under Action 5 of the EU Biodiversity Strategy to 2020. Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments Under Action 5 of the EU Biodiversity Strategy to 2020*. Publications Office of the European Union, Luxembourg 2013, available from: www.ec.europa.eu [12-09–2014]; *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations*, Pushpam Kumar (ed.), Earthscan, London, Washington 2010; TEEB, *The economics of ecosystems and biodiversity for local and regional policy makers*, www.teebweb.org [12-09–2014]; The UK National Ecosystem Assessment (UK NEA), *Understanding nature's value to society. Synthesis of the Key Findings*, 2011, 87 pp.; *White Cover Publication* 2013, United Nations Statistic Division, www.unstats.un.org [12-09–2014].

- to compile a list of ecosystem services supplied by various ecosystem types and assign to them direct and indirect measures;
- to compile a complete list of reliable and scientifically validated direct and indirect indicators for evaluating ES potential supply and/or demand;
- to document the actual relationship between ecosystem and landscape structure and the service supply;
- to develop a model assessing relations between services provided by ecosystems or landscapes and their flow to society.

These objectives have been used in development of the following three research hypotheses:

- measures of ecosystem/landscape structure and function can serve as indirect measures of the ES supply;
- the supply and value of an ecosystem service depend not only on ecosystem features, but also on its spatial location;
- the supply and demand for particular ecosystem service depend on preferences of local communities (user groups) and may be shaped by the spatial management.

The most important specific research goals were:

- assessment of relations between social preferences and actual use of ecosystem services;
- identification of indirect indicators (surrogate measures) for evaluating ecosystem service stocks;
- selection of an optimum set of ecosystem services provided by studied ecosystem types and a corresponding set of direct and indirect indicators;
- service valuation (using the indicators) and ranking (by importance, by advantage) for individual ecosystems;
- ecosystem valuation and ranking with regard to individual categories of services provided. Six thematic blocks (described in the chapter *Research Methodology*) were distinguished which defined a detailed research plan.

Study area

The study area is located in north-eastern Poland, in the north part of Podlaskie voivodeship. It was influenced by Vistulian glaciation and its morfolitological characteristics and structure are associated with moraine uplands, outwash plains and with postglacial lakes, what determines the present structure of land-use. The areas covered with light lithological material are dominated by forests, while areas covered by clay are dominated by farmland. The average population density is several times lower (approx. 16

inhabitants/km^2) than the average for Poland (approx. 124 inhabitants/km^2), (table 1).

Table 1. Some characteristics of studied communes

Commune	Area [km^2]	Inhabitants	Density [pers./km^2]
Nowinka	203,8	2800	13,7
Suwałki	264,8	7000	26,4
Giby	323,6	3000	9,3
Total	792,2	12800	$\bar{x}$ 16,5

Three communes: Giby, Nowinka and Suwałki have been selected for the identification, valuation and assessment of ecosystem services (figure 1). The selection of three test communes was non-random and relied on two basic criteria: (1) the degree of anthropogenic transformation (assessed on the basis of the proportion of forest in overall land cover, population density and presence or absence of industry) and (2) landscape diversity.

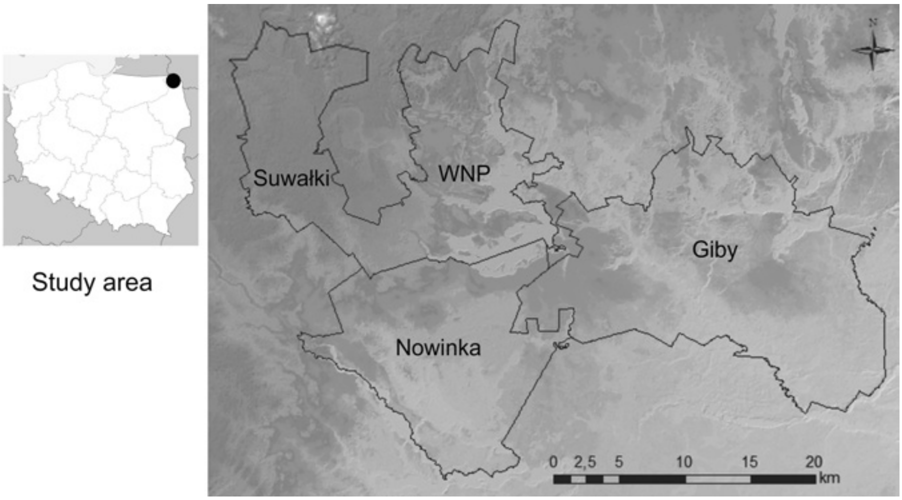

Figure 1. Study area

The Giby commune, dominated by forests (approx. 75 %), is characterized by a large number of lakes, and almost lack of industry. The large coverage of Natura 2000 sites (over 80%) confirms the high nature value in the commune. The Nowinka commune is also characterized by the predominance of forests (approx. 60%) that are part of the Wigry National Park and the Augustów Forest. Farmland comprise approx. 27% of the commune. A significant area is occupied by waters here. The commune is dominated by protected natural ecosystems, which occupy 84% of the area. Natura 2000 sites cover 78%. The biggest advantage of the commune is the beautiful landscape, tourism and rich peat deposits. The Suwałki commune has an agro-forest landscape. Farmland constitute approx. 55%, while forests – 29%. Agriculture, successfully developed on the plains, play a dominant role in the economy of the commune. Farmland is managed mostly (approx. 84%) by individual farmers. The characteristic feature of agriculture in the Suwałki commune is the diversity of production, and the dominance of dairy cattle and pigs. In contrast to two other communes, in Suwałki many small industry companies are located (carpentry, car mechanics, building industry, production of building materials, water supply and sewage systems, quarrying). The Suwałki Special Economic Zone, offering favourable conditions for investors, is partly situated within the commune.

Research methodology

The methodology and research procedure were closely related to the thematic blocks and stages presented on figure 2.

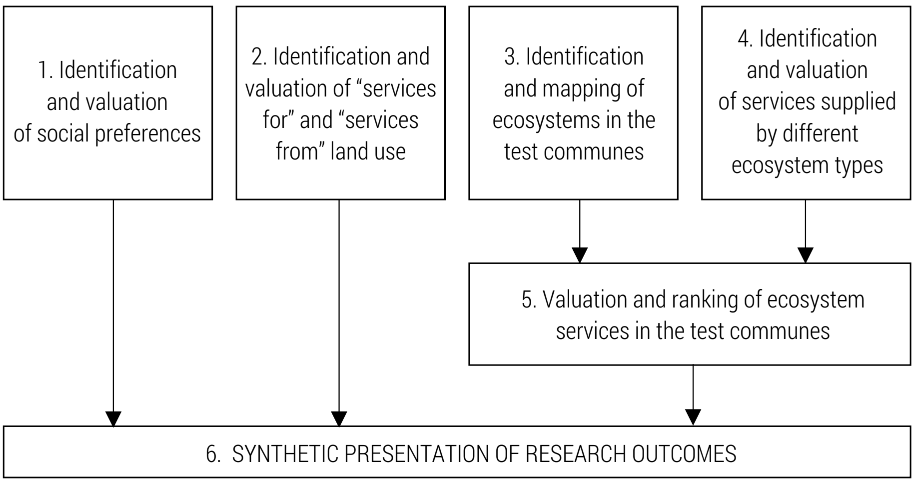

Figure 2. Thematic blocks and relations between them – basis for project activities

The tasks of Block 1 (identification and valuation of social preferences) were performed using the following basic research methods:

- a detailed analysis of written information and maps;
- development and formulation of questions included in a questionnaire for selected groups of ecosystem service users.

To conduct an overall assessment of ecosystem services in the study area it was also necessary to take into account the opinion of direct ecosystem service users. As recent studies show, participatory evaluation of the surrounding environment is becoming increasingly popular and is perceived as a solution to improve social engagement and to achieve greater public acceptance of spatial strategies and plans. Therefore, we decided to carry out a questionnaire survey among residents and tourists that consisted of four parts. The first and second part were constructed to gather information on the awareness and actual use of ecosystem services (for results see Affek and Kowalska[5]). The first one comprised only open-ended, non-suggestive questions, whereas the latter was a list of 45 provisioning and cultural services with scale 1–5 to mark usage intensity over the 3 years preceding the survey. In the third part, respondents were asked to assign services to ecosystem types and rank them in order of importance. Seven ecosystem types and 11 categories of goods and services were included. Our intention was to show the potential/capacity of each ecosystem type to deliver particular services in the view of direct landscape users (for results see Kowalska et al[6]). The last part comprised a set of socio-demographic questions regarding age, sex, education, source of income, place of residence etc. The collected data were used to verify sample representativeness and to perform between-group comparisons. The scientific term ecosystem services was not used in the survey. We replaced it by a more colloquial and intelligible phrase *goods of nature* (pol. *dobrodziejstwa przyrody*). The anonymous questionnaire was distributed with the *door-to-door* method during two summer seasons among residents and tourists staying in selected localities in the study area. In total, 251 questionnaires were collected back.

The tasks of Block 2 (identification and valuation of "services for" and "services from" land use) were accomplished via:

- a very detailed analysis of the literature data, including Studies of Determinants and Directions of Land-Use (Spatial Organization) Planning (SUiKZP);
- consultations with experts to identify as many ecosystem services that can be provided in each commune as possible (depending on its specific characteristics, especially those related to land-use structure);
- a statistical analysis of relationships to identify causal and/or correlative relationships between the indicator value and an absolute value of a given service.

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[5] A. Affek, A. Kowalska, *Benefits of nature. A pilot study on the perception of ecosystem services*, "Ekonomia i Środowisko" 2014 no. 4(51), p. 154–160.

[6] A. Kowalska et al., *Potential of cultural ecosystem services in postglacial landscape from the beneficiaries' perspective,* "Ekonomia i Środowisko" (in press).

The tasks of Block 3 (identification and mapping of ecosystems). Research results on spatial heterogeneity of ecosystem services were presented on the map of ecosystems in a local scale. The map constituted a synthetic presentation of land-cover differentiation, in a way that each ecosystem type has assigned the size or range of environmental resources that deliver definite ecosystem services (especially provisioning). We based on Common International Classification of Ecosystem Services (CICES)[7]. The map was constructed on the basis of the available cartographic materials (e.g. Database of Topographic Objects 1:10 000, Agricultural Map of Soils 1:25 000, Ortophotomaps 1:5000, Digital Forest Map) and fieldwork data. Local scale affected the legend of map, that was not based on too general MAES division[8] containing a basic ecosystem types but more detailed units. In a final version, the legend contains 44 ecosystem types of which 25 are different categories (age and habitat) of forests, three categories of grassland, three types of cropland, four categories of wetlands, six classes of lakes, one category of rivers and urban areas[9].

Block 4 (identification and valuation of services supplied by different ecosystem types) – The analyses involved the maximum number of ecosystem services and most of them, if possible, were measured directly in the field using a service-specific method (e.g. a measurement of biomass, physical and chemical characteristics of soils, phytosociological relevés to describe plant communities of ecosystems). The remaining data were collected reviewing the literature or using expert knowledge. The tasks of Block 5 (valuation and ranking of ES in individual commune) were based on desk studies of the collected data and will subsequently be used to develop a synthesis of the results (Block 6).

Summing-up

Development of a detailed methodology and work plan allowed to elaborate most of the results planned in the described project. As it was mentioned in *Introduction* authors assessed potential of ecosystem services, their indicators and measures. On the scheme presenting the steps to achieve the results we included 9 selected ES (figure 3).

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7 R. Heines-Young, M. Potschin, *Common International Classification of Ecosystem Services (CICES): Consultation on version 4*, August-December 2012, EEA Framework Contract No EEA/IEA/09/003 2013.

8 European Commission, *Mapping and Assessment of Ecosystems and their Services. Technical Report – 2013-067*, 2013.

9 B. Kruczkowska et al., *Map of ecosystems – concept and realization*, "Geographia Polonica" (in preparation).

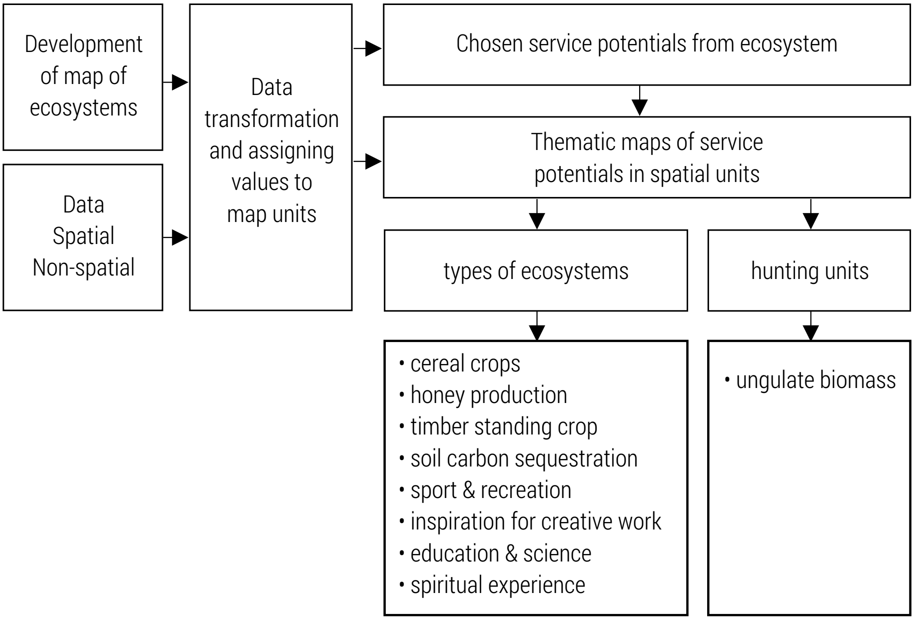

Figure 3. General scheme of ES potential evaluation

We analyzed 4 provisioning ecosystem services (cereal crops, honey production, ungulate biomass and timber standing crop), one regulating ES (carbon sequestration in the soil) and four cultural services (sport and recreation, inspiration for creative work, education and science, as well as spiritual experience). Spatial differentiation of ES potentials was presented on the thematic maps. In two volumes of "Economics and Environment" we present two papers describing these ecosystem services[10].

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[10] E. Roo-Zielińska et al., *Potential of provisioning and regulating ecosystem services in postglacial landscape*, "Ekonomia i Środowisko" 2016 no. 4(59); A. Kowalska et al., *Potential of cultural ecosystem services in post-glacial landscape from the beneficiaries' perspective*, "Ekonomia i Środowisko" 2016 (in press).

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Literature

Affek A., Kowalska A., *Benefits of nature. A pilot study on the perception of ecosystem services*, "Ekonomia i Środowisko" 2014 no. 4(51), p. 154–160

Bingham G. et al., *Issues in ecosystem valuation: improving information for decision making*, "Ecological Economics" 1995 no. 14, p. 73–90

Costanza R. et al., *The value of the world's ecosystem services and natural capital,* "Nature" 1997 no. 387, p. 253–260

Daily G.C. (ed.), *Nature's services: societal dependence on natural ecosystems*, Washington D.C. 1997

Daily G.C., Matson P.A., *Ecosystem services: From theory to implementation*, "Proceedings of the National Academy of Sciences of the United States of America. PNAS" 2008 no. 105(28), p. 9455–9456

de Groot R.S., *Functions of nature: evaluation of nature in environmental planning, management and decision making*, Amsterdam 1992

Degórski M., Solon J., *Ecosystem services as a factor strengthening regional development trajectory,* "Economics and Environment" 2014 no. 4(51), p. 48–57

EEA Annual report 2013 and Environmental statement 2014. *Air quality in Europe — 2013 report EEA,* European Environment Agency, Kopenhagen, Denmark, Report No 9/2013

European Commission, *Mapping and Assessment of Ecosystems and their Services. Technical Report – 2013-067*, 2013

Haines-Young R., Potschin M., *Methodology for defining and assessing ecosystem services,* Nottingham 2009

Heines-Young R., Potschin M., *Common International Classification of Ecosystem Services (CICES): Consultation on version 4*, August-December 2012, EEA Framework Contract No EEA/IEA/09/003 2013

Helliwell D.R., *Valuation of wildlife resources*, "Regional Studies" 1969 no. 3, p. 41–49

Hueting R., *Functions of nature: should nature be quantified*?, in: R. Hueting (ed.), *What is nature worth to us?* A collection of articles 1967–1970, (in Dutch) 1970

King R.T., *Wildlife and man,* "Conservationist" 1966 no. 20(6), p. 8–11

Kowalska A. et al., *Potential of cultural ecosystem services in post-glacial landscape from the beneficiaries' perspective*, "Ekonomia i Środowisko"(in press)

Kruczkowska B. et al., *Map of ecosystems – concept and realization*, "Geographia Polonica" (in preparation)

Limburg K.E., Folke C., *The ecology of ecosystem services: introduction to the special issue*, "Ecological Economics" 1999 no. 29, p. 179–182

Maes J. et al., *Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments Under Action 5 of the EU Biodiversity Strategy to 2020. Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments Under Action 5 of the EU Biodiversity Strategy to 2020*, Publications Office of the European Union, Luxembourg 2013

MEA, *Ecosystems and Human Well-being: Current State and Trends*, vol. 1, Findings of the Condition and Trends, Working Group of the Millennium Ecosystem Assessment, Washington, Covelo, London 2005

Odum E.P., Odum H.T., *Natural areas as necessary components of man's total environment,* Transactions of the 37th North American Wildlife and Natural Resources Conference, March 12–15, Washington D.C., 1972 no. 37, p. 178–189

Pimentel D. et al., *Economic and Environmental Benefits of Biodiversity*, "BioScience" 1997 no. 47(11), p. 747–757

Roo-Zielińska E. et al., *Potential of provisioning and regulating ecosystem services in postglacial landscape*, "Ekonomia i Środowisko" 2016 no. 4(59)

TEEB, *The economics of ecosystems and biodiversity for local and regional policy makers*, www.teebweb.org

The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations, Pushpam Kumar (ed.), Earthscan, London, Washington 2010

The UK National Ecosystem Assessment (UK NEA), *Understanding nature's value to society*. *Synthesis of the Key Findings*, 2011

Wallace K.J., *Classification of ecosystem services: Problems and solutions*, "Biological Conservation" 2007 no. 139, p. 235–246

White Cover Publication 2013, United Nations Statistic Division, www.unstats.un.org

Wilson M.A., Carpenter S.R., *Economic valuation of freshwater ecosystem services in the United States: 1971–1997,* "Ecological Applications" 1999 no. 9, p. 772–783

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ENVIRONMENTAL POLICY AND MANAGEMENT

POLITYKA EKOLOGICZNA I ZARZĄDZANIE ŚRODOWISKIEM

Maria URBANIEC

SUSTAINABLE COMPETITIVENESS. OPPORTUNITIES AND CHALLENGES FOR POLAND'S ECONOMY

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KONKURENCYJNOŚĆ W KONTEKŚCIE ZRÓWNOWAŻONEGO ROZWOJU. SZANSE I WYZWANIA DLA POLSKIEJ GOSPODARKI

STRESZCZENIE: Konkurencyjność jest koniecznym, ale niewystarczającym warunkiem dalszego dobrobytu, stąd potrzebne są dodatkowe działania w zakresie społecznego i środowiskowego wymiaru zrównoważonego rozwoju. Na podstawie dostępnej literatury na temat zrównoważonego rozwoju można stwierdzić, że kwestie konkurencyjności rzadko są brane pod uwagę. Jest to uzasadnione tym, że paradygmat zrównoważonego rozwoju jest uważany za czynnik jakościowy, wymagający analizy długoterminowej, a także trudno mierzalny. Celem artykułu jest analiza konkurencyjności polskiej gospodarki w kontekście zrównoważonego rozwoju w oparciu o Indeks Globalnej Konkurencyjności. To pozwoli na znalezienie odpowiedzi na główne pytanie badawcze, w jakim zakresie zrównoważony rozwój wpływa na konkurencyjność polskiej gospodarki? Na podstawie tej analizy będzie można określić konkurencyjność polskiej gospodarki, biorąc pod uwagę kryteria zrównoważonego rozwoju.

SŁOWA KLUCZOWE: zrównoważony rozwój, konkurencyjność, społeczny wymiar zrównoważonego rozwoju, środowiskowy wymiar zrównoważonego rozwoju, gospodarka, Globalny Indeks Konkurencyjności, Polska

Introduction

The concept of sustainable development has been an important trend of social and economic development for several decades[1]. It was first defined by the World Commission on Environment and Development (WCED) of the United Nations in 1987. In the report of "Our common future", sustainable development was defined as that which strives to meet the needs of present and future generations in full compliance with the environment[2]. The essence of sustainable development consists in integrating the economic, social and environmental dimension in such a way as to ensure development for future generations[3].

Taking action towards sustainable development occurs in almost all fields of life and activities of people, governments and businesses, e.g. in science and technology, economy, consumption, education, media, politics, ideology, religion, culture, entertainment, sports[4]. The last activities at the international level indicate intensified actions for sustainable development[5]. For example, the latest European Union strategy adopted in 2010 under the name of "Europe 2020: A strategy for smart, sustainable and inclusive growth"[6] or the new United Nations Sustainable Development Goals[7] of the 2030 Agenda for Sustainable Development, adopted by world leaders in September 2015[8], can be mentioned here.

1 R. Janikowski, *Nachhaltigkeit als Imperativ des Alltags*, "Humanities and Social Sciences" 2014 no. XIX 21(3), p. 71–82; M. Burchard-Dziubińska, *Działania na rzecz wdrażania zrównoważonego rozwoju w układzie globalnym i Unii Europejskiej*, "Ekonomia i Środowisko" 2005 no. 2(28), p. 15–26.

2 G.H. Brundtland, *Our Common Future*, Report of the World Commission on Environment and Development, Oxford 1987, p. 37.

3 J. Famielec, *W poszukiwaniu ładu gospodarki zrównoważonej*, Studia i Materiały "Miscellanea Oeconomicae" 2014 no. 1, p. 89–101; M. Urbaniec, *Sustainable Development Indicators in Poland: Measurement and System Evaluation*, "Entrepreneurial Business and Economics Review" 2014 vol. 3(1), p. 119–134.

4 L. Preisner, *Wpływ globalnych uwarunkowań środowiskowych na funkcjonowanie przedsiębiorstw*, in: A. Budnikowski, M. Cygler (red.), *Globalizacja gospodarki a ochrona środowiska*, Warszawa 2004, s. 329–338; L.W. Zacher, *Trwały rozwój – utopia czy realna możliwość*, "Problemy ekorozwoju" 2008 vol. 3(2), p. 67.

5 *The Sustainable Development Goals: An overview of relevant OECD analysis, tools and approaches*, Paris, www.oecd.org [15-09–2016].

6 *Europe 2020 "A European strategy for smart, sustainable and inclusive growth",* Brussels 2010, COM(2010) 2020 final.

7 *Transforming our World: The 2030 Agenda for Sustainable Development*, A/RES/70/1, New York 2015, www.sustainabledevelopment.un.org [15-09–2016].

8 G. Ramos, *The Sustainable Development Goals: A duty and an opportunity*, in: P. Love (ed.), *Debate the issues: New approaches to economic challenges*, Paris 2016, p. 17–21.

Based on the European strategy for smart, sustainable and inclusive growth "Europe 2020", EU Member States must take measures in the following areas: first, in innovation, education, training and lifelong learning, and digital society; secondly, in sustainable competitiveness, combating climate change and efficient energy; thirdly, inclusive in employment, skills and fighting poverty[9]. All these development directions should support efforts towards the sustainable competitiveness of the EU economy.

In general, competitiveness is increasingly seen not only in terms of the economic performance of a nation, but also in relation to environmental and social performance. The synergy between them contributes to the creation of sustainable competitiveness[10]. The measurement of sustainability requires the use of a variety of indicators[11]. These measurements usually show the strengths and weaknesses of individual world economies and also constitute an element of competitiveness research. One of the monitoring systems of global economies – developed by the World Economic Forum (WEF) – is the Global Competitiveness Index (GCI), which was recently expanded with criteria for sustainable development. The introduction of these new criteria has its justification in the fact that competitiveness in a general sense is a necessary but insufficient condition for further prosperity. Given the current challenges it can be argued that sustainable development is becoming an increasingly important competitive factor on the macroeconomic level where, aside from economic issues, social and environmental aspects are also gaining in importance.

The key aim of this article is to analyse the level of competitiveness of Poland's economy in relation to that of sustainability, as well as the assessment of strengths and weaknesses on this issue. Therefore, the research questions which arise are, first, to what extent sustainability affects the competitiveness of Poland's economy and, second, whether undertaking actions toward sustainable development contributes to improving the competitiveness of the given country. On the basis of this analysis it will be possible to determine the position of economy of Poland in the competitiveness ranking taking into account the sustainability criteria. This paper also attempts to identify the most important factors impacting on the sustainable competitiveness of the economy of Poland. The study was conducted on the basis of such research methods as the critical analysis of Polish and foreign literature

9 *Europe 2020*..., op. cit., p. 5.

10 A. Balkyte, M. Tvaronaviciene, *Perception of competitiveness in the context of sustainable development: facets of 'sustainable development'*, "Journal of Business Economics and Management" 2010 vol. 11(2), p. 341–365.

11 *Measuring Distance to the SDGs Targets: a pilot assessment of where OECD countries stand*, www.oecd.org [15-09–2016].

and documents, including GCI reports, developed by an international economic organisation, i.e. the World Economic Forum.

The definition of competitiveness and sustainable competitiveness

The concept of "competitiveness" is commonly used, but in reality it is conceptually vague and open to many interpretations[12]. This is not an absolute phenomenon that can be determined without comparison to other objects or structures. Depending on the context in which the term is used, it takes on a different meaning[13].

In the literature the word "competitiveness" conveys a different meaning when applied to an individual firm or an individual sector or economic activity within a country or region[14]. Many economists perceive competitiveness as a phenomenon occurring only at the company level and reject the concept of "national competitiveness"[15], while others claim that the lack of attention to broader concepts of national competitiveness has been a clear lack of economic research and policy[16]. Porter (1990) sees the term as synonymous with productivity, stating that: "The only meaningful concept of competitiveness at the national level is productivity"[17].

Academic definitions of competitiveness encompass both general questions about strategic choices without specifying the unit of analysis, as well as definitions at the national level. The focus of competitiveness at the country level was proposed by Scott and Lodge (1985). According to them competitiveness is a "country's ability to create, produce, distribute and/or service products in international trade while earning rising returns on its resources"[18]. In a general sense, competitiveness is defined as the economy's capability of long-term economic growth. The high competitiveness of a country is not only one of the objectives of economic policy of the economy of

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12 R.D. Atkinson, *Competitiveness, Innovation and Productivity: Clearing up the Confusion*, Washington 2013, p. 2.

13 M. Gorynia, B. Jankowska, *Klastry a międzynarodowa konkurencyjność i internacjonalizacja przedsiębiorstwa*, Warszawa 2008, p. 55–56.

14 M. Urbaniec, *Eco-innovations as a source of competitive advantage in enterprises*, in: A. Marković, S. Barjaktarović Rakočević (eds), *Proceedings of the XIV International Symposium SymOrg 2014: New Business Models and sustainable competitiveness*, Belgrade 2014, p. 1630.

15 P. Krugman, *Making Sense of the Competitiveness Debate*, "Oxford Review of Economic Policy" 1996 vol. 12, p. 17-25.

16 M.E. Porter, *The Competitive Advantage of Nations*, New York 1990.

17 Ibidem.

18 B.R. Scott, G.C. Lodge, *US competitiveness in the world economy*, "The International Executive" 1985 vol. 27(1), p. 20–26.

Poland, but is also of interest to scientists, especially economists, who constantly strive to seek out factors having an impact on building the competitiveness of each country. This phenomenon is particularly important in the globalisation process.

According to economists from the WEF, competitiveness is defined "as the set of institutions, policies, and factors that determine the level of productivity of a country"[19]. The WEF definition links micro- (company-level) to macro- (country-level) competitiveness, and reflects the complexity of the economic development process. This definition refers to productivity because growth models indicate that, in the long term, productivity is a key factor explaining the level of prosperity of the country and thus its citizens. Productivity also determines the rate of return obtained by investments in the economy, which in turn are the primary driver of its growth[20]. Therefore, a more competitive economy is considered one that can grow faster over time[21].

A similar definition of competitiveness includes the IMD's World Competitiveness Yearbook, but more broadly. Competitiveness refers to the way in which a country "manages the totality of its resources and competencies to increase the prosperity of its people"[22]. This conceptualisation underlines prosperity as the fundamental outcome of competitiveness. Prosperity is strongly dependent on national value systems and therefore changes from one country to another. The OECD's definition of competitiveness concerns a country's ability to sell goods in global markets and is "a measure of a country's advantage or disadvantage in selling its products in international markets"[23].

According to the European Commission, at the level of the economy, competitiveness refers to "the overall economic performance of a nation measured in terms of its ability to provide its citizens with growing living standards on a sustainable basis and broad access to jobs to those willing to work"[24]. The source of competitiveness are the institutional and microeconomic conditions that create opportunities for the development of enterprises. Equally important is the macroeconomic policy to promote a safe framework for business activities and a low carbon economy in order to ensure environmental sustainability.

19 *The Global Competitiveness Report 2015–2016*, Geneva 2015, p. 43–44.

20 M.E. Porter, op. cit.

21 *The Global Competitiveness Report 2015–2016*, op. cit., p. 35.

22 *IMD World Competitiveness Yearbook 2014*, Lausanne 2014, p. 494.

23 *OECD Glossary of Statistical Terms*, www.stats.oecd.org [09–10–2016].

24 *European Competitiveness Report 2009*, Commission Staff Working Document, SEC (2009)1657 final, Luxembourg 2010, DOI: 10.2769/21563, p. 20.

Competitiveness is a multilevel concept[25]. The evolution of the theory and research on competitiveness takes into account, aside from the international aspect, also the condition of the economy in the macro- and microeconomic scale. In addition, competitiveness is increasingly dependent on quality determinants related to, among others, technological progress, innovation, and economies of scale, which is reflected in various indicators presenting the level of technological and innovative competitiveness of countries.

Based on the literature on competitiveness, it can be concluded that the issues of sustainable development are rarely taken into account. This is justified by the fact that the paradigm of sustainability is considered as a quality factor, requiring long-term analysis and, in addition, being difficult to measure. The concept of competitiveness is a multifaceted term that has evolved over the years based on sustainable development paradigms from responsible competitiveness[26] to sustainable competitiveness. The latest economic literature refers to the concept of sustainable competitiveness by expanding the traditional importance of competitiveness[27]. The key objective of sustainable competitiveness is the search for a model that would reflect a sustainable approach to economic prosperity, environmental issues and social dimensions.

According to SolAbility Sustainable Intelligence[28], an independent sustainable management advisory and think-tank founded in 2005, sustainable competitiveness is defined as "the ability of a country to meet the needs and basic requirements of current generations while sustaining or growing the national and individual wealth into the future without depleting its natural, intellectual and social capital"[29]. The sustainable competitiveness model developed by SolAbility includes all relevant factors of sustained growth and wealth creation of a nation – natural capital availability, resource intensity, innovation and business capabilities, and social cohesion.

The wider meaning of sustainable competitiveness includes a definition developed by the World Economic Forum. For this purpose, sustainable competitiveness was defined as "the set of institutions, policies, and factors that make a nation productive over the longer term while ensuring social and

25 M. Gorynia, B. Jankowska, op. cit., p. 51–52.

26 A. MacGillivray, J. Sabapathy, S. Zadek, *Responsible Competitiveness Index 2003 – Aligning corporate responsibility and the competitiveness of nations. AccountAbility*, Denmark 2003.

27 Defining Sustainable Competitiveness, www.reports.weforum.org [09–10–2016].

28 SolAbility is the publisher of the Global Sustainable Competitiveness Index and the maker of 3 DJSI Suspersector Leaders.

29 *The competitiveness of sustainability*, www.solability.com [09–10–2016].

environmental sustainability"[30]. Accordingly, social sustainability is defined as "the institutions, policies, and factors that enable all members of society to experience the best possible health, participation, and security; and that maximise their potential to contribute to and benefit from the economic prosperity of the country in which they live"[31]. Whereas environmental sustainability determines "the institutions, policies, and factors that ensure an efficient management of resources to enable prosperity for present and future generations"[32]. In this context, the Global Competitiveness Index has been expanded by new indicators, which take into account two dimensions – environmental and social. The framework for the measurement of sustainable competitiveness will be presented in the following section.

The analytical framework of the sustainability-adjusted Global Competitiveness Index

By defining the functional relationship between competitiveness and sustainable development, and the identification of suitable areas and variables, the complexity of the two categories in terms of both conceptuality and measurement can be clearly observed. Therefore, a simple approach determining the linear relationship between the three dimensions has been developed. It consisted in adapting the Global Competitiveness Index for social and environmental dimensions of sustainable development. This approach does not have a scientific character, but represents a normative approach designed to stimulate discussion about political priorities, and to support research in this field.

As a result of actions taken by the World Economic Forum, a conceptual model has been developed, which aims to create a common policy platform for the integration of economic prosperity with social inclusion and environmental stewardship. This model presents a framework for adapting the measurement of global competitiveness by factors including social and environmental dimensions of sustainable development. The competitiveness model plays a key role as a factor of social welfare, where a high level of competitiveness is crucial for sustained prosperity (see figure 1).

The model shown in figure 1 indicates that competitiveness in itself does not lead to a sustainable level of prosperity. Although a certain level of economic prosperity is essential in order to achieve a high standard of living,

30 G. Corrigan, et al., *Assessing Progress toward Sustainable Competitiveness*, in: *The Global Competitiveness Report 2014–2015*, Geneva 2014, p. 55.

31 Ibidem.

32 Ibidem.

according to this concept countries are also assessed for their ability to generate long-term prosperity for citizens in a sustainable manner. In other words, competitiveness is a necessary but insufficient condition for further prosperity, hence additional efforts are needed in the field of social and environmental dimensions of sustainable development. Each of these dimensions of sustainable development is measured using different indicators presented in the table 1.

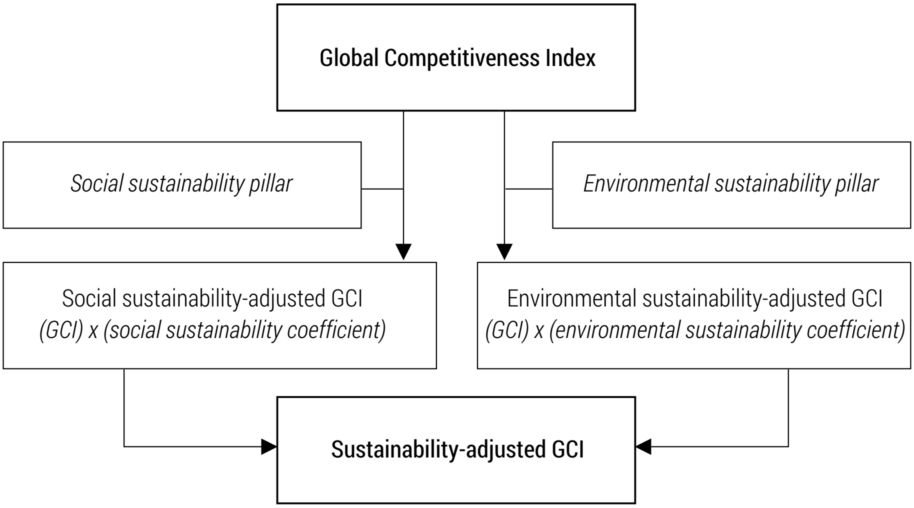

Figure 1. Structure of the sustainability-adjusted GCI

Source: own elaboration based on: *The Global Competitiveness Report 2014–2015*, Geneva 2014, p. 64.

Table 1. Components of sustainable competitiveness

GCI Pillar	Social Sustainability Pillar	Environmental Sustainability Pillar
1. Institutions	1. Access to sanitation	1. Stringency of environmental regulation
2. Infrastructure	2. Access to improved drinking water	2. Enforcement of environmental regulation
3. Macroeconomic environment	3. Access to Healthcare	3. Number of ratified international environmental treaties
4. Health and primary education	4. Vulnerable employment	4. Terrestrial biome protection
5. Higher education and training	5. Extent of informal economy	5. Baseline water stress
6. Goods market efficiency	6. Social safety net protection	6. Wastewater treatment
7. Labour market efficiency	7. Income Gini index	7. Forest cover change
8. Financial market development	8. Social mobility	8. Fish stock overexploitation
9. Technological readiness	9. Youth unemployment	9. Level of particulate matter concentration
10. Market size		10. CO_2 intensity
11. Business sophistication		11. Quality of the natural environment
12. Innovation		

Source: own compilation based on: *Global Competitiveness Report 2014–2015*, Geneva 2014, p. 9, 65–66.

The World Economic Forum (WEF) implements one of the best-known competitiveness indices, the Global Competitiveness Index (GCI), embracing a wide array of determinants of a country's productivity at both the macro- and microeconomic levels[33], and reflecting the complexity of the economic development process. Furthermore, the World Economic Forum has taken efforts to adapt the Global Competitiveness Index (GCI) by measuring sustainable development. The results are presented in the following sections.

The competitiveness of Poland's economy according to the Global Competitiveness Index

The Global Competitiveness Index (GCI) is conducted annually by the World Economic Forum in order to compare the conditions for economic development and determine the ability of each country in order to ensure long-term economic growth. The GCI measures the level of competitiveness of the economy, defined as a set of institutions, policies and factors that determine the level of productivity of the economy. The GCI is a comprehensive index, combining 114 indicators capturing concepts important for productivity. These indicators are organised into 12 categories (see table 2): institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation. These categories are in turn grouped into three sub-indexes, basic requirements, efficiency enhancers, and innovation and sophistication factors[34], which refer to the three main stages of development, i.e. factor-driven, efficiency-driven, as well as innovation-driven economies[35].

As the table shows, of the 140 countries surveyed in 2015, Poland was ranked 41st and, in 2014, was in the 43rd position of 144 countries[36]. As regards the basic requirements in 2015, Poland was ranked number 44 and, in terms of effectiveness – 34, and in the area of innovation – 57.

33 *The Global Competitiveness Report* ..., op. cit., p. 44.

34 Each of the three sub-indexes have different weights in the calculation of the overall index, depending on the stage of development of each economy.

35 *The Global Competitiveness Report*, op. cit., p. 4–5.

36 In 2015 the Report covered 140 economies, because of absence of data, such countries like Angola, Barbados, Burkina Faso, Libya, Puerto Rico, Suriname, Timor-Leste, or Yemen could not be included. However, Benin, Bosnia and Herzegovina, Ecuador, and Liberia, which could not be included in the last edition, were restored in this edition. *The Global Competitiveness Report*..., op. cit., p. 5.

Table 2. Poland's position in the Global Competitiveness Index

Global Competitiveness Index (2014: 43 position / 2015: 41 position)								
Indicator / Year	2014	2015	Indicator / Year	2014	2015	Indicator / Year	2014	2015
Basic requirements sub-index	55	44	Efficiency enhancers sub-index	32	34	Innovation and sophistication factors sub-index	63	57
Institutions	56	58	Higher education and training	34	31	Business sophistication	63	55
Infrastructure	63	56	Goods market efficiency	51	46			
Macroeconomic environment	63	46	Labour market efficiency	79	81			
Health and primary education	39	40	Financial market development	35	43	Innovation	72	64
			Technological readiness	48	41			
			Market size	19	21			
↓			↓			↓		
Key for factor-driven economies			Key for efficiency-driven economies			Key for innovation-driven economies		

Source: own study based on: *The Global Competitiveness Report 2014–2015*, Geneva 2014, p. 9; *The Global Competitiveness Report 2015–2016*, Geneva 2015, p. 6, 8, 11, 13.

As a strong point of Poland's competitiveness, the ranking from 2015 indicates a relatively well-educated society (31), well-developed financial markets (43), and the largest regional market for goods (21). Weaknesses include the area associated with infrastructure (56), in particular transport infrastructure, which, despite significant progress, continues to lag behind European standards.[37] In addition, some aspects from the area of institution (58), e.g. burdens of government regulation (122), transparency of government policymaking (106), public trust in politicians (100), also require improvement[38]. Priority actions include, among others, further improvement in labour market efficiency (81), the consolidation of business sophistication (55) and Innovation (64). In this regard, Poland should focus on strengthening the innovation ecosystem in close cooperation with the private sector. Current development trends relate to the continuation of structural reforms aimed at innovativeness and the knowledge economy, which have an impact on future economic growth.

37 *The Global Competitiveness Report ...*, op. cit., p. 298.

38 Ibidem, p. 299.

The competitiveness of Poland's economy according to the sustainability-adjusted GCI

The Sustainable Competitiveness Index developed by WEF is based on the Global Competitiveness Index (GCI) with adjusted indicators (from social and environmental sustainability pillars). The pillars and sub-pillars of the Sustainable Competitiveness Index (Sustainability – adjusted GCI) are presented in tables 3 and 4.

In terms of the social dimension of sustainable development, it can be seen that Poland ranks high in the field of the Income Gini index that measures income inequality (26). However, key problems are related to areas such as access to social safety net protection (84), healthcare services (76), and youth unemployment (74).

Table 3. Poland's position in the social-sustainability adjusted GCI (in 2014)

Indicators for social sustainability in the Global Competitiveness Index					
Population's access to basic necessities		Population's vulnerability to economic exclusion		Social cohesion	
Indicator / Year	2014	Indicator / Year	2014	Indicator / Year	2014
Access to sanitation *(total population using improved sanitation facilities)*	60	Vulnerable employment *(own-account and contributing family workers in total employment)*	35	Income Gini index *(measure of income inequality)*	26
Access to improved drinking water	45	Extent of informal economy (economic activity undeclared or unregistered)	34	Social mobility *(opportunity of individuals to improve the economic situation through their personal efforts regardless of the socioeconomic status of their parents)*	61
Access to healthcare services	76	Social safety net protection *(protection for the general population from economic insecurity in the event of job loss or disability)*	84	Youth unemployment *(total unemployed youth to total labour force aged 15–24)*	74

Source: own compilation based on: *The Global Competitiveness Report 2014–2015*, Geneva 2014, p. 65; *Sustainability adjusted GCI dataset 2014–2015 in Excel*, www.weforum.org [09–10–2016].

As regards the environmental dimension of sustainable development, the picture is more complex. The areas associated with the degradation of the environment, such as particulate matter concentration (105), CO_2 intensity (98) and quality of the natural environment (53) require urgent measures. These indicators show a weak position of the Poland's economy, which may result from emissions as well as industrial pollution. Among the positive environmental aspects, e.g. the total number of ratified international environmental treaties (10), terrestrial biome protection (10) and forest cover change (25) should be mentioned (see table 4).

Table 4. Poland's position in the environmental-sustainability adjusted GCI (in 2014)

Indicators for environmental sustainability in the Global Competitiveness Index					
Environmental policy		Use of renewable resources		Degradation of the environment	
Indicator / Year	2014	Indicator / Year	2014	Indicator / Year	2014
Stringency of environmental regulations	36	Baseline water stress (normalised (0–5) ratio of total annual water withdrawals to total available annual renewable supply)	45	Particulate matter (2.5) concentration (population-weighted exposure to PM 2.5 (micro-grams per cubic metre)	105
Enforcement of environmental regulations	41	Wastewater treatment (percentage of wastewater that receives treatment weighted by connection to wastewater treatment rate)	27	CO_2 intensity (kg of CO_2 per kg of oil equivalent energy use)	98
Total number of ratified international environmental treaties	10	Forest cover change (forest cover change, as compared to 2000 levels)	25	Quality of natural environment	53
Terrestrial biome protection (weighted average of the percentage of land area protected in each biome)	10	Overexploited fish stock (fraction of the country's exclusive economic zone with over-exploited and collapsed stocks)	39		

Source: own compilation based on: *The Global Competitiveness Report 2014–2015*, Geneva 2014, p. 66; *Sustainability adjusted GCI dataset 2014–2015 in Excel*, www3.weforum.org [09–10–2016].

To conclude, the social and environmental extension of measuring the competitiveness of economies is an important step, which enables the analysis of sustainable competitiveness on three levels, i.e. with regard to the social, environmental or general level of sustainable development, which combines these two areas. The interaction between these factors can drive the national economy to sustainable competitiveness.

The competitiveness of Poland's economy in comparison with other countries

The sustainable competitiveness represents an important goal for each economy. Table 5 presents the results of the GCI adapted to sustainable development indicators for the top 10 countries and the position of Poland's economy in the ranking for each dimension of sustainable development.

Table 5. Poland's position in comparison to the Top 10 countries in 2014

Category	Global Competitiveness Index	Social-sustainability adjusted GCI [a]	Environmental-sustainability adjusted GCI [a]	Sustainability-adjusted GCI [b]
Top 10	Switzerland United States Finland Germany Japan Holland Sweden Norway United Arab Emirates Denmark	Switzerland Norway Holland Finland Germany Japan Denmark United Arab Emirates Sweden Austria	Switzerland Norway New Zealand Germany Finland Sweden Holland Austria Japan Great Britain	Switzerland Norway Finland Germany Holland Japan Sweden New Zealand Austria Denmark
Poland	43rd place	39th place	32nd place	34th place
Poland against the background of the EU	19th place	21st place	19th place	20th place

[a] The result obtained by multiplying the result of the GCI and social coefficient of sustainable development

[b] The average for the social and environmental coefficient of sustainable development. All baseline indicators are available on the WEF website: www.weforum.org [09–10–2016].

Source: own compilation based on: *Sustainability adjusted GCI dataset 2014–2015 in Excel*, www3.weforum.org [09–10–2016].

The results show that, regardless of the competitiveness level of economies, including in relation to the two dimensions of sustainable development, countries can achieve the results presented above or below to assess their competitiveness. However, these results show that Poland indicates greater competitiveness in sustainability-adjusted GCI (34) than in the GCI (43). This is particularly evident in relation to the environmental dimension of sustainability, in particular environmental policy regulations, as well as the use of renewable resources. Whereas Poland's weak position in the social dimension results primarily from youth unemployment (74), access to healthcare services (76) and social safety net protection (84). According to the World Bank, integration in the labour market of the most vulnerable out-of-work population is constrained by a number of inefficiencies that are related to, among others, shortfalls in national policy and deficiencies in the cooperation between the central and local Governments for social and labour market policies and programs[39].

In order to achieve the priorities delineated by the European Commission in the Europe 2020 Strategy, Poland must continually improve its "soft" pillars such as innovation, business sophistication, and social cohesion. There are 19 EU member states placed ahead of Poland's economy in the sustainability-adjusted GCI, and 18 in the GCI[40]. Countries from the EU evaluated higher than Poland include, for example, Switzerland, Norway, Finland, Germany and the Netherlands. From table 5 it can also be observed that only the United States have an SD-GCI position lower than in the GCI. This means that the social and environmental areas have a negative impact on the SA-GCI of the United States. The situation is reversed in the case of the United Arab Emirates, which occupied 9th place in the GCI, and a lower position in the sustainability-adjusted GCI, not listed among the Top 10 countries.

In general, 19 EU countries still rank higher than Poland, and 33 world countries in the sustainability-adjusted GCI. But the Sustainable Competitiveness Index proposed and calculated by WEF is an index primarily based on economic performance, on national competitiveness.

Conclusions

The analysis of the competitiveness of economies in relation to sustainable development is a new research area. Depending on the level of analysis, sustainable competitiveness can be seen at the global, national, regional or microeconomic level (e.g. enterprises). It enforces a variety of indicators of its measurement. The model of the sustainability-adjusted GCI developed by the WEF indicates that competitiveness in itself does not lead to a sustainable level of prosperity. Although achieving a certain level of economic prosperity is essential in order to achieve a high living standard, in this conception countries are also evaluated for their ability to generate long-term prosperity for citizens in a sustainable manner.

39 D. Owen, et al., *Social Inclusion in Poland: Key Challenges and Opportunities for Support*, Washington 2016, p. 36.

40 P. Boguszewski, *Globalny raport konkurencyjności 2015–16 Światowego Forum Gospodarczego – prezentacja*, Warszawa 2015, p. 22, www.nbp.pl [09–10–2016].

The key aim of this article has been to analyse the level of competitiveness of Poland's economy in relation to sustainable development, and an indication of the strengths and weaknesses of the current situation. The analysis concerned the competitiveness of the Polish economy, taking into account the sustainability criteria on the basis of the survey conducted by the World Economic Forum. The analysis has also shown that sustainable development affects the competitiveness of Poland's economy because undertaking measures toward sustainable development contributes to improving the competitive position of Poland's economy. This is confirmed by measuring competitiveness with regard to sustainable development indicators, which shows that Poland is ranked higher in the sustainability-adjusted GCI than in the overall competitiveness ranking. This paper has also attempted to identify the most important factors impacting on the level of sustainable competitiveness of economy of Poland.

In spite of any disparities, the concept of competitiveness and sustainable development can be seen as a cumulative phenomenon[41]. National competitiveness should be seen as a relative rather than an absolute concept. It allows for the benchmarking of nations[42]. Considering sustainable competitiveness, the economy is dependent on society and the environment[43]. Moreover, it is important to identify the institutions, policies and factors making a productive nation in correlation with social and environmental development. Some examples of the most important factors driving toward sustainable competitiveness can be: productive capital, human capital, social/institutional capital, cultural/natural capital, infrastructural capital, knowledge/creative capital[44]. The interaction between these factors can drive the national economy to sustainable competitiveness.

It should also be emphasised that the sustainability-adjusted GCI is not the only monitoring system of world economies in terms of sustainability. Other systems worth mentioning include, for example, the Global Sustainable Competitiveness Index, provided by SolAbility Sustainable Intelligence[45], or the Green Growth Knowledge Platform, established by the Global Green Growth Institute (GGGI), the Organisation for Economic Co-operation and

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41 E. Kasimovskaya, M. Didenko, *International competitiveness and sustainable development: are they part, are they together? A quantitative approach*, "SBS Journal of Applied Business Research" 2013 vol. 2, p. 37–51.

42 T. Berger, *Concepts of national competitiveness*, "Journal of International Business and Economy" 2008 vol. 9(1), p. 91–111.

43 B. Giddings, B. Hopwood, G. O`Brien, *Environment, Economy and Society: fitting them together into sustainable development*, "Sustainable Development" 2002 vol. 10, p. 187–196.

44 R. Martin, M. Kitson, P. Tyler (eds), *Regional competitiveness*, New York 2006.

45 *The Global Sustainable Competitiveness Index*, www.solability.com [09–10–2016].

Development (OECD), the United Nations Environment Programme (UNEP), and the World Bank[46]. Another example of the measurement of economic performance and social Progress is the OECD Framework for measuring progress and wellbeing[47]. A common feature of all measurement indices on sustainable competitiveness, including the GCI, is the process of the continuous improvement and extension of new indicators. However, the major problem is the achievement of relevant and valid data comparable at the international level.

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Literature

Atkinson R.D., *Competitiveness, Innovation and Productivity: Clearing up the Confusion*, Washington 2013

Balkyte A., Tvaronaviciene M., *Perception of competitiveness in the context of sustainable development: facets of 'sustainable development'*, "Journal of Business Economics and Management" 2010 vol. 11(2), p. 341–365

Berger T., *Concepts of national competitiveness*, "Journal of International Business and Economy" 2008 vol. 9(1), p. 91–111

Boguszewski P., *Globalny raport konkurencyjności 2015–16 Światowego Forum Gospodarczego – prezentacja*, Warszawa 2015, p. 22, www.nbp.pl

Brundtland G.H., *Our Common Future*, Report of the World Commission on Environment and Development, Oxford 1987

Burchard-Dziubińska M. , *Działania na rzecz wdrażania zrównoważonego rozwoju w układzie globalnym i Unii Europejskiej*, "Ekonomia i Środowisko" 2005 no. 2(28), p. 15–26

Corrigan G., et al., *Assessing Progress toward Sustainable Competitiveness*, in: *The Global Competitiveness Report 2014–2015*, Geneva 2014

Defining Sustainable Competitiveness, www.reports.weforum.org

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[46] The Green growth strategy combines economic development in an environmentally sustainable manner. The results for Polish economy are available at: www.greengrowthknowledge.org [09–10–2016].

[47] This Framework is built around three distinct domains: material conditions, quality of life and sustainability, each with their relevant dimensions. More details are available at: www.oecd.org [20–10–2016].

Europe 2020 "A European strategy for smart, sustainable and inclusive growth", Brussels 2010, COM(2010) 2020 final

European Competitiveness Report 2009, Commission Staff Working Document, SEC(2009)1657 final, Luxembourg 2010, DOI: 10.2769/21563

Famielec J., *W poszukiwaniu ładu gospodarki zrównoważonej*, Studia i Materiały "Miscellanea Oeconomicae" 2014 no. 1, p. 89–101

Giddings B., Hopwood B., O`Brien G., *Environment, Economy and Society: fitting them together into sustainable development*, "Sustainable Development" 2002 vol. 10, p. 187–196

Gorynia M., Jankowska B., *Klastry a międzynarodowa konkurencyjność i internacjonalizacja przedsiębiorstwa*, Warszawa 2008

IMD World Competitiveness Yearbook 2014, Lausanne 2014

Janikowski R., *Nachhaltigkeit als Imperativ des Alltags*, "Humanities and Social Sciences" 2014 no. XIX 21(3), p. 71–82

Kasimovskaya E., Didenko M., *International competitiveness and sustainable development: are they part, are they together? A quantitative approach*, "SBS Journal of Applied Business Research" 2013 vol. 2, p. 37–51

Krugman P., *Making Sense of the Competitiveness Debate*, "Oxford Review of Economic Policy" 1996 vol. 12, p. 17-25

MacGillivray A., Sabapathy J., Zadek S., *Responsible Competitiveness Index 2003 – Aligning corporate responsibility and the competitiveness of nations. AccountAbility*, Denmark 2003

Martin R., Kitson M., Tyler P. (eds), *Regional competitiveness*, New York 2006

Measuring Distance to the SDGs Targets: a pilot assessment of where OECD countries stand, www.oecd.org

OECD Glossary of Statistical Terms, www.stats.oecd.org

Owen D., et al., *Social Inclusion in Poland: Key Challenges and Opportunities for Support*, Washington 2016

Porter M.E., *The Competitive Advantage of Nations*, New York 1990

Preisner L., *Wpływ globalnych uwarunkowań środowiskowych na funkcjonowanie przedsiębiorstw*, in: A. Budnikowski, M. Cygler (red.), *Globalizacja gospodarki a ochrona środowiska*, Warszawa 2004

Ramos G., *The Sustainable Development Goals: A duty and an opportunity*, in: P. Love (ed.), *Debate the issues: New approaches to economic challenges*, Paris 2016

Scott B.R., Lodge G.C., *US competitiveness in the world economy*, "The International Executive" 1985 vol. 27(1), p. 20–26

The competitiveness of sustainability, www.solability.com

The Global Competitiveness Report 2015–2016, Geneva 2015

The Sustainable Development Goals: An overview of relevant OECD analysis, tools and approaches, Paris, www.oecd.org

Transforming our World: The 2030 Agenda for Sustainable Development, A/RES/70/1, New York 2015, www.sustainabledevelopment.un.org

Urbaniec M. , *Sustainable Development Indicators in Poland: Measurement and System Evaluation*, "Entrepreneurial Business and Economics Review" 2014 vol. 3(1), p. 119–134

Urbaniec M., *Eco-innovations as a source of competitive advantage in enterprises*, in: A. Marković, S. Barjaktarović Rakočević (eds), *Proceedings of the XIV International Symposium SymOrg 2014: New Business Models and sustainable competitiveness*, Belgrade 2014

www.greengrowthknowledge.org

www.oecd.org

www.weforum.org

Zacher L.W., *Trwały rozwój – utopia czy realna możliwość*, "Problemy ekorozwoju" 2008 vol. 3(2)

Joachim MAES

MAPPING AND ASSESSMENT OF ECOSYSTEMS AND THEIR SERVICES (MAES): HIGHLIGHTS AND UNCERTAINTIES OF A SCIENCE-POLICY INTERFACE ON BIODIVERSITY AND ECOSYSTEM SERVICES

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ROZPOZNANIE I OCENA EKOSYSTEMÓW I ICH ŚWIADCZEŃ (MAES): WYBRANE ZAGADNIENIA I NIEPEWNOŚCI WSPÓŁDZIAŁANIA NAUKI I POLITYKI W ZAKRESIE BIORÓŻNORODNOŚCI I ŚWIADCZEŃ EKOSYSTEMÓW

STRESZCZENIE: Działanie 5 sformułowane w Unijnej Strategii Bioróżnorodności do 2020 r. zobowiązuje kraje członkowskie do rozpoznania i oceny ekosystemów oraz dostarczanych przez nie świadczeń (MAES). Ostatnie analizy wskazują, że działanie to zostało zainicjowane przez prawie wszystkie kraje członkowskie Unii Europejskiej. Oceny na poziomie krajowym są wspierane wytycznymi przygotowanymi przez Grupę Roboczą MAES (raporty techniczne MAES). Podejście MAES jest oparte na modelu "wspólnota praktyk", zgodnie z którym naukowcy i politycy wypracowują wspólnie wskazania dla państw członkowskich, oparte na ich wiedzy oraz ekspertyzach dotyczących ekosystemów i ich świadczeń. Ocena w skali europejskiej jest prowadzona w oparciu o czteroetapowe postępowanie: rozpoznanie ekosystemów, ocenę stanu ekosystemów, kwantyfikację świadczeń ekosystemów oraz integrację wyników uzyskanych na powyższych etapach w celu wsparcia procesu tworzenia i wdrażania polityk. W artykule zaproponowano trzy podejścia dla rozwiązania wątpliwości, które pojawiają się podczas rozpoznania i oceny ekosystemów oraz w trakcie wykorzystywania tej wiedzy na potrzeby polityki: lepsze rozpoznanie publikowanych dowodów naukowych, porównanie rezultatów procesu MAES w różnych skalach przestrzennych, a także jednoczesne współtworzenie wiedzy przez naukowców i polityków.

SŁOWA KLUCZOWE: MAES, ocena ekosystemów, świadczenia ekosystemów, mapowanie, Unia Europejska, niepewność

Introduction

Target 2 of the EU Biodiversity Strategy to 2020 aims to maintain and enhance ecosystem services by developing green infrastructure and by restoring 15% of Europe's degraded ecosystems by 2020. A similar target exists at global level. Aichi target 15 aims to enhance ecosystem resilience and the contribution of biodiversity to carbon stocks through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

To meet these targets, the European Commission and the EU Member States have made the commitment to develop a strategic framework to set priorities for the development of green infrastructure and for restoration activities at sub-national, national and EU level: which degraded ecosystems need to be restored in priority? Clearly, such planning needs to be well informed, which requires spatially explicit information on ecosystem condition and delivery of ecosystem services.

This knowledge base is currently developed under the MAES initiative on Mapping and Assessment of Ecosystems and their Services. MAES is the implementation of the first part of Action 5 of the EU Biodiversity Strategy which encourages the EU Member States, with the assistance of the Commission, to map and assess the state of ecosystems and their services in their national territory.

This paper presents a review of the work that has been developed so far under Action 5. It firstly describes the MAES approach to ecosystem assessment. Next the implementation of the MAES process is evaluated at national and EU levels. Finally the paper briefs on how scientific uncertainty and gaps between science and policy related to mapping and assessment can be addressed.

The MAES approach

Ecosystem assessments form an essential knowledge base to provide information for decision making in policy and practise. In this context, an assessment refers to the analysis and review of information derived from research for the purpose of helping someone in a position of responsibility to evaluate possible actions or think about a problem. In Europe, several approaches for ecosystem assessment are used, which have been recently reviewed[1]. The Millennium Ecosystem Assessment (MA)[2], completed in 2005, spurred several national ecosystem assessments including assessments in Portugal, Spain and the United Kingdom. They are founded on the MA conceptual model which links biodiversity and ecosystems to human well-being (MA 2005). Other countries, including Germany[3], The Netherlands and Finland, adopted the TEEB (The Economics of Ecosystems and Biodiversity) approach, which puts focus on making visible the values ecosystems and ecosystem services for the economy, often using case studies. The MAES approach, which is under development since 2012, differs from the MA and TEEB approaches in that, besides assessment, it also focuses on mapping. This focus originates from the conviction that spatially-explicit information is needed to guide decisions on restoration and the development of green infrastructure in urban and rural settings. Ecosystems are inherently spatial and so, too, is their condition and their capacity to deliver services.

The working group MAES is mandated to coordinate and oversee Action 5. The working group consists of different actors: staff members of different services of the European Commission and the European Environment Agency, official representatives of the member states with a mandate of the ministry which implements the biodiversity strategy, and independent scientific experts. The working group MAES carries out its activities as a community of practise with two main areas of attention: guidance to member states based on ecosystem pilots, and EU wide assessments of ecosystems and ecosystem services. Specific guidance for member states on how to map and assess ecosystems and their services is given in a series of MAES reports. A first report[4] proposes a conceptual framework linking biodiversity, ecosystem condition and ecosystem services to human well-being. Furthermore, it develops a typology for ecosystems in Europe and adopted the CICES classification as a typology for ecosystem services (Common International Classification for Ecosystem Services). The second MAES[5] report describes a common assessment framework for measuring ecosystem condition and ecosystem services for forests, cropland, grassland, wetlands, lakes and rivers, groundwater sys-

1 M. Schröter et al., *National Ecosystem Assessments in Europe: A Review,* “BioScience” 2016 (in press).

2 *Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis*, Washington 2005.

3 B. Hedden-Dunkhorst, L. Braat, H. Wittmer, *TEEB emerging at the country level: Challenges and opportunities*, “Ecosystem Services” 2015 no. 14(37).

4 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*, Publications office of the European Union, Luxembourg 2013.

5 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*, Publications office of the European Union, Luxembourg 2014.

tems and four marine ecosystem types. The third report[6] describes the state of the art in mapping and assessment of ecosystem condition at European scale while the fourth report[7] presents guidance for mapping and assessment of urban ecosystems.

The community-of-practise model which is adopted by the working group MAES ensures that the guidance is scientifically sound while at the same time relevant for policy and decision making. The different ecosystem pilots have been set up as working groups which include scientists and civil servants employed a public administration responsible for biodiversity. The MAES urban ecosystem pilot for instance formulated guidance on mapping assessment using the support of local planners and administrators from 10 European cities.

Current implementation of MAES at EU and member state level

The EU biodiversity strategy was adopted on 3 May 2011 and subsequently endorsed by the Council of Ministers and the European Parliament. The working group MAES started its activities on 13 March 2012 with a first working group meeting. Four years later, substantial progress on mapping and assessment has been achieved. While much of the focus went to biophysical mapping and assessment of ecosystems and ecosystem services, current attention will increasingly shift to develop methods and indicators to quantify ecosystem condition and to assess the economic value of ecosystems in Action 5.

Progress made by the EU Member States

The progress made by the EU member states has been evaluated by the Esmeralda project, a coordination action funded under the Horizon 2020 programme with the specific aim to support the implementation of Action 5. Kopperoinen and co-workers[8] have analysed the progress of each country based on country fact sheets which contain information on the policy process, the relevant actors and the executive agencies involved in Action 5, the problems encountered, the data needs, the research capacity, and the actual

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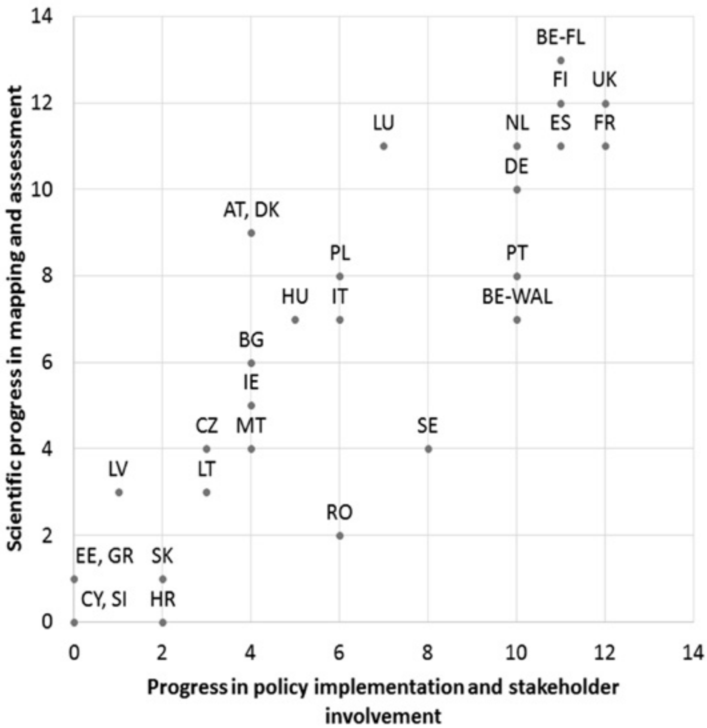
6 M. Erhard et al., *Mapping and Assessment of Ecosystems and their Services: Mapping and assessing the condition of Europe's ecosystems – Progress and challenges*, Publications office of the European Union, Luxembourg 2016.

7 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Urban ecosystems*, Publications office of the European Union, Luxembourg 2016.

8 L. Kopperoinen et al., *Ecosystem service mapping and assessment gaps in EU member states and recommendations to overcome them. Deliverable 2.2*, EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 2016.

results and outcomes. These fact sheets are made available on BISE, the biodiversity information system for Europe[9].

Most EU member states are now actively involved in mapping and assessing the state of ecosystems and their services on their national territory. However, differences in policy response to the ambitions set forward in the Biodiversity Strategy, lack of sufficient resources and research capacity, different levels of stakeholder engagement and problems related to data availability have resulted in different implementation levels of Action 5 across the EU member states.



Country codes according to the international two digit codes. A separate assessment was made for two Belgian regions (BE-WAL stands for Wallonia, BE-FL for Flanders).

Figure 1. Implementation of Action 5 of the EU Biodiversity Strategy to 2020 in the EU Member States. Assessment from the Esmeralda project

Source: L. Kopperoinen et al., *Ecosystem service mapping and assessment gaps in EU member states and recommendations to overcome them. Deliverable 2.2,* EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, 2016.

9 www.biodiversity.europa.eu/maes [29–10–2016].

Figure 1 shows the progress made by the different countries along two main working streams which are deemed necessary to successfully implement Action 5: progress made in policy activities and stakeholder consultation and progress made in the scientific activities (mapping and assessment). Each axis measures progress by summing the number of positive answers (yes) to a set of questions (see also Annex 1 in Kopperoinen et al.). The maximum score on the policy and stakeholder axis of figure 1 is 12; the maximum score on the research axis of figure 1 is 15. The analysis is based on data collected before December 2015. Consider for instance the position of Poland (PL) on the biplot. Questions for Poland about the policy implementation and stakeholder involvement of the MAES initiative resulted six times in a positive answer (yes) and six times in a negative or unknown answer. As for research (status of mapping and assessment) Poland received eight positive answers (see also Annex 2 in Kopperoinen et al.). This puts Poland exactly in the middle of the implementation process.

Two main findings emerge when inspecting figure 1. First, there is a high variability in progress made across the EU and second, progress in policy and stakeholder involvement is positively correlated to scientific progress.

Countries in the upper right corner have implemented MAES or have made substantial progress over the last two years. These include for instance the UK, Spain and Portugal which already carried out a national MA type ecosystem assessment. Countries in the lower left corner including the Baltic countries and several Balkan countries have yet to implement MAES. Often a lack of sufficient resources is at the basis of slow implementation. Countries in the middle of the cloud such as Austria, Malta or Ireland are in the process of implementation and several of these countries have started MAES-type projects and assessments.

Figure 1 clearly shows that Action 5 has resulted in a functional science-policy interface across the EU. Both processes, policy and research, go hand in hand and are probably reinforcing each other. There are no countries in the upper left corner or the lower right corner of the biplot which would suggest that either policy or research are disproportionally developed.

Figure 1 represents a snapshot of the situation how it is assessed at the end of 2015 but it is a useful baseline to measure progress of the MAES process in the next years.

Progress at EU level

Whereas Action 5 requires implementation at national level, progress has also been made at EU level where the work is mainly guided by the MAES common assessment framework (figure 2). The MAES conceptual model[10] builds on the premise that the delivery of certain ecosystem services upon which we rely for our socio-economic development and long-term human well-being is strongly dependent on both the spatial accessibility of ecosystems as well as on ecosystem condition. This working hypothesis has been translated into a working structure which follows a four step approach to pan-European ecosystem assessment:

- Mapping ecosystems;
- Assessment of ecosystem condition;
- Quantification of the services provided by the ecosystem;
- Compilation of these into an integrated ecosystem assessment (figure 2).

The process of mapping and assessment of ecosystems and their services starts with mapping ecosystems themselves. A full map of European ecosystems has now been completed by the European Environment Agency. The dataset combines the Corine based MAES ecosystem types (figure 2) with the EUNIS habitat classification[11].

The second step is to assess ecosystem condition, which is defined as the physical, chemical and biological condition of an ecosystem at a particular point in time which can also be referred to as its quality. Different EU environmental directives already require the collection of data which can be used to assess the condition of ecosystems. Under Article 17 of the Habitats Directive the conservation status of vulnerable habitats and species is assessed every six years (Art. 17 assessment, figure 2). The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) also foresee in regular EU wide assessments of ecological status and environmental status, respectively. These data are of prior importance to assess the condition of ecosystems under Action 5. In addition other data can be used to approximate ecosystem condition including drivers and pressures on ecosystems such as nitrogen loadings, habitat fragmentation or pollution. A recent assessment of the condition of the different MAES ecosystem types[6] reveals similarities and differences, but also strong linkages between many ecosystems. Most striking is the level of threat to European ecosystems: well over half of all the habitats and species covered by the Habitats Directive are assessed as being in ‘unfavourable’ condition and their status is generally declining or stable, with only a small proportion ‘improving’.

10 J. Maes et al., *An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020*, “Ecosystem Services” 2016 no. 17, p. 14–23.

11 www.eea.europa.eu [20–10–2016].

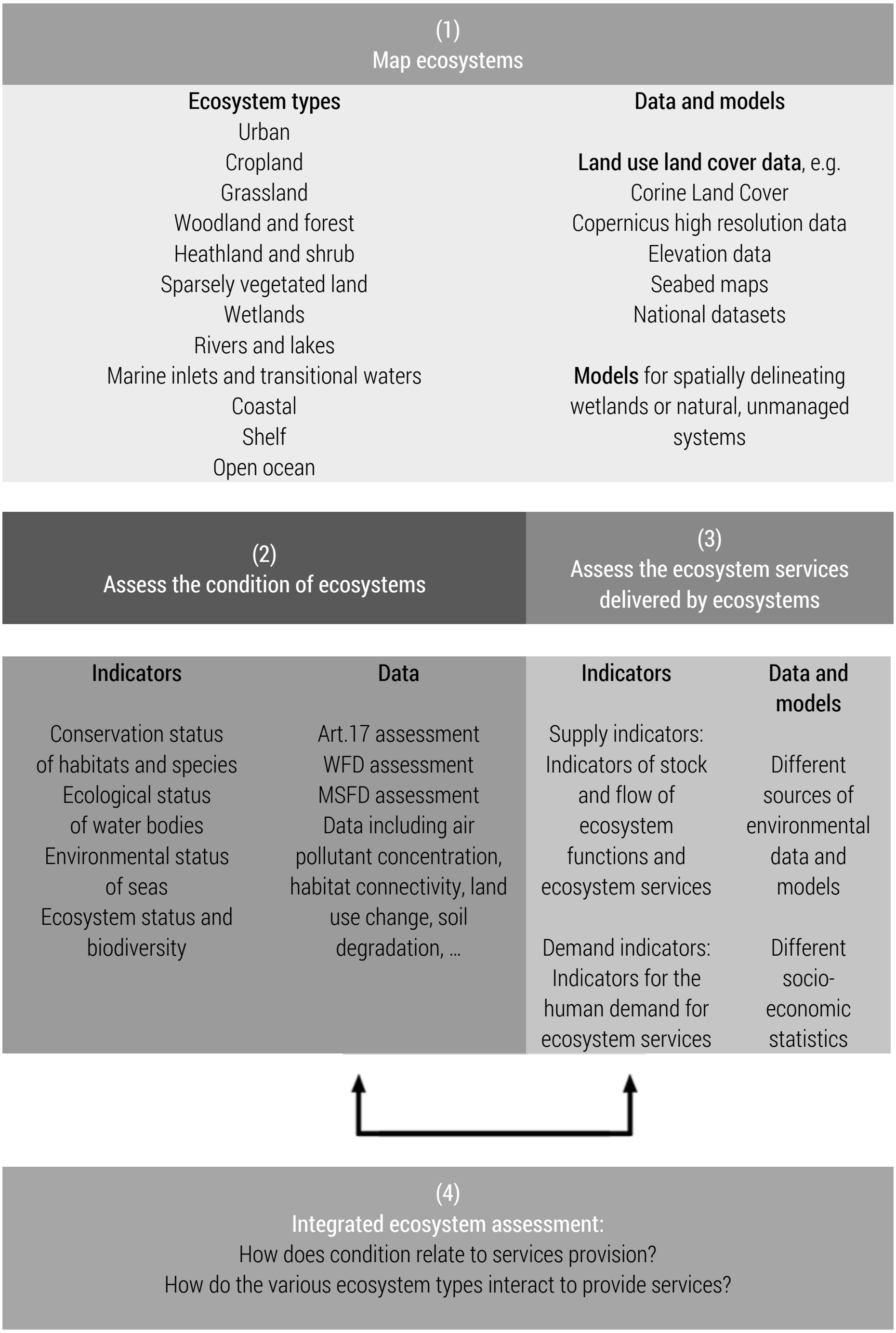


Figure 2. The MAES common assessment framework for mapping and assessment of ecosystems and their services

The third step is to assess ecosystem services based on an assessment of supply and demand for ecosystem services (figure 2). Maes et al.[12] assessed the trends of ecosystem services at the European scale between 2000 and 2010 based on a set of 30 indicators. Most provisioning services showed increasing trends. More crops were produced on less arable land. Organic farming gained importance. More timber was removed from forests with increasing timber stocks. The increasing extent of forests resulted in positive influences on erosion control, carbon storage, water retention, air quality regulation and recreation. Indicators for these services remained stable or showed upward trends. More nature was protected in 2010 than in 2000 but in contrast, the trends of two ecosystem services indicators which are directly related to biodiversity, pollination and habitat quality, were worsening.

The fourth step is integrated assessment which is currently under development. The capacity of an ecosystem to deliver different ecosystem services is related to the condition of this ecosystem. In a "healthy state", an ecosystem may provide a sustained flow of a variety of services compared to an ecosystem, which is managed to provide only a maximum amount of one specific service, e.g. fish, crops or timber. As a result, the overall capacity of such a system to provide services will be higher. Ecosystems in a "healthy state" are considered resilient systems, which are able to recover after disturbance and they are generally characterized by higher species diversity and a balanced trophic community. Every ecosystem delivers multiple services. The mapping work is therefore not targeted to identify the maximum potential of one service but to understand the spatial delivery of multiple services by interconnected ecosystems.

Addressing uncertainties of a science-policy interface

The conceptual model which was developed to support MAES-type ecosystem assessments links biodiversity and ecosystems to the socio-economic system via the flow of ecosystem services, and through the drivers of change that affect ecosystems either as consequence of using the services or as indirect impacts due to human activities in general. Uncertainty emerges at several points in the model. How certain are we that biodiversity underpins the delivery of ecosystem services as suggested by the MAES conceptual model? What is the uncertainty associated to mapping or quantifying ecosystem services? How to communicate scientific uncertainty when designing or imple-

12 J. Maes et al., *Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010*, Publications office of the European Union, Luxembourg 2015.

menting biodiversity policy? It is essential to address these uncertainties and finding ways to reduce them if we want to mainstream biodiversity and ecosystem services into policy and decision making processes.

One obvious but often overlooked way of addressing uncertainty is to map the evidence[13]. The digital revolution has not only resulted in an increase of scientific articles and reports but has also increased the accessibility to scientific results. This has greatly improved the capacity to synthesise what is known, develop an evidence base and to map uncertainties, gaps and unknowns. Mapping the evidence is particularly useful in the debate on the nature of the relation between biodiversity and ecosystem services. Sound and correct evidence in support of this relation is crucial to the development of biodiversity policy and for the conservation and management of natural resources. An illustration of an evidence map on the linkages between biodiversity and ecosystem services is provided by Harrison et al.[14] as part of the BESAFE project. These authors reviewed 530 studies and mapped the relation between biodiversity attributes and 11 ecosystem services. They found that most reported relationships between biodiversity attributes and ecosystem services were positive. The OpenNESS project, also funded under the 7th framework program for research and innovation of the European Commission, has further elaborated the analysis by Harrison et al (2016) including more studies and more ecosystem services[15].

The MAES initiative has undoubtedly triggered many studies in Europe which map ecosystem services. However, the lack of data for many ecosystem services and the consequent reliance on models to approximate them may result in considerable error. Seppelt et al.[16] reviewed 153 studies of ecosystem services and found that less than 40% of the studies derived their results on primary data from observations or measurements whereas about two-thirds based their results on mainly unvalidated, secondary data. They concluded that less than one-third of all studies provided a sound basis for their conclusions. Clearly, more efforts are needed to collect primary data of ecosystem service flows, to validate model-based proxies for ecosystem services and to compare outcomes among different models within and across geographic scales. Examples of such comparison are already available. Schulp et

13 M.C. McKinnon et al., *Sustainability: Map the evidence*, "Nature" 2015 vol. 528, no. 7581.

14 P.A. Harrison et al., *Linkages between biodiversity attributes and ecosystem services: A systematic review,* "Ecosystem Services" 2014 no. 9, p. 191–203.

15 M. Pérez Soba et al., *Database and operational classification system of ecosystem service – natural capital relationships*, European Commission FP7, 2015.

16 R. Seppelt et al., *A quantitative review of ecosystem service studies: Approaches, shortcomings and the road ahead*, "Journal of Applied Ecology" 2011 no. 48, p. 630–636.

al.[17] compared four different approaches to map the same ecosystem services at European scale. Differences among the maps were caused by differences in indicator definition, level of process understanding, mapping aim, data sources and methodology. Yet, comparing the maps revealed that they broadly agree (between 50% and 80% agreement) on the location of hotspots and coldspots for ecosystem services in Europe. Dick et al.[18] downscaled a set of ecosystem service maps developed at the European scale to quantify ecosystem service delivery of 11 long-term ecological monitoring sites and compared the results with locally collected data and measurements of ecosystem services. Then they used multivariate and regression statistics to compare the results of the two separate methods. The data collected at EU level captured between 20% and 40% of the variance present in the locally collected data. So despite differences emerging across methods and scales, these sorts of collaborative mapping have provided encouraging results and can contribute to delivering a coherent message on the condition of ecosystems and the services and benefits they provide to society.

Even if scientific uncertainty is reduced, there remains a science-policy gap on how citizens, policy makers or practitioners can use new information of ecosystem condition and services which is collected in the MAES process. Science typically produces cognitive dissonance, uncomfortable levels of uncertainty, and resistance in policy and practise[19]. Knowledge co-production is potentially a powerful approach to increase the acceptance of new data and information and thus to increase its potential use in policy-making processes. In the framework of the MAES initiative the European Commission has organised several so-called hands-on mapping workshops20. The Member states were invited to these workshops in order to engage in a joint mapping effort. Every member states was asked to send a mixed team consisting of the mandated MAES representative (or someone from the ministry or an agency involved in the national implementation of Action 5), a scientist working on the biodiversity and ecosystem services science-policy interface and a specialist in digital mapping and geographical information systems. Based on policy questions, these teams started mapping ecosystem services such as timber, pollination, carbon sequestration and recreation using a vari-

17 C.J.E. Schulp et al., *Uncertainties in ecosystem service maps: A comparison on the European scale*, "PLOS ONE" 2014 nr 9.

18 J. Dick et al., *Cross-scale analysis of ecosystem services identified and assessed at local and European level*, "Ecological Indicators" 2014 no. 38, p. 20–30.

19 G.A. Bradshaw, J.G. Borchers, *Uncertainty as information: narrowing the science-policy gap*, "Conservation Ecology" 2000 no. 4(7).

20 M. Pérez-Soba et al., *Training member states on ecosystem services mapping through hands on workshops*, Final report to DG Environment, Alterra Wageningen University and Research centre and ETEH Zurich 2015.

ety of tools and methods while going through a process of several iterations to improve the maps and to reduce their uncertainty. In the context of MAES it is expected that knowledge co-production (i.e. the joint mapping of ecosystem condition and ecosystem services) enhances uptake of the scientific outcomes in policy.

Conclusions

Halfway through the MAES initiative on Mapping and Assessment of Ecosystems and their Services to ecosystem assessment delivered varying outcomes ranging from almost full implementation by some countries to a relatively poor uptake by others. At EU level substantial efforts have been made to map ecosystems, to assess their condition and to quantify the provision of ecosystem services but an integrated approach which links good ecosystem condition to the delivery of multiple services is still lacking. Such information and related case studies are essential to support the future development and implementation of policies such as agriculture, fisheries, climate change, and disaster risk reduction and management. The next steps will increasingly focus on the integrated valuation of ecosystem services and the translation of the knowledge base on ecosystem condition and services to reporting and accounting systems.

The successful experiments of knowledge co-production using training and mapping workshops where policy-makers and scientists work hand in hand to deliver useful products based on reliable data and scientific expertise may also serve as an example for the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) regional assessments. The European and Central Asian assessment of biodiversity and ecosystem services will be delivered in 2018. MAES can provide a crucial source of data and information for this assessment but also provide inspirational examples of how to set-up a science-policy interface at continental scale.

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Literature

Bradshaw G.A., Borchers J.G., *Uncertainty as information: narrowing the science-policy gap*, "Conservation Ecology" 2000 no. 4(7)

Dick J., et al., *Cross-scale analysis of ecosystem services identified and assessed at local and European level*, "Ecological Indicators" 2014 no. 38, p. 20–30

Erhard M. et al., *Mapping and Assessment of Ecosystems and their Services: Mapping and assessing the condition of Europe's ecosystems – Progress and challenges*, Publications office of the European Union, Luxembourg 2016

Harrison P.A. et al., *Linkages between biodiversity attributes and ecosystem services: A systematic review,* "Ecosystem Services" 2014 no. 9, p. 191–203

Hedden-Dunkhorst B., Braat L., Wittmer H., *TEEB emerging at the country level: Challenges and opportunities*, "Ecosystem Services" 2015 no. 14(37)

Kopperoinen L. et al., *Ecosystem service mapping and assessment gaps in EU member states and recommendations to overcome them. Deliverable 2.2*, EU Horizon 2020 ESMERALDA Project, Grant agreement No. 64 2007, 2016

Maes J. et al., *An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020*, "Ecosystem Services" 2016 no. 17, p. 14–23

Maes J. et al., *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*, Publications office of the European Union, Luxembourg 2013

Maes J. et al., *Mapping and Assessment of Ecosystems and their Services: Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*, Publications office of the European Union, Luxembourg 2014

Maes J. et al., *Mapping and Assessment of Ecosystems and their Services: Urban ecosystems*, Publications office of the European Union, Luxembourg 2016

Maes J. et al., *Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010*, Publications office of the European Union, Luxembourg 2015

McKinnon M.C. et al., *Sustainability: Map the evidence*, "Nature" 2015 vol. 528, no. 7581

Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis, Washington 2005

Pérez Soba M. et al., *Database and operational classification system of ecosystem service – natural capital relationships*, European Commission FP7, 2015

Pérez-Soba M. et al., *Training member states on ecosystem services mapping through hands on workshops*, Final report to DG Environment, Alterra Wageningen University and Research centre and ETEH Zurich 2015

Schröter M. et al., *National Ecosystem Assessments in Europe: A Review,* "BioScience" 2016 (in press)

Schulp C.J.E. et al., *Uncertainties in ecosystem service maps: A comparison on the European scale*, "PLOS ONE" 2014 nr 9

Seppelt R. et al., *A quantitative review of ecosystem service studies: Approaches, shortcomings and the road ahead*, "Journal of Applied Ecology" 2011 no. 48, p. 630–636

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THE USE OF DATA FROM THE LAND AND BUILDING REGISTER AND SOIL AND AGRICULTURAL MAPS FOR QUANTIFICATION OF PROVISIONING AGROECOSYSTEM SERVICES

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WYKORZYSTANIE DANYCH Z EWIDENCJI GRUNTÓW I BUDYNKÓW ORAZ MAP GLEBOWO-ROLNICZYCH DO KWANTYFIKACJI ŚWIADCZEŃ ZAOPATRUJĄCYCH AGROEKOSYSTEMÓW

STRESZCZENIE: Kwantyfikacji świadczeń zaopatrujących związanych z wytwarzaniem biomasy użytkowej przez agroekosystemy można dokonać przy użyciu map glebowo-rolniczych (MG-R) oraz ewidencji gruntów i budynków (EGiB). Oba opracowania uwzględniają różne systemy klasyfikacji jakości gleb, stąd niezbędne jest określenie wskaźników przeliczeniowych dla uzyskania porównywalności wyników.
Celem badań było opracowanie wskaźników przeliczeniowych plonów normatywnych zbóż podstawowych i siana łąkowego, obliczonych na podstawie danych z EGiB i MG-R dla użytków rolnych gminy Krajenka. Wypracowane współczynniki dają możliwość dwukierunkowej transformacji rezultatów kwantyfikacji analizowanych świadczeń ekosystemów.

SŁOWA KLUCZOWE: zaopatrujące świadczenia ekosystemów, agroekosystem, wskaźniki, mapa glebowo-rolnicza, ewidencja gruntów i budynków

Introduction

Agricultural services fulfil a range of ecological, cultural and economic functions which are of deciding importance for the human existence. The superior role in relation to the other ones is the production of biomass, in particular, the production of plant biomass which constitutes food for people and fodder for animals[1]. In this aspect, the ability to produce usable biomass in agroecosystems, connected with the circulation of matter and the flow of energy, is the most important service from the provisioning services as it serves the satisfaction of basic biological needs of people[2]. It must be added that the provision of food and other organic material depends on the supply of supporting and regulating services, in particular those related to the pollination of cultivated plants by insects and the control of crop pest populations[3].

The level of usable biomass production in agroecosystems is determined by natural factors as well as organizational and economic ones connected, amongst other things, with the adopted cultivation system and the agricultural technology used[4]. The main natural factors that determine the size of yield include the quality of soil, relief (lay of the land), soil humidity and agroclimate, which are the basis for valuation of the agricultural production area in Poland[5].

Soil quality diversification in our country is presented in two spatial aspects. On a detailed scale, the land and building register (LBR) is usually used, which takes into account the valuation classification of agricultural land. On less detailed scales, the agricultural value of soils is reflected using soil and agricultural maps (SAM) based on division into agricultural soil suitability complexes. Both classification systems differ from each other, therefore, it is necessary to determine conversion factors between them to obtain

1 Z.M. Rosin et al., *Koncepcja świadczeń ekosystemowych i jej znaczenie w ochronie przyrody krajobrazu rolniczego*, "Chrońmy Przyrodę Ojczystą" 2011 no. 67(1), p. 3–20.

2 M. Degórski, *Wykorzystanie świadczeń ekosystemów w rozwoju regionów*, "Ekonomia i Środowisko" 2010 no. 1(37), p. 85–97; M. Degórski, *Socio-economic responses to the environment and ecosystem services in regional development*, "Geographia Polonica" 2010 no. 83(2), p. 83–95.

3 K. Norris, S.G. Potts, S.R. Mortimer, *Ecosystem services and food production*, in: R.E. Hester, R.M. Harrison (eds), *Ecosystem services, Issues in Environmental Science and Technology*, vol. 30, 2010, p. 52–69.

4 J. Kopiński, S. Krasowicz, *Regionalne zróżnicowanie warunków produkcji rolniczej w Polsce*, "Studia i Raporty IUNG-PIB" 2010 z. 22, p. 9–29.

5 T. Witek (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski według gmin*, Puławy 1981; S. Krasowicz, T. Stuczyński, A. Doroszewski, *Produkcja roślinna w Polsce na tle warunków przyrodniczych i ekonomiczno-organizacyjnych*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 27–54.

comparable results. It is of significant importance for quantification of provisioning services for agroecosystems related to the provision of usable biomass.

Due to the spatial character of ecosystem services (ES), maps and datasets are a very important source of information in research conducted in this area[6]. This is confirmed by the common use of maps in various studies devoted to the quantification of ES[7].

Aim of the study

The aim of the research was to determine conversion factors of normative yields of basic cereals and meadow hay calculated on the basis of data from LBR and SAM.

An important stage on the way to achieving this research objective is updating the normative size of the yields of cereals assigned to soil valuation classes and agricultural soil suitability complexes based on literature sources. The update of crop yield indices was necessary due to the progressive, gradual increase in the average size of the cereal yield at its very high annual fluctuations[8], which is confirmed by statistical data about varied yields of basic cereals in the years 1992–2015 (figure 1).

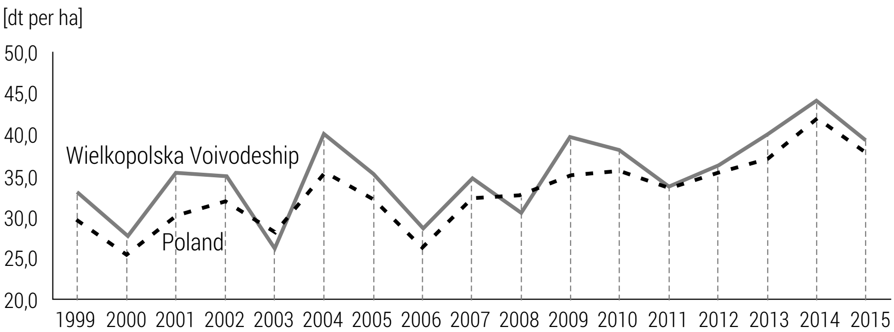

Figure 1. Variation of basic cereals' yield in years 1999–2015 in Poland and Wielkopolska Voivodeship

Source: own work based on CSO data.

6 J. Boyd, *Location, Location, Location: The Geography of Ecosystem Services*, "Resources" 2008 no. 170, p. 10–15; J. Boyd, S. Banzhaf, *What are ecosystem services? The need for standardized environmental accounting units*, "Ecological Economics" 2007 no. 63, 2007, p. 616–626.

7 According to the Web of Science database in the period 2007–2016 (as of 11/10/2016) were published 1176 English-language articles, the subject of which was associated with the use of maps in the study of ecosystem services (the search question was: *TS=[ecosystem AND services] AND TS=[map*]*).

8 J. Grabiński, G. Podolska, *Stan aktualny i perspektywy zmian w produkcji zbóż w Polsce*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 55–70.

An additional objective of the study was to estimate potential revenues from the sale of usable biomass per hectare of production area in a given soil valuation class and agricultural soil suitability complexes.

Research area

The research included agroecosystems in the Krajenka Municipality (Złotów District) in the northern part of the Wielkopolska Voivodeship. The municipality is situated within two geographical regions – Krajenka Lakeland and Gwda River Valley.

The analyzed unit was the object of the author's research aimed at obtaining more details on the quantification of recreational and aesthetic services[9] and a determination of the influence of the scale of spatial data on the estimated size of selected ES[10].

Methods and assumptions

The research was based on simulation. It followed the assumption that provisioning services such as the production of usable plant biomass in agroecosystems may be estimated on the basis of detailed information about the yield from five basic cereal species (arable land) and meadow hay (grassland), depending on the natural production capacity of soils that belong to various valuation classes and agricultural suitability complexes.

The normative quantitative valuation method, supported by Geographic Information Systems (GIS), was used. To estimate the monetary value, the market price method was used to determine the potential revenues from the sale of usable biomass.

The spatial diversity of the biomass production level was determined by assigning the normative yield of basic cereals [t/ha/year], (i.e. wheat, rye, triticale, oats and barley) to soil valuation classes and agricultural soil suitability complexes and in the case of grasslands, the index yield of meadow hay [t/ha/year]. Elementary information about the yields of basic cereals was obtained from a research team of the Institute of Soil Science and Plant Cultivation in Puławy supervised by T. Witek[11]. Yield levels from the latest studies

9 P. Lupa, *Ecosystems' local recreational services valuation. Krajenka municipality case study*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 209–222.

10 P. Lupa, A. Mizgajski, *The influence of the data analysis scale on the estimated size of ecosystem services*, "Ekonomia i Środowisko" 2014 no. 4(51), p. 125–136.

11 T. Witek (ed.), op. cit.

on cereal productivity were the basis for proportionate adjustment of yield levels for individual classes and complexes[12]. For this purpose, an assumption was adopted on the constant difference in the size of basic yields between soil valuation classes of agricultural land and between agricultural soil suitability complexes. Apart from grain, as the main yield, the studies included data on the secondary yield in the form of straw was included (t/ha/year). The size of the secondary yield production was estimated according to a conversion factor as 0.48 of the primary yield[13]. It was the arithmetic value of the indices estimated by the cited authors. For grasslands, the size of meadow hay production was estimated by taking into account the standards defined in the thematic literature[14].

The monetary valuation of the analyzed services was performed using arithmetic means of the price of agricultural products calculated on the basis of the data published by Central Statistical Office (CSO) for the 2006–2015 decade. Based on this kind of statistical data for the country, the average prices of basic cereal grain prices – PLN 574.32 per ton, basic cereal straw – PLN 266.40 per ton, meadow hay – PLN 364.52 per ton were adopted and taken into account in the valuation of provisioning services.

The spatial data about the agricultural soil suitability complexes and soil valuation classes of arable land were obtained from the Soil and Agricultural Map of the Piła Province (1:100 000) and the Land and Building Register (1:2000–1:5000) kept by the District Centre of Geodesic and Cartographic Documentation in Złotów.

Using the updated normative values of yields concerning two soil quality classification systems, spatial data from cartographic studies and GIS tools, the contours of soil valuation classes (figure 2A) were plotted on agricultural soil suitability complexes (figure 2B) and compared. In this way, new soil contours were determined, which constitute intersections of two sets of pol-

12 T. Witek, K. Bukowski, *Produktywność gruntów ornych*, Puławy 1997; H. Terelak, S. Krasowicz, T. Stuczyński, *Środowisko glebowe polski i racjonalne użytkowanie rolniczej przestrzeni produkcyjnej,* Pamiętnik Puławski – Materiały Konferencji, z. 120, 2000, p. 455–469; S. Nawrocki, H. Terelak, *Bonitacja a wartość użytkowa gleb Polski*, in: S. Nawrocki, B. Dobrzański, S. Grundas (eds), *Bonitacja i klasyfikacja gleb Polski*, Lublin 2004, p. 7–10; S. Krasowicz, T. Stuczyński, A. Doroszewski, op. cit., p. 27–54.

13 Index was the arithmetic mean value of the ratios estimated by: D.H. McCartney et al., *Review: The composition and availability of straw and Schaff from small grain cereals for beef cattle in western Canada*, "Canadian Journal of Animal Science" 2006 no. 86(4), 10.4141/A05-092, p. 443–455; W. Denisiuk, *Słoma – potencjał masy i energii*, "Inżynieria Rolnicza" 2008 no. 2(100), p. 23–30.

14 H. Czyż, E. Niedźwiecki, M. Trzaskoś, *Charakterystyka czynników siedlisk łąkowych*, in: M. Rogalski (ed.), *Łąkarstwo*, Poznań 2004, p. 13–21; S. Bródka, A. Macias, *Kryteria i metody waloryzacji zasobów przyrodniczych*, w: S. Bródka (ed.), *Praktyczne aspekty ocen środowiska przyrodniczego*, Poznań 2010.

ygons representing the spatial distribution of complexes and classes (figure 2C). This made it possible to determine differences in normative yields and the construction of conversion factors[15].

Factors calculated in this way make it possible to convert the results of quantification of analyzed provisioning services obtained using the SAM data in a scale of 1: 100 000 into a value which would have been estimated for a given area with high probability, if the data on soil valuation classes of agricultural land from LBR had been used originally.

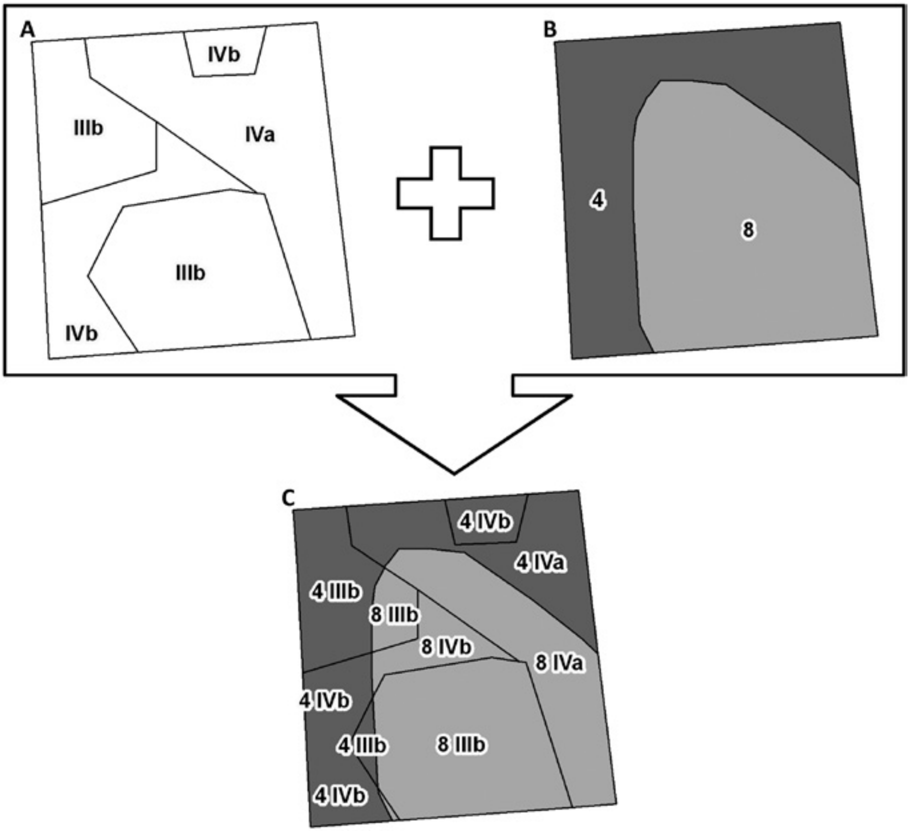

Figure 2. The scheme of determination of the new soil contours

15 The weighted average amount of yield was determined individually for each soil valuation class, based on the spatial data of soil suitability complexes. Calculated amount was compared to the normative yield assigned to a given soil valuation class (table 1 and 2).

Results

Table 1. Updated normative yields of basic cereals (grain and straw) with indices of potential revenue from the sale of usable biomass (arable land)

Classification of soil quality – arable land cereal grain		Yields of [t/ha/year]			Potential revenue from the sale of usable biomass [PLN/ha/year]		
		cereal straw	total	cereal grain	cereal straw	total	
Soil valuation classes of arable land							
I	arable soils of the best quality	5,48	2,63	8,11	3 147	701	3 848
II	arable soils of very good quality	5,08	2,44	7,52	2 918	650	3 568
IIIa	arable soils of good quality	5,01	2,40	7,41	2 877	639	3 517
IIIb	arable soils of medium-good quality	4,52	2,17	6,69	2 596	578	3 174
IVa	arable soils of medium quality, higher	3,97	1,90	5,87	2 280	506	2 786
IVb	arable soils of medium quality, lower	3,41	1,63	5,04	1 958	434	2 393
V	arable soils of poor quality	2,76	1,33	4,09	1 585	354	1 939
VI	arable soils of the poorest quality	2,08	1,00	3,08	1 195	266	1 461
Soil suitability complexes of arable land							
1	very good wheat complex	5,25	2,52	7,77	3 015	671	3 687
2	good wheat complex	4,99	2,39	7,38	2 866	637	3 503
3	poor wheat complex	4,01	1,92	5,93	2 303	511	2 815
4	very good rye complex	4,54	2,18	6,72	2 607	581	3 188
5	good rye complex	3,81	1,83	5,64	2 188	488	2 676
6	poor rye complex	2,75	1,32	4,07	1 579	352	1 931
7	very poor rye complex	2,55	1,22	3,77	1 465	325	1 790
8	good cereal-fodder complex	4,30	2,06	6,36	2 470	549	3 018
9	poor cereal-fodder complex	2,77	1,33	4,10	1 591	354	1 945
10	mountain wheat complex	4,98	2,39	7,37	2 860	637	3 497
11	mountain cereal complex	4,35	2,09	6,44	2 498	557	3 055
12	mountain oat-potatoes complex	3,06	1,47	4,53	1 757	392	2 149
13	mountain oat-fodder complex	2,05	0,99	3,04	1 177	264	1 441
14	arable land suitable for grassland	-	-	-	-	-	-

Source: own work based on literature review and CSO data.

Based on the literature data, the estimated value of provisioning services related to the production of plant biomass was assigned to soil valuation classes and agricultural soil suitability complexes (table 1 and 2).

On the best quality arable land (Class I), the total level of basic cereal production was determined at 8.1 t/ha, which is 2.6 times more than the yield value adopted for the poorest soils (Class VI). In the monetary aspect, the difference between the revenues from the sale of produce was nearly PLN 2400. For agricultural soil suitability complexes, the total cereal yield level on very good wheat complex was estimated at nearly 7.8 ha/t. It was 2 and 2.5 times higher than the potential yield obtained on very poor rye complex and mountain oat-fodder complex. The discrepancy between the potential revenue was nearly PLN 1900 in the first case and PLN 2200 in the second case (table 1).

Depending on the quality of soil of grasslands, the normative yield of the meadow hay was specified at 5 t/ha in Class I up to 1.5 t/ha in Class VI. The difference in the estimated revenues from the sale of such biomass reached nearly PLN 1300. The span of the meadow hay yield per hectare of grassland between the extreme complexes was nearly 3 t, while the difference between revenues was PLN 1050 (table 2).

Table 2. Normative yields of meadow hay with indices of potential revenue from the sale of usable biomass (grasslands)

Classification of soil quality – grasslands		Yields of meadow hay [t/ha/year]	Potential revenue from the sale of usable biomass [PLN/ha/year]
Soil-valuation classes of grasslands			
I	grasslands soils of the best quality	5,0	1823
II	grasslands soils of very good quality	4,0	1458
III	grasslands soils of good quality	3,0	1094
IV	grasslands soils of medium quality	2,0	729
V	grasslands soils of poor quality	1,7	620
VI	grasslands soils of the poorest quality	1,5	547
Soil suitability complexes of grasslands			
1z	very good and good grasslands	4,5	1640
2z	moderate grasslands	2,5	911
3z	poor and very poor grasslands	1,6	583

Source: own work based on literature review and CSO data.

Table 3. Conversion factors of provisioning services value related to production of usable plant biomass in agroecosystems

Classification of soil quality – arable land and grasslands		Conversion factor of total yield (for provisioning agroecosystem services)
Soil suitability complexes of arable land *		
2	good wheat complex	0,763
4	very good rye complex	0,822
5	good rye complex	0,843
6	poor rye complex	1,040
7	very poor rye complex	0,991
8	good cereal-fodder complex	0,904
9	poor cereal-fodder complex	1,003
Soil suitability complexes of grasslands *		
2z	moderate grasslands	0,753
3z	poor and very poor grasslands	1,032
Soil valuation classes of arable land **		
IIIa	arable soils of good quality	0,880
IIIb	arable soils of medium-good quality	0,980
IVa	arable soils of medium quality, higher	1,078
IVb	arable soils of medium quality, lower	1,150
V	arable soils of poor quality	1,220
VI	arable soils of the poorest quality	1,450
Soil-valuation classes of grasslands **		
III	grasslands soils of good quality	0,833
IV	grasslands soils of medium quality	1,248
V	grasslands soils of poor quality	1,468
VI	grasslands soils of the poorest quality	1,626

The use of a factor makes it possible to convert the quantification results for provisioning services connected with the annual production of usable biomass in agroecosystems expressed in tons of biomass per surfaces occupied by:
* a given agricultural soil suitability complex into the size of usable biomass production, which would be estimated for a given surface if data about soil valuation classes from LBR were used; ** a given soil valuation class into the size of usable biomass production which would be estimated for a given surface if data about agricultural soil suitability complexes from SAM in a scale of 1:100 000 were used.

The factors developed on the basis of data obtained for agricultural land in the Krajenka municipality where no soils from complexes 1, 3, 10–14 and 1z and from the valuation classes of soils and grasslands I-II were classified.

In the case of soil valuation classes of arable land, the highest value of the conversion factor was estimated for the poorest arable soils (1.450) and the lowest for good arable soils (0.880). In the case of agricultural soil suitability complexes of arable land, the highest value of the conversion factor was estimated for the poor rye complex (1.040) and the lowest for the good wheat complex (0.763), (table 3).

While transforming the results of quantification from values obtained on the basis of SAM in a scale of 1:100 000 (complexes) into values which would be estimated for the same surface using data from the LBR (classes), reducing coefficients apply more often (<0). This shows that higher quantification results are obtained on the basis of data from SAM than those which were calculated for a given area using LBR data, which was confirmed in previous studies[16].

Conclusions

To quantify provisioning services of agroecosystems related to the production of usable plant biomass, it is recommended that first LBR data should be used, as it is updated on a regular basis by district centres of geodesic and cartographic documentation. Moreover, it is characterized by a higher degree of detail of its contents measured by the average size of the demarcated soil contours, which was 1.45 ha for the analyzed area and which was 64 times smaller than the value from SAM demarcations in a scale of 1:100 000. A drawback of using LBR data is the difficulty in obtaining them for larger areas, e.g. from the entire country or individual regions and the necessity of incurring high costs to gain access to such data.

While using SAM, one should consider the use of conversion factors. They make it possible to obtain similar quantification results for provisioning services using data with a considerably smaller degree of details from SAM in a scale of 1:100 000.

The updated normative yield values, together with indices of the sale of biomass, can be used for the assessment of the agroecosystem potential to provide provisioning services.

Quantification models of agroecosystem services, based on the normative basic cereal yield values are characterized by high sensitivity due to observed considerable fluctuations of the average yield in Poland and in individual regions.

Further research should be aimed at providing missing conversion factors and their testing on other research areas.

16 P. Lupa, A. Mizgajski, op. cit., p. 125–136.

Literature

Boyd J., Banzhaf S., *What are ecosystem services? The need for standardized environmental accounting units*, "Ecological Economics" 2007 no. 63, 2007, p. 616–626

Boyd J., *Location, Location, Location: The Geography of Ecosystem Services*, "Resources" 2008 no. 170, p. 10–15

Bródka S., Macias A., *Kryteria i metody waloryzacji zasobów przyrodniczych*, w: S. Bródka (ed.), *Praktyczne aspekty ocen środowiska przyrodniczego*, Poznań 2010

Czyż H., Niedźwiecki E., Trzaskoś M., *Charakterystyka czynników siedlisk łąkowych*, in: M. Rogalski (ed.), Łąkarstwo, Poznań 2004

Degórski M., *Socio-economic responses to the environment and ecosystem services in regional development*, "Geographia Polonica" 2010 no. 83(2), p. 83–95

Degórski M., *Wykorzystanie świadczeń ekosystemów w rozwoju regionów*, "Ekonomia i Środowisko" 2010 no. 1(37), p. 85–97

Denisiuk W., *Słoma – potencjał masy i energii*, "Inżynieria Rolnicza" 2008 no. 2(100), p. 23–30

Grabiński J., Podolska G., *Stan aktualny i perspektywy zmian w produkcji zbóż w Polsce*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 55–70

Kopiński J., Krasowicz S., *Regionalne zróżnicowanie warunków produkcji rolniczej w Polsce*, "Studia i Raporty IUNG-PIB" 2010 z. 22, p. 9–29

Krasowicz S. , Stuczyński T., Doroszewski A., *Produkcja roślinna w Polsce na tle warunków przyrodniczych i ekonomiczno-organizacyjnych*, "Studia i Raporty IUNG-PIB" 2009 z. 14, p. 27–54

Lupa P., *Ecosystems' local recreational services valuation. Krajenka municipality case study*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 209–222

Lupa P., Mizgajski A., *The influence of the data analysis scale on the estimated size of ecosystem services*, "Ekonomia i Środowisko" 2014 no. 4(51), p. 125–136

McCartney D.H. et al., *Review: The composition and availability of straw and Schaff from small grain cereals for beef cattle in western Canada*, "Canadian Journal of Animal Science" 2006 no. 86(4), 10.4141/A05-092, p. 443–455

Nawrocki S., Terelak H., *Bonitacja a wartość użytkowa gleb Polski*, in: S. Nawrocki, B. Dobrzański, S. Grundas (eds), *Bonitacja i klasyfikacja gleb Polski*, Lublin 2004

Norris K., Potts S.G., Mortimer S.R., *Ecosystem services and food production*, in: R.E. Hester, R.M. Harrison (eds), *Ecosystem services, Issues in Environmental Science and Technology*, vol. 30, 2010, p. 52–69

Rosin Z.M. et al., *Koncepcja świadczeń ekosystemowych i jej znaczenie w ochronie przyrody krajobrazu rolniczego*, "Chrońmy Przyrodę Ojczystą" 2011 no. 67(1), p. 3–20

Terelak H., Krasowicz S. , Stuczyński T., Środowisko glebowe polski i racjonalne użytkowanie rolniczej przestrzeni produkcyjnej, Pamiętnik Puławski – Materiały Konferencji, z. 120, 2000, p. 455–469

Witek T. (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski według gmin*, Puławy 1981

Witek T., Bukowski K., *Produktywność gruntów ornych*, Puławy 1997

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THE USE OF THE FOREST FUND IN THE PROTECTION OF NATURAL RESOURCES IN POLAND

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WYKORZYSTANIE FUNDUSZU LEŚNEGO W OCHRONIE ZASOBÓW NATURALNYCH W POLSCE

STRESZCZENIE: W artykule przedstawiono zasady gromadzenia i wydatkowania środków Funduszu Leśnego oraz przeanalizowano wielkość i strukturę jego dochodów i wydatków. Ze względu na sposób prezentacji danych dotyczących kierunków wydatków Funduszu Leśnego przez PGL LP i GUS trudności sprawia dokładne oszacowanie, w jakim stopniu środki Funduszu są przeznaczane na działania służące ochronie zasobów leśnych. Można jednak przyjąć, uwzględniając specyfikę i zasady prowadzenia gospodarki leśnej w PGL LP, że większość środków Funduszu Leśnego wspiera ochronę tych zasobów.

SŁOWA KLUCZOWE: fundusze ekologiczne, ochrona zasobów leśnych, Lasy Państwowe

Introduction

In the system for financing environmental protection in Poland, a special role is played by environmental funds whose essence is to collect funds in accordance with the "polluter pays" principle and their redistribution aimed at supporting projects for the protection of natural resources and sustainable development. Ecological funds include the Polish National Fund for Environmental Protection and Water Management (NFEPWM) and its provincial counterparts (PFEPWM), currently operating as public entities. By 2010, there were also district and municipal earmarked funds for environmental protection and water management that have been incorporated directly into the budgets of the local government units and are the so-called environmental budgets of districts and municipalities. Environmental funds also include the Forest Fund[1] which is "a form of the management of funds for the purposes specified in the Forest Act"[2] and constitutes a separate account of the State Forests National Forest Holding.

The aim of the article is to demonstrate the functioning of the Forest Fund and to evaluate its use in terms of the financial support for the protection of natural resources.

Principles of the Forest Fund's operations

The Forest Fund that has been existing in Poland for more than 40 years in its current form was created under the Forest Act of 1991[3] and plays an important role in the financial management of the State Forests. Its financial resources are under the control of the General Director of the State Forests National Forest Holding. The income of the Forest Fund, as defined in the Forest Act, includes:

- the basic write-off calculated from the value of timber sales, burdening the operating costs of forest districts;

1 A. Barczak, E. Kowalewska, *Źródła finansowania zadań z zakresu ochrony środowiska w Polsce – przegląd stosowanych rozwiązań,* "Prawo Budżetowe Państwa i Samorządu" 2014 no. 1(2), p. 43; A. Lipiński, *Prawne podstawy ochrony środowiska,* Warsaw 2010, p. 353.

2 The Forest Act of 28 September 1991 ("Journal of Laws" 1991 no. 101, item 444, as amended).

3 J. Piekutin, *Analiza funkcjonowania funduszu leśnego w systemie finansowym Lasów Państwowych na przykładzie Regionalnej Dyrekcji Lasów Państwowych w Radomiu*, "Sylwan" 2006 no. 6, p. 4.

- charges, penalties and fees associated with the exclusion of forest land from production;
- claims arising from damages:
  - civil law for damages being as a result of the impact of industrial gases and dust, as well as other titles,
  - due for the premature felling forests on the basis of the Act on the protection of agricultural and forest land[4],
  - for damages resulting from fires, mining and geological activities;
- income resulting from the shares or from the sale of shares in companies;
- budgetary subsidies;
- other income.

The size of the basic write-off calculated as a percentage for the year in relation to the income planned from timber sales on the basis of the financial and economic plan of the State Forests National Forest Holding in the years 2002–2016 ranged from 10% to 15%.

The amendment to the Forest Act dated 2016[5] extended the possibilities for the use of the Forest Fund by supporting national parks, among others, at the purchase of real estate located within parks to the Treasury and the creation by parks of the infrastructure necessary for the nature conservation implemented through forest management methods.

According to the amended Forest Act, the income of the Forest Fund is spent on offsetting shortfalls of financial resources (funding) in forest districts resulting from the implementation of the tasks of forest management arising from the differing conditions of the economy and (in 2016) the tasks relating to public administration in the field of forestry. The funds for offsetting shortfalls of financial resources are determined according to the financial result, liquidity ratios and debt of forest districts[6].

Other trends include spending the Forest Funds' financial resources on[7]:

- joint ventures of the organizational units of the State Forests, in particular in the field of forest management;
- scientific research;
- creating the necessary infrastructure for forest management;
- preparation of forest management plans;

4 The Act on the protection of agricultural and forest land of 3 February 1995 ("Journal of Laws" 1995 no. 16, item 78, as amended).

5 The Act of 11 March 2016 amending the Forest Act and the Nature Protection Act ("Journal of Laws" 2016, item 422).

6 Decree No. 1 of the General Director of State Forests of 31 January 2012 on the rules and procedures in the organizational units of the State Forests in terms of disposing of the Forest Fund, "Bulletin of the State Forests" 2012 no. 3(231), pp. 3–14.

7 The Forest Act of 28 September 1991 ("Journal of Laws" 1991 no. 101, item 444, as amended).

- works related to the assessment and forecasting of the state of forests resources;
- protection in the forests implemented through the methods of forest management;
- acquisition by the State Treasury of forests and land for afforestation;
- other tasks in the field of forest management in forests.

The use of the Forest Fund's income arising from receivables, penalties and fees associated with the exclusion of forest land from production and due for premature felling forests in the forests not owned by the Treasury and in national parks is strictly defined and includes, among others, afforestation of non-state land and the purchase by national parks of real estate located within their boundaries.

Since the late 90s of the previous century, various legislative proposals have been developed focusing on the use of the Forest Fund's financial resources for other tasks than those associated with forest management, as defined in the Forest Act. They mainly concerned compensation for lost property within re-privatization settlements. The government draft act on the re-privatization of property and some personal belongings taken by the State or the municipality of the city of Warsaw and compensations dated 1999 provided for the redemption of re-privatization bonds by the State Forests National Forest Holding from their owners who had to receive them for the loss of forest real estates. The redemption of bonds was to be financed by the Forest Fund. A similar proposal was included in another government draft act dated 2008 on redress in respect of the damages resulting from the nationalization processes during the years 1944–1962. The draft act amending the Public Finance Act and other acts of September 2010 provided for including the State Forests National Forest Holding in the public finance sector. The Minister of Finance was to be authorized to dispose of the free funds of National Forests, including the financial resources of the Forest Fund, in order to reduce the borrowing needs of the state budget. Finally, the provisions have not been implemented.

Income of the Forest Fund

In Poland, the annual income of the Forest Fund in the years 2006–2015 (see figure 1) was at the level of 737 – 1,244 mill. PLN (in fixed prices of 2015). The amount of the financial resources held by the Fund is relatively large in comparison with other funds for environmental protection: the National Fund, provincial funds for environmental protection and water management and environmental budgets of districts and municipalities. According to the data published by the Polish Central Statistical Office[8], the Forest Fund was the second among environmental funds, following the National Fund, in terms of the size of income as well as expenditure in 2012–2014[9]. Figure 2 shows the increase and decrease of environmental protection funds in 2014.

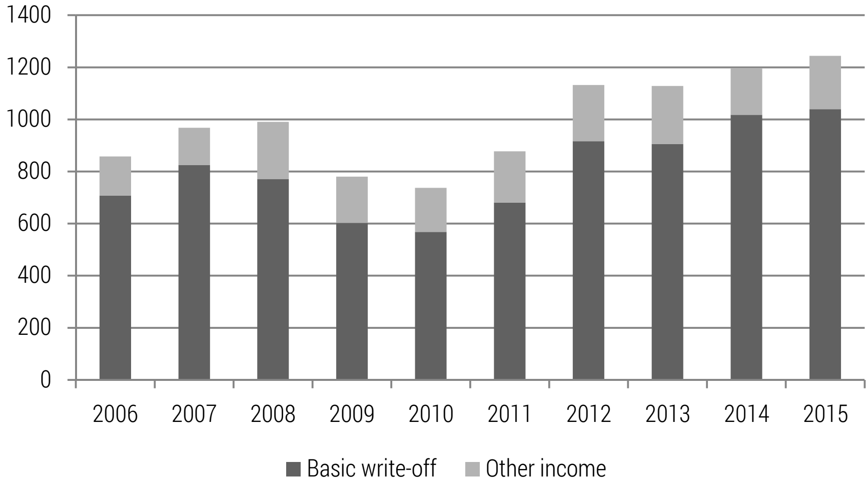

Figure 1. The income of the Forest Fund in the years 2006–2015 in mill. PLN (fixed prices 2015)

Source: own development based on: *Forestry 2007*, Warsaw 2007; *Forestry 2008*, Warsaw 2008, financial and economic reports of the State Forests National Forest Holding for 2008–2015 and the Central Statistical Office data concerning the annual price indices of consumer goods and services.

As in the case of other environmental funds, the financial resources collected for the Forest Fund are primarily associated with the use of natural resources (felling forests) and the negative impact of human activities on the environment, in line with the "polluter pays" principle.

The main source of the income of the Forest Fund, from the beginning of its operations, has been the basic write-off burdening forest districts, the size of which depends on the price and sales volume of the harvested timber and the fixed percentage surcharge on income from timber sales. In 2011–2015, the share of the basic write-off in the total income of the Fund ranged from 78% to 85%. Detailed data on the Forest Fund's income structure is presented in table 1.

[8] *Environmental protection* [2013–2015]; Central Statistical Office, Warsaw [2013–2015]; *Forestry* [2013–2015], Central Statistical Office, Warsaw [2013–2015].

[9] The exception is 2012 when the income of provincial environmental protection funds was greater than the income of the Forest Fund by 7 mill. PLN.

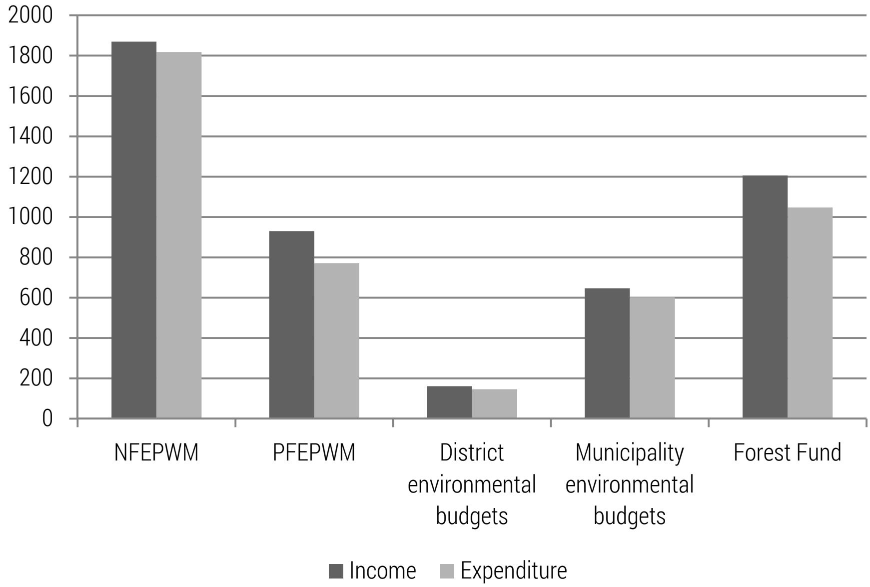

Figure 2. The income and expenditure of funds for environmental protection and water management, environmental budgets and the Forest Fund in 2014 [mill. PLN]

Source: *Environmental protection 2015*, Warsaw 2015, p. 449–450; *State Forests National Forest Holding. Financial and economic report 2014*, Warsaw 2015, p. 17.

Table 1. The Forest Fund's income structure in 2011–2015 [%]

Specification	2011	2012	2013	2014	2015
The basic write-off burdening the costs of forest districts	77.6	80.9	80.2	85.1	83.5
Additional income a)	12.9	10.1	10.0	9.9	11.2
Additional income b)	3.8	3.1	3.8	3.2	3.7
Income from shares in companies	0.2	0.4	0.0	0.0	0.0
Other income related to the State Forests	4.6	4.5	5.5	1.3	1.2
Other income for the forests constituting property of the Treasury and national parks	1.0	0.9	0.5	0.5	0.4
Total	100.0	100.0	100.0	100.0	100.0

a) Receivables, penalties and fees associated with the exclusion of forest land from production; receivables arising from compensations for damages resulting from the impact of industrial gases and dust, fires, mining and geological activities and due for the premature felling forests on the basis of the Act on the protection of agricultural and forest land
b) the funds related to the exclusion of forest land constituting property of the Treasury and the forests managed by national parks from production.
Source: own development based on financial and economic reports of the State Forests National Forest Holding for the period 2011–2015.

The share of income related to compensations for the negative impact of economic activity on the quantity and quality of forest resources (dues, penalties and fees associated with the exclusion of forest land from production, receivables arising from compensation for damages resulting from the impact of gases and industrial dust, fires, mining and geological activities and due for the premature felling forests on the basis of the Act on the protection of agricultural and forest land and related funds, excluding the production of forest land not owned by the State Treasury and the forests managed by national parks) totaled approx. 13–17% in the total income of the forest Fund in the reporting period of 2011–2015.

The least important to extending the Forest Fund is the income due from the bonds and shares in companies held by the State Forests National Forest Holding. In 2011 and 2012, they amounted to 1.8 mill. PLN and 4.4 mill. PLN, which accounted for 0.2% and 0.4% of the total income of the Fund.

Trends of Forest Fund's expenditure

The level of expenditure of the Forest Fund in the years 2006–2015 varied and ranged between 611 and 1312 mill. PLN (in fixed prices of 2015, cf. figure 3). The annual average expenditure in the period amounted to 931 mill. PLN. The expenditure incurred accounted for 43% (in 2010) to 68% (in 2006) of the disposable funds, the total of the Fund's income at the beginning of the year and collected over the year. This means that the Forest Fund has certain reserve funds which, under unfavorable natural and/or economic conditions, can provide financial stability necessary for forest management, taking into account the principles of sustainable development.

The largest share in the total expenditure of the Fund is the so-called gross surcharge to the activities of forest districts allocated to offsetting shortfalls of the financial resources (funds) of forest districts resulting from the implementation of the tasks of forest management. In 2011–2015, the share of the surcharge in the total expenditure was from 61% to 75% each year. The structure of the Fund's expenditure in the reported period is presented in table 2. Other important categories of expenditure in terms of the share in the total volume include: "the creation of infrastructure for forest management" (5%–16%) and "joint ventures of the organizational units of the State Forests" (7%–9%).

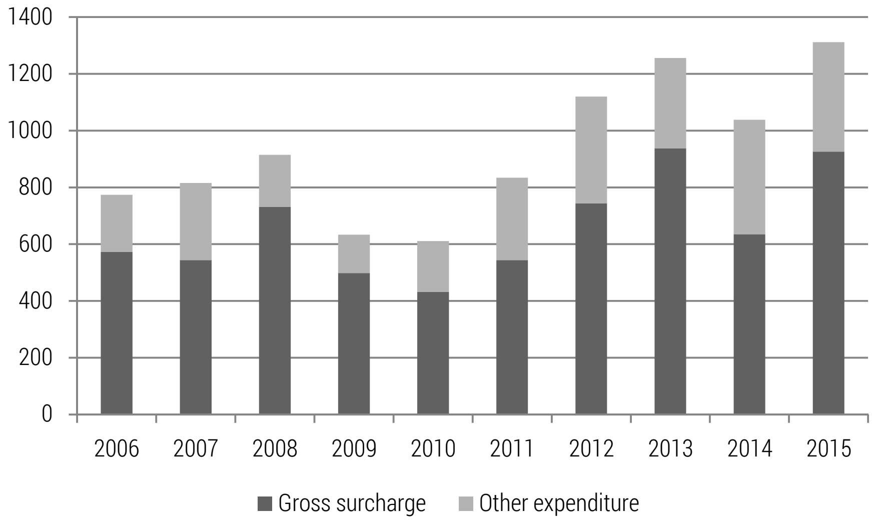

Figure 3. Expenditure of the Forest Fund in the years 2006–2015 mill. PLN (fixed prices 2015)

Source: own development based on: *Forestry 2007*, Warsaw 2007; *Forestry 2008*, Warsaw 2008, financial and economic reports of the State Forests National Forest Holding for 2008–2015 and the Central Statistical Office data concerning the annual price indices of consumer goods and services.

The ratio of the size of gross surcharge to the size of the basic write-off in the period 2011–2015 amounts to 78, 80, 81, 104% and 62% respectively, which indicates that the Forest Fund is mainly used as a tool for the redistribution of funds between forest districts.

The level of the available Central Statistical Office data detail (the *Forestry* yearbook) and the data from the State Forests National Forest Holding (financial and economic reports) shown in table 2 do not enable specifying how much of the Fund's expenditure can be classified as expenditure for the protection of forest resources.

For example, the subject of the joint ventures of the organizational units of the State Forests can be tasks including the field of telecommunications and road construction10, not environmental.

10 The guidelines on the participation of the organizational units of the State Forests in the implementation of joint projects with the involvement of the funds of the State Forests, the Annex to Order No. 44 of the Director General of the State Forests of 29 June 2009.

Table 2. Forest Fund's expenditure structure in 2011–2015 [%]

Specification	2011	2012	2013	2014	2015
Offsetting shortfalls of financial resources (gross surcharge for forest districts' activities)	65.2	66.4	74.7	61.2	70.6
Joint ventures of the organizational units of the State Forests	8.4	8.0	8.1	8.6	7.3
Creating infrastructure for forest management	16.1	15.3	5.3	15.3	10.7
Scientific research	3.7	3.8	3.4	4.3	3.2
Preparation of forest management plans	5.8	4.6	4.8	6.5	5.4
Work related to the assessment and forecasting the state of forests and forest resources	0.1	0.1	0.1	0.1	0.1
Funding afforestation of land not owned by the State Treasury and scientific research and tasks within forest management in national parks	0.7	1.2	2.4	3.3	2.2
Other expenditure	0.0	0.7	1.2	0.7	0.5
Total	100.0	100.0	100.0	100.0	100.0

Source: own development based on financial and economic reports of the State Forests National Forest Holding for the period 2011–2015.

Not all scientific research funded by the Forest Fund is related to the preservation, protection and enlargement of forest resources. For example, in 2011, out of the 69 implemented research projects 15 were related to forest protection, 8 – environmental protection, 33 – forest cultivation and use, the other 13 were related to such areas as marketing, economics, human resources and occupational health and safety[11].

Table 3. Financing the protection of forest ecosystems in national parks from the Forest Fund

Specification	2012	2013	2014	2015	2016
Number of parks receiving support	9	16	21	21	20
Number of contracts signed with national parks	16	21	24	26	No data
Amount of contracts signed [mill. PLN]	11.9	19.8	24.6	30.2	60.5
Use of funds [mill. PLN]	No data	No data	19.7	20.5	No data

Source: own development based on financial and economic reports of the State Forests National Forest Holding, the information at the Coordination Centre for Environmental Projects; www.ckps.lasy.gov.pl [15-09–2016] and the websites of national parks.

11 *The State Forests National Forest Holding financial and economic report 2011*, Warsaw 2012.

It should be noted, however, that in accordance with art. 8 of the Forest Act, forest management should be conducted according to the principles of universal forest protection, durability, maintenance of forests, continuity and sustainable use of all of the functions of forests and expansion of forest resources. It can therefore be assumed that offsetting shortfalls of financial resources in forest districts as well as other generally defined trends of the Forest Fund spending partly benefit, directly or indirectly, the expended protection of forest resources.

More detailed data on the use of the Fund for strictly environmental purposes concerns financial support for national parks. The financing projects aimed at environmental protection implemented using the methods of forest management and scientific research carried out in these entities have been taking place in a wide range from 2012[12] (cf. table 3). The websites of national parks include information about contracts concerning the use of the Fund along with descriptions of the funded projects (in most parks) and the size of funding granted. In some national parks (including the Tatra National Park, the Gorce National Park), the funds from the Forest Fund have been the main and significant source of funding for projects in recent years. For example, the Gorce National Park signed an agreement for co-financing projects from the financial resources of the National Fund for Environmental Protection and Water Management in 2013–2016 totaling 3,425 thous. PLN and from the financial resources of the Forest Fund in the total amount of 6,055 thous. PLN.

Conclusions

The Forest Fund, classified as environmental fund, is an element of the financial management of the State Forests. The size of the income and expenditure is comparable to the (total) funds collected and used by provincial funds for environmental protection and water management. The structure of the income and expenditure of the Forest Fund has not been subject to fundamental change from the beginning of its activities. The main source of its income is the basic write-off burdening the operating costs of forest districts. Most of the expenditures of the Fund is intended to offset the shortfalls of the financial resources of forest districts arising from the differing conditions of forest management. The use of the Fund is therefore primarily for the redistribution of funds between individual forest districts.

The Forest Fund has been becoming an increasingly important source of financing for the protection of forest ecosystems in national parks since

12 *The State Forests National Forest Holding financial and economic report 2014*, Directorate General of State Forests, Warsaw 2015, p. 21.

2012. Due to the presentation of the data on the spending trends of the Forest Fund by the State Forests National Forest Holding and the Central Statistical Office, accurate estimation of the extent to which the Fund's financial resources are spent on measures aimed at protecting forest resources is difficult. However, it can be assumed, taking into account the specificities and principles of forest management at the State Forests National Forest Holding, that the majority of the Forest Fund financing supports the protection of natural resources.

Literature

Barczak A., Kowalewska E., *Źródła finansowania zadań z zakresu ochrony środowiska w Polsce – przegląd stosowanych rozwiązań*, "Prawo Budżetowe Państwa i Samorządu" 2014 no. 1 (2), pp. 37–58

Decree No. 1 of the General Director of State Forests of 31 January 2012 on the rules and procedures in the organizational units of the State Forests in terms of disposing of the Forest Fund, "Bulletin of the State Forests" 2012 no. 3(231), pp. 3–14

www.ckps.lasy.gov.pl

Lipiński A., *Prawne podstawy ochrony środowiska,* Warsaw 2010

Piekutin J., *Analiza funkcjonowania funduszu leśnego w systemie finansowym Lasów Państwowych na przykładzie Regionalnej Dyrekcji Lasów Państwowych w Radomiu*, "Sylwan" 2006 no. 6, pp. 3–18

The Act on the protection of agricultural and forest land of 3 February 1995 ("Journal of Laws" 1995 no. 16, item 78, as amended)

The Act of 11 March 2016 amending the Forest Act and the Nature Protection Act ("Journal of Laws" 2016 item 422)

The Forest Act of 28 September 1991 ("Journal of Laws" 1991 no. 101, item 444, as amended)

The guidelines on the participation of the organizational units of the State Forests in the implementation of joint projects with the involvement of the funds of the State Forests, the Annex to Order No. 44 of the Director General of the State Forests of 29 June 2009

The State Forests National Forest Holding financial and economic report 2008–2015, Warsaw 2009–2016

Marta SYLLA

MAPPING AND ASSESSMENT OF THE POTENTIAL TO SUPPLY SELECTED ECOSYSTEM SERVICES AT A SUB-REGIONAL SCALE. THE EXAMPLE OF WROCLAW AND ITS SURROUNDING MUNICIPALITIES

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MAPOWANIE I OCENA POTENCJAŁU ŚWIADCZENIA USŁUG EKOSYSTEMÓW W SKALI SUB-REGIONALNEJ NA PRZYKŁADZIE WROCŁAWIA I GMIN OŚCIENNYCH

STRESZCZENIE: Usługi ekosystemów przyczyniają się do podnoszenia jakości życia mieszkańców miast i obszarów suburbialnych, co sprawia, że ich kwantyfikacja i przestrzenne rozmieszczenie jest istotne z punktu widzenia planowania przestrzennego. W pracy przedstawiono wyniki kartowania potencjału dostarczania dwóch wybranych usług ekosystemów dla skali sub-regionalnej na przykładzie miasta Wrocławia i gmin ościennych. Badanie dotyczy usług ekosystemów zaopatrujących (dostarczanie pożywienia) oraz regulacyjnych (regulacja klimatu globalnego poprzez zmniejszenie koncentracji gazów cieplarnianych).

SŁOWA KLUCZOWE: usługi ekosystemów, kartowanie za pomocą narzędzi GIS, obszary podmiejskie

Introduction

The urban and suburban areas undergo increased human pressure due to urbanisation processes[1]. In Europe about 75% of population lives in urbanised areas[2]. In Poland about 60 percent of population consists of urban dwellers[3]. Cities host daily activities of their inhabitants; they are also important academic and business centres that attract people from rural surroundings. Transportation infrastructure and built up areas constitute a great share of cities' surfaces, leaving green infrastructure fragmented and under constant pressure of pollution[4]. The condition of living in cities affects human health[5]. Climate change is going to increase the negative effects of air pollution, traffic noise, and urban heat island to our health[6]. The ecosystems provide us with benefits that can reduce the risks to human health and well-being[7]. The benefits provided by ecosystems are captured by the ecosystem service (ES) concept. The ecosystem service concept can serve as a comprehensive approach in understanding the dynamic feedbacks between human and environmental components of the urban systems[8]. Ecosystem services in cities are mainly provided by green infrastructure within the city boundaries[9]. However, urban dwellers also take direct advantage of ecosystem services provided in the surrounding areas[10]. The aim of the study is to assess spatial changes in Wroclaw and its suburban municipalities in terms of the potential of ecosystems to provide selected ecosystem services.

1 T. Elmqvist et al., *History of Urbanization and the Missing Ecology,* in: *Urbanization, biodiversity and ecosystem services: challenges and opportunities. A Global Assessment*, Dordrecht, Heidelberg, New York, London 2013, p. 14.

2 *Urban Environment*, www.eea.europa.eu [01-09–2016].

3 www.stat.gov.pl [01-09–2016].

4 E. Andersson et al., *Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services*, "AMBIO" 2014 no. 43, p. 445–453.

5 I. Douglas, *Urban ecology and urban ecosystems: understanding the links to human health and well-being*, "Current Opinion in Environmental Sustainability" 2012 no. 4(4), p. 385–392.

6 *Urban adaptation to climate change in Europe 2016*. EEA Report No 12/2016.

7 T. McPhearson et al., *Resilience of and through urban ecosystem services*, "Ecosystem Services" 2014 no. 12, p. 152–156.

8 T. McPhearson et al., Advancing Urban Ecology toward a Science of Cities, "BioScience" 2016 no. XX(X), p. 1–15.

9 J. Langemeyer et al., *Contrasting values of cultural ecosystem services in urban areas: The case of park Montjuïc in Barcelona*, "Ecosystem Services" 2014, p. 1–9.

10 D. Łowicki, *Land prices as an indicator of the recreational services of ecosystems*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 167–175.

Study area

The case study area consists of the city of Wroclaw and its suburban municipalities (figure 1). The suburban municipalities (i.e. Kostomłoty, Miękinia, Oborniki Śląskie, Wisznia Mała, Czernica, Długołęka, Kąty Wrocławskie, Kobierzyce, Sobótka, Święta Katarzyna /Siechnice, Żórawina) cover the area of 1430 km^2. Together with the city of Wroclaw (293 km^2) they constitute a major part of the Wroclaw Metropolitan area. The case study area is located in the Lower Silesia region in the west-south part of Poland. The climate of this area belongs to the temperate group of climates and in detail is described as transitional between maritime and continental. Average annual precipitation is 590 mm of rainfall and the annual average temperature is 9,3°C[11]. These parameters together with high quality soils constitute highly favourable agriclimate.

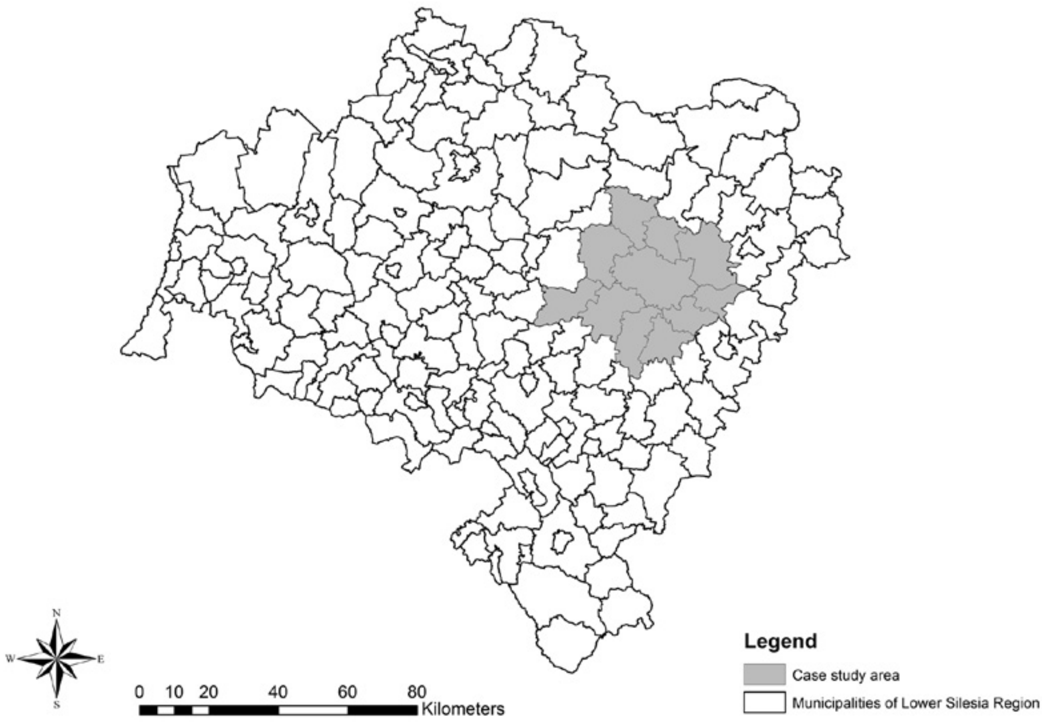

Figure 1. The case study area

[11] *Stan i zmiany właściwości gleb użytkowanych rolniczo w województwie dolnośląskim w latach 2000–2005*, Puławy Wrocław 2007, p. 19–20.

The study area was chosen based on land use change and the results of the study on every day commuting to work of the inhabitants of Wroclaw and surrounding municipalities[12]. The surrounding municipalities undergo intensive processes of suburbanisation. The land cover patterns of the main CORINE land cover classes for Wroclaw and suburban municipalities proves main challenges that the suburban area is facing. The biggest losses in terms of land cover are of non-irrigated arable lands and biggest gains in the urbanised areas. The urbanised areas have increased by 3 times, when arable land has decreased by 12%. The previous studies concerning this area prove the increasing land use changes into urbanised areas are supported and enhanced by the spatial planning documents[13]. The spatial policies are designed to enlarge urban area to host 2,600,000 inhabitants, which is more than three time the current number of citizens[14].

Materials and methods

The author analyses spatial distribution of two ecosystem services representing the two main types of ES distinguished in CICES 4.3 over the course of years 1990–2012. Food provision and global climate regulation by reduction of greenhouse gas concentrations were approached according to different quantification methods (table 1). The mapping activity was based on Corine Land Cover (CLC) data sets provided by the European Environment Agency for years 1990, 2000, 2006, and 2012. Therefore, unlike Urban Atlas, the use of CLC enabled the comparisons between different time spans. The spatial resolution of CLC is enough for setting the policy guidelines at sub-regional scale[15]. At the local level, though, the use of CLC may lead to overestimation of ecosystem service provision[16].

12 *Dojazdy do Pracy*. Narodowy Spis powszechny Ludności i Mieszkań 2011, Warszawa 2014, p. 170.

13 J. Kazak, Sz. Szewrański, J. Sasik, *Gospodarowanie zasobami przestrzennymi w strefie podmiejskiej Wrocławia* (Spatial Resource Management in the Suburban Area of Wroclaw), Studia Komitetu Przestrzennego Zagospodarowania Kraju PAN (Studies of Committee for Spatial Economy and Regional Planning of Polish Academy of Science) 2013 vol. 22, no. 1, p. 185–197.

14 J. Kazak, Sz. Szewrański, P. Decewicz, *Holistic Assessment of Spatial Policies for Sustainable Management: Case Study of Wroclaw Larger Urban Zone (Poland),* in: D. Lee, E. Dias, H.J. Scholten (eds), *Geodesign by Integrating Design and Geospatial Sciences*, Springer 2014.

15 F. Kroll, et al., *Rural-urban gradient analysis of ecosystem services supply and demand dynamics*, "Land Use Policy" 2012 no. 29(3), p. 521–535.

16 M. Kandziora, B. Burkhard, F. Müller, *Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution*, "Ecosystem Services" 2013 no. 4, p. 47–59.

Table 1. Overview of ES indicators and quantification methods used in the assessment

Ecosystem Service		Method	Description	Unit	Relevant ecosystem type
Provisioning services					
Food supply	Crops production	Proxy-based method	The capacity of ecosystem to provide winter wheat crop service	[t/ha/yr]	Agricultural land
Regulating services					
Global climate regulation	Reduction of greenhouse gas concentrations	Benefit transfer	The capacity of ecosystem to store carbon in the above- and below-ground part of living plant material	[tC/ha/yr]	Forest and urban

Food provision

Food provision is a providing ecosystem service defined as "the capacity of agro-ecosystems to provide crop services"[17]. Food provision can be quantified using different methods. Egoh et al[18] classified the quantification methods into three categories:

- collection of primary data through direct observations;
- proxy methods in which a single or combined indicators are used to define ES, such as composite indicators;
- process models in which indicators are used as variables in the equation.

Food provision, as the ecosystem service that is soil and climate dependant, is spatially explicit. The most common data used for mapping food provision is land cover/land use maps, soil data and vegetation types. MAES 2nd Technical Report[19] suggests two indicators for the food supply quantification: as the volume of yields of food and feed crops in t/ha [ton dry matter/ha, or MJ/ha] and food and feed crop area [ha].

In this study, the food supply is defined as the potential of agro-ecosystems to provide crop services. The potential depends on various environmental factors related to soil quality and its type, agriclimate, water relations, topography and human induced factors such as agrotechnique, machinery and grains type, time of seeding, etc. In the case study region, the agricultural production consists mainly of cereals (71% of total farmland), among which

17 J. Maes, M.L. Paracchini, G. Zulian, *A European assessment of the provision of ecosystem services. Towards an atlas of ecosystem services,* European Union 2011.

18 B. Egoh, et al., *Indicators for mapping ecosystem services: a review*, European Union 2012.

19 *Mapping and Assessment of Ecosystems and their Services*, Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020, 2nd Report – Final, European Union 2014, s. 42.

the wheat production has the greatest share (36% of total farmland[20]). Therefore, in the food provision wheat production is taken as a proxy of food supply. The composite indicator for evaluation of agricultural production area is used for describing the ecological potential for food provision. The indicator consists of four elements: soil quality and type suitability for agricultural production, agroclimate, water relations (soil moisture) and topography[21]. The case study areas is 1430 km^2 of similar topography and agriclimate. Therefore, it is the soil type and class that have the biggest effect on changes in the agricultural production for this case study area. The potential wheat harvest in the case study areas is explained using two main variables: soil classes suitable for agricultural production and field study data on harvest with the use of basic agrotechnique (table 2).

Table 2. Soil classes suitable for agricultural production and field study data on harvest

Soil class number	Soil class description	Harvest volumes of winter wheat with basic agrotechnique (a1) –averages for 1999–2013 [t/ha]
1	Wheat very good	8,3
2	Wheat good	7,8
3	Wheat defective	5,8
4	Rye very good (wheat-rye)	7,0
5	Rye good	5,6

Source: *Stan i zmiany właściwości gleb użytkowanych rolniczo w województwie dolnośląskim w latach 2000–2005*, Puławy Wrocław 2007; Polish Official Variety Testing. Variety Testing Experimental Station database.

Global climate regulation

Global climate regulation by reduction of greenhouse gas concentrations is a regulating ecosystem service. The main greenhouse gas that is considered in prevailing studies on mapping and assessment of this service is carbon dioxide. The IPCC 2006[22] distinguishes five carbon pools: above- and below-ground biomass, deadwood, litter and soil organic carbon. These pools

20 *Podstawowe informacje według podregionów, powiatów i gmin województwa dolnośląskiego,* Powszechny Spis Rolny 2010, Wrocław 2012.

21 *Stan i zmiany właściwości…*, op. cit., s. 19–20.

22 IPCC 2006 Guidelines for National Greenhouse Gas Inventories, www.ipcc-nggip.iges.or.jp [08-08–2016].

are ecosystems that can store and sequester carbon. Carbon sequestration can be estimated by physically measured gas exchange, expressed in the ecosystem productivity indicators[23], or same as carbon storage, by applying different equations, the most of which include biomass expansion factor, carbon fraction of dry matter or net annual increment. Due to data limitation, the final values of carbon storage of different ecosystem were transferred to the case study area. Each land use class of CLC was attributed with the possible carbon storage capacity in hectares per year based on literature review and default numbers provided in the IPCC Guidelines for National Greenhouse Gas Inventories 2006. The benefit transfer of tonnes of carbon stored in the above- and below-ground parts of living plant material per year is applied to different land use classes. The main criteria for benefit transfer were climatic zone, geolocation of the study site, and year of publication of results.

Carbon storage is equated with the net removal of CO_2 and therefore any land use/cover classes that have no net accumulation of biomass carbon stocks within the year are excluded from the analysis. These are: agricultural areas, complex cultivation patterns and pastures, construction sites and mineral extraction sites.

The spatial distribution of the above- and below-ground carbon stored in living plant material is presented. The carbon storage is estimated for the following ecosystems and land use types: forest, settlements and woody plantations (table 3).

Table 3. Default and literature review values for carbon stored in biomass

Land Cover Class	[tC/ha/yr]	Source
Broad-leaved forest	123,17	IPCC 2006, Forest data bank
Coniferous forest	133,84	IPCC 2006, Forest data bank
Mixed forest and fruit trees and berries	119,73	IPCC 2006, Forest data bank
Green urban areas and transitional woodland shrub	69,7	Literature review[a)]
Discontinuous urban fabric and transport, sport and leisure facilities	12,5	Literature review[a)]
Continuous urban fabric	10	Literature review[b)]

a) T. Elmqvist et al., *Benefits of restoring ecosystem services in urban areas*. "Current Opinion in Environmental Sustainability" 2015 no. 14, p. 101–108.
b) M.W. Strohbach, D. Haase, *Above-ground carbon storage by urban trees in Leipzig, Germany : Analysis of patterns in a European city*, "Landscape and Urban Planning" 2012 no. 104(1), p. 95–104.

23 A. Danielewska, M. Urbaniak, J. Olejnik, *Growing season length as a key factor of cumulative net ecosystem exchange over the pine forest ecosystems in Europe*, "International Agrophysics" 2015 no. 29, p. 129–135.

Results

Food provision

The results show changes in the proxy-based estimated capacity of the ecosystem to provide food supply ecosystem service and in the possible harvest of winter wheat according to the assumptions taken. The main differences between two referencing years are caused by land use change taking place taken place on the soils that have the biggest ecological potential for food provision. The harvest area shrank by 2,75% which constitutes 668 ha (figure 2).

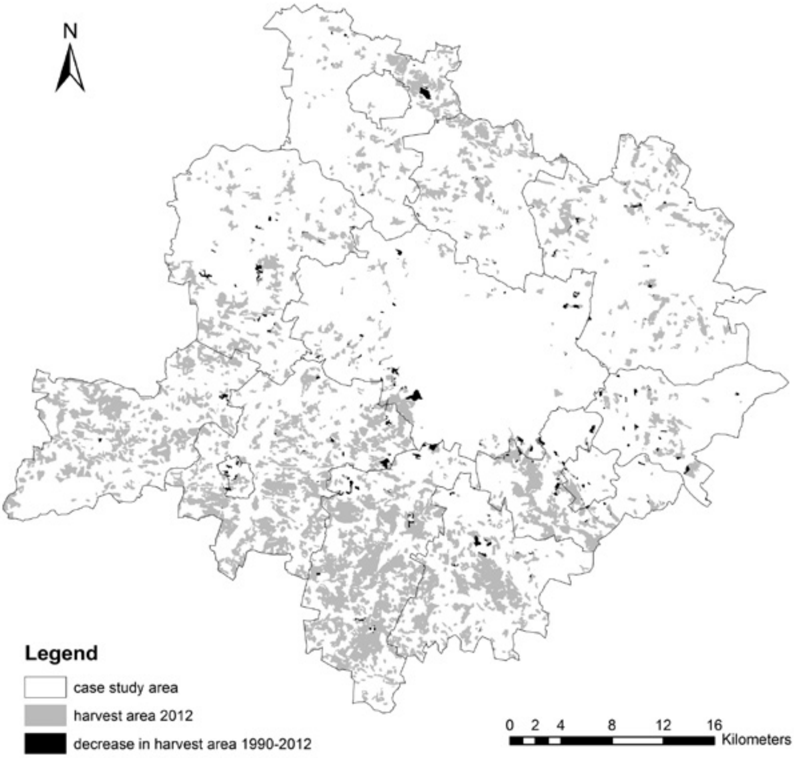

Figure 2. The spatial distribution of food supply service in 2012 and decrease in harvest area between 1990–2012

The loss in the harvest area could lead to the possible loss of 5271,6 t of harvested winter wheat. Almost 48% of land use changes resulted of the conversion from agricultural areas with high quality soils to discontinuous urban fabric. Next most often directions of land use changes were into industrial or commercial units (8%) and pastures (7%).

Global climate regulation

The potential of the ecosystems to provide global climate regulation vary between the 1990 and 2012 in the case study area (figure 3 and 4). The change in the potential provision is mainly due to the land use change between these years. The change from agricultural land (with no net accumulation of biomass carbon stocks) into discontinuous urban fabric, meaning mostly single-family housing estates in the suburbs, cause increase in the carbon storage potential by 4,89%. That is 170212,8 tC more in 2012 than compared to the year 1990. The biggest increase occurred between the years 2000 and 2006. Especially after 2004, the year of access of Poland to the European Union, the real estate market was at its boom[24].

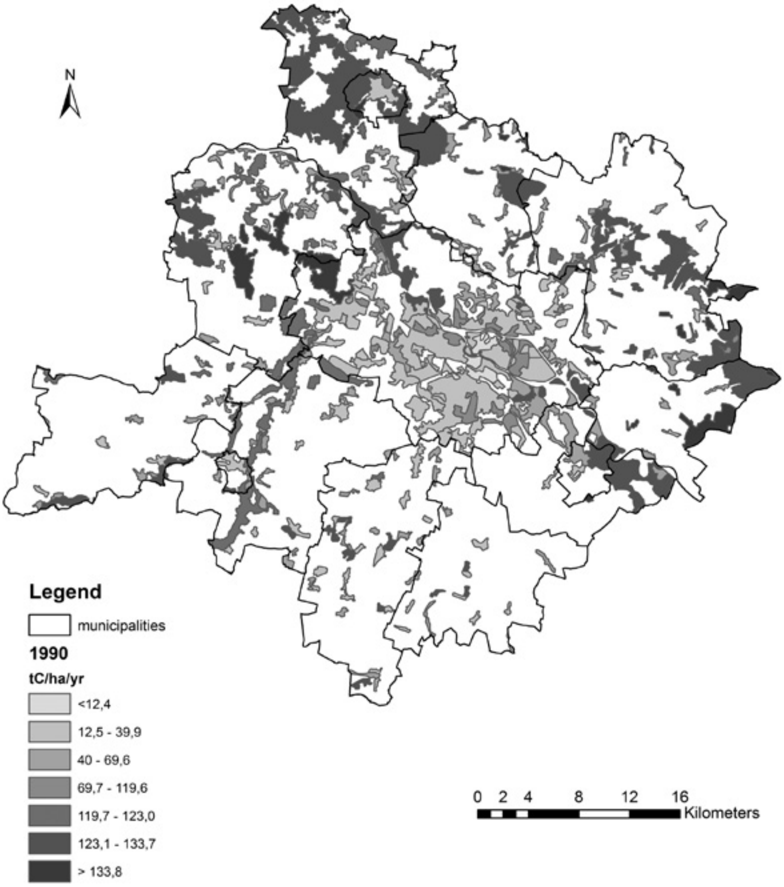

Figure 3. The spatial distribution of global climate regulation service in 1990

24 E. Sawiłow, *Zmiany cen na wrocławskim rynku nieruchomości po wejściu Polski do Unii Europejskiej*, "Studia i Materiały Towarzystwa Naukowego Nieruchomości" 2007 vol. 15, no. 1–2, p. 149–157.

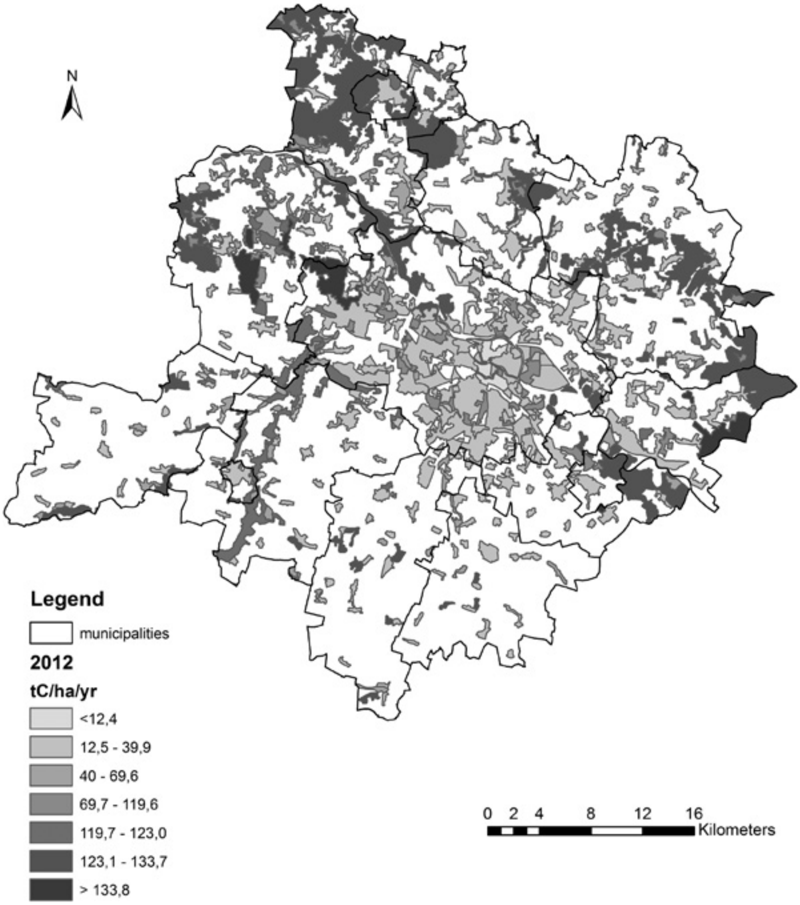

Figure 4. The spatial distribution of global climate regulation service in 2012

Conclusions, limitations and challenges

The study presents the use of two methods to assess and map two different ecosystem services in the suburban case study area of Wroclaw. The results show the proxy-based method as well as benefit transfer can be used at the subregional scale for assessment of the selected ecosystem services for the decision-support purpose. The results enable to provide the relative change of the potential provision of the assessed ecosystem services. The potential provision of carbon storage has increased while the food provision has decreased. Even though the ecosystem services were assessed with the use of different methods, results of both methods are closely linked to the land use/cover change in the case study area. The use of CLC enabled the comparability of the case study area between different time frames.

The considerable limitation to the study is the lack of the ecosystem service condition assessment. That could be overcome by either enlarging the set of indicators describing ecosystem condition or by applying a different method. Other limitations are closely related to the use of the selected methods. The benefit transfer could be improved by the use of benefit function transfer or meta analysis method. The proxy-based method used to assess the crop provision could be exchanged for process-based modelling. The use of more sophisticated methods is, however, limited by the time and capacity. Another important limitation is the unassessed level of uncertainty of the results of this case study. The benefit transfer method imposes a high degree of uncertainty involved in the quantification of the carbon storage due to the use default and literature review values. For the case of spatial planning, the uncertainties should be explained to the stakeholders so that the expectations about the accurateness of results are met.

The main challenge to the ecosystem service assessment that has come out of this case study is the data availability. The data on crop harvest disaggregated to the local scale is not freely available for the first ecosystem service of this case study. In the assessment of the second ecosystem service, the main challenge was the data on carbon storage in this particular area. The data on Polish National Gas Inventory is not freely available. The use of the benefit transfer method was mainly the outcome of the data limitations. The possible way to overcome this challenge would be to do field sampling and laboratory measurements.

Literature

Andersson E. et al., *Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services*, "AMBIO" 2014 no. 43, p. 445–453

Danielewska A., Urbaniak M., Olejnik J., *Growing season length as a key factor of cumulative net ecosystem exchange over the pine forest ecosystems in Europe*, "International Agrophysics" 2015 no. 29, p. 129–135

Dojazdy do Pracy. Narodowy Spis powszechny Ludności i Mieszkań 2011, Warszawa 2014

Douglas I., *Urban ecology and urban ecosystems: understanding the links to human health and well-being*, "Current Opinion in Environmental Sustainability" 2012 no. 4(4), p. 385–392

Egoh B. et al., *Indicators for mapping ecosystem services: a review*, European Union 2012

Elmqvist T. et al., *Benefits of restoring ecosystem services in urban areas*. "Current Opinion in Environmental Sustainability" 2015 no. 14, p. 101–108

Elmqvist T. et al., *History of Urbanization and the Missing Ecology,* in: *Urbanization, biodiversity and ecosystem services: challenges and opportunities. A Global Assessment*, Dordrecht, Heidelberg, New York, London 2013

IPCC 2006 Guidelines for National Greenhouse Gas Inventories, www.ipcc-nggip.iges.or.jp

Kandziora M., Burkhard B., Müller F., *Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution*, "Ecosystem Services" 2013 no. 4, p. 47–59

Kazak J., Szewrański Sz., Decewicz P., *Holistic Assessment of Spatial Policies for Sustainable Management: Case Study of Wroclaw Larger Urban Zone (Poland),* in: D. Lee, E. Dias, H.J. Scholten (eds), *Geodesign by Integrating Design and Geospatial Sciences*, Springer 2014

Kazak J., Szewrański Sz., Sasik J., *Gospodarowanie zasobami przestrzennymi w strefie podmiejskiej Wrocławia* (Spatial Resource Management in the Suburban Area of Wroclaw), Studia Komitetu Przestrzennego Zagospodarowania Kraju PAN (Studies of Committee for Spatial Economy and Regional Planning of Polish Academy of Science) 2013 vol. 22, no. 1, p. 185–197

Kroll F. et al., *Rural-urban gradient analysis of ecosystem services supply and demand dynamics*, "Land Use Policy" 2012 no. 29(3), p. 521–535

Langemeyer J. et al., *Contrasting values of cultural ecosystem services in urban areas: The case of park Montjuïc in Barcelona*, "Ecosystem Services" 2014, p. 1–9

Łowicki D., *Land prices as an indicator of the recreational services of ecosystems*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 167–175

Maes J., Paracchini M.L., Zulian G., *A European assessment of the provision of ecosystem services. Towards an atlas of ecosystem services,* European Union 2011

Mapping and Assessment of Ecosystems and their Services, Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020, 2nd Report – Final, European Union 2014

McPhearson T. et al., Advancing Urban Ecology toward a Science of Cities, "BioScience" 2016 no. XX(X), p. 1–15

McPhearson T. et al., *Resilience of and through urban ecosystem services*, "Ecosystem Services" 2014 no. 12, p. 152–156

Podstawowe informacje według podregionów, powiatów i gmin województwa dolnośląskiego, Powszechny Spis Rolny 2010, Wrocław 2012

Sawiłow E., *Zmiany cen na wrocławskim rynku nieruchomości po wejściu Polski do Unii Europejskiej*, "Studia i Materiały Towarzystwa Naukowego Nieruchomości" 2007 vol. 15, no. 1–2, p. 149–157

Stan i zmiany właściwości gleb użytkowanych rolniczo w województwie dolnośląskim w latach 2000–2005, Puławy Wrocław 2007

Strohbach M.W., Haase D., *Above-ground carbon storage by urban trees in Leipzig, Germany : Analysis of patterns in a European city*, "Landscape and Urban Planning" 2012 no. 104(1), p. 95–104

Urban adaptation to climate change in Europe 2016. EEA Report No 12/2016

Urban Environment, www.eea.europa.eu

www.stat.gov.pl

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ECOSYSTEM SERVICES IN THE CIRCULAR ECONOMY

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USŁUGI EKOSYSTEMÓW W KONCEPCJI GOSPODARKI CYRKULACYJNEJ

STRESZCZENIE: Zrównoważone wykorzystanie zasobów wymaga oszacowania ich dostępności oraz ochrony ekosystemów. Istotne jest utrzymanie zdolności środowiska do pochłaniania zanieczyszczeń i zachowanie różnorodności biologicznej. Koncepcja gospodarki cyrkulacyjnej, w szerokim ujęciu, obejmuje nie tylko zagadnienia efektywności produkcji i eliminacji powstawania odpadów lecz całokształt usług ekosystemów. Zmniejszenie ilości wykorzystanych zasobów oraz zanieczyszczeń niesie za sobą poprawę jakości życia jak również i ekonomikę przedsięwzięć.

SŁOWA KLUCZOWE: świadczenia ekosystemów, gospodarka cyrkulacyjna

Introduction

The increased interest in problems of dwindling natural resources and environmental pollution occurred in the seventies of the twentieth century due to the crisis of raw material and energy and the progressive degradation of the environment. The effect of consideration on the environmental protection aspects in the field of economic and environmental sciences were concepts of "decoupling", the green economy and the circular economy.

Sustainable and long-term use of resources requires the estimation of their availability, to ensure the security of supply and protection of ecosystems. It is also important to maintain the environment's capacity to absorb the pollutants and keep the balance of nature and biodiversity.

The main purpose of the article is to discuss actions taken in the quest for sustainable growth and the role of ecosystem services in the development of the circular economy. The hypothesis in this study is that knowledge of ecosystem services and its application in the economy will offer a number of benefits (environmental and economic).

The article also contains information regarding the first proposals for the development of the circular economy in Poland, co-developed by partners of the international project titled "*Improving skills in the Green Economy through Advanced Training Program" on Cradle to Cradle "(C2C SMEs)*".

Relationships between circular economy and ecosystem services

The concept of ecosystem services can be considered not only as services, but also goods which are mobilized with the functioning of ecosystems. It's a set of material goods, directly used, and ecosystem services, useful for society (supporting the possibility of life – for example, the functions of cleaning, and raising its quality-for example, the aesthetic and cultural or scientific)[1].

The ecosystem was recognized as an object of research, important in the development of economic theory. Considering obtaining benefits, ecosystem services can be divided into four categories[2]:

- supporting, which allow the life and operation of the other components of the ecosystems, including humans;
- provisioning, consisting of the supply of goods;

1 B. Raszka, M. Hełdak, *Świadczenia ekosystemów w polityce przestrzennej gmin powiatu wrocławskiego*, Wrocław 2013, p. 14

2 A. Mizgajski, *Świadczenia ekosystemów jako rozwijające się pole badawcze i aplikacyjne*, "Ekonomia i Środowisko" 2010 no. 1(37), p. 10–19.

- regulating, associated with the settlement of local microclimate and water retention by the tree and preventing flooding by natural floodplains;
- cultural, referring to the aesthetic, recreational, educational, spiritual, etc.

All these processes necessary for life and human development, remained outside the area of interest of economic analysis until the intense anthropopressure and economic use of resources has led to, among others, extinction of species and biodiversity loss. Many of these ecosystem services were used almost as if their supply is unlimited. They were treated as "free" commodities, their economic value was not properly accounted for on the market.

The idea of sustainable development started from the reports of the General Secretary of the United Nations U'Thant *Man and his environment* (1968) and reports the Club of Rome entitled: *The Limits of growth* (1972), *Mankind at the turning point* (1973), *About a new international order* (1978) and the final took place through the adoption of the sustainable development strategy during the first Earth Summit in Rio de Janeiro in 1992.

Issues associated with using the environment are presented in contemporary economics in the different scope, but they can be distinguished in two general ways, ie.:

- ecological paradigm of economics (the greening of the economy), identified as ecological economics, and
- economization of environment in the context of its economic use and conservation, identified as environmental economics.

In the ecological paradigm of economics, environmental conditions have a higher value – natural capital (rather than physical capital and its accumulation), ecosystem services are the most important limitation of the development. The state of the environment and its stability is the ultimate goal of development. The opposite view is the paradigm of economization of environment which indicates using of economic instruments to minimize costs to run environmental policy with more efficient use of resources.

An analysis of the economic and ecological considerations in economic theory reveals another postulate of consensus in balancing the processes of economization of the environment and greening the economy – sustainable economics.

In the economy of sustainable development, development implements a strong principle of sustainability and complementarity of capital, which means that the various types of capital must be retained, each separately. It follows from the assumption, that capital – natural and anthropogenic – are mutually complementary rather than substitutional and the loss of one type of resource should be supplemented by the same resource – not compensated by another kind. The barrier of capacity of the environment sets environmentally safe boundaries of economic development. The slow depletion of existing factors of economic growth (relatively low labor costs, the cheap raw materials availability) makes it necessary to seek new sources of competitive advantage. If we want to achieve a maintain stable economic development we need to develop innovation, and, in particular – new business models, including new forms of organization concentrated on increasing of the resource efficiency.

The integration of environmental, economic and social policy helps to meet the challenges of sustainable development. This requires to treat environmental resources as limited economic resources and using of natural capital in a way that would preserve the ecosystem in the long term.

Figure 1.
The use of resources in the economy

Sustainable development is the basis for the European Union strategic planning. There is a great number of documents in the form of, i.a *EU Sustainable Development Strategy* and *the Europe 2020 Strategy – A strategy for smart, sustainable and inclusive growth*[3]. Smart, sustainable development is based on knowledge and innovation, with environmental issues taking into account. Responsibilities of the Member States can be realized by promoting and implementing of the circular economy which provides the stability of the products, materials and resources value and reduction of waste[4].

3 T. Borys, *Nowe kierunki ekonomii środowiska i zasobów naturalnych w aspekcie nowej perspektywy finansowej Unii Europejskiej*, "Ekonomia i Środowisko" 2013 no. 1(44), p. 14–23.

4 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *Closing the loop – An EU action plan for the circular economy*, COM(2015) 614, p. 2.

Transition to a more the circular economy with requires changes in every phase of the value chain, from the design phase of the product (eco-design), new business and market models (closed circulation of water, non-waste technology, limiting waste and harmful emissions, use of ecological returnable packaging or packaging materials), new ways of turning waste into a resource (effective waste collection and recycling) to the new consumer behavior (prolonging product life). This is a complete systemic change and innovation is not only technological but also organizational. By helping to decouple economic growth from resource use and its impacts, it offers the prospect of sustainable growth that will last.

The report of The Ellen MacArthur Foundation – *Towards a Circular Economy, I* – which was presented in early 2012, defines the objectives as follows: "A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models"[5].

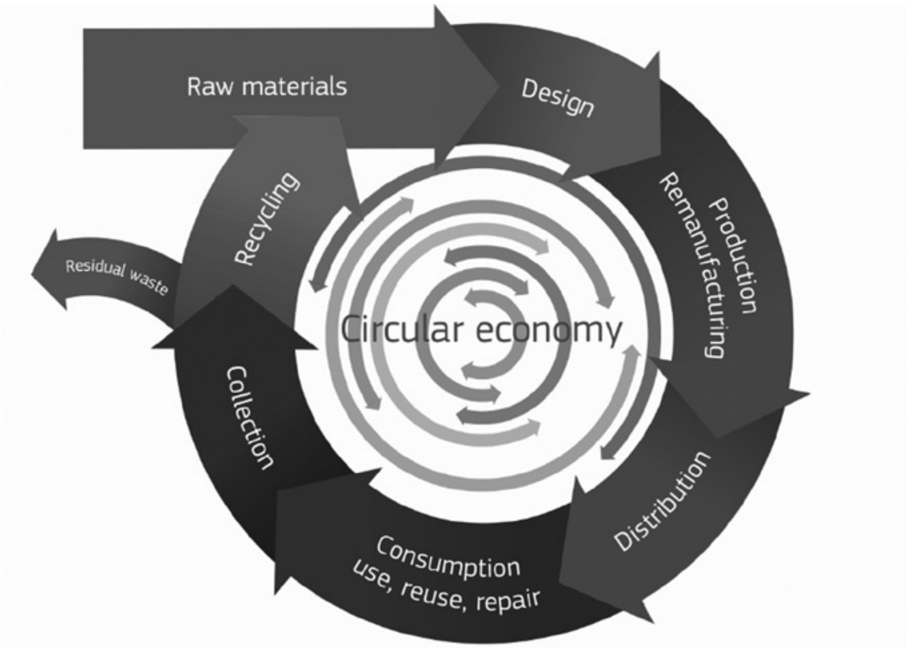

Figure 2. Main phases of a circular economy model: COM (2014) 0398

5 *Towards a Circular Economy*, The Ellen MacArthur Foundation, 2012, p. 8.

The diagram illustrates the main phases of a circular economy model. The aim is to minimise the resources use and escaping from the circle so that the system functions in an optimal way[6].

The concept of circular economy has important value to the conservation status of ecosystems and increasing of the ecosystem services potential. It helps to create more efficient ways of producing and consuming. At the same time, it saves energy and helps avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil and water pollution.

On the other hand, the idea of the circular economy make use of the concepts of ecosystem services and natural capital – the functioning of ecosystems is an exemplar for industrial processes and systems.

Below we can find examples of solutions for circular economy in the context of defined ecosystem services and associated with the solution environmental and economic effects.

Table 1. Examples of solutions related to the circular economy in the context of ecosystem services

Ecosystem services	The circular economy solutions	Environmental and economic effects
Provisioning: delivery of food, raw materials	• reducing the quantity of materials required for the delivery of goods/ services (lightweighting) • reducing energy consumption and materials at the production and use • extension of products using • reducing the use of hazardous materials or products difficult to recycle • design of products easier to repair, modernization, recovery and recycling • closed circulation of water • the creation of markets for secondary raw materials (recyclates) (based on standards, public procurement, etc.) • industrial symbiosis • incentivising and supporting waste reduction and high-quality separation by consumers • incentivising separation, collection systems that minimise the costs of recycling and reuse • development of the services to consumers in an area of (maintenance/repair etc.)	• the efficiency of resource use • lower transport costs • durability of products • reduction of the amount of waste, (including hazardous waste) and the cost of recovery and recycling

[6] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Towards a circular economy: A zero waste programme for Europe*. COM (2014) 0398, p. 2.

Regulating: noise reduction	the process of the absorption, reflection of sound waves by vegetation in the construction and the design of urban spaces (e.g acoustic screens construction)	• reduction in the consumption of non-renewable resources • reduction of costs associated with the regulation of noise level
Regulating: thermal and humidity contrast reduction. Improvement of air quality	the process of regulating the bioclimatic conditions and the absorption of co2 and o2 release by vegetation in the construction and the design of urban spaces	• reduction in the consumption of non-renewable resources • reduction of cooling and heating costs
Regulating: counteraction of water degradation (filtration, self-cleaning in reservoirs)	filtering, purifying water in production processes and services	• reduction of the amount of product in the treatment process • closing the loop • reduction of the cost of water treatment

In the time of transition economies into the circular economies, the main efforts are focused on increasing production efficiency and reducing the amount of resources used, but after that, circular economy should cover the whole complex ecosystem services, to keep the natural balance and stop the decline of biodiversity.

The circular economy is focused on technological systems, but it can benefit from a better understanding of connected ecological processes. Knowledge of ecosystem services and its application in the economy offers a number of benefits (environmental and economic). Valuating natural capital and the flows of ecosystem services provides a strong economic driver to preserve nature, and to use nature-based solutions to address today's economical challenges.

Development of the circular economy in Poland

Decades ago the concept "Cradle to Cradle" was introduced by Walter Stahel, Founder-Director of the Product Life Institute and leading advocate of resource efficiency. Later, the concept was advocated by prof. Michael Braungart and William McDonough based on research at the Environmental Protection Encouragement Agency in Hamburg, Germany, for designing beneficial economics, social and environmental featers into products, processes and system.

C2C promotes innovation partnerships along the chain of products to limit the amount of waste in production processes and technology through appropriate design and the elimination of toxic substances. It requires focusing on three basic principles:

- Treatment of waste as a potential raw material (waste = food);
- Use of renewable energy sources;
- Celebrate Diversity, Species, Cultural and Innovation Diversity.

To apply those principles, Cradle to Cradle focuses on optimizing the use of product. Products for consumption are designed in a way that degradation by products generated during their use can support the biological systems, for example: biodegradable textiles, cosmetics. Products for service are designed to be chemically stable during use and get dismantled into material resources.

The project "Improving of Skills in the Green Economy through Advanced Training Program on "Cradle to Cradle (C2C SMEs)" was carried out by lead partner Hanse-Parlament – an umbrella organization of 50 chambers of commerce, crafts and industry from 13 Baltic and 6 further partners from Germany, Finland, Poland and Hungary:

- EPEA – Internationale Umweltforschung GmbH (Germany);
- Berufsbildungs Und Technologiezentrum der Handwerkskammer Schwerin (Germany);
- Lower Silesia Chamber of Crafts in Wroclaw (Poland);
- Ipartestuletek Orszagos Szovetsege (Hungary);
- Satakunta University of Applied Sciences (Finland);
- The Regional Fund for Environmental Protection and Water Management in Gdansk (Poland) in the period from September 1st, 2014 to August 30th, 2016.

The aim of the project was to disseminate the concept (C2C) in the sector of Small and Medium Enterprises (SMEs) by: development, test and evaluation of the curriculum for C2C training staff (staff of universities, chambers of craft and economic and promoters of SMEs) and by development of a new training program C2C for SMEs and adapting to the specific needs of SMEs[7].

Comments made by participants on the implementation of the concept of C2C include:

- The need for environmental education of society;
- Assumptions C2C are easier to introduce new companies than in the plants functioning from the 70s (required deep modernization)'
- The need for audits and environmental consultancy (including cost analysis and benefits);
- Concerns about the necessity of formalizing cooperation between companies;
- Limited organization of reverse logistics;

7 E. Priedulena, M. Hogeforster, *Improving of Skills in the Green Economy through Advanced Training Program on "Cradle to Cradle (C2C SMEs)*, Baltic Sea Academy e.V, 2016, p. 9–16.

- Reduced impact on suppliers;
- The need for systemic support from the public administration and self-government.

It is also known, that market forces are not likely to move towards a more decoupled structure of the economy by themselves. A move towards a more circular economy would require a set of policy measures –a combination of regulation and economic instruments as well as significant investments in infrastructure, construction and manufacturing aiming at reducing the energy and material throughput in society[8].

Conclusions

Relative decoupling of economic growth from resource use has been happening over the past decades but the resources freed up by increased efficiency are used up very soon through increased consumption. There is the reason, why concept of the circular economy needs to include not only issues of the production efficiency and waste elimination, but the whole of ecosystem services.

Transition to a green, circular economy requires analysis of the economics of biodiversity and ecosystem services. We need to map the state of ecosystems and their services, assess their economic value, and promote the integration of these values into accounting.

Sustainable business practices and sustainable corporate strategies in economic system have become a majority economic measure of development. The circular economy or "Cradle to Cradle" design concept have good assumptions, but comments of participants of "Improving of Skills in the Green Economy through Advanced Training Program on "Cradle to Cradle (C2C SMEs)" project confirm the importance of implementing a comprehensive program covering all sectors of the economy, with defined objectives, targets and strategy measures to support enterprises in implementing a circular economy. The investments would be needed primarily in the following sectors[9]:

- agriculture, forestry, timber, pulp and paper to promote biofuels and to develop new biobased products;
- installation services and construction/renovation to promote energy-efficiency and renewable energy sources;

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8 A. Wijkman, K. Skånberg, *The Circular Economy and Benefits for Society Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and Resource Efficiency*, The Club of Rome, 2015, p. 44.

9 Ibidem, p. 10.

- sustainable infrastructure concerning especially energy and transport;
- maintenance and repair, recycling and development to promote material-efficiency;
- engineering services like product design, recycling and remanufacturing as well as new business models.

The development of low-carbon, resource-efficient and competitive economy also depends on the increase in public awareness of the required changes in production and consumption patterns.

Literature

Borys T., *Nowe kierunki ekonomii środowiska i zasobów naturalnych w aspekcie nowej perspektywy finansowej Unii Europejskiej*, "Ekonomia i Środowisko" 2013 no. 1(44), p. 14–23

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *Closing the loop — An EU action plan for the circular economy*, COM(2015) 614

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, *Towards a circular economy: A zero waste programme for Europe*. COM (2014) 0398

Mizgajski A., Świadczenia ekosystemów jako rozwijające się pole badawcze i aplikacyjne, "Ekonomia i Środowisko" 2010 no. 1(37), p. 10–19

Priedulena E., Hogeforster M., *Improving of Skills in the Green Economy through Advanced Training Program on "Cradle to Cradle (C2C SMEs)*, Baltic Sea Academy e.V, 2016, p. 9–16

Raszka B., Hełdak M., Świadczenia ekosystemów w polityce przestrzennej gmin powiatu wrocławskiego, Wrocław 2013

Towards a Circular Economy, The Ellen MacArthur Foundation, 2012

Wijkman A., Skånberg K., *The Circular Economy and Benefits for Society Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and Resource Efficiency*, The Club of Rome, 2015

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MANAGEMENT OF LAND RESOURCES AND SUSTAINABLE DEVELOPMENT OF RURAL AREAS

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GOSPODAROWANIE ZASOBAMI ZIEMI A ROZWÓJ ZRÓWNOWAŻONY OBSZARÓW WIEJSKICH

STRESZCZENIE: Celem opracowania jest przedstawienie zmian gospodarowania zasobami ziemi jako naturalnego czynnika środowiska i produkcji rolniczej w kontekście rozwoju zrównoważonego obszarów wiejskich. Nie można traktować ziemi jako zasobu w pełni odnawialnego, gdyż niewłaściwe jej użytkowanie może doprowadzić do utraty jej właściwości i zagrożeń dla przyszłych pokoleń, co jest sprzeczne z paradygmatem rozwoju zrównoważonego. Analizą objęto zmiany zachodzące na terenie Polski oraz województwa dolnośląskiego z podziałem na regiony funkcjonalne. W Polsce i województwie zmniejsza się powierzchnia ziemi wykorzystywana na cele rolnicze oraz ulega zmianie struktura jej użytkowania. Zbyt duży ubytek gruntów przeznaczanych na cele rolnicze może doprowadzić do obniżenia produkcji zabezpieczającej potrzeby życiowe populacji ludzkiej, dlatego gospodarowanie ziemią musi opierać się na jej ochronie i maksymalnym wykorzystaniu.

SŁOWA KLUCZOWE: obszar wiejski, zasoby naturalne, ziemia, zrównoważony rozwój

Introduction

Due to the human activity, the natural environment surrounding us undergoes constant degradation. Consumption of renewable and non-renewable resources increases. In the face of such phenomena, it is necessary to search for solutions which would deter such degradation. Limiting the use of non-renewable resources results in the search for renewable raw materials.

The most important resources and values of nature include:

- the space of inanimate nature – minerals, soil, water, air,
- resources of living nature – animals, plants,
- other components of the biosphere such as landform, landscape, climate, flows of energy and in particular solar energy[1].

Kotarbiński after Łojewski[2] most accurately explains how actions should be implemented in terms of space and matter. Thus, every fragment in space should be used so that there is enough space left for everything and the managed area could serve many purposes at once. As to matter, no more resources should be used than it is necessary to manufacture products nor is it allowed to waste any kinds of refuse. All activities must be limited to savings and thriftiness. Therefore, it is necessary to apply such scientific and technical solutions which consist in the optimal use of resources as the basis for development, in accordance with the concept of sustainable development.

Among renewable resources focus is put on renewable resources which are exhaustible such as; soil, agriculture, animal population or forest biomass. While using such renewable resources it is necessary to manage them so as to obtain maximum benefit from their exploitation without compromising the ability of their natural renewal[3]. Only such utilization of them ensures the possibility to develop rural areas, in compliance with the paradigm of sustainable development.

According to Buks[4] agricultural production is based on natural resources and therefore environmental changes have an impact on it. Agricultural producers are forced to adapt their business solutions to the changing environment and management in accordance with sustainable development. The production volume should be maintained simultaneously with its positive impact on the environment. The production function of agriculture cannot be

1 S. Łojewski, *Environmental economics*, Bydgoszcz 1998, p. 39–41.

2 S. Łojewski, *Economics of resources and the environment*, Bydgoszcz 2007, p. 54–63.

3 J.S. Zegar, *Basic issues of sustainable development*, Bielsko-Biala 2007, p. 229.

4 J. Buks, *Land factor as an element of sustainability*, "Scientific Annals SERIES" 2012 vol. XI, issue 1, 2012, p. 82.

realized without protection of the environment[5]. Breaking this rule may result in lower production and inhibition of economic development in rural areas and the entire state. Therefore, it is necessary to manage both environmental and land resources so as not to violate the ecological balance nor reduce their contribution to creation of social welfare. Thus, economic exploitation of natural resources is associated not only with their exploitation but also with their security[6].

The aim of this paper is to present changes in land resources management as a natural factor of the environment and agricultural production in the context of sustainable development of rural areas.

The importance of land resources management

Land is a basic resource of the environment and a factor of agricultural production. In the context of the concepts of sustainable development the significance of land is even much wider. Apart from its production function, land has many other functions, as it creates landscape and has recreational, sports, tourist as well as environmental values. As a factor of production, land is characterized by immovability, irreproducibility and indestructibility[7]. Immovability of land is associated with its fixed location as the use of it may occur under conditions created by nature. Irreproducibility of land results from the limited area of it – its supply is limited and not subject to reproduction. However, land is stable and indestructible in relation to durable goods and the natural environmental.

The rapid development of civilization, which is the hallmark of modern times, leads to degradation of the natural environment as well as land. The change occurs not only in the area used for agriculture, but also in the composition and properties of soil. Degradation of land results not only from the human activity, but also from the impact of natural factors. Threats to soils (erosion, loss of organic matter; adverse changes in biodiversity, acidification of soils, etc.) result from agricultural and non-agricultural activities as well as from the loss of land used for production purposes. In this situation, action is needed to ensure the proper use and protection of land.

Protection of soils against erosion can be achieved by means of anti-erosion drainage treatments (terracing of slopes; strengthening ravines, rivers,

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5 J.S. Zegar, *The concept of research on socially sustainable agriculture* (10), Final Report, Synthesis and recommendations, Warsaw 2009, p. 175.

6 H. Adamska, *Sustainable development of rural areas on the example of Lower Silesia*, Wrocław 2015, p. 111.

7 A. Woś, F. Tomczak, *Agricultural Economics. Outline of Theory*, Warsaw 1983, p. 84.

streams and landslides; keeping road routes along small declines in terrain) as well as by agricultural treatments (no-till crops or crops with minimum tillage; stoppage of animal grazing; transformation of arable land into permanent grassland; maintaining landcover, including permanent meadow, forest and woodland cover; the use of strip fields, buffer zones; improving crop rotation; the use of deep-rooting plants, various types of set-aside; avoiding the use of heavy equipment and farm machinery, etc.). Soil protection against chemical degradation can be realized by means of the rational use of pesticides, mineral and natural fertilizers as well as sewage sludge, liming of soil, the use of natural fertilizers on a larger scale, the use of biological and mechanical plant protection products[8].

In the face of emerging phenomena, the assumption that land is indestructible must be regarded as erroneous. Land is destructible and must be protected.

The importance of land was recognized by the UN and the year 2015 was declared the International Year of Soils. Such a move was to draw public attention to the quality of land and its impact on economy and the environment on a global scale.

Sustainable management of land resources is difficult but indispensable due to rapidly growing needs for food for the increasing population[9]. Land turns out to be a resource of varying values depending on its location and people's inclination to pay for their non-food needs[10]. Therefore, it is necessary to take special care of land and its rational use. Misuse of land and its area is hazardous both for agricultural and non-agricultural activities. Increasing soil degradation processes may ultimately lead to a complete loss of the function which they perform: functions of habitat, production and retention. Krasowicz[11] believes that the changes related to land use result from economic development, therefore it is necessary to change the patterns of production and consumption. Such an approach should be regarded as appropriate, but how to persuade the society to change consumption patterns in order to protect land resources for future generations in accordance with the concept of sustainable development.

Systematic decrease in the area of agricultural land in Poland is a permanent phenomenon, and it coincides with global trends. It is primarily associ-

8 A. Muzalewski et al., *Implementation of transversal objectives – the environment, climate change mitigation, adaptation to climate change – within the framework of investment activities of the Rural Development Programme 2014–2020*, Warsaw 2014, p. 70.

9 A. Czudec, *Economic conditions of the development of multifunctional agriculture*, "Scientific Papers, Monographs and Studies" 2009 no. 6, p. 10–13.

10 S. Kozłowski, *The future of sustainability*, Lublin 2005, p. 95.

11 S. Krasowicz, *Premises of rational use of soil in Poland*, "Scientific Papers SERIES" 2012 vol. XIV, no. 5, p. 113.

ated with development of housing, infrastructure accompanying housing estates, as well as progressive industrialization of the state. Land excluded from agriculture is allocated not only for construction of housing estates and industry but also for afforestation. The total area of crops is an indicator of the production capacity of agriculture, which in turn determines the degree of satisfaction of the population's food needs. With a decrease in the total area of agricultural land, significant changes in the total area under cultivation cannot be expected. As a result of varying market conditions there may occur changes in the structure of different crops[12].

Materials and methods of research

The carried out study had a theoretical and empirical character. The empirical study included secondary materials. The CSO statistical data as well as elaborations of the Wroclaw Marshal's Office of 1999–2015 were made use of. The study included the area of Poland and Lower Silesia divided into five functional regions of rural areas. The functional regions vary in respect of their development goals: I – region of intensive agriculture with a dominant agricultural sector, II – agro-recreational region based on tourism and recreation development, III – industrial, recreational and tourist region covering mostly foothill and mountainous area, IV – agro-industrial region influenced by copper industry and V – agro-industrial and recreational region influenced by its three economic functions: industry, agriculture and tourism.

The following research questions were stated:

- How have area structure and agricultural land use changed?
- How can agricultural production influence the quality of soils?

The assumption of land use structure has been purposeful as it shows the natural load of land. The quantity of applied mineral and organic fertilizers improves soil fertility, and therefore is associated with the issues of rational use, protection and restoration of soil fertility.

The method of descriptive and comparative analysis was applied. Based on the collected materials, the direction and dynamics of changes in the use of land resources were indicated.

12 E. Wasilewska, *Changes in the crop structure in Poland in 1996–2007*, "Scientific Papers of University of Life Sciences – Economics and Organization of Food Economy" 2008 no. 71, p. 123–135.

Changes in the structure of land use

One of the indicators influencing the sustainable soil use are changes in the structure of land use. Improper use of land inhibits sustainable development of the entire state, including rural areas. Considering the period of 1999–2015, the area of land used for agriculture decreased, as less land was allocated for agricultural purposes. That occurred both in the state and Lower Silesia Province and in its respective sub-regions (15%). In 2015 compared to 1999, the dynamics of changes in the area of agricultural land amounted respectively to 78.9% and 78.0% (i.e. approx. 22%), (table 1) both in the state and the province. Agricultural land comprised: arable land, perennial crops and permanent grassland. In the structure of the use of arable land there also occurred a similar rate of changes as in the case of agricultural land. The loss of arable land was higher in the state and it amounted to 77 (23%), whereas in the province 85 (15%). The highest dynamics of changes took place in the area of permanent grassland including meadows and pastures. In 2015 compared to 1999 the area of permanent grassland in Poland dropped to 941.2 thousand ha (dynamics of changes 76.7%). In Lower Silesia the area of permanent agricultural land decreased by more than half, from 278.8 thous. ha (1999) to 128.5 thous. ha (2015), (table 1). Among others, two factors had an impact on the structure of agricultural land. One of them was increasing allocation of farmland for investment purposes. The other was related to economic conditions of agricultural production, in favor of crop production, which led to reduction of the area of permanent grassland.

A growing trend was observed in the area of forest land. In the state, the area of forest land increased from 8970.2 thous. ha (1999) to 9420.0 thous. ha (2015), i.e. by 5% (dynamics of changes was 105), while in Lower Silesia from 572.9 (1999) to 609.4 thousand ha (2015), i.e. by 6.4% (dynamics of changes 106.4), (table 1). The increase in forest area resulted from the state policy adopted by the Council of Ministers in 1995, "The National Afforestation Programme", the aim of which was to achieve 30% of the forest area in the state. Similar patterns related to the management of land took place in the functional regions of Lower Silesia. In the period 1999–2014 agricultural land disappeared in its respective functional regions. The biggest loss of agricultural land took place in region V, where the dynamics of changes was 95.5%. Except for region I, arable land diminished in all the regions. In region I there was an increase in arable land from 385.4 (1999) to 392.4 thous. ha (2014), i.e. by 1.8% (dynamics of changes 101.8). In respective regions there occurred a large loss of land allocated for perennial crops – orchards. The largest loss was observed in region V (dynamics of changes 68.5%), and the smallest in region III (dynamics of changes 92).

Table 1. Land use in Poland and Lower Silesia [thous. ha]

Year	Total area	Agricul-tural land	Including			Forest area	The remaining area
			Arable land	Perennial crops	Meadows & pastures pastures		
Poland							
1999	31267.9	18434.6	14134.2	266.4	4034.0	8970.2	3863.1
2004	31267.9	16327.4	12684.6	282.4	3365.1	9126.7	5813.8
2007	31267.9	16177.1	11748.0	375.0	3271.2	9229.3	5861.5
2010	31267.9	14859.7	10797.5	389.7	3229.5	9328.9	7079.3
2013	31267.9	14609.2	10759.5	412.2	3206.4	9382.9	7275.8
2014	31267.9	14558.4	10895.1	376.0	3119.8	9403.1	7306.4
2015	31267.9	14545.2	10887.0	390.9	3092.8	9420.0	7302.7
Dynamics of changes – 1999=100							
2004	100	88.6	89.7	106.0	83.4	101.7	150.5
2007	100	87.8	83.1	140.8	81.1	102.9	151.7
2010	100	80.6	76.4	146.3	80.1	104.0	183.3
2013	100	79.2	76.1	154.7	79.5	104.6	188.3
2014	100	79.0	77.1	141.1	77.3	104.8	189.1
2015	100	78.9	77.0	146.7	76.7	105.0	189.0
Lower Silesia Province							
1999	1994.7	1165.3	901.2	8.7	272.8	572.9	256.5
2004	1994.7	1053.5	869.4	7.4	175.7	585.9	355.3
2007	1994.7	971.3	759.0	8.1	148.1	600.3	423.1
2010	1994.7	967.5	749.7	10.7	142.7	605.1	422.1
2013	1994.7	922.9	756.2	8.4	143.2	608.0	463.8
2014	1994.7	934.9	766.4	7.7	151.1	608.8	451.0
2015	1994.7	909.5	766.8	7.0	128.5	609.4	475.8
Dynamics of changes – 1999=100							
2004	100	90.4	96.5	85.1	64.4	102.3	138.5
2007	100	83.4	84.2	93.1	54.3	104.8	165.0
2010	100	83.0	83.2	123.0	52.3	105.6	164.6
2013	100	79.2	83.9	96.6	52.5	106.1	180.8
2014	100	80.2	85.0	88.5	55.4	106.3	175.8
2015	100	78.0	85.1	80.5	47.1	106.4	185.5

Source: own calculations based on the Central Statistical Office (CSO) data.

A large loss of the area of meadows and pastures took place in region I (dynamics of changes 80.7%), and the smallest in region V. In all the regions the share of forest area increased. The biggest changes in the forest area occurred in region V, from 146.9 to 163 thous. ha (dynamics of changes 111), (figure 1).

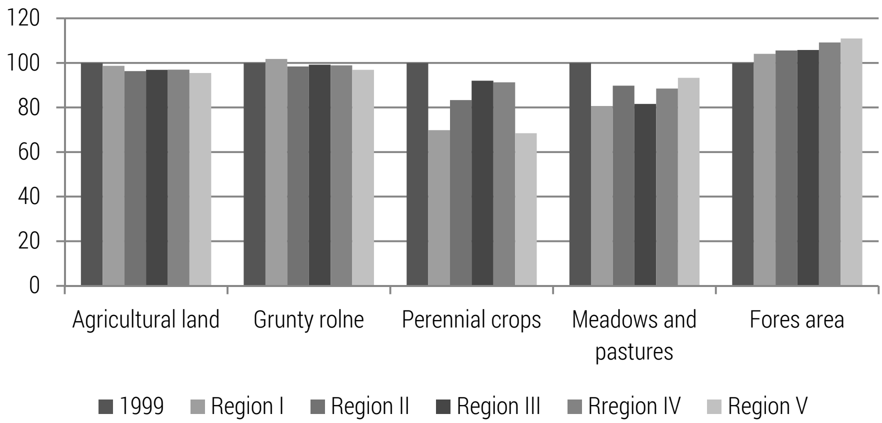

Figure 1. Dynamics of changes in land use in the functional regions of Lower Silesia

Source: own study based on: Z. Surdyk, I. Warchił, *Analysis of changes in the agrarian structure and the monitoring of changes in land use in the rural areas of Lower Silesia in the years 1999–2007, 2013*, Wroclaw 2015, p. 9.

Changes in the structure of land use might result from allocation of land for implementation of investment objectives, in particular for the purpose of development industry. The area of forest land increased as a significant area of agricultural land was allocated for this purpose. Such a course of changes resulted from RDP of 2007–2013 which was ensured subsidies for farmers who allocated so called marginal land for afforestation.

Production factors affecting the quality of land

There are a number of production factors affecting the quality of land. Among others, the main factors include: fertilization, the use of plant protection products, crop structure, cultivation technologies.

The use of mineral and organic fertilizers increases the yield of plants, however it contributes to environmental pollution. Therefore, the use of very high doses of fertilizers may cause deterioration of soil quality.

Despite the increasing use of mineral fertilizers, Poland is a state with its average use. In the years 2004–2014, there was an increase in the use of mineral fertilizers from 99.3 kg NPK / ha to 132.9 kg NPK / ha (figure 2). That increase might have resulted from the accession of Poland to the European Union and introduction of the system of subsidies for agricultural production.

While assessing the level of soil fertilization it is necessary to take into account natural fertilization which, in addition to mineral fertilization, is a valuable source of essential plant nutrients. The importance of natural fertilizers (natural manure, liquid manure, slurry) is commonly known. They have a significant effect on all the properties of soils. The lighter the soil, the greater is the importance of organic fertilization. It affects a better efficiency of mineral fertilization, it increases water capacity of soils and therefore provides protection – it secures stable yields under adverse weather conditions, and most importantly it provides protection in case of committing agro-technical errors[13]. The conducted analyses indicated a decrease in the use of organic and calcium fertilizers – whereas acidification of soils and shortage of humus are very important for the quality of soil. Therefore, it is necessary to undertake actions aiming at introduction of the systems of production and agricultural technology conducive to accumulation of organic matter in the soil.

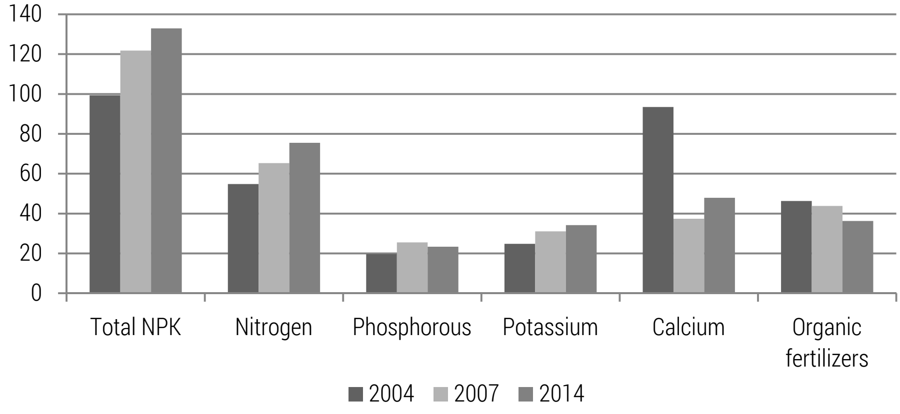

Figure 2. The use of mineral, organic and calcium fertilizers in Poland in terms of pure NPK ingredient [kg/ha]

Source: own study based on Central Statistical Office (CSO) data.

13 A. Grześkowiak, *Vademecum of fertilization – a set of basic*, Practical information about fertilization, the Azoty Group Tarnow, Tarnow 2013, p. 122.

It is important to remember that plant selection and cultivation technology influence the quality of soil. The crop structure was dominated by cereals which had a detrimental impact on soil. A big share of cereals decreased the amount of organic matter as well as humus and resulted in deterioration of the soil structure. In addition, most of cereal crops did not tolerate each other. Consequently, there occurred problems with crop rotation, diseases as well as strong weed infestation of fields[14]. Cultivation of potatoes – which normally leave good grounds for cultivation of other plants[15] – was reduced. All these trends were not conducive to rational land use, but led to deterioration of its condition.

Conclusions

Land is one of the basic natural resources of the environment. The conducted study has revealed that land should not be treated as a fully renewable resource because its improper use may lead to the loss of its properties and risks for future generations, which is not in accordance with the concept of sustainable development.

Over the past several years in the state and Lower Silesia Province as well as its regions, there have occurred changes in the structure of land use. The area of agricultural land has not only diminished, but changes in their internal structure have also been observed.

The quality of soil resources is extremely important. In rural areas, it is mainly shaped by agricultural production: fertilizers, plant protection, technology of cultivation, plant succession. Improper trends in fertilization and crop structure lead to the deterioration of soil quality.

Excessive loss of land and its inadequate protection may result in reduction of the production essential to safeguard vital needs of the future human population, which does not comply with the concept of sustainable development. Therefore, it is necessary to base land management on its protection and maximum utilization.

The contribution of the authors in the article:

Hanna Adamska, Ph.D, MSc., Eng. – 50%
Irina Kazakowa, Ph.D, MSc. – 50%

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14 D. Gołaszewska, *Crop structure then and now*, "The Mazowieckie County" 2003 no. 1.

15 E. Wasilewska, *Changes in crop structure in Poland in 1996–2007*, "Scientific Papers of Warsaw University of Life Sciences – Economics and Organization of Food Management" 2008 no. 71, p.123–135.

Literature

Adamska H., *Sustainable development of rural areas on the example of Lower Silesia*, Wrocław 2015

Buks J., *Land factor as an element of sustainability*, "Scientific Annals SERIES" 2012 vol. XI, issue 1, 2012

Czudec A., *Economic conditions of the development of multifunctional agriculture*, "Scientific Papers, Monographs and Studies" 2009 no. 6, p. 10–13

Gołaszewska D., *Crop structure then and now*, "The Mazowieckie County" 2003 no. 1

Grześkowiak A., *Vademecum of fertilization – a set of basic*, Practical information about fertilization, the Azoty Group Tarnow, Tarnow 2013

Kozłowski S., *The future of sustainability*, Lublin 2005

Krasowicz S., *Premises of rational use of soil in Poland*, "Scientific Papers SERIES" 2012 Vol. XIV, no. 5

Łojewski S., *Economics of resources and the environment*, Bydgoszcz 2007

Łojewski S., *Environmental economics*, Bydgoszcz 1998

Muzalewski A. et al., *Implementation of transversal objectives – the environment, climate change mitigation, adaptation to climate change – within the framework of investment activities of the Rural Development Programme 2014–2020*, Warsaw 2014

Wasilewska E., *Changes in crop structure in Poland in 1996–2007*, "Scientific Papers of Warsaw University of Life Sciences – Economics and Organization of Food Management" 2008 no. 71, p.123–135

Woś A., Tomczak F., *Agricultural Economics. Outline of Theory*, Warsaw 1983

Zegar J.S., *Basic issues of sustainable development*, Bielsko-Biala 2007

Zegar J.S., *The concept of research on socially sustainable agriculture* (10), Final Report, Synthesis and recommendations, Warsaw 2009

STUDIES AND MATERIALS

STUDIA I MATERIAŁY

Anna BERNACIAK

THE VALUATION OF ECOSYSTEM SERVICES FOR THE SAKE OF REVITALIZATION PROCESSES

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WYCENA ŚWIADCZEŃ EKOSYSTEMOWYCH NA RZECZ PROCESÓW REWITALIZACJI PRZESTRZENI

STRESZCZENIE: Wycena świadczeń ekosystemów miejskich może stać się elementem ewaluacji działań strategicznych i planistycznych w miastach. Szczególnie wartościowa wydaje się w odniesieniu do procesów rewitalizacji przestrzeni. Specyfika procesu odnowy przestrzeni miejskiej, połączonej z szerokim spektrum interwencji społeczno-ekonomicznej, umożliwia wykorzystanie co najmniej kilku metod wyceny świadczeń. Zdecydowanie mniej kosztowne wydaje się jednak posługiwanie się wynikami badań prowadzonych dla innych potrzeb lub adaptowanie wyników z innych jednostek przestrzennych. Jako przykład praktycznego zastosowania zaprezentowano ewaluację świadczeń dla terenów zieleni poddawanych rewitalizacji w Gnieźnie.

SŁOWA KLUCZOWE: świadczenia ekosystemów, rewitalizacja, park, tereny odłogowane, ogrody działkowe

Introduction

The valuation of urban ecosystem services may be a valuable diagnostic tool for programming revitalization processes. At the same time, the specific nature of these processes and a multitude of their aspects, thus, a high cost of implementing them (as it involves extended social research, field studies, etc.), make it unjustifiable to undertake yet another environmental diagnosis due to financial and time reasons. It would thus seem reasonable to include such issues in the situations when it is possible to use data from other studies and analyses carried out in a given area or comparable data from other spatial units.

Such an approach is illustrated by the case of programming the revitalization of a part of Osiedle Grunwaldzkie (Grunwaldzkie housing estate) in Gniezno. The valuation of different forms of ecosystem existing there was based on comparable results of survey made in different parts of Gniezno. The main aim was to present the possibility of use the results of other studies for the purpose of planning revitalization processes of green areas in cities. It helped to assess the value of environmental factor, which is often overlooked in analyses and may be costly as well.

An overview of literature

The existing body of literature, both Polish and international, lacks extensive studies devoted to the environmental implications of revitalization, especially in the context of ecosystem services.

There are a variety of works, however, which discuss ecosystem services, including their valuation in urbanised areas, and the opportunities and barriers to the application of this approach in the planning procedure. They range from comprehensive studies in the form of book publications e.g. Elmqvist et al.[1], through review papers e.g., Żylicz, Dobbs et al., Gómez-

[1] T. Elmqvist et al. (eds), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, Springer 2013.

Baggethun and Barton, Mizgajski et al.[2], to detailed environmental or economic issues – Escobedo et al., Pataki et al., Nowak et al. or Szczepanowska[3].

The issue of the valuation of services in urbanised areas, in various contexts, has been also the subject of a large number of analytical and practical studies. An interesting approach in this field was proposed by Baró et al.[4], who performed a qualitative analysis of the supply and demand for ecosystem services in five European cities.

As regards green areas in cities and changes in their productivity resulting from functional transformations, it is worth mentioning an interesting work by Middle et al.[5]. Considering the issue of the organisation of housing estate gardens in the space of public parks, they raised the related problem of the potential for increasing ecosystem services. Littke[6] discussed the practical aspects of this issue in the context of the green area development strategy in Stockholm. Niemelä et al.[7], in turn, dealt with the application of ecosystem services as an element which improves the planning and protection of green zones in built-up areas, using the example of Finnish cities.

It should also be indicated that Kronenberg and Bergier[8], in their study concerning challenges of sustainable development in Poland, raised the issue

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2 T. Żylicz, *Valuation of ecosystem services. An overview of world research* "Ekonomia i Środowisko" 2010 no 1(37), p. 31–45; C. Dobbs, F.J. Escobedo, W.C. Zipperer, *A framework for developing urban forest ecosystem services and goods indicators*, "Landscape and Urban Planning" 2011 no. 99, p. 196–206; E. Gómez-Baggethun, D.N. Barton, *Classyfying and valuating ecosystem services for urban planning*, "Ecological Economics" 2013 no. 86, p. 235–245; A. Mizgajski et al., *Development of the ecosystem services approach in Poland*, "Ekonomia i Środowisko" 2014 no 4(51), p. 10–19.

3 F.J. Escobedo, T. Kroeger, J.E. Wagner, *Urban forests and pollution mitigation: analyzing ecosystem services and disservices,* "Environmental Pollution" 2011 no. 159, p. 2078–2087; D.E. Pataki et al., *Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions*, "Frontiers in Ecology and the Environment" 2011 no. 9, p. 27–36; D.J. Nowak, D.E. Crane, J.F. Dwyer, *Compensatory value of urban trees in the United States,* "Journal of Arboriculture" 2002 no. 28, p. 194–199; H.B. Szczepanowska (ed.), *Metoda wyceny wartości drzew na terenach zurbanizowanych dla warunków polskich*, Warszawa 2009.

4 F. Baró et al., *Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities*, "Ecological Indicators" 2015 no. 55, p. 146–158.

5 I. Middle et al., *Integrating community gardens into public parks: An innovative approach for providing ecosystem services in urban areas*, "Urban Forestry and Urban Greening" 2014 no. 13(4), p. 638–645.

6 H. Littke, *Planning the green walkable city: Conceptualizing values and conflicts for urban green space strategies in Stockholm*, "Sustainability" 2015 no. 7, p. 11306–11320.

7 J. Niemelä et al., *Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study*, "Biodiversity and Conservation" 2010 no. 19(11), p. 3225–3243.

8 J. Kronenberg, T. Bergier (ed.), *Wyzwania zrównoważonego rozwoju w Polsce,* Kraków 2010.

of revitalization as one of the significant aspects contributing to the improvement of environmental conditions in cities.

The functional diversity of the selected types of urban ecosystems. The case of Osiedle Grunwaldzkie in Gniezno

A part of Osiedle Grunwaldzkie that has been selected for revitalization covers the area of around 68 ha located in the southern part of Gniezno. The residential area includes multi-family buildings, mainly barracks, but also a few blocks and tenement houses. The unused green area in its northern part covers the territory of 9 ha, including a 6.5-hectare area that was divided into allotment gardens in the past. At present, all this territory may be considered as abandoned land, used neither for cultivation nor for recreation. Its services are reduced to a group of regulating and maintaining services, as well as to provisioning ones to a limited extent. It is also a source of ecosystem disservices in the social, spatial and environmental dimension. In the social aspect, this is the area which generates danger for people staying there, as well as for local residents. It creates conditions conducive to the development of harmful social phenomena, such as homelessness, addictions, and crime. As regards space, it constitutes a functional gap in the structure of the estate, at the same time being the area of high potential that is not being used at the moment. When it comes to the environmental aspect, it has lost its original farming and recreational function, having been covered with ruderal species in an unorganised way.

The value of services provided by the green area under discussion has never been assessed. No field studies, combined with wildlife inventory, have been conducted. At the same time, other parts of the city were the subject of an extensive study consisting in the valuation of services provided by selected types of ecosystems[9]. As a result, it has become possible to adopt the research results for the sake of the revitalization process, to assess the comprehensive cost-effectiveness of the process taking into account the environmental factor. Their informational value was of auxiliary importance. For example, the cultural services of the ecosystems under study were not evaluated, which, from the point of view of revitalization, would add to the significance of the research. However, limiting oneself to the results of the study of the valuation

[9] The study was conducted in the years 2013–14 by the team headed by A. Bernaciak, consisting of the representatives of Poznan University of Economics and Business, Adam Mickiewicz University, WSB University: A. Bernaciak, B. Trafna, P. Mudrak, J. Celiński, K. Harendziak, K. Silska, M. Hejna, N. Maciejuniec, M. Wojcieszak.

of regulating and resource services, it is possible to define the environmental diversity of the area under consideration.

Originally, the area was used for allotment gardens. The way they were developed was not much different from the way other gardens of this type were developed in the city. As the authorities decided to discard them, their owners took some of the plants with them. With time, the area was becoming covered with flora in an unorganised way. As the result of social consultation procedures and field analyses during planning the revitalization process, it was decided that the estate park would be the most desirable target function of this land.

The distinction between three development types – allotment gardens, abandoned land and a park – entails changes in the dominant function of the area, its availability, maintenance costs and species diversity (or in a broader sense – biodiversity), (table 1).

Table 1. The functional and spatial diversity of the area of allotment gardens, abandoned land and the park

Development type	Allotment gardens	Abandoned land	Estate park
Function	Regulating, recreational, resource, leisure	Regulating	Regulating, recreational, leisure, cultural
Accessibility	Limited	Limited/Unlimited	Unlimited
Maintenance costs	Medium	Marginal	High
Species diversity	Low	High	Medium

From the point of view of the local community, it is the estate park and allotment gardens that perform the biggest number of functions. Apart from the regulating services they provide, they also fulfil recreational and leisure functions. Moreover, allotment gardens provide resource services, while the park offers cultural services. As far as the functionality of abandoned land is concerned, it is the provision of regulating functions that is of the highest importance. What is also significant is the differentiation of these areas in terms of their availability. There is unlimited access to the estate park, which is not the case when it comes to the allotment gardens, used only by their owners, their friends and family members. People from outside are not allowed to enter this space. The issue of the availability of abandoned land is controversial. There are no physical barriers which disturb the access to this area, nor there are effective formal barriers to entry. However, the fact that it is undeveloped land, perceived as a dangerous place, does not encourage residents to visit it. The other elements that differentiate the selected development types include maintenance costs – the lowest in the case of abandoned land (they are practically non-existent), the highest for the park (it does not matter whether the costs are incurred by natural persons, legal persons or local government units). The species diversity in this area was also the lowest in the case of its original function (allotment gardens). It was moderate in the case of the park, while abandoned land exhibits the highest diversity in this respect.

The change in the function of this area in time and the proposed new function also entail changes in the value of services provided. The study of the valuation of resource and regulating services provided by allotment gardens, abandoned land and parks in Gniezno has been conducted (it did not include this area, though). Its results, however, may be used to make general conclusions referring to the area under consideration.

The methodology and results of the research

The research methodology was based on the valuation of basic regulating services, such as water retention, the absorption of carbon dioxide, and oxygen supply. What is more, with reference to parks and allotment gardens, the value of trees and – only for gardens – the value of crops was evaluated as a significant element of their functioning (table 2). What was the principal research tool used for the valuation of the provision of allotment gardens' services were survey questionnaires and direct interviews with people growing plants in the gardens (the total number of the respondents was 112). Additionally, individual in-depth interviews with the representatives of the College of Heads of Family Allotment Gardens were conducted. The principal research methods included the replacement cost method and the replacement value method[10]. As far as abandoned land is concerned, it was evaluated on the basis of natural inventory, supplemented by the methods of spatial analysis and mapping. The basic elements that were evaluated included: the degree of succession and the density and diversity of vegetation, as well as its size. The main method was the replacement cost method. The valuation of parks, performed for four separate areas, was principally based on detailed species natural inventory combined with the evaluation of the size and condition of trees. Its results were mainly obtained with the application of the replacement value method. The provided values always refer to the time span of one year.

10 The detailed elements of the research procedure, due to the limited size of the study, were not presented.

Table 2. The methodology of the study of the valuation of services provided by areas of different development type in Gniezno

Development type	Allotment garden	Abandoned land	Park
Evaluated elements	Regulating • Water retention • Absorption of carbon dioxide • Oxygen supply		
	Provisioning (Crops) Value of trees (replacement value + ecosystem services value)	–	Value of trees (replacement value + ecosystem services value)
Research tools	Questionnaires and direct interviews among randomised allotment owners	Natural inventory (the degree of succession and density of vegetation)	Natural inventory in 5 city parks
Research methods	Replacement cost method, replacement value method	Replacement cost method	Replacement value method

Due to the differences in the availability of data and in the research methods applied in the evaluation of each ecosystem type, the obtained results are not fully comparable. However, they are of high cognitive value, defining first of all relations between the economic value of the particular types of urban ecosystems. Moreover, they indicate estimated figures that can be broadly applied.

Table 3. The value of parks in Gniezno

	Park Miejski (City Park)	Park Trzech Kultur (Three Cultures Park)	Park im. T. Kościuszki (T. Kościuszko Park)	Park im. R. Kaczorowskiego (R. Kaczorowski Park)
Total value of services [PLN]	50,529,308.45	7,526,291.14	6,395,954.59	2,665,842.87
Size [ha]	12	3.7	1.6	0.53
Average value of 1 ha of the park 1 [PLN/1 ha]	4,210,775.70	2,034,132.74	3,997,471.62	5,029,892,21
Total value of services 1 ha of a park in Gniezno				3,818,068.07

Source: author's own work based on Trafna[11].

As far as the valuation of parks is concerned, it should be pointed out that the value of services they provide is varied (table 3). It is first of all determined by the age and condition of tree stand and by the existing auxiliary

[11] B. Trafna, *Wycena wartości ekonomicznej parków miejskich Gniezna*, MA thesis, typescript.

facilities. The average value of services provided by 1ha of a park in Gniezno is thus almost 4 million PLN.

The value of abandoned land is difficult to assess since areas of such land are scattered all around the city and have a diverse structure. Therefore, the study covered only a part of the vector numerical map of the city, identifying 33 synanthropic plant communities. In the course of the applied research procedure, the average value of the services they provided was estimated at over 1 million PLN (680 thousand PLN per one hectare).

Table 4. The value of abandoned land in Gniezno

	The average value of the area under study [ha]	The average value of services [PLN]	The average value of services per 1 ha [PLN/1ha]
Abandoned land	1.75	1,117,329.10	682,853.43

Source: author's own work based on Hejna[12].

The value of allotment gardens was established for each of the gardens for which data from a survey questionnaire and a direct interview was available. Both the value of regulating and maintaining services and the value of provisioning services were analysed. That is why the value of services is relatively high in the case of garden allotments, which partly reflects their specific nature – quite intensive plant development, relatively low species diversity, and the presence of crop plants. The average annual value of services provided by one garden allotment was estimated at slightly below 200 thousand PLN (almost 5 million PLN per 1 ha).

Table 5. The value of allotment gardens in Gniezno

	Average size [ha]	Average value of services of 1 garden [PLN]*	Average value of services per 1 ha [PLN/1ha]
Allotment garden	0.04	191,538.23	4,788,455.68

* it consists of the average annual value of services of crops, the average annual value of services of a lawn, and the average annual value of services of trees and bushes.
Source: author's own work.

The presented research results indicate the high differentiation of the particular types of spatial development (figure 1). The services of allotment gardens and parks are clearly dominant, while abandoned land shows the

12 M. Hejna, *Wycena wartości świadczeń ekosystemów terenów naturalnych i półnaturalnych w obszarach zurbanizowanych na przykładzie miasta Gniezna*, MA thesis, typescript.

lowest values. The diversity would be even higher if a group of cultural services was included in the valuation of services[13].

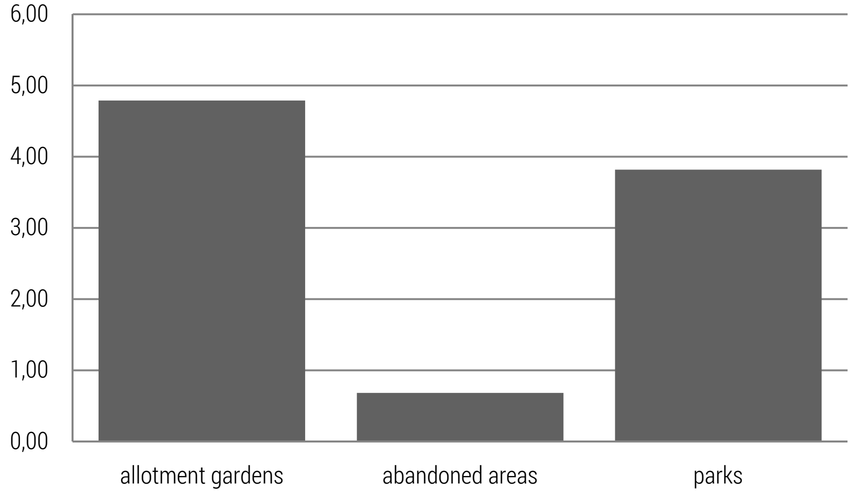

Figure 1. The average value of selected ecosystem services provided by 1 ha of areas of different development types. The case of Gniezno [PLN]

Conclusion

The presented research and its results are an important source of information for local decision-makers. The formulation of strategies, plans and programmes should be based on the broadest possible scope of diagnostic data. As it was pointed out in the introduction, this data may be particularly useful for programming the process of revitalization. It is a costly activity, thus the possibility of applying the results of research conducted for other purposes seems especially valuable. It delivers new dimensions of cost-benefit analysis and gives the possibility to consider different alternatives. In presented case, the revitalization process of Grunwaldzkie housing estate, it strictly provides to the conclusion, that planned park would be almost as "environmentally effective" space as allotment gardens were. Other park's

13 Presented results were obtained during research made on different part of the city, but as it was mentioned in the introduction, they could be useful for the sake of planning the revitalization process of Grunwaldzkie housing estate. The results cover the same types of ecosystem located within the same city, so the results seem to be comparable.

characteristic as its availability and cost of maintenance allow to assess the planned land use as the most favourable.

Moreover, the economic and social spheres are often subject to an in-depth diagnosis of strategic process. The economic efficiency of the proposed solutions is evaluated on the basis of data from the labour market, economy or social welfare indicators. At the same time, the economic analysis of environmental resources is not actually used at all. However, its effects may, as it was showed in this paper, constitute an important argument in the decision-making process (as e.g. revitalization). The presented relations between the values of services provided by the selected types of green infrastructure development refer to a specific example. The mutual relations of these values may be also examined from a dynamic perspective, as a change occurring in time with the changing development type. It seems justifiable to conduct analyses for other scenarios as well and to attempt to identify directions of changes in the values of services provided accompanying changes in the functions of green areas in cities.

Literature

Baró F. et al., *Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities*, "Ecological Indicators" 2015 no. 55, p. 146–158

Dobbs C., Escobedo F.J., Zipperer W.C., *A framework for developing urban forest ecosystem services and goods indicators*, "Landscape and Urban Planning" 2011 no. 99, p. 196–206

Elmqvist T. et al. (eds), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, Springer 2013

Escobedo F.J., Kroeger T., Wagner J.E., *Urban forests and pollution mitigation: analyzing ecosystem services and disservices,* "Environmental Pollution" 2011 no. 159, p. 2078–2087

Gómez-Baggethun E., Barton D.N., *Classyfying and valuating ecosystem services for urban planning*, "Ecological Economics" 2013 no. 86, p. 235–245

Hejna M., *Wycena wartości świadczeń ekosystemów terenów naturalnych i półnaturalnych w obszarach zurbanizowanych na przykładzie miasta Gniezna*, MA thesis, typescript

Kronenberg J., Bergier T. (ed.), *Wyzwania zrównoważonego rozwoju w Polsce,* Kraków 2010

Littke H., *Planning the green Walkable City: Conceptualizing values and conflicts for urban green space strategies in Stockholm*, "Sustainability" 2015 no. 7, p. 11306–11320

Middle I.et al., *Integrating community gardens into public parks: An innovative approach for providing ecosystem services in urban areas*, "Urban Forestry and Urban Greening" 2014 no. 13(4), p. 638–645

Mizgajski A. et al., *Development of the ecosystem services approach in Poland*, "Ekonomia i Środowisko" 2014 no 4(51), p. 10–19

Niemelä J. et al., *Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study*, "Biodiversity and Conservation" 2010 no. 19(11), p. 3225–3243

Nowak D.J., Crane D.E., Dwyer J.F., *Compensatory value of urban trees in the United States,* "Journal of Arboriculture" 2002 no. 28, p. 194–199

Pataki D.E. et al., *Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions*, "Frontiers in Ecology and the Environment" 2011 no. 9, p. 27–36

Szczepanowska H.B. (ed.), *Metoda wyceny wartości drzew na terenach zurbanizowanych dla warunków polskich*, Warszawa 2009

Trafna B., *Wycena wartości ekonomicznej parków miejskich Gniezna*, MA thesis, typescript

Żylicz T., *Valuation of ecosystem services. An overview of world research* "Ekonomia i Środowisko" 2010 no 1(37), p. 31–45

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ATTRIBUTES AFFECTING THE VALUE OF UNDEVELOPED REAL PROPERTY BASED OF COMMUNES OF KOMORNIKI AND MUROWANA GOŚLINA

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ATRYBUTY WPŁYWAJĄCE NA WARTOŚĆ NIERUCHOMOŚCI NIEZABUDOWANYCH NA PRZYKŁADZIE GMIN: KOMORNIKI, MUROWANA GOŚLINA

STRESZCZENIE: Celem pracy było wyodrębnienie czynników wpływających na wartość nieruchomości budowlanych na przykładzie gmin: Komorniki oraz Murowana Goślina, uwzględniając walory środowiskowe i społeczno-ekonomiczne. W opracowaniu przeanalizowano materiały z lat 2010–2013 zawarte w transakcjach kupna-sprzedaży nieruchomości niezabudowanych, pozyskane z PODGiK w Poznaniu. Wyniki analizowano z wykorzystaniem sieci neuronowych. Największy wpływ na kształtowanie się wartości gruntów budowlanych w gminie Komorniki miało występowanie sieci kanalizacyjnej, a w gminie Murowana Goślina – powierzchnia działki.

SŁOWA KLUCZOWE: nieruchomość niezabudowana, metoda cen hedonicznych, sieci neuronowe

Introduction

Land designated for residential development outside the possibility of mounting thanks to their location and surroundings also provide ecosystem services from which you can replace the provision of recreational and aesthetic.

Such benefits include, among others the possibility of walking through the woods and along the shores of lakes or admire the landscape from the window of your own home. Selling the land recognize some of these benefits, taking into account the values in the transaction prices of land sold.

The level of prices recorded on the local real property market in sale-purchase transactions reflects attributes affecting their value. Significant attributes influencing the value of undeveloped real property allocated to single-family housing include nature value as a unique additional income generated by the natural capital.

The process of real property appraisal is complicated, as it requires consideration of many factors. This effect is not uniform, with some factors having a greater effect than others. When estimating real property in the determination of market value of real property we most frequently apply a comparative approach, which in accordance with Art. 153 of the Act on real property economy should include e.g. attributes affecting the value of real property. Determination of weights of market attributes affecting the value of real property is a complex process. According to the National Appraisal Guidelines (Ni1 – application of a comparative approach in real property appraisal) weights of market attributes may be determined in three ways:

- Analysing data bases of prices and attributes of real property previously being objects of market turnover in the period of price analysis,
- Through analogy to local markets of similar type and area,
- Based on studies – observations of preferences of potential real property buyers (data from real property agencies).

Having a relatively large sample (the number of transactions) and certain characteristics attributed to each real property we may apply statistical methods. The application of these methods in analyses of real property markets provides significant information on the behaviour of this market. This information is objective and may be used both to conduct individual and mass-scale appraisals[1]. In developed real property markets statistical methods are acknowledged and frequently used tools in the analysis of real prop-

[1] A. Bitner, *O użyteczności metod statystycznych w wycenie nieruchomości,* "Infrastruktura i Ekologia Terenów Wiejskich" 2010 no. 12, p. 145–158.

erty markets[2, 3, 4.] In Polish literature on the subject statistical methods analysing factors affecting the value of real property were applied by[5,1, 6,7,8, 9,10.]

The aim of this study was to identify factors affecting the value of building real property in the communes of Komorniki and Murowana Goślina considering environmental and socio-economic values.

Study area

The study area comprised two communes (figure 1) (Komorniki, Murowana Goślina) located in the Poznań county, distinguished by nature value (vicinity of the Wielkopolska National Park and the Puszcza Zielonka Landscape Park).

The Murowana Goślina commune with the population of 16 thousand inhabitants is located at a distance of 20 km north of the Poznań city centre. This commune neighbours the Puszcza Zielonka Landscape Park. Marked cycling paths are 500 km in length. Around the Park the Trail of Wooden Churches was established, with a beautiful 17th century church in Długa Goślina. Attractive accommodation throughout the year is offered to tourists by 18 hotels and agritourist farms. Avid swimmers may use bathing beaches in Kamińsko, Okoniec and Wojnówko. The Śnieżycowy Jar reserve of spring snowflake, unusual for lowland areas, located in Starczanowo, in the spring is admired by tourists for its white blanket of flowers.

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2 R. Bruce, D.J., Sundell, *Multiple regression analysis: history and applications in the apprasial proffesion*, "Real Estate Appraiser" 1977 Jan/Feb, p. 37–44.

3 J. K. Eckert (ed.), *Property appraisal and assessment administration*, Chicago 1990.

4 J. Hozer, S. Kokot, W. Kuźmiński, *Metody analizy statystycznej rynku w wycenie nieruchomości*, Warszawa 2002.

5 A. Bitner, *Konstrukcja modelu regresji wielorakiej przy wycenie nieruchomości*, "Acta Sci. Pol., Administratio Locorum" 2007 no. 6(4), p. 59–66.

6 K. Gawroński, B. Prus, *Lokalny rynek nieruchomości oraz wybrane czynniki kształtujące ceny nieruchomości rolnych i działek budowlanych na przykładzie miasta Niepołomice*, "Infrastruktura i Ekologia Terenów Wiejskich" 2005 no. 4, p. 7–18.

7 P. Parzych, *Modelowanie wartości nieruchomości zurbanizowanych*, "Studia i Materiały Towarzystwa Naukowego Nieruchomości" 2007 no. 15(3–4).

8 R. Walkowiak, A. Zydroń, *Zastosowanie regresji krokowej do określenia atrybutów wpływających na wartość nieruchomości rolnych na przykładzie gminy Mosina*, "Acta. Sci. Pol., Administratio Locorum" 2012 no. 11(3), p. 239–253.

9 A. Zydroń, R. Walkowiak, *Analiza atrybutów wpływających na wartość nieruchomości niezabudowanych przeznaczonych na cele budowlane w gminie Mosina*, "Annual Set The Environment Protection" 2013 no. 15, p. 2911–2924.

10 A. Zydroń, D. Kayzer, *Podnoszenie świadomości społeczeństwa o nowych metodach wyceny wartości przyrody – Willingness to Pay oraz Willingness to Accept na przykładzie Wielkopolskiego Parku Narodowego*, Poznań 2015.

The Komorniki commune of almost 24 thousand inhabitants is located in the central part of the Wielkopolskie province. It is one of the most dynamically developing demographically communes in Poland. It results from the fact that it is one of the most developed economically communes in the Poznań conurbation, which to a considerable degree is caused by the advantageous location for transport, i.e. the vicinity of Poznań, a well-developed transport system, particularly the vicinity of the A2 motorway with the exit from this motorway in Komorniki and the commune-operated bus transportation. In the commune of Komorniki there are areas covered by legal nature protection forms, such as the Wielkopolska National Park, the Protected Landscape Area of the Wirynka River Valley and the Natura 2000 areas.

Figure 1. Location of the study area

Methods

Studies comprised an analysis of sale-purchase transactions for undeveloped land in the communes of Komorniki and Murowana Goślina in the years 2010–2013. In the study we analysed materials concerning sale-purchase transactions, i.e. 385 transactions in the commune of Komorniki and 392 transactions in the Murowana Goślina commune, which were obtained from the the County Geodesy and Cartographic Documentation Centre in Poznań. It was established that the area of a plot for building purposes should be min.

300 m^2 and max. 3000 m^2. Based on the analyses of these land sale-purchase transactions the following variables were identified:

- sewerage network (0 – not present, 1 – present);
- distance from Poznań city limits [km];
- distance from surface waters [km];
- distance from protected forested areas [km];
- plot area [m^2];
- year of study (2010, 2011, 2012 , 2013).

The dependence between the price for 1 m^2 undeveloped real property allocated to building purposes in the selected communes and the analysed characteristics in a given year was determined using artificial neural networks. Automated neural networks available in STATISTICA 10.1 were used for the statistical analyses. As a measure of fit for the model evaluating the price of 1 m^2 undeveloped real property in comparison to the actual value resulting from the sale-purchase transactions we adopted the correlation coefficient.

In order to distinguish important variables from those, which are not informative for the network operation we conducted the analysis of sensitivity. This analysis may be conducted only to learn something on input variables. Analysis of sensitivity does not provide an absolute evaluation of the usefulness of variables. It has to be exercise with caution, which does not undermine its practical usefulness. The primary measure of network sensitivity is the quotient of error obtained when initiating the network for a set of data without one variable and error obtained with a complete set of variables. The greater the error after the rejection of a variable in relation to the original error, the more sensitive the network is to a lack of this variable. If the quotient of the errors is 1 or even smaller, the elimination of the variable does not influence the quality of the network.

In order to indicate whether there is a trend for real property prices connected with individual years, a model was constructed with an additional variable – the year, in which the sale-purchase transaction was executed. Valuation of ecosystem services was made by Hedonic Pricing Method.

Results

Modelling of prices for 1 m^2 undeveloped real property for building purposes was performed using artificial neural networks. For each analysed case an original model structure was obtained. In addition, there were differences in the activation functions of hidden neurons (linear, hyperbolic tangent and exponential) and output neurons (exponential and logistic) in each model. These differences result from the essence of the learning process of neural networks, in which using iterative algorithms the network structure is cleared in order to minimise errors.

The values of the correlation coefficients specifying the quality of models in each year evaluating the level of prices for 1 m^2 undeveloped real property in the both communes varied from 0.34 to 0.84. The models take into account year research correlation coefficient for Komorniki was 0.49, and for the municipality of Murowana Goślina 0.46.

Results of sensitivity analysis for models with individual years evaluating prices for 1 m^2 undeveloped real property in the communes of Komorniki and Murowana Goślina are present in table 1, while in table 2 for this communes with an additional variable – the year.

Table 1. Sensitivity analysis of artificial neural networks for models with individual years

commune	year	sewerage network	distance from Poznań	distance from surface waters	distance from forested areas	plot area
Komorniki	2010	9.689	1.571	1.319	1.020	1.017
	2011	2.918	0.991	1.022	1.215	1.020
	2012	1.069	0.995	1.001	1.019	1.000
	2013	2.508	1.344	1.006	1.214	1.030
Murowana Goślina	2010	1.008	0.997	0.999	1.000	1.250
	2011	1.007	0.999	0.999	1.000	1.001
	2012	5.042	1.022	1.119	1.013	1.099
	2013	1.598	1.240	0.887	1.142	1.760

Table 2. Sensitivity analysis of artificial neural networks for models with an additional variable – the year

commune	sewerage network	distance from Poznań	distance from surface waters	distance from forested areas	plot area	year of study
Komorniki	3.176	1.036	0.999	1.326	1.007	1.110
Murowana Goślina	1.006	1.063	1.012	1.015	1.496	1.047

When investigating results of sensitivity analysis it was found that the price for 1 m^2 undeveloped real property for building purposes in the Komorniki commune depends mainly on the existence of the sewerage system. Based on the values of coefficients of 9.689, 2.918, 2.508 it was stated that in the years 2010, 2011 and 2013 this factor considerably modified the value of sold real property. The effect on variability of plot prices in 2010 and 2013 was additionally connected with the distance from the Poznan city limits and in 2010 with the distance from surface waters. Moreover, it was recorded that the distance from the Wielkopolska National Park in 2011 and 2013 affected changes in prices for 1 m^2 real property. In 2012 based on the results of sensitivity analyses it was not stated that the investigated factors influenced plot prices in executed sale-purchase transactions.

When investigating results of sensitivity analyses for modelling the value of 1 m^2 plots located in the Murowana Goślina commune it was found that in 2010 and 2013 the price was considerably affected by plot area, while in 2012 and 2013 it was the existence of the sewerage network. In contrast to the Komorniki commune, in this commune the prices of plots were not significantly influenced by environmental value (protected forests areas, surface waters).

In addition, it was noted that the effect of the distance from forest protected areas for the price of 1 m^2 of real estate has changed over the years. In the last year of the study noted that the price of land in the municipality greatly influence begins the direct neighborhood of the Forest Zielonka.

When analysing the assessment of coefficients obtained based on the sensitivity analysis it was observed that for modelling including variability connected with the year of sale it was not stated that the years, in which transactions were executed, considerably affected the price of 1 m^2 undeveloped real property for building purposes in the investigated communes. It may be stated that there exists a certain variability connected with years, but it is more adequate to state that prices in the investigated years remained within a certain relative stable range. Additionally it was found that the effect of the attribute of the distance from protected forested areas (in the years of analysis 2011, 2013) for the Komorniki commune on the price of 1 m^2 real property was highly significant, since it implies the effect of this factor for the constructed model including the years, in which the sale-purchase transactions were executed.

Figures 2 presents graphs for the scatter describing the relationships between the observed values of prices for 1 m^2 real property and the corresponding residuals (differences between the actual and modelled prices). On their basis it was found that among the transactions we may find those, for which the price of 1 m^2 seems underestimated in relation to the other transactions. In each of the analysed samples (learning, validation, testing) we may find cases, in which market values are lower by 100 to 200 PLN than the general trend resulting from the executed sale-purchase transactions. These cases to a considerable extent may affect the reduction of quality for the conducted modelling. Frequent occurrence of these observations in the analysed sale-purchase transactions influence the value of square errors, which significantly complicates the establishment of market value of real property taking into consideration the comparative approach.

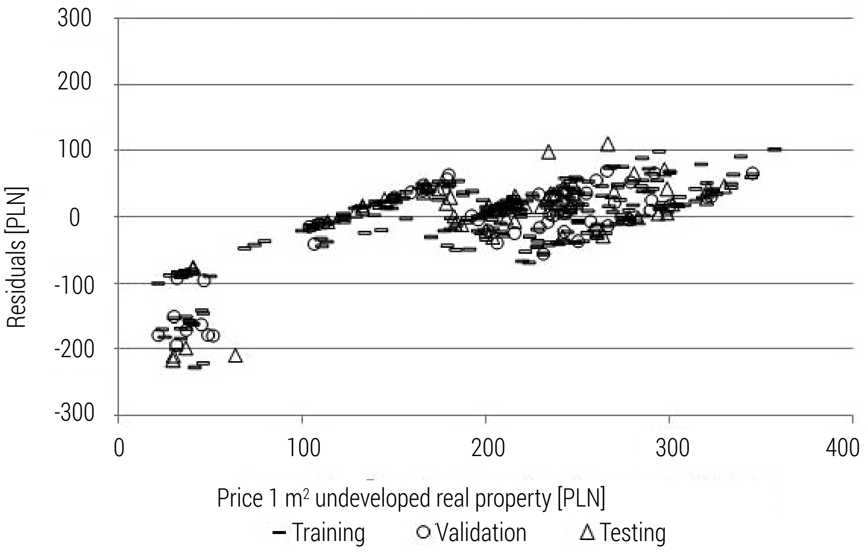

Figure 2. Comparison of the modelled and residual values

Discussion

Based on the analyses it was found that the value of undeveloped real property depending on the year of study and on the selected commune was influenced by various factors. These results are consistent with those reported by other authors[11]. It was also observed in this study that there is a dependence between plot size and the transaction price (the larger the plot, the unit price decreases). This problem was discussed in studies by[12,13,1], where a more marked relationship was obtained between these variables. The difference in the results between individual authors resulted among

11 K. Gawroński, B. Prus, *Lokalny rynek nieruchomości oraz wybrane czynniki kształtujące ceny nieruchomości rolnych i działek budowlanych na przykładzie miasta Niepołomice*, "Infrastruktura i Ekologia Terenów Wiejskich" 2005 no. 4, p. 7–18.

12 S. Źróbek, M. Bełej, *Podejście porównawcze w szacowaniu nieruchomości*, Olsztyn 2000.

13 M. Prystupa, *Wycena nieruchomości przy zastosowaniu podejścia porównawczego*, Warszawa 2001.

other things from the adopted assumptions when selecting variables applied in modelling, trends in specific years of study and attractiveness of plots related to their location. It is frequently assumed that the analysed real property have to differ in only one characteristic, which is uncommon in reality. Practically it is impossible to find around a dozen real property differing in only one characteristic, for which sale-purchase transactions were recorded[1]. Both in this study and in a study by1 the analyses included all sale-purchase transactions on the market using all available information on dependencies between the price of a plot and its attributes. In view of analyses based on multiple regression we may agree with1 that the application of linear models in the estimation of real property value is advisable thanks to the objective and simple method to determine the effect of attributes on the value of real property. This approach has another drawback, as it is assumed that explaining variables are continuous variables. These assumptions are not met in the case of such attributes as the location of high voltage grid lines or the access to the sewerage network. For this reason it is recommended to use other methods, taking into consideration attributes presented in the form of a discreet variable. One of such methods is modeling of prices of 1 m2 using neural networks. This may lead to differences in the application of these methods. In turn, one of the drawbacks of the application of neural networks is connected with a lack of objective criteria, which specify from what figure the quotient of the error obtained when initiating the network for a set of data without one attribute and the error obtained with a set of variables show the significance of this attribute.

Conclusions

1. The greatest effect on the fluctuations in the value of building land in the Komorniki commune was observed for the access to the sewerage network, while in the Murowana Goślina commune it was plot area.
2. It was noted that in the municipality of Komorniki significantly the price of 1 m^2 of undeveloped property received direct vicinity of the Wielkopolska National Park. However in the municipality of Murowana Goślina it noted that the neighborhood of the Forest Zielonka year increasingly affects the price of 1 m^2 plot.
3. It was observed that in the Murowana Goślina commune only in the years 2012–2013 the price of 1 m^2 undeveloped real property was influenced by access to the sewerage network.
4. It was not stated that the price of 1 m^2 real property was significantly influenced by the year, in which the transaction was concluded.

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Literature

Bitner A., *O użyteczności metod statystycznych w wycenie nieruchomości,* "Infrastruktura i Ekologia Terenów Wiejskich" 2010 no. 12, p. 145–158

Bitner A., *Konstrukcja modelu regresji wielorakiej przy wycenie nieruchomości*, "Acta Sci. Pol., Administratio Locorum" 2007 no. 6(4), p. 59–66

Bruce R., Sundell D.J., *Multiple regression analysis: history and applications in the apprasial proffesion*, "Real Estate Appraiser" 1977, Jan/Feb, p. 37–44

Eckert J.K. (ed), *Property appraisal and assessment administration*, Chicago 1990

Gawroński K., Prus B., *Lokalny rynek nieruchomości oraz wybrane czynniki kształtujące ceny nieruchomości rolnych i działek budowlanych na przykładzie miasta Niepołomice*, "Infrastruktura i Ekologia Terenów Wiejskich" 2005 no. 4, p. 7–18

Hozer J., Kokot S., Kuźmiński W., *Metody analizy statystycznej rynku w wycenie nieruchomości*, Warszawa 2002

Parzych P., *Modelowanie wartości nieruchomości zurbanizowanych*, "Studia i Materiały Towarzystwa Naukowego Nieruchomości" 2007 no. 15(3–4)

Prystupa M., *Wycena nieruchomości przy zastosowaniu podejścia porównawczego*, Warszawa 2001

Walkowiak R., Zydroń A., *Zastosowanie regresji krokowej do określenia atrybutów wpływających na wartość nieruchomości rolnych na przykładzie gminy Mosina*, "Acta.Sci. Pol., Administratio Locorum" 2012 no. 11(3), p. 239–253

Źróbek S., Bełej M., *Podejście porównawcze w szacowaniu nieruchomości*, Olsztyn 2000

Zydroń A., Kayzer D., *Podnoszenie świadomości społeczeństwa o nowych metodach wyceny wartości przyrody – Willingness to Pay oraz Willingness to Accept na przykładzie Wielkopolskiego Parku Narodowego*, Poznań 2015

Zydroń A., Walkowiak R., *Analiza atrybutów wpływających na wartość nieruchomości niezabudowanych przeznaczonych na cele budowlane w gminie Mosina*, "Annual Set The Environment Protection" 2013 no. 15, p. 2911–2924

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ECONOMIC VALUATION OF ECOSYSTEM SERVICES PROVIDED BY THE WILANÓW PARK. A BENEFIT TRANSFER STUDY

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"EKONOMICZNA WYCENA USŁUG EKOSYSTEMOWYCH ŚWIADCZONYCH PRZEZ PARK W WILANOWIE. BADANIE METODĄ TRANSFERU KORZYŚCI

STRESZCZENIE: Rezydencja królewska w Wilanowie to unikalne połączenie zdumiewającej architektury, historii i przyrody. Park w Wilanowie dostarcza wielu korzyści zarówno odwiedzającym go turystom, jak i mieszkańcom Warszawy. W niniejszym badaniu podjęto się oszacowania wartości ekonomicznej tych z korzyści, które mają związek z przyrodą, to jest wartości usług ekosystemowych świadczonych przez park. W oparciu o metodę transferu korzyści wartość usług ekosystemowych dostarczanych przez park w Wilanowie oszacowano na 500 tys. euro rocznie. Choć liczba wydaje się duża, jest znacznie niższa niż wartość innych świadczeń dostarczanych przez zasoby rezydencji.

SŁOWA KLUCZOWE: ekonomiczna wycena wartości; usługi ekosystemowe; metoda transferu korzyści; Park w Wilanowie

Introduction

King Jan III Sobieski (1629–1696), known as an excellent military commander who defeated the Turkish army near Vienna in 1683, was a profound nature lover. Unhappy with living in a castle in the capital city, he bought Wilanów near Warsaw, where he established his suburban residence with a beautiful baroque palace and gardens. After the World War II, the estate was nationalised, restored and turned into a museum.

There are probably no trees planted by king Jan III Sobieski himself, but the Park is remarkable. It comprises gardens in various styles (baroque, neo-Renaissance, English and English-Chinese) and a nature reserve Morysin with valuable habitats of meadows and forests. Woodlands, grasslands and ponds constitute three main ecosystems in the Park.

Tourists and Warsaw inhabitants appreciate the nature of the gardens and of the Morysin reserve. In addition to their unquestioned historical and cultural value, the Park ecosystems provide multiple environmental benefits. In this paper, we estimate the economic value of these benefits.

Ecosystem services

Economic assessments of ecosystem services have been conducted for at least two decades. Costanza et al. (1997)[1] is an early example of a global valuation exercise. In 2014[2] they revisited their study and found the value reported therein was largely underestimated. Costanza and his team are credited for grouping ecosystem services into three general categories: provision of raw materials, regulation of natural processes and societal functions (such as recreation).

The original 1997 study identifies 17 types of ecosystem services. This list has been amended. Current assessments typically use the *Common International Classification of Ecosystem Services* (CICES 2015)[3]. The latest CICES list includes 46 items, of which 15 refer to the provision of raw materials, 20 to the regulation of natural processes and 11 to societal functions.

1 R. Costanza et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997 vol. 387, p. 253–260.

2 R. Costanza et al., *Changes in the global value of ecosystem services*, "Global Environmental Change" 2014 vol. 26, p. 152–158.

3 CICES 2015 *Towards a common classification of ecosystem services*, cices.eu [21-05–2016].

Benefit transfer technique

To assess ecosystem services, an empirical study at the location of interest is the first-best approach. However, it is often impossible because of time and cost constraints. Alternatively, one can extrapolate results from another study, similar in relevant aspects to the site analysed. This method is called "benefit transfer"[4].

The literature provides two main approaches how to use values from a study of a different site. One approach splits a good G into components g_1, g_2, ..., g_n, and identifies the value of each component on the basis of other studies. Formally,

$$G = (g_1, g_2, ..., g_n), \text{ and } TEV(G) = TEV(g_1) + TEV(g_1) + ... + TEV(g_n), \tag{1}$$

where TEV denotes the total economic value. The approach is useful in assessing projects with multiple benefits. For instance, if switching from using a car to a bus reduces air pollution, noise and road accidents, then the overall gain from the change in the transport mode can be decomposed into gains from the separate elements, each of which is evaluated using earlier assessments.

The second approach interprets value estimates for one site from a perspective of another site[5]. If good G is assessed at site s (the empirical study site) at the level $TEV_s(G)$, then the approach gives $TEV_p(G)$, the value of the same good at site p (the policy site).

The simplest way would be to assume $TEV_p(G) = TEV_s(G)$, but it may generate high errors of the estimates[6]. Why may $TEV_p(G)$ be different from $TEV_s(G)$?

4 R.J. Johnston et al., *Benefit transfer of environmental and resource values: A guide for researchers and practitioners*, Dordrecht 2015.

5 H. Ahtiainen et al., *Performance of different approaches in international benefit transfer: Insights from a nine country experiment*, Working Paper Series of the Department of Economics of the University of Warsaw 2015 no. 28(176); M. Czajkowski, M. Ščasný, *Study on benefit transfer in an international setting. How to improve welfare estimates in the case of the countries' income heterogeneity?* "Ecological Economics" 2010 vol. 69(12), p. 2409–2416.

6 L.M. Londoño, R.J. Johnston, *Enhancing the reliability of benefit transfer over heterogeneous sites: A meta-analysis of international coral reef values*, "Ecological Economics" 2012 vol. 78, p. 80–89; I.J. Bateman et al., *Making benefit transfers work: Deriving and testing principles for value transfers for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe*, "Environmental and Resource Economics" 2011 vol. 50(3), p. 365–387; H. Lindhjem, S. Navrud, *How reliable are meta-analyses for international benefit transfers?* "Ecological Economics" 2008 vol. 66(2–3), p. 425–435.

One reason is that the people whose preferences are examined have different incomes in both sites (say Y_p and Y_s, $Y_p \neq Y_s$). Let the value of good G depend on the incomes with constant elasticity ε (that is, $TEV_p(G)/TEV_s(G) = (Y_p/Y_s)^{\varepsilon}$, then

$$TEV_p(G) = TEV_s(G)(Y_p/Y_s)^{\varepsilon}. \quad (2)$$

(2) is, perhaps, the most frequently used statement in benefit transfers. The elasticity ε has to be determined based on additional information. Lacking this information, analysts may assume ε = 1[7].

Another reason for $TEV_p(G) \neq TEV_s(G)$ is that people's characteristics other than income may affect the value of G : $TEV_s(G) = f(x_s, y_s, ..., z_s)$, where x_s, y_s, ..., z_s are variables observed at s that influence $TEV_s(G)$; function f is called a benefit function. The benefit transfer gives

$$TEV_p(G) = f(x_p, y_p, ..., z_p). \quad (3)$$

(2) is a special case of (3), with income Y being the only relevant variable and $f(Y_p)$ defined as $TEV_s(G)(Y_p/Y_s)^{\varepsilon.}$

Some researchers claim the more explanatory variables in f, the better[8]. Increasing the number of the variables improves the estimation fit, however, this needs not imply better transfer accuracy. The more variables taken into account at site s, the more likely that some of them are specific for site s and not for site p. It may give rise to a high error of the assessment.

The benefit transfer function f should have firm foundations in economic theory[9]. Parsimony is a good guide when transferring results from a study site to a policy site. Economic theory heavily relies on income, and neither age nor attained education seem to play a similarly strong role. Thus, including income in benefit transfer functions is inevitable.

7 H. Lindhjem, S. Navrud, *Reliability of meta-analytic benefit transfers of international value of statistical life estimates: Tests and illustrations*, in: R. J. Johnston et al. (eds), *Benefit transfer of environmental and resource values: A guide for researchers and practitioners*, Dordrecht 2015, p. 441–464.

8 I.J. Bateman et al., op. cit.

9 Ibidem.

Study of Wilanów Park

Using the benefit transfer technique, we evaluate ecosystem services provided by the Wilanów Park.

The first group of ecosystem services in CICES (2015)[10] encompasses provision of raw materials. The Park produces only one material of that sort: compost from grass and other organic residues in the amount of 350 tonnes annually. Assuming the market price of compost is 15 euro per tonne, it gives the year value of 5,250 euro.

The second group of ecosystem services covers regulation of natural processes. We evaluate them using two benefit transfer approaches. Our study area is composed of three ecosystems: grasslands, woodlands and ponds. Their surfaces are 17 ha, 8 ha and 17 ha, respectively, with additional 41 ha of woodlands in the Morysin reserve. Figure 1 presents the study area.

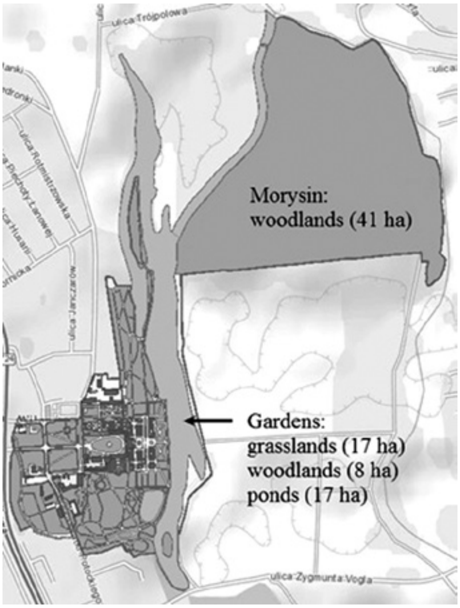

Figure 1.
A map of the study area

Our benefit transfer analysis shows that regulation of natural processes in the Park is valued annually 3,100 euro per ha of grasslands, 3,200 euro per ha of woodlands and 8,900 euro per ha of ponds. Given the Park area, the total year value of regulation services is 320,000 euro. Including Morysin increases the value by 135,000 euro.

The estimates in the paragraph above are based on the extensive literature review[11]. Only

10 CICES 2015, op. cit.

11 J. Barreiro et al., *How much are people willing to pay for silence? A contingent valuation study*, "Applied Economics" 2005 vol. 37(11), p. 1233–1246; T.B. Bjørner, *Comparing the value of quiet from contingent valuation and hedonic pricing methods*, paper presented at the 13th Annual Conference of the European Association of Environmental and Resource Economists, Budapest, Hungary 2004, June 25–28; T.B. Bjørner, *Combining socio-acoustic and contingent valuation surveys to value noise reduction*, "Transportation Research Part D: Transport and Environment" 2004 vol. 9(5), p. 341–356;

studies conducted in objects similar in terms of biotopes to the Wilanów Park were used to derive the estimates.

Relative to other biotope types, ponds provide ecosystem services of a high value. This is because empirical studies emphasise the important role of aquifers in regulating the water cycle and neutralising contamination. Although, this may seem an overstatement at first glance, ponds in the Park indeed play a significant environmental role, given that water pollution from southern Warsaw flows through the ponds, instead of reaching the Vistula river directly.

C.K. Chau et al., *A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes*, "Building and Environment" 2010 vol. 45(11), p. 2553–2561; W.Y. Chen, C.Y. Jim, *Assessment and valuation of the ecosystem services provided by urban forests*, in: M.M. Carreiro, Y.-C. Song, J. Wu (eds), *Ecology, planning, and management of urban forests*, New York 2008, p. 53–83; B. Day et al., *Beyond implicit prices: Recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model*, "Environmental and resource economics" 2007 vol. 37(1), p. 211–232; R. de Groot et al., *Global estimates of the value of ecosystems and their services in monetary units*, "Ecosystem services" 2012 vol. 1(1), p. 50–61; M. Fosgerau, T.B. Bjørner, *Joint models for noise annoyance and willingness to pay for road noise reduction*, "Transportation Research Part B: Methodological" 2006 vol. 40(2), p. 164–178; C.Y. Jim, W.Y. Chen, *Ecosystem services and valuation of urban forests in China*, "Cities" 2009 vol. 26(4), p. 187–194; T. Kroeger, *The economic value of ecosystem services in four counties in Northeastern Florida*, Conservation Economics Working Paper 2005 no. 2; E. MacMullan, S. Reich, *Economic arguments for protecting the natural resources of the east buttes area in southeast Portland*, Eugene, OR 2009; B. Martín-López et al., *The conservation against development paradigm in protected areas: Valuation of ecosystem services in the Doñana social-ecological system (southwestern Spain)*, "Ecological Economics" 2011 vol. 70(8), p. 1481–1491; A.A. Millward, S. Sabir, *Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada?* "Landscape and urban planning" 2011 vol. 100(3), p. 177–188; S. Navrud, *Economic benefits of a program to reduce transportation and community noise – A contingent valuation survey*, in: *Proceedings of Internoise* 2000 vol. 5, p. 3395–3400; S. Navrud, *Economic valuation of transportation noise in Europe*, "Revista italiana di Acustica" 2010 vol. 34(3), p. 15–25; J.E. Noel et al., *A benefit transfer estimation of agro-ecosystems services*, "Western Economics Forum" 2009 vol. 8(1), p. 18–28; N. Olewiler, *The value of natural capital in settled areas of Canada*, Ducks Unlimited and the Nature Conservancy of Canada, Manitoba 2004; D. Pimentel et al., *Economic and environmental benefits of biodiversity*, "BioScience" 1997 vol. 47(11), p. 747–757; A. Troy, K. Bagstad, *Estimating ecosystem services in southern Ontario*, Ontario Ministry of Natural Resources, Ontario 2009; S.J. Wilson, *Lake Simcoe basin's natural capital: The value of the watershed's ecosystem services*, David Suzuki Foundation, Friends of the Greenbelt Foundation Occasional Paper Series 2008, June; S.J. Wilson, *Ontario's wealth, Canada's future: appreciating the value of the Greenbelt's eco-services*, David Suzuki Foundation 2008; S.J. Wilson, *Natural capital in BC's Lower Mainland: Valuing the benefits from nature*, David Suzuki Foundation 2010; S.J. Wilson, *Canada's wealth of natural capital: Rouge National Park*, David Suzuki Foundation, 2012; H. Xu et al., *Assessment of indirect use values of forest biodiversity in Yaoluoping national nature reserve, Anhui province*, "Chinese Geographical Science" 2003 vol. 13(3), p. 277–283; D. Xue, C. Tisdell, *Valuing ecological functions of biodiversity in Changbaishan Mountain Biosphere Reserve in northeast China*, "Biodiversity and Conservation" 2001 vol. 10(3), p. 467–481.

To evaluate the regulating ecosystem services, we also took another approach, based on an inventory of more than 3,000 trees in the Park. Empirical studies show that urban trees provide many benefits, such as stabilising the temperature and removing toxic substances[12]. We focus on the latter as removing toxic substances is the main service the Park trees provide. Tree species, their physical characteristics and ability to decrease the air concentration of toxic substances such as sulphur dioxide (SO_2), nitrogen dioxide (NO2), particulate matter (PM10) and volatile organic compounds (VOCs) are identified as in McPherson et al. (2007)[13]. Based on that, we estimate the total year pollution removal by the Park trees at the following levels: 1.82 tonne of SO2, 1.16 tonne of NO2, 1.65 tonne of PM10 and 0.1 tonne of VOCs. We use the estimates of external costs of pollutants developed in the EU research project NEEDS (2008)[14] to express the monetary value of the pollution removal. Table 1 shows the external year costs of each of the considered air pollutants for Poland as given by NEEDS.

Table 1. The estimates of external costs of air pollutants based on NEEDS (2008)

	SO_2	NO_2	PM_{10}	VOC
External cost (in euro per tonne of the pollutant)	7,767	5,760	667	566

Source: P. Preiss *et al.*, *Report on the procedure and data to generate averaged / aggregated data*, NEEDS project, Stuttgart 2008.

Based on the above estimates, the total year value of the ecosystem services provided by the Park trees is 22,000 euro. This value is lower than the estimate from the preceding approach because it omits the value provided by other elements of the Park ecosystems than trees.

Valuation of the third group of ecosystem services (societal functions) would ideally be based on surveys among actual and potential visitors to the Park and people living nearby. Surveys are widely applied to find people's

12 S. Pauleit, F. Duhme, *GIS assessment of Munich's urban forest structure for urban planning*, "Journal of Arboriculture" 2000 vol. 26(3), p. 133–141; N.D. Dawe, *Sprinting toward sustainability*, "American Forests" 1996 vol. 102(2), p. 22–30, 45; C. Rosenzweig et al., *Green roofs in the New York metropolitan region: Research report*, Columbia University Center for Climate Systems Research and NASA Goddard Institute for Space Studies 2006; P.J. Peper et al., *New York municipal forest resource analysis. Technical report*, New York 2007; D.J. Nowak, *Atmospheric carbon dioxide reduction by Chicago's urban forest*, in: McPherson et al. (eds), *Climate urban forest ecosystem: Results of the Chicago urban forest climate project*, Chicago 1994.

13 E.G. McPherson et al., *Northeast community tree guide: Benefits, costs, and strategic planting*, Albany, CA 2007.

14 P. Preiss et al., *Report on the procedure and data to generate averaged / aggregated data*, NEEDS project, Stuttgart 2008.

preferences. In surveys, respondents are asked (i) directly about their preferences or (ii) about their consumption behaviour. Approach (ii) enables a travel cost analysis: based on people's choices, the demand for visits to the Park could be estimated, which would reflect the value of the Park's societal functions. However, we do not have data for such an analysis. Given high costs of conducting a survey, we refer to value estimates from other studies. Because the Wilanów Park is unique, a direct transfer of benefits identified in other objects (as done above for regulating ecosystem services) is associated with large uncertainty. Thus, we only say that the year value estimates in the existing assessments range from 200 euro per ha for open space[15] to 2,000 euro per ha for urban forests[16]. On this basis, a rough estimate of societal functions of the Park is 1,000 euro per ha, which gives the value of 42,000 euro per year. Including Morysin doubles this number.

Table 2 summarises our valuation. In terms of year flows, the Wilanów gardens supply services: of providing raw materials at 5,250 euro, of regulating natural processes at 320,000 euro and of societal functions at 42,000 euro. Including Morysin increases the values to: 455,000 euro for the regulating services and 83,000 euro for the societal functions. Summing the numbers gives the *TEV* of the Park's services of 365,250 euro annually, and of 543,250 euro annually when Morysin is included.

Table 2. The year values of ecosystem services provided by the Wilanów Park [euro]

	Gardens	Gardens and Morysin
Providing raw materials	5,250	5,250
Regulating natural processes	320,000	455,000
Societal functions	42,000	83,000
Total	365,250	543,250

To account for uncertainty and divergence in the existing valuations, we estimate that the year *TEV* of the Park's ecosystem services (with the mean of 365,250 euro) would be 41,000 euro if lower bounds of the relevant values were adopted, or 546,000 euro if the respective upper bounds were adopted. As we do not have any hints about the income elasticity of these services, we use the benefit transfer approach as in (1).

The *TEV* of the Park's services is a large number, but it yields to the historical value of the place. In 2013, the state budget allocated 5.75 million euro for the Wilanów Museum. This number reflects a so-called *implicit*

15 A. Troy, K. Bagstad, op. cit.; R. de Groot et al., op. cit.

16 W.Y. Chen, C.Y. Jim, op. cit.

value: it shows what the society pays for the supply of the good (here, the Palace with the Park). This number exceeds by far the value of the ecosystem services.

Conclusion

The total *implicit value* of the Wilanów Park is much higher than the value of ecosystem services. This does not imply that these ecosystems are of little value, but rather shows the high value of the Park's historical assets. Protecting the Park nature is certainly called for, but it cannot be the main argument for adequate financing of the estate.

The Park is a unique combination of magnificent architecture and nature. Both ingredients are valuable, but the uniqueness of the architecture and the historical tradition is probably more important. The local natural resources are precious and provide users with many benefits. Nevertheless, losing the natural assets, however painful, would imply smaller economic damage to the society than a loss of the Palace. Subsidies from the state budget reflect these proportions.

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Literature

Ahtiainen H. et al., *Performance of different approaches in international benefit transfer: Insights from a nine country experiment*, Working Paper Series of the Department of Economics of the University of Warsaw 2015 no. 28(176)

Barreiro J. et al., *How much are people willing to pay for silence? A contingent valuation study*, "Applied Economics" 2005 vol. 37(11), p. 1233–1246

Bateman I.J. et al., *Making benefit transfers work: Deriving and testing principles for value transfers for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe*, "Environmental and Resource Economics" 2011 vol. 50(3), p. 365–387

Bjørner T.B., *Combining socio-acoustic and contingent valuation surveys to value noise reduction*, "Transportation Research Part D: Transport and Environment" 2004 vol. 9(5), p. 341–356

Bjørner T.B., *Comparing the value of quiet from contingent valuation and hedonic pricing methods*, paper presented at the 13th Annual Conference of the European Association of Environmental and Resource Economists, Budapest, Hungary 2004, June 25–28

Chau C.K. et al., *A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes*, "Building and Environment" 2010 vol. 45(11), p. 2553–2561

Chen W.Y., Jim C.Y., *Assessment and valuation of the ecosystem services provided by urban forests*, in: M.M. Carreiro, Y.-C. Song, J. Wu (eds), *Ecology, planning, and management of urban forests*, New York 2008

CICES 2015 *Towards a common classification of ecosystem services*, cices.eu

Costanza R. et al., *Changes in the global value of ecosystem services*, "Global Environmental Change" 2014 vol. 26, p. 152–158

Costanza R. et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997 vol. 387, p. 253–260

Czajkowski M., Ščasný M., *Study on benefit transfer in an international setting. How to improve welfare estimates in the case of the countries' income heterogeneity?* "Ecological Economics" 2010 vol. 69(12), p. 2409–2416

Dawe N.D., *Sprinting toward sustainability*, "American Forests" 1996 vol. 102(2), p. 22–30, 45

Day B. et al., *Beyond implicit prices: Recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model*, "Environmental and resource economics" 2007 vol. 37(1), p. 211–232

de Groot R. et al., *Global estimates of the value of ecosystems and their services in monetary units*, "Ecosystem services" 2012 vol. 1(1), p. 50–61

Fosgerau M., Bjørner T.B., *Joint models for noise annoyance and willingness to pay for road noise reduction*, "Transportation Research Part B: Methodological" 2006 vol. 40(2), p. 164–178

Jim C.Y., Chen W.Y., *Ecosystem services and valuation of urban forests in China*, "Cities" 2009 vol. 26(4), p. 187–194

Johnston R.J. et al., *Benefit transfer of environmental and resource values: A guide for researchers and practitioners*, Dordrecht 2015

Kroeger T., *The economic value of ecosystem services in four counties in Northeastern Florida*, Conservation Economics Working Paper 2005 no. 2

Lindhjem H., Navrud S., *How reliable are meta-analyses for international benefit transfers?* "Ecological Economics" 2008 vol. 66(2–3), p. 425–435

Lindhjem H., Navrud S., *Reliability of meta-analytic benefit transfers of international value of statistical life estimates: Tests and illustrations*, in: R. J. Johnston et al. (eds), *Benefit transfer of environmental and resource values: A guide for researchers and practitioners*, Dordrecht 2015

Londoño L.M., Johnston R.J., *Enhancing the reliability of benefit transfer over heterogeneous sites: A meta-analysis of international coral reef values*, "Ecological Economics" 2012 vol. 78, p. 80–89

MacMullan E., Reich S., *Economic arguments for protecting the natural resources of the east buttes area in southeast Portland*, Eugene, OR 2009

Martín-López B. et al., *The conservation against development paradigm in protected areas: Valuation of ecosystem services in the Doñana social-ecological system (southwestern Spain)*, "Ecological Economics" 2011 vol. 70(8), p. 1481–1491

McPherson E.G. et al., *Northeast community tree guide: Benefits, costs, and strategic planting*, Albany, CA 2007

Millward A.A., Sabir S., *Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada?* "Landscape and urban planning" 2011 vol. 100(3), p. 177–188

Navrud S., *Economic benefits of a program to reduce transportation and community noise – A contingent valuation survey*, in: *Proceedings of Internoise* 2000 vol. 5, p. 3395–3400

Navrud S., *Economic valuation of transportation noise in Europe*, "Revista italiana di Acustica" 2010 vol. 34(3), p. 15–25

Noel J.E. et al., *A benefit transfer estimation of agro-ecosystems services*, "Western Economics Forum" 2009 vol. 8(1), p. 18–28

Nowak D.J., *Atmospheric carbon dioxide reduction by Chicago's urban forest*, in: McPherson et al. (eds), *Climate urban forest ecosystem: Results of the Chicago urban forest climate project*, Chicago 1994

Olewiler N., *The value of natural capital in settled areas of Canada*, Ducks Unlimited and the Nature Conservancy of Canada, Manitoba 2004

Pauleit S., Duhme F., *GIS assessment of Munich's urban forest structure for urban planning*, "Journal of Arboriculture" 2000 vol. 26(3), p. 133–141

Peper P.J. et al., *New York municipal forest resource analysis. Technical report*, New York 2007

Pimentel D. et al., *Economic and environmental benefits of biodiversity*, "BioScience" 1997 vol. 47(11), p. 747–757

Preiss P. et al., *Report on the procedure and data to generate averaged/ aggregated data*, NEEDS project, Stuttgart 2008

Rosenzweig C. et al., *Green roofs in the New York metropolitan region: Research report*, Columbia University Center for Climate Systems Research and NASA Goddard Institute for Space Studies 2006

Troy A., Bagstad K., *Estimating ecosystem services in southern Ontario*, Ontario Ministry of Natural Resources, Ontario 2009

Wilson S.J., *Canada's wealth of natural capital: Rouge National Park*, David Suzuki Foundation, 2012

Wilson S.J., *Lake Simcoe basin's natural capital: The value of the watershed's ecosystem services*, David Suzuki Foundation, Friends of the Greenbelt Foundation Occasional Paper Series 2008, June

Wilson S.J., *Natural capital in BC's Lower Mainland: Valuing the benefits from nature*, David Suzuki Foundation 2010

Wilson S.J., *Ontario's wealth, Canada's future: appreciating the value of the Greenbelt's eco-services*, David Suzuki Foundation 2008

Xu H. et al., *Assessment of indirect use values of forest biodiversity in Yaoluoping national nature reserve, Anhui province*, "Chinese Geographical Science" 2003 vol. 13(3), p. 277–283

Xue D., Tisdell C., *Valuing ecological functions of biodiversity in Changbaishan Mountain Biosphere Reserve in northeast China*, "Biodiversity and Conservation" 2001 vol. 10(3), p. 467–481

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RECREATIONAL POTENTIAL OF FORESTS AS AN INDICATOR OF LEISURE RELATED SERVICES PROVIDED BY FOREST ECOSYSTEMS

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POTENCJAŁ REKREACYJNY LASÓW JAKO WSKAŹNIK ŚWIADCZENIA USŁUG WYPOCZYNKOWYCH EKOSYSTEMU LEŚNEGO

STRESZCZENIE: Celem pracy było określenie potencjału rekreacyjnego lasów położonych wokół uzdrowiska Rymanów Zdrój. Potencjał rekreacyjny lasów oceniono stosując metodę waloryzacji rekreacyjnej dla terenów o zróżnicowanej orografii. Lasy przydatne do rekreacji stanowią aż 86,31% z 2229,23 ha poddanych ocenie. Potencjał rekreacyjny badanych lasów wynosi ok. 82 500 osób na rok. Wskaźnik ten umożliwia właściwe sterowanie ruchem rekreacyjnym i równomierne jego rozłożenie na tereny naturalnie bardziej odporne na uszkodzenia.

SŁOWA KLUCZOWE: rekreacja leśna, świadczenia ekosystemów, czas wolny, użytkowanie lasu, uzdrowisko

Introduction

Apart from being the source of lumber, forests play other functions: they can be used for leisure and recreation, they protect soils against erosion and waters against pollution, they greatly contribute to water retention system and to biological diversity, they purify the air and enrich landscapes. Out of all the functions which foresters refer to as non-productive (unrelated directly to timber production), in recent years the first one on the list has been rapidly growing[1].

Increasing interest in forest-based leisure is particularly notable among residents of urban agglomerations[2], and the larger the city the greater the interest in relaxation in forests developed for recreational purposes[3]. This trend is expected to continue in the near future[4].

Location of a spa resort near forests brings measurable effects to patients' recuperation. It has been proven that contact with forests beneficially affects human mind and body[5]. This can be attributed e.g. to phytoncides produced by trees[6]. Falencka-Jabłońska believes that forests surrounding sanatoriums, because of their leisure related functions and healing climatic properties, contribute to the potential development of wellness tourism[7]. At the end of 2010 the total of 44 places in Poland had a status of spa resort, including four locations in the Podkarpackie Region: Rymanów Zdrój, Iwonicz Zdrój, Polańczyk and Horyniec Zdrój. All of these are surrounded by forests.

1 *Raport o stanie lasów w Polsce 2013*, Warszawa 2014, p. 27–45.

2 P. Paschalis-Jakubowicz, *Leśnictwo a leśna turystyka i rekreacja*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2009 no. 23, p. 30; S. Destan, S. Bekiroǧlu, *Evaluation of the territorial system of forest recreation by natural indicators: Belgrade forest example*, "African Journal of Agricultural Research" 2011 no. 6(1), p. 222.

3 T. Dudek, *Needs of the local population related to development of forests for recreational purposes: example of south-eastern Poland*, "Journal of Forest Science" 2016 no. 62, p. 37.

4 S. Bell et al., *European Forest Recreation and Tourism: A Handbook*, London 2009, p. 262.

5 B.J. Park et al., *Physiological effects of forest recreation in a young conifer forest in Hinokage Town, Japan*, "Silva Fennica" 2009 no. 43(2), p. 291.

6 A. Szponar, *Reconvalescent and recreational value of the forest environment*, in: J. Marak, Wyrzykowski, M. Szymczyk (eds), *Tourism Role in the Regional Economy, Health, wellness & spa tourism as the regional product – Theory and Practice*, Wrocław 2014, p. 119.

7 M. Falencka-Jabłońska, *Walory przyrodnicze polskich lasów i ich uzdrowiskowo-turystyczne wykorzystanie*, "Inżynieria Ekologiczna" 2012 no. 30, p. 68.

It is estimated that the value of forest-based recreational services in various regions of the world is in the range from 2 to 279 US/ha[8]. It is expected that by 2050 recreational value of forests will increase, with the highest growth in China, North America and Europe[9].

This author has been studying recreational potential of forests for a few years. Recreational potential is expressed as natural recreation carrying capacity of tree stands in person-hours/ha/day, defining the number of people who can stay at a given place at the same time without posing considerable hazard to the forest environment. In this form the indicator does not account for elements of forest development for recreational purposes, known to significantly reduce the risk of damage[10].

The purpose of the study was to examine recreational potential of forests near the spa resort of Rymanów Zdrój and to apply the results to identify the possible leisure related services rendered by these forests.

Research area

The study was carried out in the woods of Rymanów Forest District, surrounding the spa resort of Rymanów Zdrój. The area is located within the Low Beskids, at the altitude ranging from approx. 400 to over 600 metres above sea level. The areas with lower altitude comprise a broad valley of the River Tabor and its right-hand tributary the Czarny Potok, and those with higher altitude consist of gentle slopes covered with beech and fir forests. The major elevations here include Sucha Góra (611 m.a.s.l.), Mogiła (606 m), Zamczyska (568 m), Kopiec (634 m) and Dział (673 m).

The spa resort was established in Rymanów Zdrój in 1873. The profile of treatments provided here is linked with the specific climate and with the local resources The local climate is affected by the nearby mountains and resembles continental climate. Mean annual air temperature is +7.3°C, with the mean in February –4.3°C and July +16.4°C (as measured at the station in Iwonicz Zdrój). Vegetation period ranges from 170 to 190 days. Average annual precipitation rate is high, ranging from 745 to 966 mm. Snow cover is

8 K.N. Ninan, M. Inoue, *Valuing forest ecosystem services: What we know and what we don't*, "Ecological Economics" 2013 no. 93, p. 145.

9 A. Chiabai et al., *Economic Assessment of Forest Ecosystem Services Losses: Cost of Policy Inaction*, "Environmental and Resource Economics" 2011 no. 50, p. 429.

10 A. Cieszewska, M. Deptuła, *Czynniki wpływające na degradację szlaków turystycznych na terenie Tatrzańskiego Parku Narodowego*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2013 no. 4(37), p. 81.

retained for 90–110 days during a year. Southern and northern winds prevail in the area[11].

The spa resort was established in Rymanów Zdrój in 1873. The profile of treatments provided here is linked with the specific climate and with the local resources of carbonated mineral water. The spa resort is situated in one of the least polluted areas of Poland. The air is characterized by high contents of iodine, ozone, salts, and relatively high humidity. The carbonated saline and sodium containing water ranks among the most potent in Europe. Other healing minerals include iodide, bromide and boron saline waters, and therapeutic mud. Treatments are provided for lower and upper respiratory tract diseases, cardiovascular disorders, orthopedic and post-traumatic conditions, rheumatic, kidney and urinary tract disorders[12].

Recreational potential was examined in 64 forest units, administered by Rymanów Forest District, comprising a total 2,229 ha. These forests are situated in the closest proximity to the spa resort and they directly contribute to the local microclimate; they are also eagerly visited by spa resort clients. A number of walking routes lead directly from Rymanów Zdrój to these forests. Along one of these, called "wellness path", there are stations with exercise equipment and boards with explanations. This path leads through forest units: 88, 89, 101–103 selected for the study. Another interesting option for spa resort clients is the route designed for Nordic Walking. The five-kilometre long trail leads through areas with interesting natural features, from Wilcza Polana to Wołtuszowa.

Method

Recreational potential of the forests was assessed with recreational valorisation method designed for areas with varied orography[13]. Assessment based on this approach takes into account three main criteria: habitat moisture, age of stands, and inclination of the terrain; and four additional criteria: stand density, presence of undergrowth and underbrush, soil cover and species composition of the stand. The potential, expressed by recreational capac-

[11] Plan Urządzenia lasu, plan dla lasów Nadleśnictwa Rymanów na okres 2009–2018, Krosno 2009, p. 34.

[12] T. Kozłowska-Szczęsna et al., *Bioklimat uzdrowisk polskich i możliwości jego wykorzystania w lecznictwie*, "Monografie Instytutu Geografii i Przestrzennego Zagospodarowania im. Stanisława Leszczyńskiego PAN" no. 3, Warszawa 2002, p. 408–417; www.uzdrowisko-rymanow.com.pl [27-06–2016].

[13] T. Dudek, *Assessment of recreational potential of forests in areas with diverse orography: Czarnorzecko-Strzyżowski Landscape Park case study*, "Sylwan" 2013 no. 157, p. 775–779.

ity indicator, is calculated as a product of multiplying the level of the tree stand recreational suitability by the surface of the stands of a given level. Then, average recreation carrying capacity of the forests was calculated as a quotient of the recreation carrying potential of the terrain and the overall surface of the stands in the relevant area. By multiplying the mean recreation carrying capacity by the number of days in a year and dividing the product by 24 hours the obtained result shows the acceptable number of visitors per one hectare during one year.

Unfortunately, management of Rymanów Spa Resort did not agree to provide information on the number and the structure of its clients. Hence, the author has referred to the data published by the Central Statistical Office in Kraków. Although majority of these data are related to provinces rather than individual facilities, they enable rough estimation of potential recreational traffic in the forests surrounding the spa resort. In 2010 the four spa resorts within the Podkarpackie Region were visited by the total of 57,479 patients staying for extended period of time, which accounted for 10.83% of all spa resort clients in Poland. This number was similar for 10 years, ± 10%. In the same year the number of spa resort clients in the commune of Rymanów amounted to approx. 14,000, including children accounting for 4% of the total number[14]. By reference to the previous findings related to the preferences of Podkarpackie region population related to forest-based leisure[15], it can be assumed that 80% of spa resort clients will visit forests at least once a week. Average duration of a stay in a sanatorium is approx. 17 days[16]. After multiplying 80% of the number of spa resort clients by the number of forest visitors we will obtain an estimated annual number of visits to the relevant forests.

The characteristics of the study forests are based on the forest management plan drawn up for Rymanów Forest District[17].

Results

The examined stands, predominantly fir and beech forests, grow in the following habitats: mountain fresh forest (LGśw) – 80.19%, mountain mixed fresh forest (LMGśw) – 10.05% and highland fresh forest (Lwyżśw) – 9.76%.

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14 B. Bubula et al., *Lecznictwo uzdrowiskowe w Polsce w latach 2000–2010*, Kraków 2011, p. 49, 67, 90.

15 T. Dudek, *Recreational potential of Rzeszów suburban forests versus the demand for spending leisure time in forests among the residents of the Podkarpackie Province*, "Sylwan" 2016 no. 160, p. 169–176.

16 B. Bubula et al., op. cit., p. 69.

17 Plan Urządzenia Lasu, op. cit.

Nearly half of them were more than 100 years old (42.02%) or approaching this age (7.03%). Large part of the forests near the spa resort were in the age range of 61–80 years (34.46%), and the remaining 16.49% are in the 3rd age class (41–60 years, the classes are counted every 20 years). All of the examined tree stands grow in sloping areas; majority of them in gentle and steep slopes (total of 49.46%) and in inclined areas (37.15%). The remaining 13.39% grow on precipitous slopes. Vast majority of the forests have moderate density, only 4.49% are found with high, and 3.62% with scarce density. The additional species found in the tree stands, most notably include: European larch (*Larix decidua* Mill.), Scots pine (*Pinus sylvestris* L.), common ash (*Fraxinus excelsior* L.) and sycamore maple (*Acer pseudoplatanus* L.).

Because of the exclusively fresh forest habitats, their favourable age structure and the lay of the land, the forests around the spa resort are highly useful for recreation. The forests suitable for recreation (table 1, level 2–4) account for 86.31% of the 2229.23 ha subjected to the assessment. On the other hand the forests poorly suitable or unsuitable for recreation (level 1 and 0), mainly due to their young age (80% in level 1 and 0), comprise only 13.69% of the area.

The calculated average recreation carrying capacity of the forests is 2.45 person-hour/ha/day, i.e. during a year 37 persons can stay in an area of 1 ha. Based on these calculations, the recreational potential of the examined forests amounts to approx. 82,500 people per year. The forests surrounding the spa resort of Rymanów Zdrój in a given year may be visited by approx. 28,000 spa resort clients. The estimated result suggests that the calculated recreational potential of these forests is utilized at the level of approx. 33%. Notably, these estimates to not take into account the local residents, tourists and people paying visits to spa resort clients.

Table 1. Recreation carrying capacity in the forests surrounding the spa resort of Rymanów Zdrój

Degree of recreational suitability	Area of forest stands [ha]	Percentage by area [%]	Recreational capacity [person-hours/day]
forests extremely suitable	260.66	11.69	1042
forests highly suitable	856.38	38.43	2569
forests moderately suitable	806.84	36.19	1613
forests poorly suitable	234.59	10.52	234
forests unsuitable for recreation	70.76	3.17	0
Total	2229.23	100.00	5458

Discussion

Recreation is recognized among cultural ecosystem services, just like aesthetic assets as well as science and education[18]. Forest ecosystems render cultural services in all these areas. They provide space for leisure and recreation[19], they enrich landscapes[20] , and they constitute a place for educating the public about nature[21]. Typically, cultural ecosystem services can be used many times in various ways[22]. A good example of this is the fact that forests provide a place for various forms of recreation, e.g. hiking, Nordic walking, cycling, horse-riding, etc.

The presented results show that a vast majority of the forests adjoining the spa resort of Rymanów Zdrój are suitable for recreational purposes (86%). This is far more than in the suburban forests of Rzeszów (56%), growing at a distance of up to 10 km from the administrative border of the city[23], in the Bolimów Landscape Park (57%)[24], in Magura National Park (60%)[25] and Czarnorzecko-Strzyżowski Landscape Reserve (73%)[26]. The same approach was applied in all the above studies, with some minor modifications in the studies carried out by Dudek. This large difference in the rate of forests suitable for recreation reported earlier partly results from the fact that the present study examined the smallest area of forests. The research area was limited to the forests adjoining the spa resort. For many years these

18 J. Solon, *Koncepcja "Ecosystem Services" i jej zastosowanie w badaniach ekologiczno--krajobrazowych*, "Problemy Ekologii Krajobrazu" 2008 no 21, p. 29.

19 B.J. Park et al., op. cit., p. 297; B. Ważyński, *Urządzanie i rekreacyjne zagospodarowanie lasu*, Warszawa 2011, p. 19.

20 E.G. Petrova et al., *Comparing the visual perception and aesthetic evaluation of natural landscapes in Russia and Japan: cultural and environmental factors*, "Progress in Earth and Planetary Science" 2015 no. 2, p. 6; A. Senetra, *Las jako istotny komponent przestrzeni w aspekcie opracowywania map wartości krajobrazów wiejskich*, "Sylwan" 2015 no. 159(9), p. 764.

21 E. Janeczko, Ścieżki edukacyjne jako element rekreacyjnego zagospodarowania lasu, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2010 no. 1(24), p. 106; A. Grzywacz, *Podstawy programowe w szkołach podstawowych w zakresie wiedzy o lesie a treści kształcenia w edukacji leśnej realizowanej przez nadleśnictwa Lasów Państwowych*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2011 no. 1(26), p. 121; H. Kruk, *Działalność edukacyjna leśnych kompleksów promocyjnych w Polsce – wyniki badań*, "Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania" 2015 no. 42, p. 54.

22 J. Solon, op. cit., p. 29.

23 T. Dudek, *Recreational potential of Rzeszow…*, op. cit., p. 174.

24 J. Kikulski, *The usefulness of selected forest areas of the Bolimowski Landscape Park for tourism and recreational needs*, "Sylwan" 2006 no. 150(6), p. 45.

25 T. Dudek, *Recreational potential of the Magurski National Park versus the actual number of visitors*, "Sylwan" 2014 no. 158, p. 877.

26 T. Dudek, *Assessment of recreational…*, op. cit., p. 777.

forests have been managed in sustainable manner, with emphasis on their protective functions (related to waters, microclimate and soils). As a result of these long-term efforts, there is a high proportion of over 100 year old stands of beech and fir forests (42%) in good condition.

Taking into account the supplementary criteria, the assessment was mostly impacted by the presence of undergrowth and underbrush and the soil cover. In 19% of the area, young trees grow in large numbers, covering ≥ 40% of the area, which resulted in decreased suitability of the forest stands for recreation. Similarly, Heyman[27] and Dudek[28] point out that dense underbrush is a factor adversely affecting recreational value of forests. Conversely, if it occurs in clusters occupying no more than 10% of the area it constitutes an added value, contributing to greater biological diversity and landscape attractiveness of the forests, in particular in single-story and single-species forests.

Monitoring applied to investigate the stress on forest ecosystems may be conducted with the use of discreet photocells located along the trails, designed to count the individuals walking by. Such solution would be less controversial than ongoing surveillance based on video cameras. This form of observation is proposed by Arnberger[29]. Using such approach it is possible to acquire more comprehensive information, not only about the number of visitors but also related to the preferred leisure activities (e.g. hiking, cycling, walking a dog, running, etc.), and the use of equipment installed for recreation related purposes.

This author believes, however, that the mental pressure linked with the presence of cameras, so common in cities, may negatively affect people's ability to relax in forests where they look for tranquillity and solitude. Research conducted worldwide has indeed confirmed that people mainly visit forests in order to relax[30].

Monitoring is designed to keep up the number of forest visitors at a level which is assumed to be safe for the forest environment. Resulting from excessive stress to an ecosystem, the most vulnerable species may disappear from a given area which consequently leads to decreased biological diversity. Kostecka et al. emphasize that by paying attention to biological diversity of flora

27 E. Heyman, *Analysing recrational values and management effects in an urban forest with the visitor – employed photography method*, "Urban Forestry & Urban Greening" 2012 no. 11, p. 267.

28 T. Dudek, *Recreational potential of Rzeszow*..., op. cit., p. 175.

29 A. Arenberger, *Recreation use of urban forests: An inter-area comparison*, "Urban Forestry & Urban Greening" 2006 no. 4, p. 135–144.

30 C.Y. Jim, W.Y. Chen, *Ecosystem services and valuation of urban forests in China*, "Cities" 2009 no. 26, p. 191; P. Gołos, *Rekreacyjna funkcja lasów miejskich i podmiejskich Warszawy*, "Leśne Prace Badawcze" 2013 no. 74(1), p. 62.

we also take care of the foundations of ecosystem services, and indeed, our own future[31]. Therefore, we can say that excessive exploitation of cultural services provided by forest ecosystems may lead to decreased availability or loss of certain services in this domain; so it is important to identify recreational potential and ensure compliance with it. Likewise, Plieninger et al. claim it is necessary to protect biological diversity and cultural heritage which are components of multifunctional ecosystem services. They also emphasize the fact that cultural ecosystem services are more appreciated by the public than regulating and supporting services, and frequently are more important than provisioning services[32]. A number of surveys have shown that leisure in forests is reported by a predominant (76–90%) part of the society[33], hence forest based recreation constitutes a very important component of cultural services provided by forest ecosystems. This need was recognized in Sweden as early as the 1950s, when the so-called recreational forests were first designated; they were characterized by older age, large proportion of deciduous trees and alternative renewal methods[34]. The forests investigated in the present study, located in close proximity to Rymanów Zdrój spa resort, meet these three criteria attributed to recreational forests. Nearly half of these forests are more than 100 years old, they contain a large proportion of deciduous species and young generations of trees are initiated as a result of complex felling systems, in a natural way, with long period of renewal.

Conclusion

The study has shown that the forests around the spa resort of Rymanów Zdrój have large recreational potential, which by spa clients is used at the level of approx. 33 %.

It must be ensured that these advantages resulting from the location of the spa resort amidst forest will not be impaired due to excessive or inadequately directed recreation traffic. To achieve this it is necessary to identify

31 J. Kostecka et al., *Pojęcie "świadczenia ekosystemowe" i jego rola w edukacji dla zrównoważonego rozwoju (na przykładzie bzu czarnego Sambucus nigra L.)*, "Inżynieria i Ochrona Środowiska" 2012 no. 4, p. 415.

32 T. Plieninger et al., *Assessing, mapping, and quantifying cultural ecosystem services at community level*, "Land Use Policy" 2013 no. 33, p. 118, 127.

33 T. Dudek, *Recreational potential of Rzeszów…*, op. cit., p. 172; P. Gołos, op. cit., p. 60; J. Kikulski, *Preferencje rekreacyjne i potrzeby zagospodarowania rekreacyjnego lasów nadleśnictw Iława i Dąbrowa (wyniki pierwszej części badań)*, "Sylwan" 2008 no. 5, p. 61.

34 T. Paluch, *Rekreacyjna rola lasów w Szwecji,* "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2006 no. 3(13), p. 184, 185.

recreation carrying potential of the forests, to lead the recreational traffic to the forest areas with higher natural resistance to damage, and to provide designated parts of the forest with necessary infrastructure improving safety and conditions for relaxation. It is also necessary to monitor any changes occurring in the forest ecosystem as a result of its exploitation.

Literature

Arenberger A., *Recreation use of urban forests: An inter-area comparison*, "Urban Forestry & Urban Greening" 2006 no. 4, p. 135–144

Bell S. et al., *European Forest Recreation and Tourism: A Handbook*, London 2009

Bubula B. et al., *Lecznictwo uzdrowiskowe w Polsce w latach 2000–2010*, Kraków 2011

Chiabai A. et al., *Economic Assessment of Forest Ecosystem Services Losses: Cost of Policy Inaction*, "Environmental and Resource Economics" 2011 no. 50

Cieszewska A., Deptuła M., *Czynniki wpływające na degradację szlaków turystycznych na terenie Tatrzańskiego Parku Narodowego*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2013 no. 4(37)

Destan S., Bekirogˇlu S., *Evaluation of the territorial system of forest recreation by natural indicators: Belgrade forest example*, "African Journal of Agricultural Research" 2011 no. 6(1)

Dudek T., *Assessment of recreational potential of forests in areas with diverse orography: Czarnorzecko-Strzyżowski Landscape Park case study*, "Sylwan" 2013 no. 157, p. 775–779

Dudek T., *Needs of the local population related to development of forests for recreational purposes: example of south-eastern Poland*, "Journal of Forest Science" 2016 no. 62

Dudek T., *Recreational potential of Rzeszów suburban forests versus the demand for spending leisure time in forests among the residents of the Podkarpackie Province*, "Sylwan" 2016 no. 160, p. 169–176

Dudek T., *Recreational potential of the Magurski National Park versus the actual number of visitors*, "Sylwan" 2014 no. 158

Falencka-Jabłońska M., *Walory przyrodnicze polskich lasów i ich uzdrowiskowo-turystyczne wykorzystanie*, "Inżynieria Ekologiczna" 2012 no. 30

Gołos P., *Rekreacyjna funkcja lasów miejskich i podmiejskich Warszawy*, "Leśne Prace Badawcze" 2013 no. 74(1)

Grzywacz A., *Podstawy programowe w szkołach podstawowych w zakresie wiedzy o lesie a treści kształcenia w edukacji leśnej realizowanej przez nadleśnictwa Lasów Państwowych*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2011 no. 1(26)

Heyman E., *Analysing recrational values and management effects in an urban forest with the visitor – employed photography method*, "Urban Forestry & Urban Greening" 2012 no. 11

Janeczko E., Ścieżki edukacyjne jako element rekreacyjnego zagospodarowania lasu, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2010 no. 1(24)

Jim C.Y., Chen W.Y., *Ecosystem services and valuation of urban forests in China*, "Cities" 2009 no. 26

Kikulski J., *Preferencje rekreacyjne i potrzeby zagospodarowania rekreacyjnego lasów nadleśnictw Iława i Dąbrowa (wyniki pierwszej części badań)*, "Sylwan" 2008 no. 5

Kikulski J., *The usefulness of selected forest areas of the Bolimowski Landscape Park for tourism and recreational needs*, "Sylwan" 2006 no. 150(6)

Kostecka J.et al., *Pojęcie "świadczenia ekosystemowe" i jego rola w edukacji dla zrównoważonego rozwoju (na przykładzie bzu czarnego Sambucus nigra L.)*, "Inżynieria i Ochrona Środowiska" 2012 no. 4

Kozłowska-Szczęsna T. et al., *Bioklimat uzdrowisk polskich i możliwości jego wykorzystania w lecznictwie*, "Monografie Instytutu Geografii i Przestrzennego Zagospodarowania im. Stanisława Leszczyńskiego PAN" no. 3, Warszawa 2002

Kruk H., *Działalność edukacyjna leśnych kompleksów promocyjnych w Polsce – wyniki badań*, "Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania" 2015 no. 42

Ninan K.N., Inoue M., *Valuing forest ecosystem services: What we know and what we don't*, "Ecological Economics" 2013 no. 93

Paluch T., *Rekreacyjna rola lasów w Szwecji,* "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2006 no. 3(13)

Park B.J. et al., *Physiological effects of forest recreation in a young conifer forest in Hinokage Town, Japan*, "Silva Fennica" 2009 no. 43(2)

Paschalis-Jakubowicz P., *Leśnictwo a leśna turystyka i rekreacja*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2009 no. 23

Petrova E.G. et al., *Comparing the visual perception and aesthetic evaluation of natural landscapes in Russia and Japan: cultural and environmental factors*, "Progress in Earth and Planetary Science" 2015 no. 2

Plan Urządzenia lasu, plan dla lasów Nadleśnictwa Rymanów na okres 2009–2018, Krosno 2009

Plieninger T. et al., *Assessing, mapping, and quantifying cultural ecosystem services at community level*, "Land Use Policy" 2013 no. 33

Raport o stanie lasów w Polsce 2013, Warszawa 2014

Senetra A., *Las jako istotny komponent przestrzeni w aspekcie opracowywania map wartości krajobrazów wiejskich*, "Sylwan" 2015 no. 159(9)

Solon J., *Koncepcja "Ecosystem Services" i jej zastosowanie w badaniach ekologiczno-krajobrazowych*, "Problemy Ekologii Krajobrazu" 2008 no 21

Szponar A., *Reconvalescent and recreational value of the forest environment,* in: J. Marak, Wyrzykowski, M. Szymczyk (eds), *Tourism Role in the Regional Economy, Health, wellness & spa tourism as the regional product – Theory and Practice*, Wrocław 2014

Ważyński B., *Urządzanie i rekreacyjne zagospodarowanie lasu*, Warszawa 2011

www.uzdrowisko-rymanow.com.pl

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STUDY OF SOIL CONTAMINATION WITH HEAVY METALS AND COST ESTIMATION OF ITS REMEDIATION ON THE EXAMPLE OF THE CITY TRZEBINIA

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BADANIE ZANIECZYSZCZENIA GLEBY METALAMI CIĘŻKIMI ORAZ SZACUNEK KOSZTU JEJ REKULTYWACJI NA PRZYKŁADZIE MIASTA TRZEBINIA

STRESZCZENIE: Celem artykułu było określenie zawartości metali ciężkich w glebach na terenie silnie zdegradowanym przez przemysł wydobywczy i przetwórczy. Badania przeprowadzono w zachodniej części województwa małopolskiego w mieście Trzebinia. Stwierdzono, że średnia zawartość miedzi w glebie miasta nie przekroczyła wartości dopuszczalnych stężeń tego pierwiastka według regulacji krajowych dla użytków rolnych. Uzyskane wyniki średnich stężeń kadmu, ołowiu i cynku w glebie dla miasta Trzebinia przekroczyły normę krajową wartości dopuszczalnych stężeń tych pierwiastków. Przeprowadzona kalkulacja kosztorysowa wykazała, że koszt zrekultywowania metodą szczegółową (biologiczną) 100 m^2 terenów zdegradowanych zanieczyszczonych metalami ciężkimi w mieście Trzebinia wyniesie 168,69 zł.

SŁOWA KLUCZOWE: metale ciężkie, gleba, rekultywacja, kosztorys

Introduction

Environmental measures taken for several decades are justified in the context of increasingly discernible, negative consequences regarding the impact of toxic heavy metals. This influence directly affects the state of soil, water, air, natural ecosystems and, indirectly, human health and agricultural production[1]. Public awareness of ubiquitous pollution and environmental degradation by substances containing trace elements is gradually increasing[2]. It manifests itself not only in the rapidly increasing number of specialized publications, numerous ongoing research projects, but also in the presence of environmental issues in the public discourse on national and international level, and social actions performed ad hoc[3]. Environmental pollution with heavy metals, although undesirable and expensive, seems to be an inevitable result of advancing globalization processes and industrialization of societies, technologization of industry and agriculture, transport mechanisation, affecting in particular the populations of large cities and large-scale farms[4]. The problem of toxic heavy metals in the soils of Trzebinia is long-term and it is a result of anthropogenic human impact on the environment through various activities (industrial, mining and processing of local raw material). The effects of historical industrialization of Trzebinia region are visible to this day and they are reflected in the state of contamination of soils with heavy metals in the discussed area. There is a need to restore biological and productive value to the soils in the area (remediation), either for agricultural or recreational use. The possibility of their afforestation (biological remediation) is not excluded.

Sources of soil contamination with heavy metals

Pollution and contamination are not identical concepts. The first refers to the presence of foreign substance, which does not cause any visible damage to the environment. Contamination, however, is synonymous with the unmis-

1 B.J. Alloway, D.C. Ayres, *Chemiczne podstawy zanieczyszczenia środowiska,* Warsaw 1999.

2 W. Preżdo, L. Nowakowski, *Chemia środowiska,* university script, Opole 1995.

3 J. Curzydło, *Skażenia motoryzacyjne wzdłuż dróg i autostrad oraz sposoby przeciwdziałania ujemnym skutkom motoryzacji w środowisku*, "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 265–270; B.J. Alloway, D.C. Ayres, op. cit.; P. O'Neil, *Chemia środowiska*, Warsaw 1997; S. Zieliński, *Skażenia chemiczne w środowisku*, second edition revised and supplemented, Wrocław 2007.

4 L.G. Bondariew, *Pierwiastki śladowe – dobre i złe zarazem*, Warsaw 1989; S.F. Zakrzewski, *Podstawy toksykologii środowiska,* Warsaw 1995.

takable and noticeable occurrence of harmful effects, hindering the proper use of natural resources and constituting a threat to the ecological system, living organisms, human health, inanimate structure, and the beauty of nature[5]. Four factors are present in all cases of contamination: source of contamination, harmful substance, the medium carrying the substance (for example: water, air and soil) and the object exposed to it[6]. There are two types of harmful substances: originally harmful, i.e. producing harmful effects in the form in which they were brought into the environment and secondarily harmful, whose harmfulness is the result of chemical processes in the environment[7]. Another factor degrading the soil environment is any factor that reduces the biological activity of the soil. Anthropopressure as well as climatic and biological conditions are important in the process of degradation[8]. Due to the genesis of degradative processes, one may distinguish: natural, communication, geotechnical, urban, and industrial degradations. Owing to specific properties of the soil, to which these processes are related to, one can enumerate physical, physicochemical, nutritional, toxicological and biological degradations[9]. Soil resistance to degradations depends on its physical and chemical properties: soil pH, its sorption and oxidative capacity, concentrations of soil macro- and microelements, content of humic acids and organic matter[10]. Biochemical processes associated with the presence of microorganisms in the soil are also important. The reduction in the production of biomass, intensive acidification (especially by rainfall of sulphur compounds and the use of fertilizers), the accumulation of phytotoxic substances, deficiency of nutrients for plants and violation of ion balance between them are classified as external signs of soil degradation[11]. Degradation leads to changes in the soil structure, impoverishment of its humus level, reduction in the biological activity of the soil environment, violations of its ion balance, excessive alkalization or salinification of this environment. This results in soil depletion or excess

5 Ibidem.

6 J. Siuta, *Gleba-diagnoza stanu i zagrożenia,* Warsaw 1995.

7 B.J. Alloway, *Heavy metals in soils*, Glasgow 1995; P. O'Neil, op. cit.

8 J. Siuta, op. cit.

9 J. Siuta, *Ochrona i rekultywacja gleb,* Warsaw 1978; Z. Trzyszcz, *Przekształcenie geochemiczne, hydrologiczne i chemiczne pokrywy glebowej w woj. Katowickim,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 117–126; R. Turski, S. Baran, *Degradacja, ochrona i rekultywacja gleb,* Lublin 1995; H. Terelak, et al., *Zawartość Cd, Cu, Ni, Pb, Zn i S w glebach woj. krakowskiego i Polski,* Materials from Scientific Conference: Management of areas contaminated by human activity, 1996, p. 69–81.

10 H.C. Buckman, N.C. Brady, *Gleba i jej właściwości*, Warsaw 1971; J. Siuta, *Rekultywacja gruntów,* Warsaw 1998; G.V. Motuzova et al., *Soil contamination with heavy metals as a potential and real risk to the environment,* "Journal of Geochemical Exploration" 2014 no. 144, p. 241–246.

11 A. Karczewska, *Ochrona gleb i rekultywacja terenów zdegradowanych,* Wrocław 2008.

insertion of nutrients into plants, fragmentation of biologically active surface and proper soil as well as drying or waterlogging of soil or decrease in its sorption capacity[12].

In Poland, contamination with heavy metals includes up to 3% of arable land. The toxic presence of heavy metal ions in the soil solution considerably reduces the activity of soil enzymes: dehydrogenase, alkaline phosphatase, acid phosphatase, and urease. The most harmful in this regard is lead, while zinc and copper are the least toxic[13]. Soils showing high content of clay materials and organic matter can accumulate substantial amounts of heavy metals, stopping them in the surface layers, and therefore they are considered to be resistant to chemical contamination. The soil pH and its sorption capacity influence the distribution and mobility of zinc, lead, copper and cadmium in the soil profile and their precipitation. This impact is especially characteristic of acid soils[14]. The course of soil formation and soil profile development are dependent on the type of organic and mineral connections, biodegradation of organic component of the complex, adsorption of the complex on the mineral particle of the soil and the degree of saturation with the metal ion[15]. The greatest concentration of heavy metals is observed in the humic level of soil[16]. The potential for bioaccumulation of metals intensifies their negative impact on the soil environment. Heavy metals take readily soluble forms. This facilitates their bioavailability and migration into waters, and thus accelerates the chemical degradation of soil[17]. In soil, metals adopt non-labile (spare) and labile (movable) forms. The occurrence of a particular form affects the scope of potential harmfulness of metal. In non-labile forms, metal ions bind to the humus and soil minerals and they are occluded on the oxides of manganese and iron. Labile forms are metal ions interchangeably adsorbed by soil col-

12 A. Kabata-Pendias, *Zanieczyszczenia pierwiastkami śladowymi gleb użytków rolnych. Wybrane zagadnienia związane z chemicznym zanieczyszczeniem gleb,* Warsaw 1989; K. Łopata, E. Rudnik, E. Nowak, *Tajemnice gleby. Chroń swoje środowisko,* Warsaw 1997; H. Greinert, *Ochrona gleb,* Zielona Góra 1998; P. Kowalik, *Ochrona środowiska glebowego,* Gdańsk 1999; P. Kowalik, *Ochrona środowiska glebowego,* Warsaw 2001.

13 W. Jarosz, E. Marchwiński, *Wpływ emisji z tras komunikacyjnych na skażenia gleby i żywności,* in: *Ekosystemy żywicielskie i żywność. Zagrożenia i problemy ochrony*, Warsaw 1991; K. Turnau, O. Wenhrynowicz, *Mechanizmy obronne roślin i grzybów w siedliskach skażonych ołowiem*, Materials from the symposium Lead in the environment. Environmental Problems and Methodology, Warsaw 1997.

14 K. Dziadek, W. Wacławek, *Metale ciężkie w środowisku,* cz. 1, *Metale ciężkie (Zn, Cu, Ni, Pb, Cd) w środowisku glebowym,* "Chemia, Dydaktyka, Ekologia, Metrologia" 2005 no. 10(1–2), p. 33–44.

15 F. Woch, *Wademekum klasyfikatora gleb,* Collective work, Second edition supplemented and revised, Puławy 2007; D. Hillel, *Gleba w* środowisku, Warsaw 2012.

16 R. Ciepał, *Przenikanie S, Pb, Cd, Zn, Cu i Fe do biomasy oraz gleby ekosystemu leśnego. Znaczenie bioindykacyjne,* Katowice 1992; J. Curzydło, op. cit.

17 E. Kociołek-Balawejder, E. Stanisławska, *Chemia środowiska,* Wrocław 2012.

loids[18]. The occurrence of two or more toxic metals in soil solution may lead to an antagonistic effect (weakening metal's assimilability and toxicity), a synergic effect (the enhancement of metal's assimilability and toxicity), or an additive effect (strengthening assimilability and toxicity of metal by a neutral element)[19]. An example of the antagonistic effect is the reduction in assimilability and toxicity of cadmium with increased amounts of copper and zinc. The appearance of lead leads to increased assimilability and toxicity of cadmium, which is an example of the synergic effect. The additive effect is created due to an increase in assimilability and toxicity of manganese because of presence iron oxides and hydroxides[20].

Research results

Below there are the research results regarding the content of heavy metals in the soils of the city Trzebinia and the properties of these soils affecting the mobility of heavy metals.

Content of heavy metals in the soil of the city Trzebinia

The average content of cadmium in soil at a depth of 0–20 cm was equal to 5.95 mg/kg, and the median was 5.17 mg/kg. The content of this element ranged from 2.10 mg/kg to 14.90 mg/kg in this soil layer. At a depth of 20–40 cm the average cadmium content was 5.10 mg/kg, with a median of 4.76 mg/kg. In this soil layer, the content of this metal was included in the range of 0,82–15,30 mg/kg.

The average content of lead in soil at a depth of 0–20 cm was equal to 209.77 mg/kg, and the median was 151.77 mg/kg. In this soil layer, the content of the element ranged from 65.65 mg/kg to 845.15 mg/kg. At a depth of 20–40 cm the average lead content was 182.60 mg/kg, and the median was 163.35 mg/kg. In this soil layer, the content of this metal was in the range of 30,87–824,10 mg/kg.

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18 T. Chodak, C. Kabała, *Powierzchnia właściwa-złożony parametr charakteryzujący stan środowiska glebowego,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 501–506; R. Bednarek, et al., *Badania ekologiczno-gleboznawcze,* Warsaw 2011.

19 E. Gorlach, *Metale ciężkie jako czynnik zagrażający żyzności gleby*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 1995 no. 421a, p. 113–122; K. Cedzyńska, B. Smolińska, *Wpływ metali ciężkich na aktywność enzymatyczną gleby. Obieg pierwiastków w przyrodzie,* Monograph. Vol. III., 2005, p. 541–544; Cz. Jasiewicz, A. Baran, *Przewodnik do wykładów i ćwiczeń z toksykologii*, Cracow 2008.

20 M. Gębski, W. Stepski, S. Mercik, *Ocena metod oznaczania metali ciężkich w glebie w oparciu o ich zawartości w roślinach*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 2000 no. 472, p. 267–273.

The average zinc content in soil at a depth of 0–20 cm was equal to 2795.47 mg/kg, and the median was 616.44 mg/kg. In this soil layer, the scope of element content ranged from 165.85 mg/kg to 2091.81 mg/kg. At a depth of 20–40 cm the average zinc content was 715.20 mg/kg, and the median was 512.81 mg/kg. In this soil layer, this metal had content in the range of 108,20–1892,10 mg/kg.

The average copper content in soil at a depth of 0–20 cm was equal to 22.82 mg/kg, and the median was 19.47 mg/kg. In this soil layer, element content range is from 4.86 mg/kg to 54.62 mg/kg. At a depth of 20–40 cm average copper content was 18.85 mg/kg, the median 12.75 mg/kg. In this soil layer, the metal had content in the range of 3,22–59,69 mg/kg.

Soil properties affecting the mobility of heavy metals

The average percentage content of organic matter in soil for a depth of 0–20 cm was 4.28%, and the median 4.08%. Matter content for this depth is in the range of 2,00–8,10%. For a depth of 20–40 cm the average content of organic matter in soil was equal to 2.92% and the median 2.95%. In this soil layer, matter content shaped in the range of 1,05–6,05%.

Average electrolytic conductivity of soil at a depth of 0–20 cm was equal to 206.05 µS, and the median was 214,00 µS. The conductivity in this soil layer took the range of values 57,00–390,00 µS. For a depth of 20–40 cm average electrolytic conductivity was lower and it amounted to 174,64 µS, and the median was 163,90 µS. The range of value concerning the electrolytic conductivity of the soil in the analysed layer amounted to 57,00–370,00 µS.

The average pH of the soil determined in water regarding the 0–20 cm layer was 6.54 and the median was 6.70, and it took acid reaction. The pH values ranged from 5.90 to 7.10, that is, from acidic to slightly alkaline reaction. For a depth of 20–40 cm, the average value of soil pH specified in water was 6.74, and the median was 6.80, which corresponds to acid reaction, like the soil reaction in the layer 0–20 cm. The pH range for the depth of 20–40 cm ranged from 6.70 to 7.60, hence from acid to alkaline reaction, similarly to the 0–20 cm layer of soil. The average value of soil pH determined in KCl for the 0–20 cm layer was 6.24, and the median of 6.40, showing acid reaction. Range of the pH varied from 5.20 to 6.80, which is in the range of acid reaction. For a depth of 20–40 cm, the average value of soil pH determined in KCl was 6.39, median was 6.50. Thus, it was acid reaction, such as in a layer of 0–20 cm. At a depth of 20–40 cm soil pH value ranged from 5.10 to 7.20, included in the range from acid to slightly alkaline reaction, in contrast to the 0–20 cm layer, in which soil only showed the acid reaction.

The granulometric composition of Trzebinia soils is dominated by clay and sandy soils. The average percentage content of sand fraction was 72.39%, silt 18.22%, clay 9.39%.

Methods and criteria for remediation of soils contaminated with heavy metals

Land remediation relies on restoring their utility or natural value through execution of necessary procedures. Methods for remediation of soils contaminated with heavy metals are based on immobilization of metals in soil or in their mobilisation and removal from soil. Immobilisation effect of heavy metals in the solid phase of soil is achieved by modifying the pH and its sorption capacity. The basic procedure limiting the mobility of metals is deacidification of soils by liming. Mobilisation and removal can be achieved by phytoextraction, which involves the use of plants for the removal of heavy metals from the soil. Biomass from such lands, rich in heavy metals, is regarded as hazardous waste[21].

The decision about the direction of remediation is undertaken on the basis of the following factors that can be grouped into:

- economic,
- formal and legal – the direction of remediation must be consistent with the local development plan,
- technical,
- hydrogeological,
- cultural,
- social[22].

According to the Act of 21 August 1997 *on real estate management*, every property, regardless of the type, location and purpose, has a value that can be referred to as[23]:

- market value,
- replacement value,
- cadastral value,
- hypothetical bank value – or another kind of value provided by separate regulations.

For the valuation of real estate one uses comparative, income or cost approach. Table 1 shows the classification of property valuation.

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21 A. Karczewska, op. cit.

22 A. Ostręga, *Sposoby zagospodarowania wyrobisk i terenów po eksploatacji złóż surowców węglanowych na przykładzie Krzemionek Pogórskich w Krakowie,* doctoral dissertation, Cracow 2004.

23 Ustawa z dnia 21 sierpnia 1997 roku o gospodarce nieruchomościami (Dz.U. 2010 nr 102 poz. 651 z późn. zm.).

Table 1. Classification of methods for real estate valuation

Approach	Method	Technique
Comparative	Comparing pairs	-
	Statistical analysis of the market	
	Correcting the average price	
Income	Investment	Simple capitalization Discounted cash flows
	Profits	
Cost	Restoration costs	Detailed Merged elements Indicator
	Replacement costs	
	Liquidation costs	Detailed Indicator
Mixed	Residual	-
	Liquidation costs	
	Estimated indicator of land	

Source: A. Janik, *Wielokryterialna metoda wyceny wartości terenów zdegradowanych*, "Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i zarządzanie" 2012 no. 62, p. 57–79.

Determination of the restoration value according to the cost approach requires identifying the value of land as the expenditure value that must be covered for the purchase of land with the same function and characteristics similar to the land on which the buildings are constructed. The list of difficulties affecting the quality of degraded lands, due to anthropogenic activities, is shown in table 2.

Table 2. Difficulties affecting the quality of valuation concerning properties degraded by anthropogenic activities

Approach	Difficulties
Comparative	• lack of data for comparisons • incomplete information on land prices
Income	• it is not possible to apply in the case of abandoned areas
Cost	• inability to obtain market information about the costs of full restoration • in the case of high pollution levels, e.g. with heavy metals, land's value can be negative in value

Source: A. Jadach-Sepioł, *Możliwości zarządzania wartości nieruchomości*, in: W. Rydzik (ed.), *Aspekty prawne i organizacyjne zarządzania nieruchomością,* Cracow 2009.

Commonly for the valuation of costs that need to be covered to restore degraded soils to their utility value, one uses, among others, professional standards of real estate appraisers – Standard IV *Dotyczy wpływu czynników środowiskowych na wycenę nieruchomości (Eng. Concerning the impact of environmental factors on real estate valuation*.) Standard IV takes into account the costs of restoring the property to its state before contamination, providing outlays on the removal of contaminated soil, e.g. using the techniques of remediation[24].

Estimate price calculation using the detailed method for remediation of soils contaminated with heavy metals in Trzebinia – cost estimate approach

Cost estimate value of the outlays was determined by Council of Ministers Regulation of 21 September 2004 *w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego (Eng. – on the property valuation and preparation of the appraisal report)* (§35.1 paragraph 2. point 2.) with the use of the detailed technique, which specifies the restoration costs on the basis of the necessary amounts to execute the construction works and unit prices of these works. Cost estimate made by means of the detailed method was used to determine the remediation price of areas degraded by heavy metals. Detailed calculation is based on calculating the estimate price as the sum of products: the amount of fixed premeasured units, units of material outlays and their prices, and appropriately added indirect costs and profit, including the value-added tax (VAT)[25]. The value of individual material outlays (labour, materials, work of equipment and means of technological transport) indispensible to make an estimate, adopted on the basis of Catalogue of Standard Prices and Rates[26] (tab. 0215, 0216). Unit standards of material outlays, unit prices of production factors, indirect costs, calculation profit and VAT were taken into account[27]. Remediation cost of 100m^2 will amount to 168,69 zl (table 3). Calculated costs include the cost of remediation by detailed biological method, involving the reconstruction of soils using agrotechnical methods (mechanical cultivation of the soil), and seeding legumes and grasses. This requires a series of procedures, including arrangement of the

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24 Rozporządzenie Rady Ministrów z dnia 21 września 2004 roku *w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego* (Dz.U. nr 207, poz. 2108 i 2109).

25 R. Cymerman, *Wycena nieruchomości a ochrona środowiska (ekologiczne uwarunkowania wyceny nieruchomości),* "Nieruchomości" 2000 no. 7.

26 Katalog Nakładów Rzeczowych nr 2–21. Tereny zieleni tab. 0215-Wysiew nawozów mineralnych lub wapna nawozowego, tab.0216-Uprawa gleby przy zastosowaniu nawozów zielonych.

27 K. Jóźwiak-Jaworska, *Podstawy kosztorysowania w architekturze krajobrazu,* Warsaw 2012.

Table 3. Estimate price calculation using the detailed method for remediation of soils contaminated with heavy metals in Trzebinia

No. item	Description of work, expenditures	UOM	The amount of work, standards	Price	R (estimated value of labour)	M (estimated value of construction materials)	S (estimated value of the work of construction equipment)	Total
	SCOPE OF REMEDIATION WORKS							
	1.1. LIMING- KNR 2-21 table 0215							
	Sowing of mineral fertilizers or lime fertilizer							
		m²	**100,00**					
	Labour							
	Gardeners - group I (analogy)	r-g	0,6637	15,00	9,96			
	Materials							
	Agrofoska (analogy)	t	0,0051	1 230,96		6,28		
	Equipment							
	Wheeled tractor 25-28 KM (1)	m-g	**0,0132**	**87**			**1,15**	
	Harrow	m-g	**0,0094**	**39,27**			**0,37**	
	Fertilizer seeder (fertilizer spreader)	m-g	**0,0038**	**34,34**			**0,13**	
	Total running costs				9,96	6,28	1,65	17,88
	Indirect costs 65% R+S				6,47		1,07	7,54
	Profit 11% R+S+Kp (R+S) (Kp - Eng. indirect costs)				1,81		0,30	2,11
	Total heading				**18,23**	**6,28**	**3,02**	**27,53**
	1.2. SEEDIND LEGUMES KNR 2-21 table 0216							
	Cultivation of the soil by using green manure							

	m²	**100**					
Labour							
Gardeners - group I (analogy)	r-g	0,0238	15	0,357			
Gardeners - group II (analogy)	r-g	0,2626	15	3,939			
Materials							
potassium salt 38-42%	t	0,002	1453,6		2,91		
superphosphate 17,5%	t	0,002	1361,6		2,72		
saletrzak 20,5%	t	0,001	1214,4		1,21		
Seeds of legumes	t	0,0025	24800		62,00		
Equipment							
Wheeled tractor 25-28 KM (1)	m-g	0,139	87			12,09	
Harrow	m-g	0,052	39,27			2,04	
Ploughing plough	m-g	0,0867	44,2			3,83	
Total running costs				4,30	68,84	17,97	91,11
Indirect costs 65% R+S				2,79	44,75	11,68	59,22
Profit 11% R+S+Kp (R+S) (Kp - Eng. indirect costs)				0,78	12,50	3,26	16,54
Total heading				7,87	126,09	32,91	166,86
Total: Remediation works							
Total running costs				14,25	75,12	19,62	108,99
Purchase costs 0%				0	0,00	0	0,00
Indirect costs 65% R+S				9,26	0,00	12,75	22,01
Profit 11,4% R+S+Kp(R+S) (Kp - Eng. indirect costs)				2,59	0,00	3,56	6,15
Total				26,10	75,12	35,93	**137,15**
Together with VAT 23%				**32,10**	**92,40**	**44,19**	**168,69**

land surface. The duration of remediation depends on the type of wasteland, physicochemical properties of the substrate and the type of farming[28].

Conclusions

1. Considering the obtained results regarding average concentrations of cadmium, lead and zinc in the soil of Trzebinia, it should be stated that they exceeded the allowable concentrations of these elements according to national regulations (Dz.U. 2002) for farmlands, both at a depth of 0–20 cm and 20–40 cm. The statement about soil pollution with the aforesaid elements in Trzebinia is eligible.
2. The obtained results of soil pollution with zinc, cadmium and lead show a connection with activities from the past (industrial, agricultural, mining and processing local raw materials) in the rural administrative units of Trzebinia.
3. Analysing the obtained results of the average copper content in the soil of Trzebinia, it must be concluded that they have not exceeded the permissible concentrations of this element according to national regulations (Dz. U. 2002) for farmlands (<150 mg/kg s.m), both at depth 0–20 cm and 20–40 cm. Therefore, the soils of Trzebinia have not been contaminated with copper.
4. Standards for soil and land quality were exceeded in the area of the Trzebinia city. Taking into account cost-benefit analysis, soil remediation should be carried out.
5. The performed estimate calculation showed that the cost of remediation by detailed biological method regarding 100 m^2 of degraded lands will amount to 168,69 zl.

Literature

Alloway B.J., Ayres D.C., *Chemiczne podstawy zanieczyszczenia środowiska,* Warsaw 1999

Alloway B.J., *Heavy metals in soils*, Glasgow 1995

Bednarek R., et al., *Badania ekologiczno-gleboznawcze,* Warsaw 2011

Bondariew L.G., *Pierwiastki śladowe – dobre i złe zarazem*, Warsaw 1989

Buckman H.C., Brady N.C., *Gleba i jej właściwości*, Warsaw 1971

Cedzyńska K., Smolińska B., *Wpływ metali ciężkich na aktywność enzymatyczną gleby. Obieg pierwiastków w przyrodzie,* Monograph. Vol. III., 2005, p. 541–544

28 A. Karczewska, op. cit.

Chodak T., Kabała C., *Powierzchnia właściwa-złożony parametr charakteryzujący stan środowiska glebowego,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 501–506

Ciepał R., *Przenikanie S, Pb, Cd, Zn, Cu i Fe do biomasy oraz gleby ekosystemu leśnego. Znaczenie bioindykacyjne,* Katowice 1992

Curzydło J., *Skażenia motoryzacyjne wzdłuż dróg i autostrad oraz sposoby przeciwdziałania ujemnym skutkom motoryzacji w środowisku*, "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 265–270

Cymerman R., *Wycena nieruchomości a ochrona środowiska (ekologiczne uwarunkowania wyceny nieruchomości),* "Nieruchomości" 2000 no. 7

Dziadek K., Wacławek W., *Metale ciężkie w środowisku,* cz. 1, *Metale ciężkie (Zn, Cu, Ni, Pb, Cd) w środowisku glebowym,* "Chemia, Dydaktyka, Ekologia, Metrologia" 2005 no. 10(1–2), p. 33–44

Gębski M., Stepski W., Mercik S., *Ocena metod oznaczania metali ciężkich w glebie w oparciu o ich zawartości w roślinach*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 2000 no. 472, p. 267–273

Gorlach E., *Metale ciężkie jako czynnik zagrażający żyzności gleby*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 1995 no. 421a, p. 113–122

Greinert H., *Ochrona gleb,* Zielona Góra 1998

Hillel D., *Gleba w środowisku*, Warsaw 2012

Jadach-Sepioł A., *Możliwości zarządzania wartości nieruchomości*, in: W. Rydzik (ed.), *Aspekty prawne i organizacyjne zarządzania nieruchomością,* Cracow 2009

Janik A., *Wielokryterialna metoda wyceny wartości terenów zdegradowanych*, "Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i zarządzanie" 2012 no. 62, p. 57–79

Jarosz W., Marchwiński E., *Wpływ emisji z tras komunikacyjnych na skażenia gleby i żywności,* in: *Ekosystemy żywicielskie i żywność. Zagrożenia i problemy ochrony*, Warsaw 1991

Jasiewicz Cz., Baran A., *Przewodnik do wykładów i ćwiczeń z toksykologii*, Cracow 2008

Jóźwiak-Jaworska K., *Podstawy kosztorysowania w architekturze krajobrazu,* Warsaw 2012

Kabata-Pendias A., *Zanieczyszczenia pierwiastkami śladowymi gleb użytków rolnych. Wybrane zagadnienia związane z chemicznym zanieczyszczeniem gleb,* Warsaw 1989

Karczewska A., *Ochrona gleb i rekultywacja terenów zdegradowanych,* Wrocław 2008

Kociołek-Balawejder E., Stanisławska E., *Chemia środowiska,* Wrocław 2012

Kowalik P., *Ochrona środowiska glebowego,* Gdańsk 1999

Kowalik P., *Ochrona środowiska glebowego,* Warsaw 2001

Łopata K., Rudnik E., Nowak E., *Tajemnice gleby. Chroń swoje środowisko,* Warsaw 1997

Motuzova G.V. et al., *Soil contamination with heavy metals as a potential and real risk to the environment,* "Journal of Geochemical Exploration" 2014 no. 144, p. 241–246

O'Neil P., *Chemia środowiska*, Warsaw 1997

Ostręga A., *Sposoby zagospodarowania wyrobisk i terenów po eksploatacji złóż surowców węglanowych na przykładzie Krzemionek Pogórskich w Krakowie,* doctoral dissertation, Cracow 2004

Preżdo W., Nowakowski L., *Chemia środowiska,* university script, Opole 1995

Rozporządzenie Rady Ministrów z dnia 21 września 2004 roku *w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego* (Dz.U. nr 207, poz. 2108 i 2109)

Siuta J., *Gleba-diagnoza stanu i zagrożenia,* Warsaw 1995

Siuta J., *Ochrona i rekultywacja gleb,* Warsaw 1978

Siuta J., *Rekultywacja gruntów,* Warsaw 1998

Terelak H., et al., *Zawartość Cd, Cu, Ni, Pb, Zn i S w glebach woj. krakowskiego i Polski,* Materials from Scientific Conference: Management of areas contaminated by human activity, 1996

Trzyszcz Z., *Przekształcenie geochemiczne, hydrologiczne i chemiczne pokrywy glebowej w woj. Katowickim,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 117–126

Turnau K., Wenhrynowicz O., *Mechanizmy obronne roślin i grzybów w siedliskach skażonych ołowiem*, Materials from the symposium Lead in the environment. Environmental Problems and Methodology, Warsaw 1997

Turski R., Baran S., *Degradacja, ochrona i rekultywacja gleb,* Lublin 1995

Ustawa z dnia 21 sierpnia 1997 roku o gospodarce nieruchomościami (Dz.U. 2010 nr 102 poz. 651 z późn. zm.).

Woch F., *Wademekum klasyfikatora gleb,* Collective work, Second edition supplemented and revised, Puławy 2007

Zakrzewski S.F., *Podstawy toksykologii środowiska,* Warsaw 1995

Zieliński S., *Skażenia chemiczne w środowisku*, second edition revised and supplemented, Wrocław 2007

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THE PERSPECTIVE OF SOLAR AND WIND ENERGY UTILISATION IN THE COPPER ELECTROREFINEMENT

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PERSPEKTYWA WYKORZYSTANIA ENERGII SŁOŃCA I WIATRU W ELEKTRORAFINACJI MIEDZI

STRESZCZENIE: Odnawialne źródła energii (OZE) pozwalają na wykorzystanie energii promieniowania elektromagnetycznego Słońca w formie bezpośredniej lub poprzez produkty fotosyntezy, energię kinetyczną wiatru, wody itd. W przypadku fotosyntezy, której akumulowana energia jest później pośrednio wykorzystywana w biogazowniach oraz w innych systemach OZE trzeba mieć świadomość niskiej 3–6% wydajności tego procesu. Proponujemy rozważenie zastosowań uwzględniających ograniczenia wynikające z natury OZE w technologiach akceptujących te uwarunkowania. Rozważania opieramy na przykładzie energochłonnego procesu elektrorafinacji miedzi, w którym zużywane jest 300 400 kWh (1,08 1,44 GJ) energii elektrycznej na wydzielenie tony (10^3 kg) miedzi. Zapewnienie ciągłości procesu można osiągnąć poprzez nowe rozwiązania technologiczne lub w najgorszym przypadku przez wspomaganie energią ze źródeł konwencjonalnych. Nie można wykluczyć, że efektem tych działań będą rozsiane po całym kraju niewielkie instalacje rafinujące miedź, spełniające wymogi środowiskowe i sprzężone z nimi wytwórnie specjalistycznych stopów miedzi. Podejście nie powinno być ograniczone do elektrorafinacji miedzi. Przy źródłach OZE można będzie lokować inne technologie, a nowe rozwiązanie staną się inspiracją do multidyscyplinarnych innowacji.

SŁOWA KLUCZOWE: odnawialne źródła energii, elektroliza, elektrorafinacja, miedź, innowacyjne technologie

Introduction

The European non-ferrous metals industry has larger economic significance than it would be indicated by the employment, capital and trade statistics[1]. The copper, which finds versatile applications in the economy is obtained from fossil minerals and recycling[2]. Naturally, it occurs in the form of oxides and sulphides. Only small quantities of copper are in the native form[3].

Procedure for the obtainment of crude copper consists of several energy-consuming steps involving flotation and metallurgical processes[4]. Even though the resulting crude blister copper contains 98.5 to 99.5% pure metal, it still requires further purification. In the energy-consuming process of electrolysis in acidified copper sulphate solution, due to the electric current with a low voltage and high density, the metal from which the anodes are made is "transferred" to the cathodes. During the electrolysis lasting 9–15 days, pure copper (99.95 99.99%) is deposited on the cathode and the silver, gold, nickel, platinum-group-metals and other metal and metalloid compounds are left in the slimes[5].

Industrial electrolysis baths are rectangular boxes made from polymer-concrete, which provides hermeticity, strength, good electrical insulation and high resistance to aggressive chemicals[6]. Thereby optimization of the electro-refining process allows energy consumption of 300–400 kWh (1.08 to 1.44 GJ) per tonne of copper (10^3 kg)[7].

Despite the economic fluctuations, the demand for copper grew dramatically over the last hundred years, driving the rate of production nearly exponentially[8]. However, from the economic point of view, the copper processing

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1 Joint Research Centre, *Best Available Techniques (BAT) Reference Document for the Non Ferrous Metals Industries (Final Draft)*, 2014, p. 1–1242.

2 International Copper Study Group, *Sustainable Development*, www.icsg.org [16-07–2015]; S. Northey, N. Haque, G. Mudd, *Using sustainability reporting to assess the environmental footprint of copper mining,* "Journal of Cleaner Production" 2013 no. 40, p. 118–128.

3 S. Northey, N. Haque, G. Mudd, op. cit.

4 Joint Research Centre, op. cit.; S. Northey, N. Haque, G. Mudd, op. cit.

5 J. Marcinowski, *Główne przyczyny uszkodzeń wanien elektrolitycznych stosowanych w hutnictwie miedzi,*, "Przegląd Budowlany" 2010 no. 81, p. 124–127; G. Cifuentes, J. Hernández, N. Guajardo, *Recovering Scrap Anode Copper Using Reactive Electrodialysis*. "American Journal of Analytical Chemistry" 2014 no. 5(15), p. 1020; International Copper Study Group, *The World Copper Factbook*, 2014, p. 1–63; R. Marković et al., *Behaviour of non standard composition copper bearing anodes from the copper refining process*, "Journal of Hazardous Materials" 2010 no. 182(1), p. 55–63.

6 J. Marcinowski, *Główne przyczyny uszkodzeń wanien elektrolitycznych stosowanych w hutnictwie miedzi*, "Przegląd Budowlany" 2010 no. 81, p. 124–127.

7 Joint Research Centre, op. cit.

8 S. Northey, N. Haque, G. Mudd, op. cit.

has certain disadvantages. The use of copper products has negative impact on the environment, often imperceptible to the consumer[9]. If the overall cycle of metal (from mining to recycling) is taken into the account, the scale of the environmental impact extends from local (water consumption and toxic waste) to global (climate changes)[10]. In the global perspective, the energy demand and related to it CO_2 emission contributes to global warming[11]. Despite the implementation of new technologies to copper processing, the current dimension of the environmental effects of this sector and no liability for their formation makes the situation difficult to maintain in its present form. Consequently, companies engaged in mining, refining and recycling are under growing pressure to reduce negative environmental impact[12].

The way how society uses and exploits its resources, is an important factor ensuring the sustainable development, which became one of the strongest incentives shaping the progress of industry in mining and processing of minerals and metals[13]. One of the ways to achieve better efficiency in the use of raw materials is dematerialisation – the reduction of energy and materials needed to perform economic functions. This process complements the reuse of materials and forms a closed loop, allowing to achieve smaller and lighter products with longer lifespan, which could be recycled[14]. Such an approach can contribute to limiting production of primary copper, thereby reducing the energy expenditure, and as a result CO_2 emission. Improving the circulation of the material is still not sufficient to fully secure the society from the harmful effects of the copper production. It is impossible to propose a concept solving all of the problems, separated from comprehensive analysis. Therefore an integrated, innovative approach bonding various ideas and solutions is necessary. An exemplary voice in the discussion may be the use of renewable energy sources (RES), such as wind and photovoltaics for supplying electric energy-dependent stage of copper refining – electrorefining.

9 Ibidem.

10 D. Giurco, J.G. Petrie, *Strategies for reducing the carbon footprint of copper: New technologies, more recycling or demand management?*, "Minerals Engineering" 2007 no. 20(9), p. 842–853.

11 W. Kuckshinrichs, P. Zapp, W.R. Poganietz, *CO_2 emissions of global metal industries: the case of copper*, "Applied Energy" 2007 no. 84(7), p. 842–852.

12 D. Giurco, J.G. Petrie, op. cit.

13 International Copper Study Group, *Sustainable Development*, www.icsg.org [16-07–2015]; R. van Berkel, *Eco efficiency in primary metals production: Context, perspectives and methods*, "Resources, Conservation and Recycling" 2007 no. 51(3), p. 511–540.

14 T.E. Norgate, S. Jahanshahi, W.J. Rankin, *Assessing the environmental impact of metal production processes*, "Journal of Cleaner Production" 2007 no 15(8), p. 838–848.

Data, methods and assumptions

In Poland, the electrorefinement of copper is carried out in two smelters owned by KGHM Polska Miedź – "Głogów" and "Legnica" works[15]. Thus, a case study was conducted – surroundings of Legnica were taken as a hypothetical localisation for the considerations. The productivity of wind farm in Taczalin (Legnica county) was estimated to be 2.66 GWh×MW^{-1} (9.58 TJ×MW^{-1}) of installed power[16]. Data presenting wind velocity around Legnica on an hourly basis for the years 1985–2004, taken from SoDa[17] were averaged to daily values and compared with measurements conducted by the Institute of Meteorology and Water Management.

The methodology for calculations of energy generated by renewable energy sources was adopted from[18]. Electric power generated by the wind turbine was calculated according to the formula (1), while the yield of electric energy for photovoltaic system by means of formula (2).

$$P(TW) = \begin{cases} 0 \text{ if } v < v_1 \\ P(v) \text{ if } v_1 \le v < v_r \\ P_r \text{ if } v_r \le v < v_2 \\ 0 \text{ if } v \ge v_2 \end{cases} \quad (1),$$

where:

P(TW) – power generated by wind turbine, MW
P(v) – power curve of turbine depending on wind velocity
v_1 – start velocity at which turbine starts to generate electric energy, m×s^{-1}
v_2 – critical velocity at which operation of turbine has to be suspended, m×s^{-1}
v_r – velocity from which turbine operates at nominal power, m×s^{-1}

Equation (1) form is determined by the work specificity of a particular wind turbine model. The reference used was Vestas V90 turbine with nominal power P_r = 2 MW. According to the information on the turbine it was assumed that: v_1 = 4 m×s^{-1}, v_2 = 25 m×s^{-1}, v_r = 12 m×s^{-1} [19].

$$E(PV) = \frac{GHI * P * P_R}{GHI_{STC}} \quad (2),$$

where:

15 KGHM Polska Miedź, *Smelting and refining*, www.kghm.com [30-07–2015].

16 WSB Parki Wiatrowe, *Projekty. Park wiatrowy Taczalin*, www.wsb parkiwiatrowe.pl [29-07–2015].

17 SoDa, *Time Series of Solar Radiation Data from MACC RAD*, www.soda pro.com [31-07–2015].

18 G. Notton, S. Diaf, L. Stoyanov, *Hybrid photovoltaic/wind energy systems for remote locations*, "Energy Procedia" 2011 no. 6, p. 666–677.

19 Vestas Wind Systems, *V 90 2.0 MW*, www.vestas.com [28-07–2015].

E(PV) – yield of electric energy from PV (photovoltaic) system, kWh (MJ)
GHI – value of solar radiation incidence on a surface, kWh×m^{-2} (MJ×m^{-2})
P – nominal power installed in a PV system, kW
P_R – degree of efficiency (adopted as 0.8)
GHISTC – standard conditions, at which photovoltaic modules are examined, 1 kW×m^{-2}

Within the further analysis, variability of energy production from both sources in a shorter time horizon have been assessed – calculated as the average monthly energy yields for the years 2005–2014. The last step in the analysis of energy resources of wind and the Sun was to evaluate the variability of electric energy production in daily terms.

For photovoltaic farm, the estimated cost is assumed to be 3.9–4.8 million PLN/MW$_p$[20]. However, in the case of wind power plants on land, the cost is higher and oscillates at 5–7 million PLN/MW[21]. Economic considerations, were conducted on the basis of assumptions shown in the table 1.

Table 1. Assumptions in the economic calculations

Assumed parameter	Unit	Value
Copper production	t×day^{-1} (kg×s^{-1})	9000 (104.17)
	t×h^{-1} (kg×s^{-1})	53.57 (14.88)
Energy consumption	MWh×t^{-1} (MJ×kg^{-1})	0.4 (1.44)
	MWh×h^{-1} (MJ×s^{-1})	21.43 (21.43)
Purchase from grid energy price	PLN×MWh^{-1} (PLN×GJ^{-1})	350 (97.22)
Resale to grid energy price	PLN×MWh^{-1} (PLN×GJ^{-1})	150 (42.22)
Green certificate price	PLN×MWh^{-1} (PLN×GJ^{-1})	180 (50)
Average increase in energy prices	%×year^{-1} (%×s^{-1})	2.5 (7.93×10^{-7})
Wind park initial cost	PLN×MW^{-1}	5 800 000
PV farm initial cost	PLN×MW$_p^{-1}$	4 500 000
Wind park yearly maintenance	% of initial cost	2
PV farm yearly maintenance	% of initial cost	1.5
PV farm efficiency decrease	%×year^{-1} (%×s^{-1})	1 (3.17×10^{-7})
Wind turbine efficiency decrease	%×year^{-1} (%×s^{-1})	1.6 (5.07×10^{-7})
Maintenance cost increase	%×year^{-1} (%×s^{-1})	1.2 (3.81×10^{-7})

20 B. Szymański, *Farma fotowoltaiczna podstawowe fakty*, www.solaris18.blogspot.com [09-07–2015].

21 Centrum Informacji o Rynku Energii, *Energetyka wiatrowa w Polsce*, 2010, p. 1–52.

It has been assumed that electric energy obtained from the hybrid system (wind park plus photovoltaic farm) will be utilized to cover current demand for energy in the copper manufacturing process. Covering the demand generates savings in the amount equal to the cost of purchasing electric energy from the grid, while the resale of surpluses is associated with income equal to the price of resale of electric energy to the grid. The considerations also include the decrease in efficiency of energy sources and an increase in the cost of their maintenance.

In the first stage of the considerations, an analysis of how the structure of the hybrid system (the share of capacity installed in wind turbines and photovoltaic panels) affects the degree of coverage of current demand. The next stage was to determine how simple return period of financial outlays is shaped, depending on the installed power in the individual power plants. For this purpose, the cost of generating a single MWh of energy from a given hybrid system was calculated, with a 25 year of investment duration. In the subsequent stage, average profit arising from the generated unit of electric energy, was calculated. Such profit is calculated as the sum of the savings arising from electric energy not purchased for the production process and surplus energy resold to the grid. System optimisation was single-objective – the shortest simple payback time (SPT). A variety of methods exist for optimising these systems[22], but for performed analyses their implementation was not necessary.

Results

Comparing data for wind speed near Legnica in hourly basis for the years 1985–2004 with measurements carried out by the Institute of Meteorology and Water Management, gave correlation coefficient of 0.85. This value indicates partial compatibility of data sources. It should however be kept in mind that the correlation coefficient value was influenced by i.a.: a mesh of satellite measurements (spatial resolution of 50 kilometres), averaging daily values by Institute of Meteorology and Water Management on the basis of four readings (for satellite based on 24) and increasing roughness of the terrain around the weather stations (leading to the reduction of wind velocity and changes in its character).

Figure 1 shows the energy yield from the photovoltaic plant and wind turbine for particular periods of time, according to equations (1) and (2).

22 W. Zhou, et al., *Current status of research on optimum sizing of stand-alone hybrid solar–wind power generation systems*, "Applied Energy" 2010 no. 87, p. 380–389.

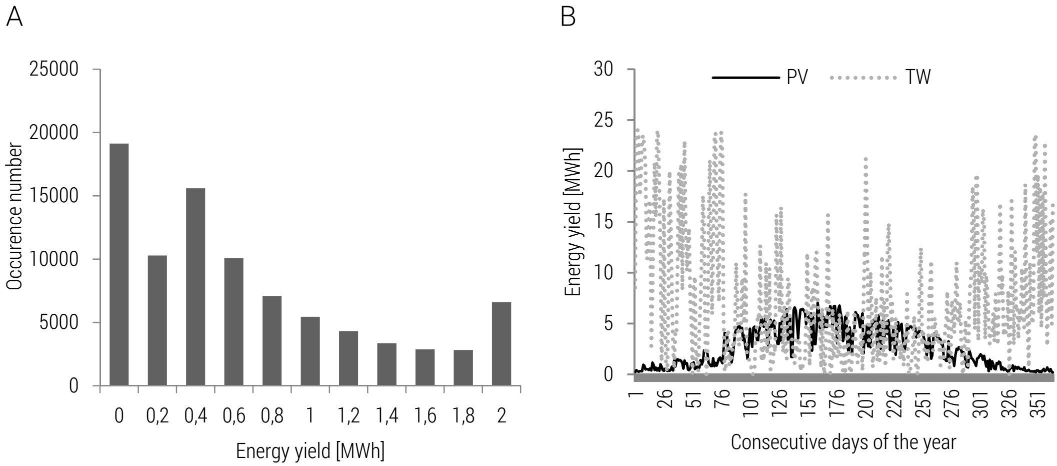


Figure 1. Electric energy yields obtained from components of the hybrid system

(A) The histogram of hourly energy yield from wind turbine with capacity of 2 MW between 2005 and 2014 (B) The average daily yield of electric energy from the photovoltaic system and wind turbine calculated per 1 MW of installed power in 2005.

Variability and complementarity of wind and solar sources are shown on the multi-annual, monthly and daily basis. Figure 2 presents the variability of annual sums of obtained electric energy from photovoltaic farm with a power of 1 MW and wind turbine with nominal power of 2 MW.

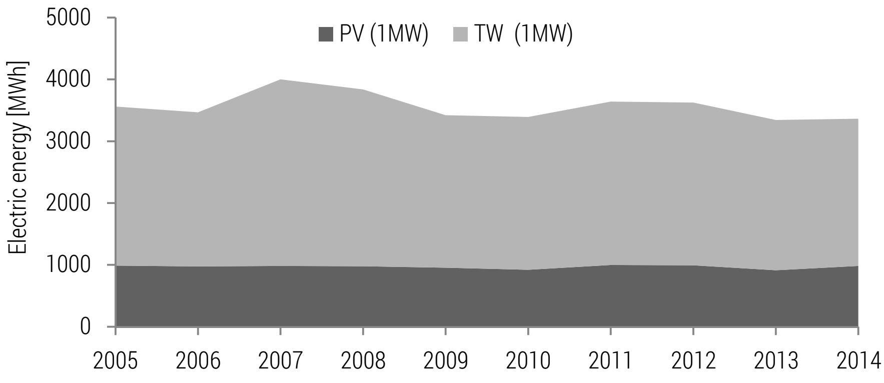


Figure 2. Multi-annual variability of energy yield from photovoltaic system and wind turbine

Turbine power was recalculated for 1 MW. In the analysed period, the energy yield of photovoltaic farm was relatively stable at approx. 970 MWh×MW^{-1} (3,49 TJ×MW^{-1}) while in the case of wind turbine approx. 2600 MWh×MW^{-1} (9,36 TJ×MW^{-1}).

Multi-annual variability of the wind turbine work is much clearer than in the case of the photovoltaic installation. The average monthly energy gains over the years 2005–2014 are summarized in figure 3.

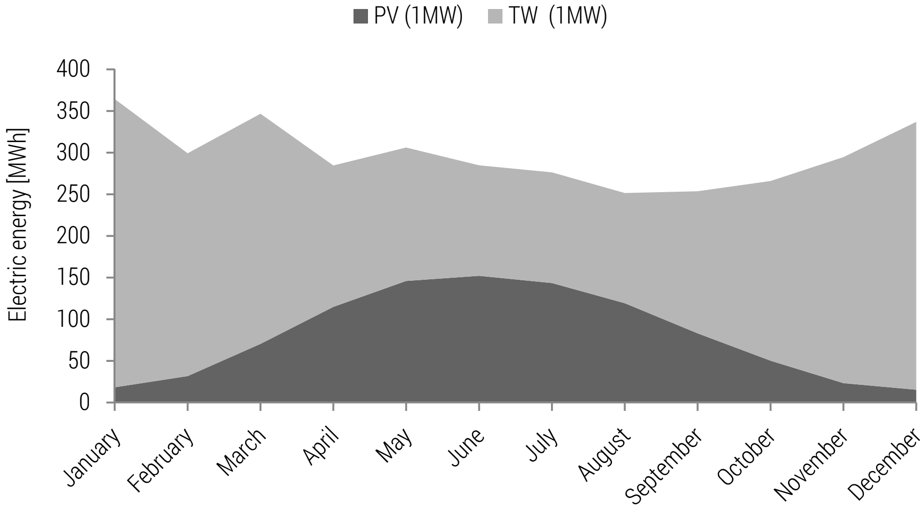


Figure 3. Annual variability of energy yield from photovoltaic system and wind turbine

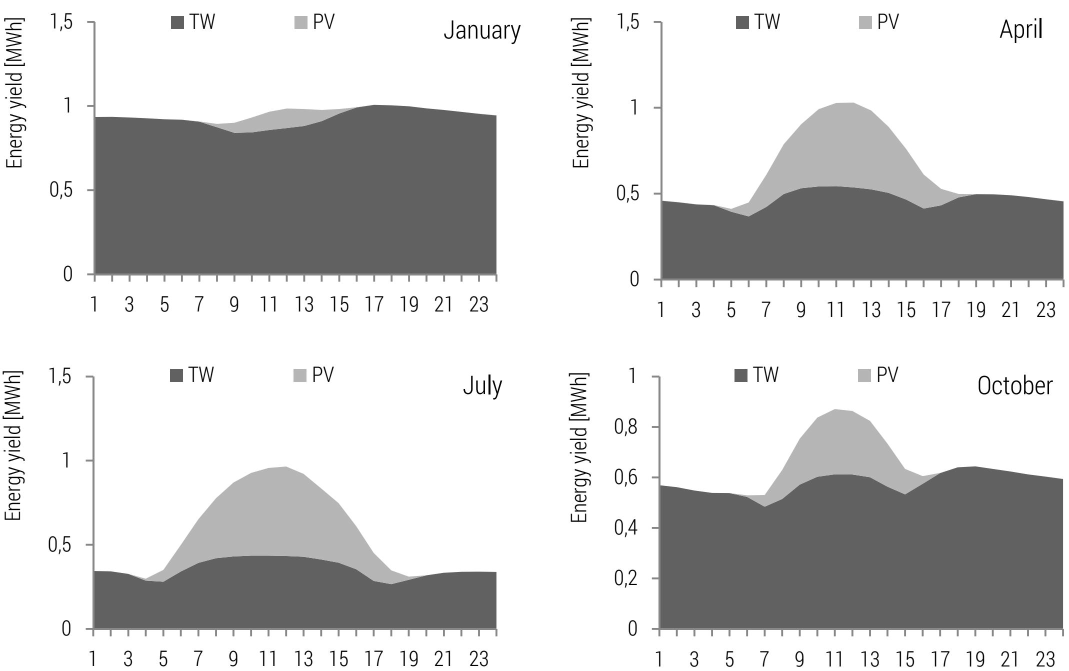


Figure 4. Statistical hourly energy yield from the wind turbine and photovoltaic farm in the individual hours of the day in selected months

The results of calculations aimed at assessing the variability of electric energy production in daily terms are shown in figure 4, where statistical values of generated electric energy are presented in the consecutive hours of a day.

Figure 5 illustrates the values of correlation coefficients between the recovery of energy from the photovoltaic system and wind turbine in the particular months. As can be seen only in November-February, the correlation between these energy sources is advantageous from the recipient point of view.

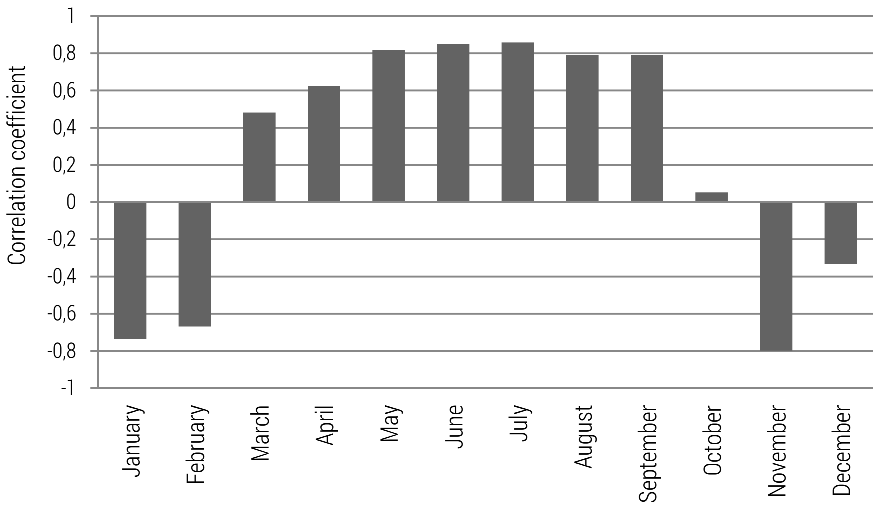
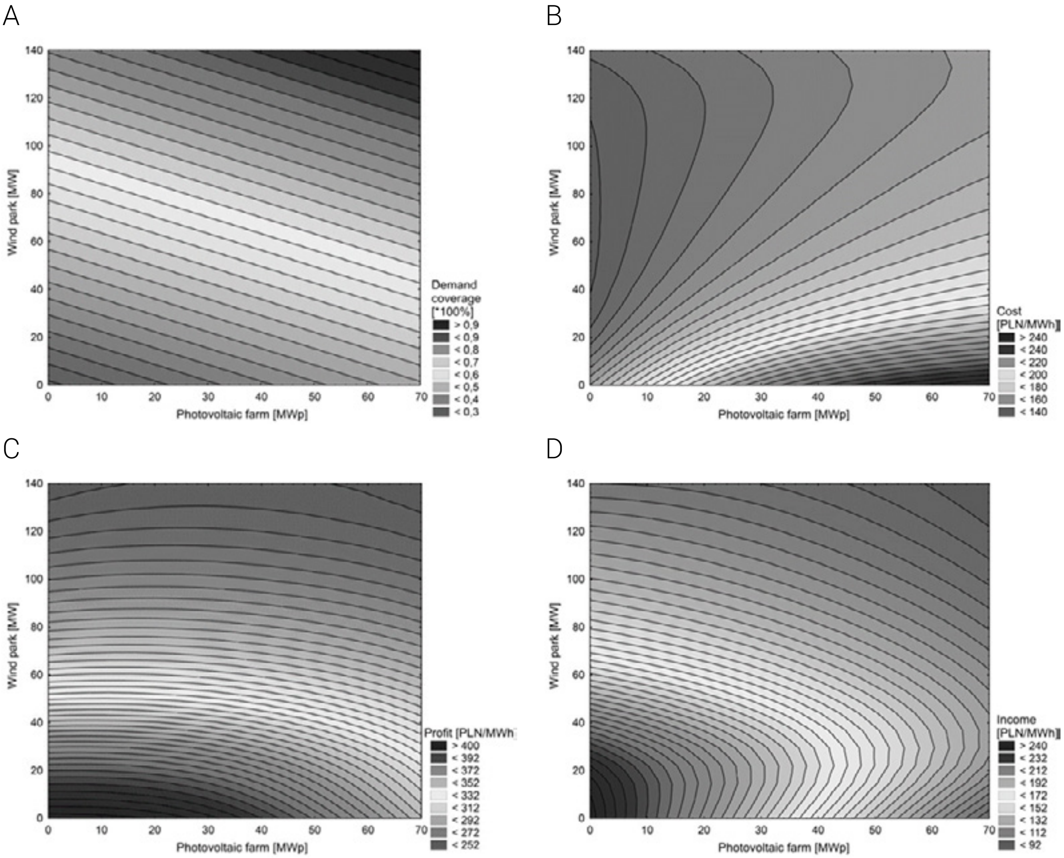


Figure 5. The correlation coefficient for hourly energy yields from photovoltaic system and wind turbine

Analysis of the structural influence of the hybrid system (the share of installed power in wind turbines and photovoltaic panels) on the coverage of current demand is visualized in figure 6A. The results of the calculations of the cost of generating single MWh of energy from given hybrid system, with the 25-year period of the investment, depending on the installed power in the individual power plants are shown in figure 6B. The average profit from the generated unit of electrical energy is expressed as the sum of the savings arising from electric energy not purchased for the production process and surplus energy resold to the grid. It is presented in figure 6C. Profit from generated energy, decreased by the cost of obtaining it is the size of the income from a single megawatt hour of electric energy. Thus, we get the answer to the question, what configuration of the hybrid system will allow to generate electric energy which value, from the point of view of economics, will be the most advantageous. The results of the calculations are shown in figure 6D.



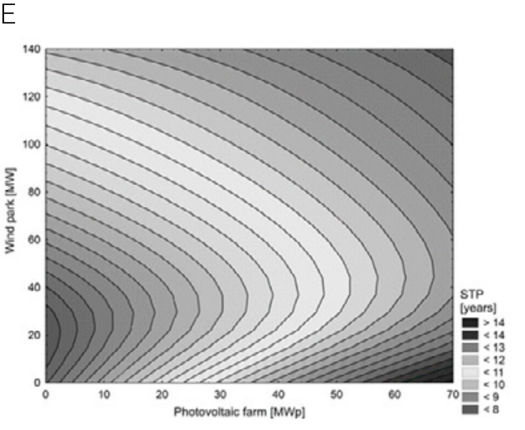


Figure 6. Analysis of the profitability of the considered investment

(A) Coverage of the demand for electric energy depending on the nominal power of the various energy sources. (B) The cost of obtaining 1 MWh of energy from the perspective of 25 years of work of energy sources with the selected nominal powers. (C) The average profit from the savings and resale of energy for energy sources with given powers (figure does not include green certificates). (D) Income from a unit of electric energy produced, which is the difference between profit and the cost of obtaining it. (E) The average simple payback time (SPT) – not taking into account the green certificates.

The length of the payback time of financial outlays results both from the extent to which the sources cover the requirements, as well as their initial and maintenance costs. The values of a simple payback time of financial expenses, excluding the green certificates are presented in figure 6E.

Discussion

Renewable energy sources are an attractive topic of media. Often the discussion about their use does not include the realities and limitations. Annual energy carried by the Sun rays in Poland has a value of approx. 950–1250 kWh×m^{-2}. In the use of this energy, limited efficiency of converters and their impact on the environment (recycling) must be considered[23]. For example, the energy balance of biomass production, based on the photosynthesis process is dependent on the time of day and year, and its yield is estimated to be 3 to 6%[24]. Another example would be biodiesel production technology, in which beneficial energy balance is affected by the use of straw, which is not anticipated final product. Additionally, adverse environmental effects should be taken into account, involving the unsolved problem of processing waste material – glycerol[25].

However, critical look at the RES does not relieve from the discussion and exploration. In recent years, due to the scale effect, dynamic development of manufacturing plants, optimization of production processes and implementation of programs aimed at the development of renewable energy sources, a systematic drop in investment expenditures incurred by both the small and large renewable energy sources is being observed.

From a national perspective, Legnica is located in an area where wind conditions are not promising for the development of wind energy. However, making decisions based on a summary map of wind speeds in Poland turns out to be wrong, and this fact is confirmed by the rapid development of wind parks in the areas of rural municipalities located near Legnica[26].

The production curve of electric energy from wind and photovoltaic plants indicates high instability of these sources (figure 1), which may result

23 H. Lorenc, *Atlas klimatu Polski*, Warszawa 2005, p. 21–24.

24 X.G. Zhu, S.P. Long, D.R. Ort, *What is the maximum efficiency with which photosynthesis can convert solar energy into biomass?*, "Current opinion in biotechnology" 2008 no. 19(2), p. 153–159.

25 T.K. Dobek, M. Dobek, O. Šařec, *Ocena efektywności ekonomicznej i energetycznej produkcji pszenicy ozimej i rzepaku ozimego wykorzystanych do produkcji biopaliw*, "Inżynieria Rolnicza" 2010 no. 14, p. 161–168.

26 Regionalna Dyrekcja Ochrony Środowiska we Wrocławiu, *Farmy wiatrowe w województwie dolnośląskim*, www.bip.wroclaw.rdos.gov.pl [29-07–2015].

in incomplete coverage of demand for a given time. In the global perspective (eg. the country) when a group of wind parks and solar farms spread over a large area is analysed, a positive effect is observed, resulting from the spatial distribution, which leads to smoothing of the production curve[27]. However, from the perspective of a single recipient, that uses such sources located in small area, the only solution is to resize the system and simultaneously store the surplus energy. When the electric energy sources are able to complement themselves in the energy production, it can be spoken of complementarity. This term can be considered both in time (variation in wind and sunlight per year) and space (eg. stronger winds on the coast of the Baltic Sea and larger amounts of sunlight in the Voivodship of Lublin on a national scale).

Due to the relatively spotty nature of the analysed hybrid system, only the time complementarity has been analysed. As an example of a perfect time complementarity, the situation can be considered, in which a first source operation is described by the sine function while the second source operation is the sine function, but shifted in phase by $\pi/2$. As can be seen, the energy sources are clearly complementing each other in terms of energy yield per year (figure 3). In these time series, the correlation coefficient is at the level of 0.91. Appropriate configuration of installed power in both of these sources could allow smoothening of the statistical curve of energy yield per year. However, its adaptation to the curve of electric energy demand should be kept in regard. The issue of energy yield from the photovoltaic system is more intuitive than in the case of wind turbines. It exhibits variability considerably clearer and perceptible by the human in both the year and the day scale (figure 4). Generation of electric energy in photovoltaic system is based on the direct conversion of solar radiation to the electric energy. Thus, when the sunlight does not reach module plane, the photovoltaic effect does not occur and electric energy is not generated. In summary, photovoltaic and wind energy sources annualised show a strong negative (favourable) correlation (figure 5). In daily terms, this situation occurs only during November-December.

It can be observed that the degree of the demand coverage is increasing much faster in the case of a wind park than photovoltaic farm (figure 6A). Each additional megawatt of power installed in wind turbine, averagely contributed to covering additional 0.48% of the demand, while in the case of solar energy it was about 0.2%. This situation is mainly due to the hours in which electric energy is statistically obtained from different sources, and the

27 J. Jurasz, J. Mikulik, *Wpływ dystrybucji przestrzennej na stabilność źródeł fotowoltaicznych*, in: A. Kotowski, K. Piekarska, B. Kaźmierczak (eds), *Interdyscyplinarne zagadnienia w inżynierii i ochronie środowiska*, Wrocław 2015, p. 179–191; J. Kleissl, *Solar energy forecasting and resource assessment,* 2013, p. 21–406.

amount of energy generated per a megawatt of installed power: 970 MWh×MW^{-1} (3.49 TJ×MW^{-1}) – PV and 2600 MWh×MW^{-1} (9.36 TJ×MW^{-}1) – TW (figure 2).

It is noteworthy that for the wind conditions occurring in analysed location and assumed structure of energy consumption and its costs, generation of energy from the photovoltaic system is much more expensive (figure 6B). Due to the adopted assumptions as to the price of resale and purchase of energy, the highest profit is generated by energy sources that allow covering the current demand to the maximum extent without generating unnecessary surplus energy. Thereby, a threshold value of requirement coverage is 50%, beyond which profit from the energy starts to diminish (figure 6C). As can be seen, the installation consisting of a wind park with a capacity of 40 MW and a photovoltaic farm with a capacity of 10 MW, which will cover an average of 10 to 50% of electric energy demand, will generate the greatest income (figure 6D).

Calculated income translates directly into a simple payback time of financial outlays, which at best is 8 and at worst for over 14 years (figure 6E). Taking into account the price of green certificates assumed in table 1, the payback period is reduced averagely by three years, and is still not less than 6 years.

The considerations have been conducted on the example of the cathode copper production for situation covering industrial-scale production. In conventional technologies requiring continuous supply of electric energy technical thought contributed to the improvement of this process. However, the question must be asked – would it be possible to conduct this process in conditions of changeable supply of energy generated by RES. Asking the question should inspire the professionals to answer.

Due to scattering of renewable energy sources, the idea of small production systems powered by RES can be discussed. Technically design might differ from the standard solutions. Small installations could be more easily supervised, and the possible release of harmful gases would not be concentrated in small areas. The intermediates could be processed on the spot into small batches of special products. Creating small installations taking into account the limitation of RES could become an impulse of progress. However, this approach requires proof and should be tested in future works. It should be proven whether the unit processes comprising the entire scheme would not lead to energy consumption higher than expected savings. Also different aspects of transportation and its impact on economics and environment should be considered.

The discussion started with the issues related to the electrorefining of copper, but the problem is open to broadly understood energy consuming technologies. The continuation of research on innovative technologies absorbing the changing energy supply will be required. Specialists chemists, physicists, biologists, etc. should propose a list of issues. It may begin with the electrochemical processes, the production of nitrogen fertilizers, and so on.

Conclusions

Innovative solutions, based on the synergy of many disciplines are in the modern world, one of the most widely used tools to resolve problems within almost every sector of the economy. In the case of above analysis, the keynote was the use of electric energy generated from renewable energy sources (wind and sun) in the copper production processes. Conceptually, all generated energy should be spent on the needs of the production process, but the changeability and instability of these energy sources enforce certain oversizing of the system and coming to terms with the fact of periodic occurrence of energy surpluses and shortages. Although in the current economic realities and technological conditions, the production of copper using energy from renewable sources seems to be difficult to implement, the initial solution could be supporting it with conventional energy. Expected innovative technologies should allow to carry on the processes depending on the changeable energy supply without adverse impact on product quality. This is the challenge to be taken by modern science[28].

The contribution of the authors in the article:

Tomasz Głąb, MSc – contribution to the concept of the paper, discussion and preparation of the technological-chemical

Jakub Jurasz, MSc Eng – contribution to the concept of the paper, discussion and preparation of the economical

Prof. Janusz Boratyński, Ph.D – concept of the paper and discussion

Literature

Best Available Techniques (BAT) Reference document for the non ferrous metals industries (Final Draft), Joint Research Centre 2014, p. 1–1242

Cifuentes G., Hernández J., Guajardo N., *Recovering Scrap Anode Copper Using Reactive Electrodialysis*. "American Journal of Analytical Chemistry" 2014 no. 5(15), p. 1020

[28] A similar concept, proposed by other authors appeared online in the "Journal of Cleaner Production" during technical preparations of above manuscript http://dx.doi.org/10.1016/j.jclepro.2016.09.040. Whereas our similar paper concerning utilisation of RES in chlor-alkali industry appeared in "Przegląd Naukowo-Metodyczny 'Edukacja dla Bezpieczeństwa'" 2016 No 1 (30), p. 1180-1198.

Dobek T.K., Dobek M., Šařec O., *Ocena efektywności ekonomicznej i energetycznej produkcji pszenicy ozimej i rzepaku ozimego wykorzystanych do produkcji biopaliw*, "Inżynieria Rolnicza" 2010 no. 14, p. 161–168

Energetyka wiatrowa w Polsce, Centrum Informacji o Rynku Energii, 2010

Farmy wiatrowe w województwie dolnośląskim, www.bip.wroclaw.rdos.gov.pl

Giurco D., Petrie J.G., *Strategies for reducing the carbon footprint of copper: New technologies, more recycling or demand management?*, "Minerals Engineering" 2007 no. 20(9), p. 842–853

Jurasz J., Mikulik J., *Wpływ dystrybucji przestrzennej na stabilność źródeł fotowoltaicznych*, in: A. Kotowski, K. Piekarska, B. Kaźmierczak (eds), *Interdyscyplinarne zagadnienia w inżynierii i ochronie środowiska*, Wrocław 2015

Kleissl J., *Solar energy forecasting and resource assessment,* 2013

Kuckshinrichs W., Zapp P., Poganietz W.R., *CO_2 emissions of global metal industries: the case of copper*, "Applied Energy" 2007 no. 84(7), p. 842–852

Lorenc H., *Atlas klimatu Polski*, Warszawa 2005

Marcinowski J., *Główne przyczyny uszkodzeń wanien elektrolitycznych stosowanych w hutnictwie miedzi,*, "Przegląd Budowlany" 2010 no. 81, p. 124–127

Marković R. et al., *Behaviour of non standard composition copper bearing anodes from the copper refining process*, "Journal of Hazardous Materials" 2010 no. 182(1), p. 55–63

Norgate T.E., Jahanshahi S., Rankin W.J., *Assessing the environmental impact of metal production processes*, "Journal of Cleaner Production" 2007 no 15(8), p. 838–848

Northey S., Haque N., Mudd G., *Using sustainability reporting to assess the environmental footprint of copper mining,* "Journal of Cleaner Production" 2013 no. 40, p. 118–128

Notton G., Diaf S., Stoyanov L., *Hybrid photovoltaic/wind energy systems for remote locations*, "Energy Procedia" 2011 no. 6, p. 666–677

Projekty. Park wiatrowy Taczalin, WSB Parki Wiatrowe, www.wsb parkiwiatrowe.pl

Smelting and refining, KGHM Polska Miedź, www.kghm.com

SoDa, *Time Series of Solar Radiation Data from MACC RAD*, www.soda pro.com

Sustainable Development, International Copper Study Group, www.icsg.org

Szymański B., *Farma fotowoltaiczna podstawowe fakty*, www.solaris18.blogspot.com

The World Copper Factbook, International Copper Study Group, 2014

V 90 2.0 MW, Vestas Wind Systems, www.vestas.com

van Berkel R., *Eco efficiency in primary metals production: Context, perspectives and methods*, "Resources, Conservation and Recycling" 2007 no. 51(3), p. 511–540

Zhou W., et al., *Current status of research on optimum sizing of stand-alone hybrid solar–wind power generation systems*, "Applied Energy" 2010 no. 87, p. 380–389

Zhu X.G., Long S.P., Ort D.R., *What is the maximum efficiency with which photosynthesis can convert solar energy into biomass?*, "Current opinion in biotechnology" 2008 no. 19(2), p. 153–159

John **STEPAN**

THE IMPACT OF COPPER PRICE VARIATION ON THE ECONOMIC EFFICIENCY AND ENVIRONMENTAL SUSTAINABILITY OF KGHM OPERATIONS

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WPŁYW ZMIAN CEN MIEDZI NA EKONOMICZNĄ EFEKTYWNOŚĆ DZIAŁALNOŚCI KGHM W KONTEKŚCIE KRYTERIÓW ROZWOJU ZRÓWNOWAŻONEGO

STRESZCZENIE: Przedsiębiorstwa górniczo-hutnicze obecnie muszą sobie radzić z presją kosztową wynikającą z konieczności wydobycia rud z coraz gorszej jakości złóż oraz ze stagnacją cenową spowodowaną nadwyżkami produktów końcowych. W tym kontekście, w artykule przedstawiono możliwe reakcje firm górniczych na tę sytuacje na podstawie analizy danych operacyjnych KGHM. Firma KGHM została wybrana ponieważ poziom obrotów oraz profil firmy mogłyby sugerować, że jest bardziej narażona na przedstawioną sytuacje niż większe czy bardziej zdywersyfikowane firmy. Wyniki analizy wskazują, ze mimo tej pogarszającej się sytuacji firma podniosła wydajność operacyjną równocześnie zmniejszając uciążliwość środowiskową. KGHM mogłaby więc potencjalnie służyć jako wzór dla firm górniczych we wdrażaniu bardziej trwałych modeli biznesowych pod względem operacyjnym i środowiskowym.

KLUCZOWE SŁOWA: ceny miedzi, górnictwo i hutnictwo miedzi, ochrona środowiska, rozwój zrównoważony

Introduction

According to the World Bank, following the commodity boom of the first decade of the 21'st century, Mining Companies (or Miners in industry parlance) operate in a climate of longer-term stagnant prices[1]. This, is compounded by increasing costs due to weaker ore grades at existing or projected mines. The two forces combined mean that Miners are effectively "caught" between pricing pressure and cost pressure[2].

This is especially the case with Copper and, in this business context, the paper attempts to provide some insights into how Copper Miners respond to this situation based on an analysis of operational data for the Polish Copper Miner KGHM. KGHM was selected because a company of this size and profile could be more affected by this environment then larger or more diversified companies. A second reason for selecting KGHM was because of the knowledge available within the AGH Faculty of Management. In this context, this analysis is presented as a continuation of the contribution of the Faculty to a deeper understanding of the Copper Industry[3].

With 3.6% market share of Global Copper Production[4], KGHM volumes probably do not have significant pricing impact. Moreover, the company's largest volumes come from seams deep underground which, combined with declining ore grade quality, results in KGHM running a significantly more expensive operation than its competitors (data shown later in this paper). Therefore, an analysis of KGHM seemed appropriate to better understand how Copper Miners are responding to these challenges.

1 World Bank Group, *Commodity Markets Outlook, July 2016*. License: Creative Commons Attribution CC BY 3.0 IGO – Commodity Index Tables Washington, DC. 2016.

2 A. Lala et al., *Productivity in mining operations: Reversing the downward trend*, "McKinsey Quarterly" 2015 no. 5.

3 T. Pindór, *Przemysł miedziowy w Polsce jako uczestnik rynku światowego*, in: Conf. Proc.: *Aktualia i perspektywy gospodarki surowcami mineralnymi,* Krakow 1992; B. Barchański, T. Pindór, *Bergbau und Metallurgie der NE-Metalle in Polen (I)*, "Erzmetall", Clausthal 1993; B. Barchański, T. Pindór, *Bergbau und Metallurgie der NE-Metalle in Polen (II)*, "Erzmetall", Clausthal 1993; B. Barchański, T. Pindór, *Kupferindustrie in Polen*, "Bergbau" Clausthal 1999; T. Pindór, *Restruktuierung der Kopferindustrie in Polen*, in: L. Preisner (ed.), *Umwelt- und* Ökonomischeaspekte *der Bergbaurestrukturierung*, Krakow 2002; T. Pindór, *Zrównoważony rozwój Legnicko-Głogowskiego Okręgu Miedziowego*, in: E. Lorek (ed.), *Zrównoważony rozwój regionów uprzemysłowionych*, Katowice 2009; T. Pindór, *Przekształcenia międzynarodowych rynków miedzi w latach 1980–2012*, Wrocław 2014.

4 KGHM. *2015 Annual Report,* Lubin 2016. Total KGHM Refined Copper Production (KGHM own sources plus. KGHM International plus purchased concentrate) = 697,1kt. World Bank Group. 2016. *Commodity Markets Outlook, July 2016*: Global Refined Copper Production = 19.308kt.

The results of the analysis indicate, that despite worsening business conditions, KGHM not only successfully improved efficiency but also reduced the environmental burden of its operations as well as reducing operating costs. Thus, the company may provide guidance to Miners or other companies in implementing more sustainable operation models from both a business and environmental perspective.

To present the subject the paper is divided in five sections. The first section is this introduction followed by an introduction to the Global Copper Market describing the challenges noted above and the position of KGHM in this market. The third section consists of an overview of KGHM while the forth section presents an analysis of the company's operational data and a discussion to try to identify the company's responses to this business environment. Based on the analysis in the fourth section, the paper ends with a Conclusion presenting some ideas on how Miners could effectively reconcile Business and Environmental goals.

Global Copper Industry Challenges

According to the World Bank[1], of the 6 Base Metals (Aluminium, Copper, Lead, Nickel, Tin, Zinc), Copper is by value, the largest global base metal market and has the second highest global refined production volume (Copper – 23,097Mt, Aluminium – 57,342Mt).

Copper is also a fairly plentiful mineral. Per the U.S. Geological Survey[5], global identified resources total 2.100 Mt (around 100 years supply at current volumes) and one can conclude the supply of Copper is assured so long as prices exceed Production Costs. This abundance is to some extent shown in the actual and forecast Copper prices[6] presented in figure 1 (World Bank Actual and Forecast prices 2006–2025 at constant 2010 US$).

Reviewing figure 1, it is evident that, after a turbulent period during the commodity boom, Copper prices fell sharply after 2011 and are forecast to recover slowly from 2016. Thus, for the medium term, Miners can expect much tougher market conditions.

However, although Copper is a fairly plentiful resource, average ore grades at existing mines and planned investment projects are weaker than their historical levels. This is for two main reasons; – firstly, ore deposits are

[5] USGS, *Estimate of Undiscovered Copper Deposits of the World 2013*, Washington DC 2014. Useful background information can also be found in: T. Pindór, L. Preisner, *Wycena zasobów rud miedzi*, in: Conf. Proc.: *Rachunek ekonomiczny w gospodarce surowcami mineralnymi*, Kraków 1990.

[6] World Bank Group. 04.2016. *World Bank Commodities Prices (the Pink Sheet)/ World bank Commodities Price Forecast April 2016*. World Bank License: Creative Commons Attribution CC BY 3.0 IGO, Washington DC 2016.

of a defined size so ore grade diminishes as more ore is extracted and secondly, investment in new mine projects with lower ore grades becomes viable when Copper prices increase due to demand growth[7] (causing the "cyclical nature" of mine investments because of the 20–30 year lead-time between project start-up and start of economic exploitation).

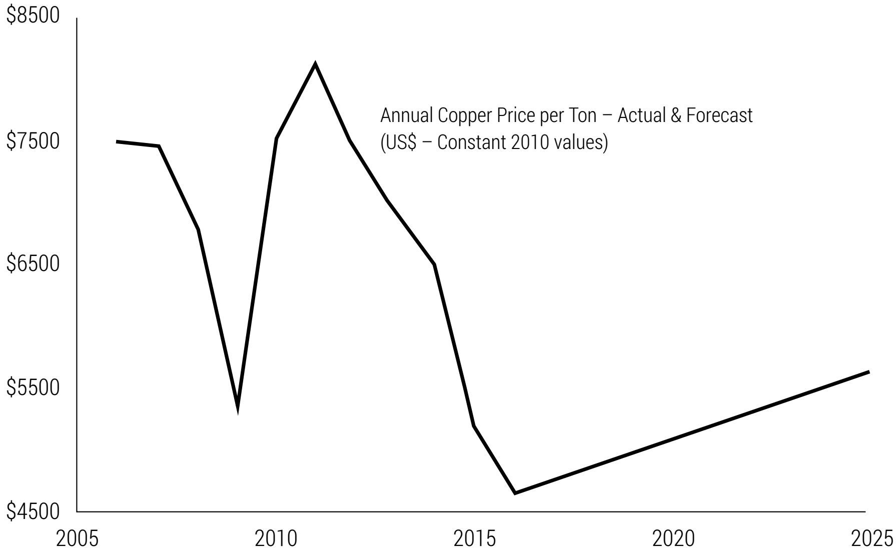

Figure 1. Actual & Forecast US$ Copper Prices (annual averages)
Source: World Bank – Pink Sheet Data & Commodity Forecast.

This weakening in ore grade is visible in the data shown in figure 2 based on data from two industry consulting companies originally presented in a report by the Investment Banking Arm of a leading international Bank[8]. Figure 2 presents on a global level over time, average ore grade combining existing mines and new mine projects.

The conclusion from figure 2 is that the steady downward ore grade trend means extraction volumes have to increase to maintain similar levels of refined Copper. This cannot but result in higher extraction costs per ton. Thus over time, Copper Miners can expect the Operating Costs of their mining activities to steadily increase.

In this context, what is the situation of KGHM compared to other Copper Miners?

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7 P. Gait, *The Growth of Productivity in Copper Mining and The Long Term Evolution of The Reserve Base*, Presentation to the ICSG Environmental & Economics Committee, Lisbon 2015

8 A. Bukacheva et al., *Copper Industry Strategy*, BDO Capital Markets, Montreal/ London 2014.

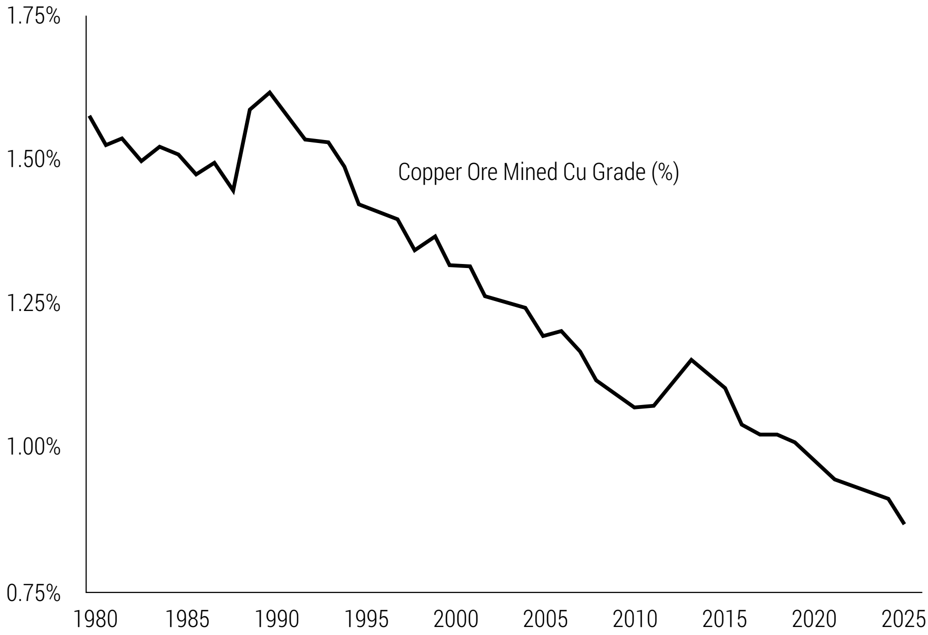

Figure 2. Global Average Percentage Refined Copper in Mined Copper Ore

Source: BMO Global Mining Research(based on Brook Hunt / Freeport McMoRan data).

Table 1, taken from a relevant article on the subject[9], presents this using data for the 10 largest Copper mine entities[10]. Mine entities are presented and not Miners (eg. the data on KGHM presents only its Polish Operations not including its Chilean or Canadian operations) because it allows a comparison across operating units (for instance: data on Daily Ore Volume Extracted from the Mine or Operational Cost of producing One Ton of Refined Copper) rather than macro level data where each Miner has a specific (and quite different) operational profile[11].

9 V. Peckham, *These 10 mines will set the Copper price for the next decade*, www.Mining.com [03–11–2015].

10 Mine Entities in this context are distinct operating units consisting of one or several mines forming a separate legal entity which may (or may not) be part of a conglomerate.

11 For instance CODELCO the largest global Copper Miner (10% global production) concentrates on mining and production of Copper Concentrate. KGHM mines and also refines all its production.

Table 1. 10 Largest Copper Mine Entities

Order	Mine Operation	Start Year	Country	Owners	Open Pit / U.grond	Exracted Ore Vol. / Day	Refined Cu Production Vol. / Yr.	Refined Cu Cash Cost	Mine Reserves	Reserve Ore Grade (Cu)	Mine Life
					OP / UG	kt	kt	US$/t	Bt	%	yrs.
1	Escondida	1990	Chile	BHP Biliton	OP	1 300	1 140	**2 440**	26.20	**0.52%**	54
2	Collahuasi	1880	Chile	Anglo American, Glencore	OP	705	470	**3 238**	3.25	**0.80%**	70
3	El Teniente	1905	Chile	CODELCO	UG	137	452	**2 622**	1.67	**0,93%**	50
4	KGHM Poland in Operations	1968	Poland	KGHM	UG	88	420	**4 391**	1.15	**1.52%**	45
5	Los Bronces	1867	Chile	Anglo American	OP	397	405	**2 052**	2.06	**0.51%**	35
6	Los Pelambres	2000	Chile	Antofa-gasta	OP	400	391	**2 690**	1.49	**0.52%**	24
7	Morenci	1872	USA	Morenci	OP	816	369	**N/A**	9.70	**0.25%**	23
8	Antamina	2000	Peru	BHP Biliton, Glencore	OP	532	345	**N/A**	0.65	**0.94%**	13
9	Chuquicamata	1911	Chile	CODELCO	OP	N/A	340	**2 166**	0.90	**0.83%**	40
10	Radomiro Tomic	1997	Chile	CODELCO	OP	N/A	327	**2 896**	2.06	**0.47%**	40

Source: Investing News: www.investingnews.com (12.10.2016).

Comparing the position of KGHM to the other mine entities, Reserve Ore Grade (1.52%) and Mine Life (45 years) are both positive factors which show the ore quality of KGHM's operations in Poland. What is less positive (compared to other mine entities), is the high extraction cost. At US$ 4,391.= per ton the cost is over 100% more than the lowest cost producer. One reason is that the mines forming the Polish KGHM Entity are deep underground with intrinsically high operating costs. However, another reason is the relatively low daily extraction rate ("Extracted Ore Vol. / Day" column) which, among other factors, is due to the lower number of work days at Polish mines[12].

This Production Cost factor will be discussed in more detail in the next section which presents an overview of KGHM with a review of some challenges the company faces.

KGHM Overview

As presented in table 1, in 2015, KGHM's operations in Poland formed the World's fourth largest Copper mining entity. In that year, the entire company (Poland plus KGHM International) extracted 562kt of Copper making KGHM the sixth largest global Copper Miner (just before the mining operations of Rio Tinto with 555kt.)[13].

As well as Copper, KGHM produces extensive quantities of Silver and in 2014 was the World's number one Silver Miner[14]. Reserves (estimated at 85kt.) place the company on a par with Australia as having the World's second largest Silver reserves[15].

There are however some challenges. The first one is ore depletion affecting the Polish mines of KGHM. This is illustrated in figure 3 which presents the volumes of ore extracted from these mines to produce broadly similar volumes of refined Copper. Figure 3 is based on data from the company's Annual Reports[16].

12 W. Bogdan et al., *Poland 2025: Europe's new Growth Engine*. 2015, McKinsey & Co, Warszawa, page 52 of this report presents a comparison of "Effective Working Time" in mines in Poland, Czech Republic, USA and Canada. Mines in Poland operate for 256 days per year, mines in the Czech Republic 355 days, mines in the U.S. and Canada 365 days.

13 Investing News, *10 Top Copper-producing Companies*, www.investingnews.com [12–10–2016].

14 The Silver Institute, *World Silver Survey 2015*, www.silverinstitute.org [12–10–2016].

15 Sources: Data on Global Silver Reserves; – USGS, *Mineral Commodity Summaries – Silver: 2016*, 2016, www.minerals.usgs.gov [12–10–2016]. Data on KGHM Silver Reserves; – KGHM, *Mineral Resources and Reserves Report – as at 31.12.2014*, 2015, www.kghm.com [12–10–2016].

16 KGHM, *KGHM Annual Reports 2000–2015*, Lubin 2001–2016.

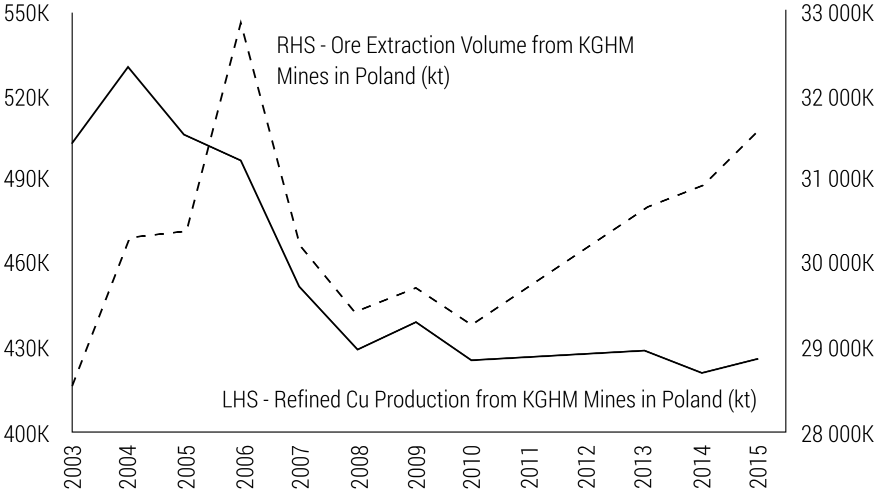

Figure 3. Refined Copper Production from KGHM Mines in Poland (LHS) / Ore Extraction Volumes from KGHM Mines in Poland (RHS)

Source: KGHM Annual Reports 2005 – 2015.

The additional extraction requirement shown in figure 3 can be seen comparing 2003 against later years. In 2003, KGHM used 28,515 kt. ore to produce 503,213 t. refined Copper. In 2010, it extracted 29,303 kt. ore from which it produced almost 78,000 t. less Copper. In 2015, the company, with 8% more ore than in 2010 (almost 2,300 kt.), produced a similar Copper volume. Thus, whilst KGHM ore grades are better than its competitors, over time Copper ore yields become significantly poorer which, combined with the low mine working days, cannot but have a negative Production Cost impact.

This impact is presented in figure 4 which plots the costs (in PLN) of producing one ton of refined Copper against annual KGHM ore grade. the Production cost is shown in PLN to more accurately reflect the cost structure of the Polish mines. This figure is also based on data from KGHM Annual Reports[17].

The visual trend over time of declining ore grade and increased Production Costs evident in figure 4 was confirmed by a Pearson Correlation Analysis of -0.94.

This Production Cost increase is despite Cost Reduction initiatives (impact evident from 2013 onwards) which resulted in a reduction of around 10% per ton refined Copper[18].

17 Ibidem.

18 Reviewing the data for 2014 and 2015, this 10% reduction in KGHM Production Costs is maintained despite the need to extract an additional 665kt. ore because of worsening grades.

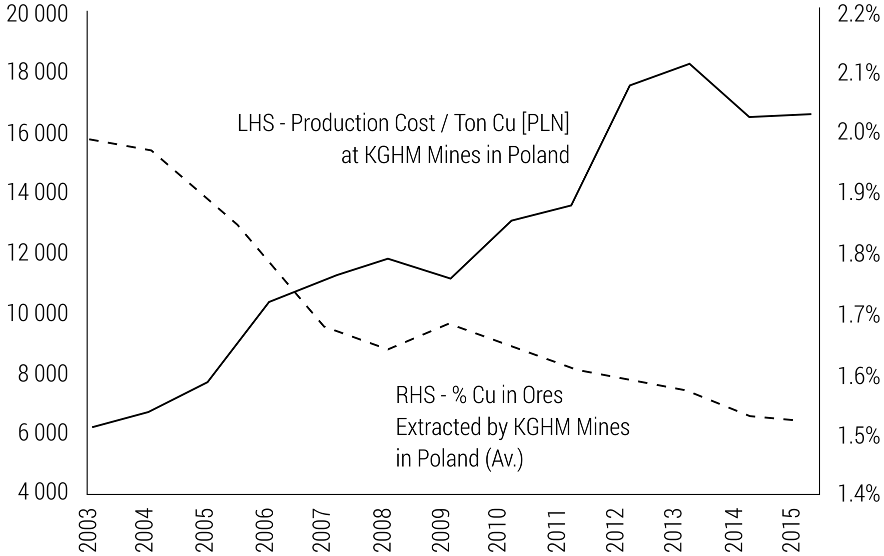

Figure 4. Refined Copper Production Cost in PLN at KGHM Mines in Poland (LHS) / Copper ore grades from KGHM Mines in Poland (RHS)

Source: KGHM Annual Reports 2005 – 2015.

However, with worsening ore grades and restrictions on the number of mine working days, there are limits to the steps KGHM can take to reduce costs. In this situation, additional steps were needed to support a viable long-term business and this aspect will be discussed in more detail in the next section of the paper.

Analysis of KGHM Polish Mine Production of Precious Metals and Co-products

The analyses presented in this section were carried out on yield data for the additional metals or other products KGHM extracts from Copper ore. The purpose was to try to identify whether the weak business environment had a positive or negative impact on process efficiency or environmental sensitivity.

The products analysed are co-products from processes for producing Copper (KGHM's primary product). Thus, comparison of co-product yields per ton of primary product yield should give an indication whether KGHM has become more or less operationally efficient. Moreover, as some co-products (such as Sulphur Dioxide or Lead) have a deleterious environmental impact, analysing co-product yield/ primary product yield for these products should also give an indication whether lower prices and higher costs were coincident with a better or worse environmental control.

Table 2 shows KGHM's extraction volumes of rare and precious metals over time. These are usually extracted from anode slime which accumulates in the final stage of the Copper refining process. Anode slime output relates to Copper volumes whereas yield for specific co-products depends on the efficacy of a specific extraction process. In this context table 2 shows; – total output volume, output volume per ton refined Copper produced and percentage change of output volume compared to 1995 as base year.

Reviewing table 2, what is immediately apparent is the increased efficiency of the Gold extraction processes. Between 1995 and 2015 Gold output improved by 441%. What is especially significant is the "jump" of just over 300% between 2013 and 2014 and this high output being maintained in 2015 (implying a process change and not a "one-off"). Whilst the quantity of Silver in the KGHM Polish mines was known from the start, it is an open question whether so much Gold was identified when the mines commenced commercial life 50 years ago. With regard to Silver, the improvement (28%) from 1995 is lower but still significant given the value of the metal. In this context, the evident conclusion reviewing table 2 has to be that, over time, KGHM has significantly improved the efficacy of its precious metal extraction processes.

Table 2. Precious Metal Extraction per ton Refined Copper from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Refined Copper [kt]	405 739	486 002	506 248	425 344	426 665	427 064	428 879	421 300	420 500
Refined Silver [t]	964	1 110	1 244	1 161	1 260	1 274	1 161	1 256	1 283
Refined Gold [t]	0.474	0.367	0.713	0.776	0.704	0.916	1.066	2.530	2.660
Refined Silver [kg] per ton Refined Copper	2.3759	2.2839	2.4573	2.7296	2.9531	2.9832	2.7071	2.9812	3.0511
Refined Gold [kg] per ton Refined Copper	0,0012	0,0008	0,0014	0,0018	0,0017	0,0021	0,0025	0,0060	0,0063
Refined Silver Improvement [%]	100%	96%	103%	115%	124%	126%	114%	125%	128%
Refined Gold Improvement [%]	100%	65%	121%	156%	141%	184%	213%	514%	541%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data.

A point about table 2 that should be noted is that KGHM also refines other metals and products from Slime (such as Pl / Pt Concentrate or Selenium) however, the quantities so far seem to be not yet fully stabilised[19] and thus are not presented in this table.

Table 3 is similar in construction to table 2 and presents two products; – Sulphuric Acid and Lead[20]. Sulphuric Acid is produced from Sulphur Dioxide, a co-product of the smelting operation, whereas Lead is a co-product of smelting which also occurs in anode slime. Thus, production volumes for these products are related to Copper production volumes permitting a similar analysis to that presented in table 2. Some additional products are also produced as part of the smelting or concentrating operations (eg. Copper Sulphate, Nickel Sulphate) but their volumes are lower and more variable so they were not included in this analysis.

Table 3. Sulphuric Acid and Lead production per ton Refined Copper from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Refined Copper [kt]	405 739	486 002	506 248	425 344	426 665	427 064	428 879	421 300	420 500
Sulphuric Acid [t]	447 100	544 400	621 570	559 668	636 248	630 837	609 019	646 074	650 000
Refined Lead [t]	12 100	12 527	21 050	20 892	25 234	27 511	26 631	26 128	30 400
Sulphuric Acid [t] per ton Refined Copper	1.10	1.12	1.23	1.32	1.49	1.48	1.42	1.53	1.55
Refined Lead [kg] per ton Refined Copper	29.82	25.78	41.58	49.12	59.14	64.42	62.09	62.02	72.29
Sulphuric Acid Improvement [%]	100%	102%	111%	119%	135%	134%	129%	139%	140%
Refined Lead Improvement [%]	100%	86%	139%	165%	198%	216%	208%	208%	242%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data.

From an efficiency improvement perspective, table 3 presents a similar picture to table 2. Over the 20 year period since 1995, KGHM has improved Sulphuric Acid output by 40% and Lead output by 142%. The efficiency gain reflects an additional 450kg Sulphuric Acid per ton (of Copper) and over 42kg of Lead. These quantities, multiplied by Copper volumes, come to almost 190kt p.a. Sulphuric Acid and 18kt. p.a. Lead. These are significant

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19 KGHM, *KGHM Annual Reports 2000–2015*, op. cit.

20 Some useful background information can be found in: L. Preisner, T. Pindór, *Heavy Metals Emission in the Copper Region in Poland*, in: Mining and Environment Research Network (MERN) "Research Bulletin and Newsletter", Bath 1995.

volumes, that previously "disappeared" into the environment and which now provide additional value as a result of improved process efficiency.

To finish the analysis, table 4 was developed to identify additional turnover KGHM generated by the extra co-product volumes shown in tables 2 and 3. Table 4 is thus based on the quantity data in tables 2 and 3 combined with price data from several sources (World Bank Commodity Prices[21], U.S. Dept. of Labor – Sulphuric Acid Price Indexes[22], CRU Consulting Group – Sulphuric Acid Price Data[23]). Included in the table 4 Precious Metal figures are the "trace quantities" of Selenium (of which KGHM occasionally produces up to 90 tons / year) and, in the Co-Product figures, the fairly low quantities of Copper and Nickel Sulphates (about 6,500 and 2,500 tons respectively) which the company sometimes produces:

Table 4. Volumes, Turnover (in 2010 US$) and % Value Contribution of Copper, Precious Metals (mainly Ag and Au) and other Co-Products (mainly Pb, H_2SO_4) from KGHM Mines in Poland

	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pl Production – Precious Metals Turnover [K.US$]	181 709	226 321	344 908	782 804	1 354 832	1 241 859	891 378	829 911	710 890
Pl Production – Other Co-Products Turnover [K.US$]	58 433	61 894	119 630	97 244	146 008	163 633	162 441	155 740	144 245
Total Pl Production Turnover [K.US$]	1 535 932	1 396 001	2 588 064	4 084 921	4 958 387	4 565 894	4 018 794	3 716 663	3 048 354
Pl Production – Copper [% Total Turnover]	84%	79%	82%	78%	70%	69%	74%	73%	72%
Pl Production – Precious Metals [% Total Turnover]	12%	16%	13%	19%	27%	27%	22%	22%	23%
Pl Production – Other Co-Products [% Total T.O.]	4%	4%	5%	2%	3%	4%	4%	4%	5%

Source: KGHM Annual & Environmental Reports 2000–2015 / KGHM Web Site Historical Data / World Bank Group / U.S.Bureau of Labor Statistics / CRU Consulting Group.

Reviewing table 4, an immediate conclusion is the increasing significance of the non-Copper turnover where, over the 20 years presented above, it has

21 World Bank Group. 04.2016. *World Bank Commodities Prices (the Pink Sheet)/ World Bank Commodities Price Forecast April 2016*. op. cit.

22 Bureau of Labor Statistics – Databases Tables & Calculators by Subject, 25.10.2016, *Producer Price Index – Series id: WPU0613020T1 / Sulfuric Acid*, U.S. Dept. of Labor – Bureau of Labor Statistics.

23 J. Peacock, *Sulphuric Acid Market Outlook – Demand for Fertilizers, Metal and Uranium*, London 2009.

increased from 16% to 28% of turnover. In Silver, the figures reflect KGHM's progress from an important Silver producer to Number 1 Global Miner in 2014. In Gold, where KGHM currently produces 2.6 tons, there was a 137% volume increase between 2013 and 2014 / 2015.

With regard to the other co-products KGHM produces, the turnover impact (around 5%) is much lower, however it is still significant and equates to around 15% EBITDA[24]. This EBITDA impact is important, but so also is the effect of lower quantities of harmful products (such as Sulphur Dioxide or Lead) released into the environment.

Because of fluctuations in prices of specific metals or products not all improvements are reflected linearly in the above data, however, a general conclusion from table 4, for KGHM's shareholders, would be that without the non-Copper volumes, turnover would be almost 30% lower in 2015. The general conclusions from this "operating impact" are reviewed in the next and final section of the paper.

Conclusion

This paper presents an example of the steps a company can take in a declining market situation coupled with increasing production costs. This is a situation which, from a business perspective, is quite common. Most companies, because of their size, volume or marketing power, have little influence on prices for the products they produce. On the other hand these companies are most often under cost pressure because of rising real wages (e.g. as currently in Poland) and / or because of the "sunk cost" needed to keep up with market developments (e.g. new technology investments). In the author's opinion a company such as KGHM is an example of what businesses can do in this situation by applying their internal skills and know-how to review and optimise the product base.

A company which is "squeezed" between prices and costs does not always have to search for new markets or develop new products. Maybe the best potential for development is by harnessing these internal capabilities and KGHM is an example of this.

Moreover, at the same time as increasing volumes of its highest value products (Gold, Silver), KGHM reduced environmental impact by lowering Sulphur Dioxide and Lead emissions by many thousand tons. All this taking place whilst the company was implementing a cost reduction programme and reducing costs by 10%.

24 KGHM, *KGHM 2015 Annual Report*, Lubin 2016.

The data presented in this paper thus shows that the triple goals of; – increased turnover, reduced environmental impact, internal cost reduction, are not incompatible with each other and perhaps this is the major conclusion from the analysis presented above which is a conclusion that may be relevant not only for Miners in other mineral areas but also for many companies operating in similar business environments to KGHM.

Literature

10 Top Copper-producing Companies, www.investingnews.com

Barchański B., Pindór T., *Bergbau und Metallurgie der NE-Metalle in Polen (I)*, "Erzmetall", Clausthal 1993

Barchański B., Pindór T., *Kupferindustrie in Polen*, "Bergbau" Clausthal 1999

Bogdan W. et al., *Poland 2025: Europe's new Growth Engine*, Warszawa 2015

Bukacheva A. et al., *Copper Industry Strategy*, BDO Capital Markets, Montreal/ London 2014

Estimate of Undiscovered Copper Deposits of the World 2013. USGS, Washington DC 2014

Gait P., *The Growth of Productivity in Copper Mining and The Long Term Evolution of The Reserve Base*, Presentation to the ICSG Environmental & Economics Committee, Lisbon 2015

KGHM. Annual Reports 2000–2015, Lubin 2001–2016

KGHM. Annual Report 2015. Lubin 2016

Lala A. et al., *Productivity in mining operations: Reversing the downward trend*, "McKinsey Quarterly" 2015 no. 5.

Peacock J., *Sulphuric Acid Market Outlook – Demand for Fertilizers, Metal and Uranium*, London 2009.

Peckham V., *These 10 mines will set the Copper price for the next decade*, www.Mining.com

Pindór T. , *Przekształcenia międzynarodowych rynków miedzi w latach 1980–2012*, Wrocław 2014

Pindór T., Preisner L., *Wycena zasobów rud miedzi*, in: Conf. Proc.: *Rachunek ekonomiczny w gospodarce surowcami mineralnymi*, Kraków 1990

Pindór T., *Przemysł miedziowy w Polsce jako uczestnik rynku światowego*, in: Conf. Proc.: *Aktualia i perspektywy gospodarki surowcami mineralnymi,* Krakow 1992

Pindór T., *Restruktuierung der Kopferindustrie in Polen*, in: L. Preisner (ed.), *Umwelt- und Ökonomischeaspekte der Bergbaurestrukturierung*, Krakow 2002

Pindór T., *Zrównoważony rozwój Legnicko-Głogowskiego Okręgu Miedziowego*, in: E. Lorek (ed.), *Zrównoważony rozwój regionów uprzemysłowionych*, Katowice 2009

Preisner L., Pindór T., *Heavy Metals Emission in the Copper Region in Poland*, in: *Mining and Environment Research Network (MERN) "Research Bulletin and Newsletter"*, Bath 1995

USGS, *Mineral Commodity Summaries – Silver: 2016*, 2016, www.minerals.usgs.gov

World Bank Group, *Commodity Markets Outlook,* Washington DC. 2016

World Silver Survey 2015, www.silverinstitute.org

www.kghm.com

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APPLICATION OF THE MODIFIED AHP METHOD AND ECO-LABELS FOR BIOMASS BOILER SELECTION FOR A SMALL HOTEL IN A MOUNTAIN REGION. A CASE STUDY

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ZASTOSOWANIE ZMODYFIKOWANEJ METODY AHP I EKOETYKIET DO WYBORU KOTŁA NA BIOMASĘ DLA PENSJONATU W MIEJSCOWOŚCI PODGÓRSKIEJ. STUDIUM PRZYPADKU

STRESZCZENIE: W artykule zaprezentowano wielokryterialną ocenę kotłów na biomasę dla pensjonatu położonego w miejscowości podgórskiej. Oceny dokonano zmodyfikowaną metodą Procesu Analizy Hierarchicznej (z ang. *Analytic Hierarchy Process*, AHP). Problem budowy hierarchii kryteriów rozwiązano w oparciu o zasadę trwałego rozwoju oraz o międzynarodowe kryteria, wypracowane w programie ekoetykiet. Wszystkie przyjęte do obliczeń dane dotyczą rzeczywistych kotłów i paliw.

SŁOWA KLUCZOWE: analiza wielokryterialna, zmodyfikowana metoda AHP, Proces Analizy Hierarchicznej, HIPRE, wybór kotła na biomasę, ekoetykiety.

Introduction

The practice shows that most decision-making situations is considered by decision-makers from the perspective of more than one criterion. The reason for this approach is the complexity of the world around and multidimensionality of human perception. Man by nature seeks to maximize his satisfaction in all possible aspects[1]. Helpful could be multi-criteria methods, which try to take into account the multitude of requirements defined by the decision maker.

The subject of the analysis is the selection of a biomass boiler for a small private hotel located in Bukowina Tatrzańska. This is a typical modern mountain hotel with an area of 500 m^2, consisting of 20 rooms, a common area and catering facilities. According to calculations, the demand for thermal power for heating purposes is 50 kW and for the preparation of hot water (accumulated in hot water tanks) 20 kW. The seasonal heat demand for heating and hot water purposes is respectively: 350 GJ and 99 GJ. According to the hotel manager, the process of heat production should not put much pressure on the environment because of use of biomass. The manager wants to expose this fact as an advertising element.

In order to evaluate the selected biomass boilers, the authors decided to use multi-criteria analysis in the form of modified AHP (Analytic Hierarchy Process) method described in the article by Stypka and Flaga-Maryańczyk[2]. The AHP-HIPRE method is both relatively easy and transparent to use, and additionally there is a free software to facilitate the analysis process[3]. The hierarchy of criteria was developed using the concept of sustainable development and the European program of ecolabeling – a voluntary method of environmental performance certification for products or services with proven environmental stand up. All the data and parameters about the boilers and analyzed fuels are real ones.

1 B. Roy, *Paradigms and challenges, Multiple Criteria Decision Analysis: State of the Art surveys*, New York 2005, p. 3–24; Z. Piotrowski, *Algorytm doboru metod wielokryterialnych w środowisku niedoprecyzowania informacji preferencyjnej*, doctoral dissertation, Szczecin 2009, p. 23–32.

2 T. Stypka, A. Flaga-Maryańczyk, *Możliwości stosowania zmodyfikowanej metody AHP w problemach inżynierii środowiska,* "Ekonomia i Środowisko" 2016 no. 2(57), p. 37–53.

3 HIPRE, www.hipre.aalto.fi [20–10–2016].

Biomass boilers

Combustion of biomass is considered beneficial to the environment than combustion of fossil fuels, because the content of harmful elements (mainly sulfur) in biomass is less than in the average coal[4]. Biomass also has a more favorable balance of carbon dioxide due to the fact that, in the growing phase, it absorbs carbon dioxide in the process of photosynthesis. In addition, the use of biomass instead of fossil fuels saves non-renewable resources of the latter.

For energy purposes are used mainly wood and waste from wood processing, plants from energy crops, agricultural products and organic waste from agriculture. Different types of biomass have different properties. The more dry and dense biomass is, the greater value presents as a fuel. Therefore, biomass is often converted into a stable form of uniform shape, calorific value and moisture content. Such processed (refined) form of biomass are briquettes and pellets, which are obtained by drying, grinding and pressing of biomass[5].

Producers of biomass boilers recommend to use high quality fuels (preferably with certificates). However, it should be taken into account that the more processed biomass is, the better energetic parameters it has of course, but also has higher price which results in higher annual cost of heating. On the other hand, the processed form of biomass enables the use of advanced technologies (e.g. automatic feeders), which guarantee a higher combustion efficiency and comfort for potential user.

Biomass combustion requires the use of suitable boilers, which are specially adapted to such fuel. In contrast to coal and coke, non-volatile carbon compounds, which in a traditional boiler burn on the grate, in the biomass constitute a minority. The major part of the biomass are volatile compounds, which burn above the grate, therefore efficient combustion of biomass requires appropriate conditions.

Since 2014, new boilers for coal and wood, introduced on the market must fulfill criteria of PN-EN 303–5: 2012 "Heating boilers"[6]. This standard defines three classes of boilers: 3 (lowest), 4 and 5 (highest). Belonging to a particular class defines the conditions relating to both the thermal efficiency of the unit and emission limit values for this class. Emission limits are

4 M. Ściążko, J. Zuwała, M. Pronobis, *Współspalanie biomasy i paliw alternatywnych w energetyce*, Zabrze 2007, p. 20.

5 BIOMASA.ORG, www.biomasa.org [05–10–2016].

6 PN-EN 303–5:2012 "Kotły grzewcze – Część 5: Kotły grzewcze na paliwa stałe z ręcznym i automatycznym zasypem paliwa o mocy nominalnej do 500 kW – Terminologia, wymagania, badania i oznakowanie."

given with regard to the type of fuel, nominal power of the boiler, and the way of fuel loading. Table 1 presents emission limit values for different classes of biofuel boilers of nominal power 50–150 kW, loaded manually or automatically. According to the limits the replacement of the class 3 boiler with the class 4 boiler reduces emissions significantly. The difference in emissions between boilers class 4 or 5 is not so dramatic. The use of class 5 boiler can, however, significantly reduce operating costs due to the greater efficiency.

Table 1. Emission limit values for biomass boilers of nominal power 50–150 kW

Way of fuel loading	Emission limit values (mg/m³ at 10% O_2*)								
	CO			OGC			Dust		
	Class 3	Class 4	Class 5	Class 3	Class 4	Class 5	Class 3	Class 4	Class 5
manual	2500	1200	700	100	50	30	150	75	60
automatic	2500	1000	500	80	30	20	150	60	40

* related to the dry flue gases, 0°C, 1013 bar
Source: own elaboration based on PN-EN 303–5:2012.

Choosing the biomass boiler is not an easy task. The decision maker should take into account the possibility of burning a given type of biomass, a variety of technical solutions guaranteeing suitable efficiency and emissions, the expected comfort for potential user and finally the costs. The authors decided to take into account many aspects of this complex issue using multi-criteria analysis in the form of modified AHP (Analytic Hierarchy Process) method[7]. The problem of the influence of the biomass boiler and fuel on the environment is solved based on the eco-labels. Due to the fact that the evaluation criteria in the eco-labeling program are prepared by experts, and are for a narrow group of products, and the evaluation covers the entire period of the production, use and disposal of the product it seems that eco-labels may be an important decision-making criterion. In developing a hierarchy of criteria for the AHP analysis also single criteria of eco-labels procedures can be used. In the article the two approaches were mixed.

Among the analyzed biomass boilers are boilers which have both Polish certificates and international eco-labels:

- Das Österreichische Umweltzeichen[8] – Austrian eco-label, which main objectives are: the use of environmentally friendly energy sources and the use of systems with low emissions and high energy efficiency.

7 T. Stypka, A. Flaga-Maryańczyk, op. cit.
8 Das Österreichische Umweltzeichen, www.umweltzeichen.at [21–10–2016].

- Blue Angel (Der Blaue Engel) – one of the oldest (since 1997) eco-labels, taking into account the entire life cycle of the product[9].
- Polish certificate "ENVIRONMENTAL SAFETY MARK" ("ZNAK BEZPIECZEŃSTWA EKOLOGICZNEGO")[10] – which contains energy-emission characteristics of the boiler (together with the class of the boiler), designated in accordance with the standard PN-EN 303–5:2012 "Heating boilers"[11].
- Polish certificate "Environmentally friendly device" ("Urządzenie przyjazne środowisku") – a document similar to "ENVIRONMENTAL SAFETY MARK".
- BAFA list – BAFA (Bundesamt für Wirtschaft und Ausfuhrkontrolle) is German Federal Office of Economics and Export Control, publishing a list of the boilers that meet the highest technical parameters and thermal efficiency[12].

The analyzed variants of solutions

The analyzed variants of solutions are combinations of boilers and fuels. (Table 2). The analysis included only the most popular types of biomass: wood, straw, pellets and briquettes. All the data and parameters about the boilers and analyzed fuels are real ones.

Table 2. Combinations of possible solutions BOILER-FUEL

		Biomass boiler					
		K1	K2	K3	K4	K5	K6
BIOMASS	Wood	K1Dr	-	K3Dr	-	-	-
	Straw	K1S	-	-	-	-	-
	Pellets	-	K2Pe	K3Pe	K4Pe	-	K6Pe
	Briquettes	-	-	K3Br	-	K5Br	-

Authors assumed that biomass will be acquired from the neighborhood, with a maximum distance of 20 km. On this basis, the availability of biomass was investigated. It was considered that if there is the possibility of permanent access (store, warehouse), it is better than random biomass source,

9 Ekologia.pl, www.ekologia.pl [20–10–2016].

10 ICHPw, www.ichpw.pl [21–10–2016].

11 PN-EN 303–5:2012 "Kotły grzewcze", op. cit.

12 BAFA, www.bafa.de [20–10–2016].

because it ensures continuity of supply. Authors selected three types of pellets, two types of briquettes, and one type of wood and straw (table 3). Selected pellets and briquettes can be purchased at shops in the neighborhood, about 20 km from the hotel. Some of them have different kinds of certificates confirming their quality, hence the analysis assumed different variants of pellets and briquettes. Straw and wood are more random in nature and seasonal (especially straw) and they do not have any certificates. For the analysis only one, the currently available, type of straw and wood was selected. Biomass prices adopted for the analysis and their calorific values were determined on the basis of literature data and information available from the manufacturers of biomass[13]. Prices include delivery.

Table 3. Types of biomass selected for analysis

Type of biomass	Calorific value [MJ/kg]	Price [PLN/t]	Certificates
PELLETS A	18	965	-
PELLETS B	19,1	983	DIN 51731 FSC
PELLETS C	19,8	1025	DINplus 7A247 ENplus A1 FSC
BRIQUETTES A	16	546	-
BRIQUETTES B	16,8	689	quality testing (accredited lab.)
WOOD	16	330	-
STRAW	15,2	230	-

Variable biomass quality is the common problem during the boiler's operation. Therefore, one of the most important criteria for biofuels, should be its quality which directly translates into calorific value and ash content. This quality can be confirmed based on specific standards (eg. ENplusA1, DIN or DINplus)[14]. In addition to the above certificates, some wooden biofuels also have FSC label (Forest Stewardship Council®) – the most reliable of the existing certification systems in the world forest resources, taking into account social, environmental and economic issues[15].

13 Energet, www.pellet.com.pl [21–10–2016]; biomasa.org, www.biomasa.org [21–10–2016]; W.M. Lewandowski, op. cit.; Zielony serwis, www.drewno-kluczynski.pl [21–10–2016]; R. Tytko, *Odnawialne źródła energii*, Warszawa 2011, p. 433–518.

14 Biomasa.org, op. cit.

15 Kupuj odpowiedzialnie, www.ekonsument.pl [22–10–2016].

Table 4. Variants of solutions

Variants of solutions	Description
K1Dr	boiler 1 fuelled by wood
K1S	boiler 1 fueled by straw
K2PeA	boiler 2 fuelled by pellets A
K2PeB	boiler 2 fuelled by pellets B
K2PeC	boiler 2 fuelled by pellets C
K3Dr	boiler 3 fuelled by wood
K3PeA	boiler 3 fuelled by pellets A
K3PeB	boiler 3 fuelled by pellets B
K3PeC	boiler 3 fuelled by pellets C
K3BrA	boiler 3 fuelled by briquettes A
K3BrB	boiler 3 fuelled by briquettes B
K4PeA	boiler 4 fuelled by pellets A
K4PeB	boiler 4 fuelled by pellets B
K4PeC	boiler 4 fuelled by pellets C
K5BrA	boiler 5 fuelled by briquettes A
K5BrB	boiler 5 fuelled by briquettes B
K6PeA	boiler 6 fuelled by pellets A
K6PeB	boiler 6 fuelled by pellets B
K6PeC	boiler 6 fuelled by pellets C

Combining possible solutions BOILER-FUEL (table 2) with selected types of biomass (table 3) 19 potential alternative solutions were created (table 4) which, in the following part, will be subject to multi-criteria evaluation.

Building hierarchy of evaluation criteria

All criteria and their weights were developed using the individual preferences of the hotel manager. The criteria of the first level were selected implementing the idea of sustainable development, and having in mind the necessary balance among social (USER), economic (ECONOMICS) and environmental (ENVIRONMENT) aspects of development. The criteria from boilers' and fuels' ecolabeling programs were used to develop the user's hierarchy[16].

16 Nordic swan, www.nordic-ecolabel.org [18.10.2016].

The criterion ECONOMICS was divided into two subcriteria: INVESTMENT COST and RUNNING COST. The criterion ENVIRONMENT was divided into: ECOLABELS, BOILER'S CLASS, FUEL CERTIFICATE, POWER CONSUMPTION, and CHLORIUM CONTENT. The category USER was divided into: AUTOMATIC fuel feeder, STORAGE, WARRANTY, FLEXIBILITY, SERVICE and CONFIDENCE of fuel supply (figure 1).

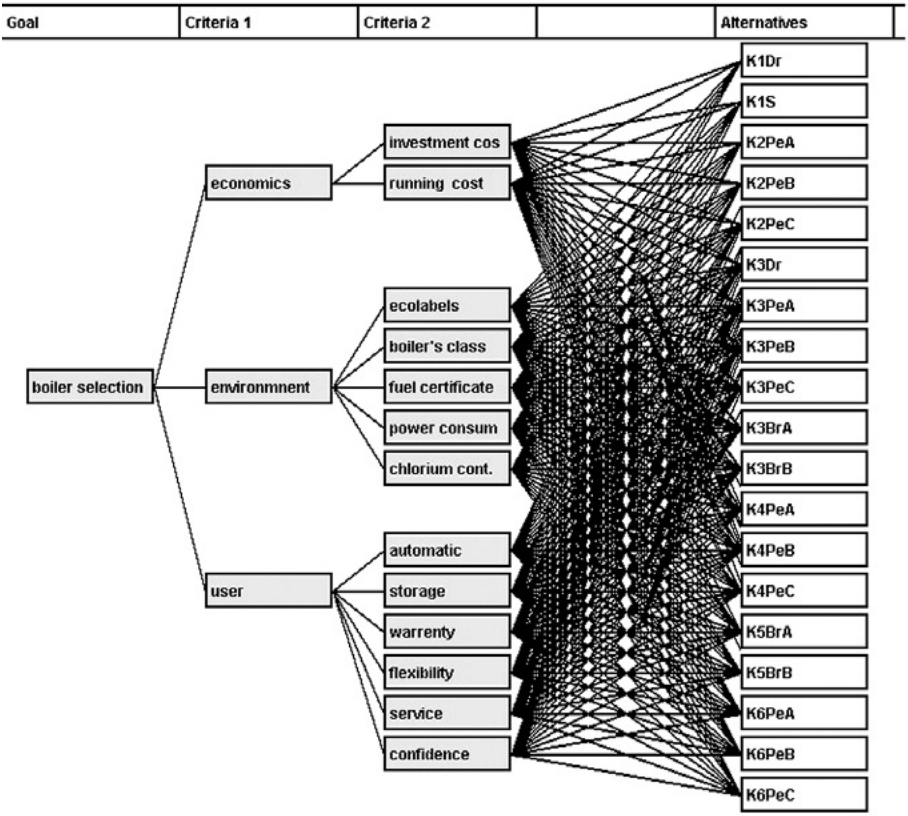

Figure 1. Hierarchy of criteria (screen from the HIPRE software)

The criteria ECOLABELS, BOILER'S CLASS, and to some extent FUEL CERTIFICATE give the user guarantee that the environmental impact of the boiler is limited. The criterion POWER CONSUMPTION reflects the impact of the selected boiler on the environment by measuring the boilers electric energy consumption.

One of the elements present in biomass is chlorium, which negatively impacts both, on the environment, and on the boiler[17]. Research shows[18] that chlorium content in fuel varies; in wood it is below 0,005% to 0,057%, but in fuels made from one year old plants (for example straw) it is up to 1%. Because of this fact, in criterion ENVIRONMENT subcriterion CHLORIUM CONTENT in fuel was distinguished. This approach allows distinction especially between the straw and wood. They both do not have the certificates like pellets do (also including chlorium content) and from environmental point of view are significantly different in chlorium content.

The level of user's satisfaction (criterion USER) of the boiler operation depends on the technical advancement of the boiler such as the presence of the automatic feeder (AUTOMATIC), the necessary fuel storage capacity for the entire heating season (STORAGE), quantity-year warranty, which should translate into a period of trouble-free operation (WARRANTY), the possibility of replacing the fuel for other (FLEXIBILITY), the availability of the service (SERVICE), and confidence of continues supply of the fuel (CONFIDENCE).

The next step in the analysis is to determine the weights of the various criteria by comparing them in pairs on a scale of 1 to 9 (from the "balance" to "total dominance")[19]. Obtained, as a result of this analysis, weights are presented in Table 5. Weights were chosen taking into account the expectations of a hotel manager for whom the most important aspect is the cost (hence the weight of 0,713 for this criterion), with a focus on investment cost (which adequately reflects the weight of 0,75). ENVIRONMENT gained weight 0,127, and the criterion USER – 0,16.

The next step in the analysis is to evaluate the options of the analyzed boilers and fuels using accepted criteria. Summary of the results, which are the input data for the analysis, presents table 6. The operating costs of each option was calculated taking into account the total annual demand for heat in the hotel, the efficiency of individual boilers and heating value of selected biofuels. Other data come from the manufacturers or sellers of boilers or biomass. Also, the minimum and maximum acceptable values for criterion was adopted. These values define for any solution, the largest or smallest satisfaction from meeting the criterion. Next, the satisfaction function for each crite-

17 D. Król, J. Łach, S. Poskrobko, *O niektórych problemach związanych z wykorzystaniem biomasy nieleśnej w energetyce*, www.rynek-energii-elektrycznej.cire.pl [24–10–2016]; T. Hardy, W. Kordylewski, K. Mościcki, *Zagrożenie korozją chlorkową w wyniku spalania i współspalania biomasy w kotłach*, www.spalanie.pwr.wroc.pl [24–10–2016].

18 N. Bątorek-Giesa, B. Jagustyn, *Zawartość chloru w biomasie stałej stosowanej do celów energetycznych*, "Ochrona Środowiska i Zasobów Naturalnych" 2009 no. 40, p. 396–404.

19 T. Stypka, A. Flaga-Maryańczyk, op. cit.

rion was adopted. Part of the functions are decreasing (user satisfaction decreases with increasing value of the parameter) eg. COST; for most parameters, user satisfaction increases with the value criteria. Satisfaction value ranges from 0 to 1 for each criterion.

Table 5. Weights of different criteria

Criteria		Weights	
ECONOMICS		0,713	
	Investement cost		0,750
	Running cost		0,250
ENVIRONMENT		0,127	
	Ecolabels		0,450
	Boiler's class		0,251
	Fuel certificate		0,137
	Power consump.		0,080
	Chlorium cont.		0,081
USER		0,160	
	Automatic		0,489
	Storage		0,177
	Warranty		0,067
	Flexibility		0,067
	Service		0,067
	Conf. of supply		0,134

Results of the AHP analysis

After inserting the ratings into the HIPRE software numerical and graphical results were obtained. Figure 2 presents in graphical form the results of the analysis. The height of each bar represents the total user's satisfaction with the selected solution. Satisfaction is set to 1 if the selected boiler and fuel meet 100% user expectations in all categories. In the adopted modified AHP method result of each solution is independent of the results of other analyzed solutions.

Table 6. Ratings of the analyzed boilers and fuels using the AHP criteria

VARI-ANTS	Running cost	Ecolabels	Boiler's class	Fuel certificate	Power consump-tion	Auto-matic	Storage	Warranty	Flexibility	Invest-ment cost	Chlorium content	Service	Confi-dence of supply
	PLN	pkt	pkt	pkt	W	0/1	0/1/2	lata	0/1	PLN	0/1	0/1	0/1/2
K1Dr	11 949	0	0	0	300	0	1	2	1	12 500	1	1	1
K1S	8 767	0	0	0	300	0	0	2	1	12 500	0	1	0
K2PeA	27 276	1	1	0	325	1	2	2	0	31 250	1	1	2
K2PeB	26 185	1	1	3	325	1	2	2	0	31 250	1	1	2
K2PeC	26 338	1	1	7	325	1	2	2	0	31 250	1	1	2
K3Dr	11 293	1	3	0	795	0	1	2	1	25 793	1	1	1
K3PeA	26 452	1	3	0	795	1	2	2	1	25 793	1	1	2
K3PeB	25 394	1	3	3	795	1	2	2	1	25 793	1	1	2
K3PeC	25 543	1	3	7	795	1	2	2	1	25 793	1	1	2
K3BrA	18 686	1	3	0	795	0	2	2	1	25 793	1	1	2
K3BrB	22 457	1	3	1	795	0	2	2	1	25 793	1	1	2
K4PeA	26 023	2	3	0	965	1	2	2	0	32 841	1	1	2
K4PeB	24 982	2	3	3	965	1	2	2	0	32 841	1	1	2
K4PeC	25 128	2	3	7	965	1	2	2	0	32 841	1	1	2
K5BrA	19153	0	1	0	1550	1	2	2	0	32 841	1	1	2
K5BrB	23018	0	1	1	1550	1	2	2	0	32 841	1	1	2
K6PeA	25553	6	3	0	102	1	2	10	0	68 866	1	1	2
K6PeB	24531	6	3	3	102	1	2	10	0	68 866	1	1	2
K6PeC	24675	6	3	7	102	1	2	10	0	68 866	1	1	2
MIN	8 767	0	0	0	0	0	0	2	0	10 000	0	0	0
MAX	27 276	6	3	7	1550	1	2	10	1	68 866	1	1	2

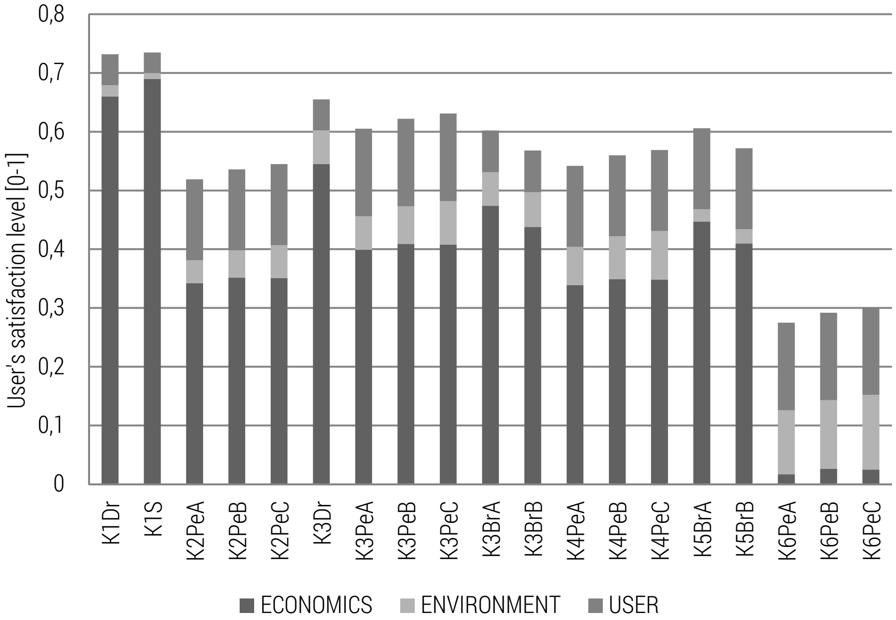

Figure 2. The results of the AHP analysis divided into core evaluation criteria

In the analyzed case user's satisfaction ranges from 74% for straw-fired K1 boiler to only 28% for pellet-fired boiler K5. A decisive impact on the overall assessment is the economic criterion, i.e. investment and operating costs. This is due to the very high weight of this criterion for the user (0,713). The options K1S, K1Dr, K3Dr, K3PeC and K3PeB turned out to be the best. All other analyzed solutions satisfy the user at a maximum of 60%. The last three options, based on K6 boiler performed the worst. The K6 is a very expensive, and technologically advanced boiler that technical superiority does not offset the prohibitively high investment costs. High efficiency of burning expensive fuel also gave no top marks for cost of operation (figure 3).

The level of user's satisfaction (USER), although different for each solution proved to be irrelevant to the final outcome. In practice, the level of user's satisfaction was determined by the ability to automatically feed fuel (AUTOMATIC). The criterion for the service turned out to be irrelevant, because after the diagnosis of the market, it was found that all analyzed boilers have service at the same level.

The crucial role of economic criteria also determines the selection of fuel. Straw and wood turned out to be the best solutions. This is due to their relatively low price. Occurring in the straw higher levels of chlorine or characteristic for this fuel unreliable supply, or the need to secure a large area for storage did not change the overall assessment.

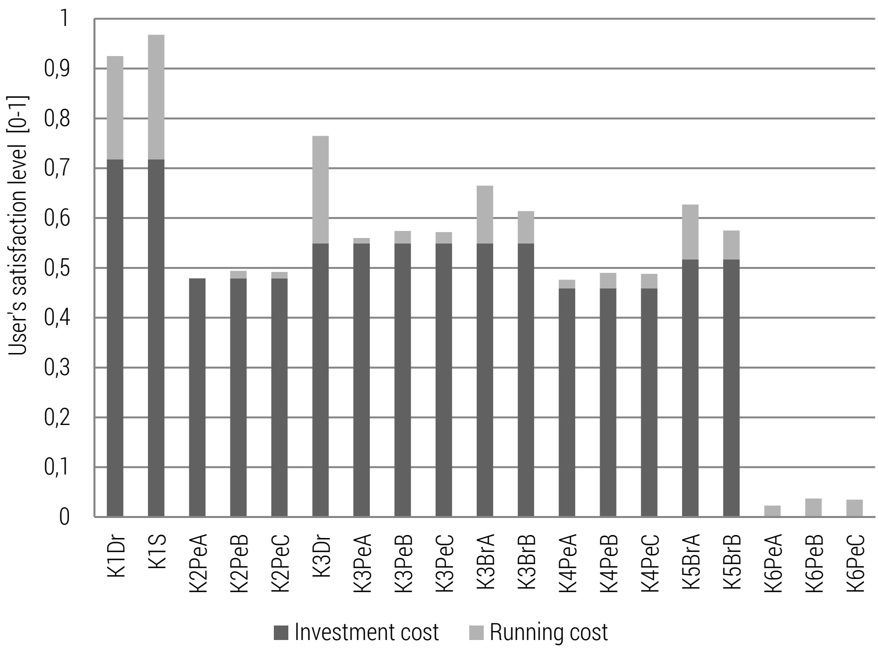

Figure 3. Results of the AHP analysis of biomass boilers due to economic criteria

The obtained results are the sum of a numerus assumptions, and are subject to errors resulting from the subjectivity of assessments. The user does not receive a clear answer, which device to choose; it seems more appropriate to propose a set of similar solutions which give the same range of total satisfaction. In the present case, this means that one should choose among solutions K1S, K1Dr possibly K3Dr, K3PeC or K3PeB. This is a choice between the boiler K1 and K3 and fuels: wood, straw and wood pellets B or C, as well as between manual (K1S, K1Dr, K3Dr) and automatic (K3PeC, K3PeB) fuel loading.

The change of criteria weights can have a very serious impact on the final results. Economic criterion proved to be decisive for the outcome of the analysis, because the user estimated its importance as 0,713. Sensitivity analysis showed that if the weight is greater than or equal to 0,61 the cheapest boiler K1 is the best solution, regardless of the type of burned fuel (straw, wood). If the economic criterion weight varies from 0,25 to 0,61 the best option proves to be solution K3PeC, which is characterized by relatively low price and high efficiency of the boiler combined with the best quality fuel (pellets C). For weight less than 0,25 K6PeC is the best solution. This is an option with an expensive efficient boiler, incinerating most expensive fuel (pellets C). All in all, solutions based on the boiler K1 and K3 (a variant with high quality pellets C), are the best solutions in quite likely weight range of economic criteria.

As to others first level criteria, if the weight of the criterion ENVIRONMENT ranges from 0,29 to 0,51, K3PeC is the best solution. If the weight is below 0,29 boiler K1 (regardless of the type of fuel burned) turns out to be the best. If the weight is above 0,51 the best is variant K6PeC – based on the boiler with the best certificates (two international ecolabels) incinerating the best quality fuel (pellets C). If the weight of criterion USER is below 0,27 the best options are K1S and K1Dr, based on the boiler without fuel feeder. Above this value, the advantage gains option K3PeC followed by K3PeB, based on boiler with the automatic fuel feeder. Just as in the case of the economic criterion, it seems, that solutions based on the boiler K1 and K3 (a variant with high quality pellets C), are the best solutions within large scope of weights for environmental and user criteria.

Conclusions

Choosing the biomass boiler is not an easy task. The multi-criteria analysis, taking into account many aspects of this complex issue, may be helpful. Particularly used in the article modified method of the Analytical Hierarchy Process is handy. This method is both relatively easy and transparent to the application, and in addition there is a free software that facilitates the analysis process. Construction of the hierarchy of criteria is a very subjective step and requires a large technical knowledge of the analyzed systems. This problem can be solved by ecolabeling programs.

In the analyzed case the best solution is simple boiler K1 burning cheap fuel (straw or wood) or advanced boiler K3 (with automatic fuel feeder) burning high quality pellets. These are the best solutions in the broad range of weights. If the weight of the economic criterion increases significantly simple and cheap boiler K1 shows its superiority. If the user weights comfort and environmental performance the boiler K3 (a variant with high quality pellets C) turns out to be better. The real case study shows that economic criteria overweight the environmental performance or user-friendliness. This has to be considered when designing the subsidies programs particularly in poor and environmentally degraded areas.

The contribution of the authors in the article:

Agnieszka Flaga-Maryańczyk, Ph.D – concept and objectives, literature review, research (50%)

Tomasz Stypka, Ph.D – concept and objectives, literature review, research (50%)

Literature

Bątorek-Giesa N., Jagustyn B., *Zawartość chloru w biomasie stałej stosowanej do celów energetycznych*, "Ochrona Środowiska i Zasobów Naturalnych" 2009 no. 40, p. 396–404

Hardy T., Kordylewski W., Mościcki K., *Zagrożenie korozją chlorkową w wyniku spalania i współspalania biomasy w kotłach*, www.spalanie.pwr.wroc.pl

Król D., Łach J., Poskrobko S., *O niektórych problemach związanych z wykorzystaniem biomasy nieleśnej w energetyce*, www.rynek-energii-elektrycznej.cire.pl

Piotrowski Z., *Algorytm doboru metod wielokryterialnych w środowisku niedoprecyzowania informacji preferencyjnej*, doctoral dissertation, Szczecin 2009

PN-EN 303–5:2012 "Kotły grzewcze – Część 5: Kotły grzewcze na paliwa stałe z ręcznym i automatycznym zasypem paliwa o mocy nominalnej do 500 kW – Terminologia, wymagania, badania i oznakowanie"

Roy B. , *Paradigms and challenges, Multiple Criteria Decision Analysis: State of the Art surveys*, New York 2005

Stypka T., Flaga-Maryańczyk A., *Możliwości stosowania zmodyfikowanej metody AHP w problemach inżynierii środowiska,* "Ekonomia i Środowisko" 2016 no. 2(57), p. 37–53

Ściążko M., Zuwała J., Pronobis M., *Współspalanie biomasy i paliw alternatywnych w energetyce*, Zabrze 2007

Tytko R., *Odnawialne źródła energii*, Warszawa 2011

www.bafa.de

www.biomasa.org

www.drewno-kluczynski.pl

www.ekologia.pl

www.ekonsument.pl

www.hipre.aalto.fi

www.ichpw.pl

www.nordic-ecolabel.org

www.pellet.com.pl

www.umweltzeichen.at

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CONNECTION BETWEEN ECOSYSTEM SERVICES OF WOODY PLANTS IN THE MUNICIPALITY OF CZERWONAK AND ADMINISTRATIVE DECISIONS ON FELLING TREES AND SHRUBS

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WPŁYW ZEZWOLEŃ NA WYCINKĘ DRZEW I KRZEWÓW NA USŁUGI EKOSYSTEMOWE ŚWIADCZONE PRZEZ ROŚLINNOŚĆ DRZEWIASTĄ W GMINIE CZERWONAK

STRESZCZENIE: Drzewa i krzewy odgrywają kluczową rolę w środowisku przyrodniczym obszarów wiejskich i miejskich, ze względu na bezpośredni kontakt społeczności lokalnych z nimi. Zapewniają one szeroki zakres usług ekosystemowych, które mogą być zaklasyfikowane do wszystkich głównych kategorii (wspierających, zaopatrujących, regulacyjnych i kulturowych). Celem badań jest identyfikacja usług ekosystemowych świadczonych przez drzewa i krzewy w gminie Czerwonak (woj. wielkopolskie) oraz zbadanie wpływu decyzji, zezwalających na wycinkę, na usługi ekosystemowe świadczone przez drzewa i krzewy.

SŁOWA KLUCZOWE: usługi ekosystemowe na terenach zurbanizowanych, mapowanie partycypacyjne, gminne tereny zielone, zezwolenia

Introduction – trees in urban and peri-urban areas

Trees and shrubs in urban and peri-urban areas provide a number of benefits to people. Besides their aesthetic value, they deliver tangible environmental benefits, that often are unrecognized and taken for granted. In recent years, there has been an increased interest of researchers in ecosystem services – the direct benefits that natural system provide to people[1]. In this paper we focus on trees and shrubs in urban and peri-urban areas and on ecosystem services they provide. In particular, we investigate whether cutting off trees and shrubs in accordance with administrative permissions undermine ecosystem services. The task undertaken in this paper involves two questions: firstly, which types of ecosystem services are provided by trees and shrubs, and secondly, do felling trees/shrubs diminish ecosystem services' provision?

Trees belong to the permanent vegetation in urban and peri-urban areas[2], shaping landscapes over the centuries. They give the characteristics of identity and unique character of places, they are dominant elements of visual shape of a territory and play substantial functional role in cleaning the environment. They also improve people's health, enhance more active lifestyle, reduce stress, stimulate social interaction, create spatial order, mask unattractive places, create the conditions for privacy and comfort[3]. Loss of these services caused by woody plants felling are often irreversible. For instance, services provided by old trees are irreplaceable due to their old age.

Benefits provided by trees and shrubs in cities contribute to all main types of ecosystem services (supporting, provisioning, regulating and cultural services[4]). These benefits can be recognized, and quantified, together

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1 R.T. Watson, A.H. Zakri (eds), *Ecosystems and human well-being, Millennium Ecosystem Assessment*, 2005.

2 N. Larondelle, D. Haase, *Urban ecosystem services assessment along a rural–urban gradient: A cross-analysis of European Cities*, "Ecological Indicators" 2013 no. 29, p. 179–190.

3 K. Beil, D. Hanes, *The influence of urban natural and built environments on physiological and psychological measures of stress–A pilot study*. "International Journal of Environmental Research and Public Health 10(4), 2013, p. 1250–1267; C.W. Thompson, *Activity, exercise and the planning and design of outdoor spaces.* "Journal of Environmental Psychology" 2013 no. 34, p. 79–96.

4 P. Bolund, S. Hunhammar, *Ecosystem services in urban areas*, "Ecological Economics" 1999 no. 29(2), p. 293–301; D.E. Bowler et al. , *Urban greening to cool towns and cities: a systematic review of the empirical evidence*, "Landscape and Urban Planning" 2010 no. 97, p. 147–155; Á. Takács et al., *Microclimate modification by urban shade trees an integrated approach to aid ecosystem service based decision-making*, "Procedia Environmental Sciences" 2016 no. 32, p. 97–109; F. Baró et al., *Contribution of ecosystem services to air quality and climate change mitigation policies: the case of urban forests in Barcelona*, "Ambio" 2014 no. 43(4), p. 466–79.

with an indication of their relation to the costs needed to maintain trees. Such information allows city planners and managers to assess investment projects in the integrated way, in order to protect natural resources, including trees. The negative impact on the environment and human health, exerted by the increasing volume of traffic and industry, grows. It negatively affects a quality of life in urban and peri-urban areas, deepening the social problems[5].

In addition to disturbance to the life of trees and shrubs in cities, related to the development of transport and infrastructure (e.g. salinity and drying of soil and air pollution), the institutional causes of these phenomena (administrative and social context) are important. Negative development can be countered by improving the quality of trees in cities and by trees management based on ecosystem services that they provide[6].

In Poland the potential for the ecosystem services provided by trees and shrubs in urban and peri-urban areas is substantial, higher than the European average[7]. Nevertheless, the number of trees in the central areas of Polish cities is decreasing, and it deteriorates the possibility of using nature as a source of ecosystem services for inhabitants. An important part of management is related to cutting off, replacing and planting trees and shrubs. In particular, cutting off trees is regulated by law (Code of Administrative Procedure[8] and Nature Conservation Act[9]). It defines procedures and conditions needed to obtain specific permissions. Felling trees and shrubs takes place in various private and public/municipal areas. Every year the large number of trees are removed from cities' green areas. The impact on the local biota and local society is not known though. In the paper we investigate whether falling trees occur in the areas, where the ecosystem services are present and whether felling off trees deteriorates them.

Research on ecosystem services in urban areas focuses mostly on environmental quality and the quality of life in densely populated areas and services provided by ecosystems, which are usually endangered by human pressures[10]. Ecosystem services in urban areas (mostly at the level of a city) are

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5 J. Kronenberg, *Barriers to preserving urban trees and ways of overcoming them*, "Sustainable Development Applications" 2012 no. 3, p. 31–49.

6 Ibidem, p. 31–49.

7 N. Larondelle, D. Haase, N. Kabisch, *Mapping the diversity of regulating ecosystem services in European cities*, "Global Environmental Change" 2014 no. 26, p. 119–129.

8 Ustawa z dnia 14 czerwca 1960 r. Kodeks postępowania administracyjnego (Dz.U. z 2016 poz. 23).

9 Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody (Dz.U. z 2015 poz. 1651).

10 B. Hunhammar, *Ecosystem services in urban areas*, "Ecological Economics" 1999 no. 29(2), p. 293–301; D. Haase et al., *A quantitative review of urban ecosystem service assessments: concepts, models, and implementation*, "Ambio" 2014 no. 43(4), p. 413–33.

analysed via standards and environmental indicators[11]; and by the institutions regulating ecosystem services management[12].

In Poland, the problem of ecosystem services provided by trees and shrubs in urban and peri-urban areas has got attention only recently[13]. However, the influence of the administrative decisions on felling trees and shrubs for ecosystem services has not been an object of investigation.

The research aim and hypothesis

The aim of the paper is to investigate whether cutting off trees and shrubs in accordance with permissions may undermine ecosystem services in the municipality of Czerwonak. In particular we test the hypothesis that administrative decisions (permissions) on felling woody plants affect all the ecosystem services equally. In order to accomplish this task two questions need to be asked: firstly, which types of ecosystem services are provided by trees and shrubs, and secondly, does felling of trees/shrubs diminish ecosystem services' provision? The task involves identification of ecosystem services related to trees in the Municipality of Czerwonak and exploration of administrative decisions on felling trees.

Czerwonak – case study area

Municipality of Czerwonak is a commune of mostly rural character, bordering however with the City of Poznań (a half a million inhabitants regional center). Czerwonak is located in the Wielkopolska province and lies in the geobotanical region referred to as the landscape of mixed forests and hornbeam associations. The West border of the municipality goes on the Warta River. Forests cover about 42% of its area as the municipality lies on the Puszcza Zielonka Landscape Park, the largest natural forest complex in the central Wielkopolska region of great natural, scenic, historical and scientific

11 F. Baro et al., *Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities,* "Ecological Indicators" 2015 no. 55, p. 146–158.

12 J. Kronenberg, *Why not to green a city? Institutional barriers to preserving urban ecosystem services*, "Ecosystem Services" 2015; M. Artmann, *Assessment of soil sealing management responses, strategies, and targets toward ecologically sustainable urban land use management*, "Ambio" 2014 no. 43(4), p. 530–41.

13 M. Giergiczny, J. Kronenberg, *How to assess the value of nature? Valuation of street trees in Lodz city center*, "Sustainable Development Applications" 2012 no. 3, p. 73–88; H.B. Szczepanowska, *Wycena wartości drzew na terenach zurbanizowanych*, Warszawa 2007.

values. The dominant tree species is Scots pine (*Pinus sylvestris* L.) constituting 83% of the forests. There are seven nature reserves, three sites of landscape protection and several monuments of nature (i.e. the Bartek Oak in the Owińska village) in the municipality of Czerwonak. The municipality's green areas play a recreation function for its inhabitants and for inhabitants of Poznan. The municipality, a rural and forested area close to Poznan, is under a pressure for urbanization facing demand for housing development. It is only partially covered by the local development plans.

Materials and methods

In order to investigate the issue of administrative decisions influence of felling trees on ecosystem services provided by trees and shrubs in the Municipality of Czerwonak, we applied two research methods: 1) participatory mapping, and 2) quantitative data analysis from administrative decisions on felling trees and shrubs. The procedure of participatory mapping was adapted from the research on ecosystem services in protected areas in Poland[14]. During the participatory mapping, firstly experts were asked the series of questions concerning ecosystem services provided by trees in the Municipality of Czerwonak. Secondly, they were asked to identify and locate (using cards prepared by the researchers) important ecosystem services provided by trees on the municipality map, using the preliminary list of 24 ecosystem services. It was prepared on the basis of ecosystem services provided by trees in the cities[15]. Finally, participants were asked to explain choices they made. The participatory mapping took place on July 2nd 2016 in the Municipality Office of Czerwonak and lasted two hours. Participants were representatives of Czerwonak Municipality, responsible for environmental issues and issuing administrative decisions on feeling trees and shrubs.

Concerning the administrative decisions on felling trees and shrubs, information was collected for the period of January to July 2015. The period was the most recent, for which information was accessible. Two hundred decisions were reviewed and coded to the database, containing information on the decisions (number of trees, species, compensations, reasons of the applications etc.). After removing incomplete data, 188 decisions for felling trees or shrubs were included to the analysis. The forests in the municipality governed by the Regional Direction of State National Forest Holding were

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14 A. Pietrzyk-Kaszyńska et al., *Usługi ekosystemów na obszarach cennych przyrodniczo z perspektywy różnych grup interesariuszy: podsumowanie wyników projektu*, 2016.

15 J. Kronenberg, *Urban ecosystem services*, "Sustainable Development Applications" 2012 no. 3 (Special Issue: Polish TEEB for Cities), p. 14–28.

excluded from our study as they are managed via the internal procedures of the Forest Holding.

The analysed cases were introduced to the map of ecosystem services indicated by experts. It allowed for further spatial analysis.

Results

The outcome of experts' participatory mapping workshop was the identification of most important ecosystem services provided by trees on the Czerwonak municipality map using preliminary list of 24 ecosystem services. The preliminary list was prepared on the basis of ecosystem services provided by trees in the cities.[16] Experts identified eight types of services from the preliminary list which were: habitat for animals and their nutritional base; regulation of air quality; noise reduction; protection from snowdrifts; strengthening social bonds; places of recreation; trees as a witness to history, e.g. monuments of nature; business benefits (table 1). They covered mostly the western part of the municipality along the Warta River.

Concerning the decisions on the cutting off trees, analysis of 188 administrative decisions showed that in 177 cases the Municipality of Czerwonak issued a permission on felling trees or shrubs, while in 11 cases applications were refused. In 17 cases, a permission involved an obligation to make the surrogate plantings.

The majority of entities applying for permission on felling trees and shrubs were natural persons (171 cases). In 29 cases applying entity was a legal person. The most frequent reason for cutting off, stated in applications were: a threat to life or property (31,5%); construction of a building or other object or demolition (14,5%); a threat to the functioning of the devices, such as power lines, sewers etc. (12,5%).

Taking into account trees and shrubs species' origin of the permissions there is the dominance of native species: 63,76%. In terms of tree species the most frequent in decisions were the following: Scots pine (*Pinus sylvestris* L.) – 541; silver birch (*Betula pendula* Roth) – 288; and trees from genus poplar (*Populus* L.) – 138. Shrubs species dominating in administrative decisions were the following: bird cherry (*Prunus padus*) – 215 m^2, shrubs from genus thuja (*Thuja* L.) – 46,5 m^2, shrubs from genus spruce (*Picea* A. Dietr.) – 30 m^2.

[16] J. Kronenberg, op. cit., p. 14–28.

Table 1. List of ecosystem services provided by trees (grey colour – most important services provided by trees according to workshop participants)

Ecosystem services type	Ecosystem services name
Supporting (habitat-related)	Habitat and nutritional base for animals
	Photosynthesis
	Retention of water in the land
Provisioning	Provision of wood and mistletoe
	Provision of fruits and nuts
Regulating	Regulation of air quality (dust retention, absorption of pollutants such as sulfur and nitrogen oxides, carbon dioxide, sulfuric, hydrochloric and nitric acid fumes, heavy metals)
	Enrichment of air and soil with moisture
	Air circulation (enhancement of vertical and horizontal convection)
	Protection from wind
	Creating "cold and humidity islands", especially in the summertime
	Shade regulation
	Noise reduction
	Secretion of antibiotic substances (phytoncides) with bactericidal, fungicidal and protozoacidal properties
	Biological field (electric charges emitted by assemblages of greenery that are beneficial to human health)
	Protection from snowdrifts
Cultural	Socio-educational role (active and passive recreation, raising awareness)
	Contribution to space aesthetics (camouflage of unsightly elements, accentuation of architectural beauty)
	Positive influence on health
	Cultural inspiration
	Strengthening social bonds (especially in the case of planting trees by communities and collaboration in caring for them)
	Place of recreation
	Psychological bonds between people and trees, a sense of place
	Trees as witnesses to history, especially legacy or veteran trees
	Business benefits (e.g. increased sales in trading districts with trees)

A decision was taken as a unit of analysis. A decision can refer to trees only, to shrubs only or to a combination of trees and shrubs, as requested by an applicant. The application varied significantly in terms of number of trees, from 1 to 1377 specimen, and in terms of shrubs from 1 m^2 to 215 m^2.

The areas where ecosystem services were identified and the location of each tree/shrubs cut off are presented in figure 1.

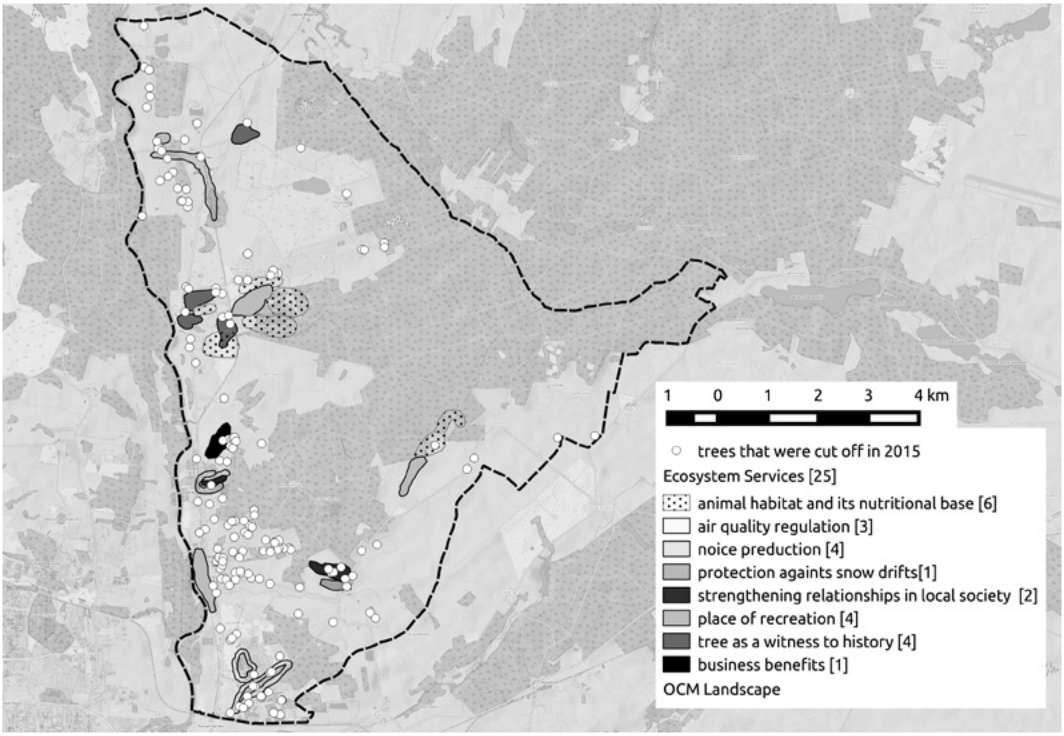

Figure 1. Map of ecosystem services areas and trees' felling locations. Numbers of areas of each ecosystem service are indicated in the brackets

In order to determine whether cutting off trees influences the ecosystem services, we measured distances of trees'/shrubs' felling locations from each identified areas, where particular types of ecosystem services were identified. We attributed the trees/shrubs into four categories: located directly in the ES areas, as identified by experts; located in the distance < 500 meters (23% of all cases); 500–1000 meters (22% of all cases); 1000–2000 meters (52% of all cases). Proposed intervals are related to the percentage of all trees/shrubs counted in given buffer. Only a small number of cut off trees/shrubs appear in the very location of an ecosystem service – about 3% of all cases (table 2).

Table 2. Number of cut off trees taking into account the distance from the ecosystem services areas.

	Ecosystem services								
Category of distance	**k_1**	**k_12**	**k_15**	**k_20**	**k_21**	**k_23**	**k_24**	**k_6**	**Total**
No. of trees in the area	2	4	1	7	2	3	2	4	25
No. of trees max. 500 m from the border area	18	39	8	10	44	10	8	25	162
No. of trees 500–1000 m from the border area	4	33	9	38	37	7	6	23	157
No. of trees 1000–2000 m from the border area	17	73	43	43	62	30	30	64	362
Total	41	149	61	98	145	50	46	116	

Codes of ecosystem services: k_1: habitat for animals and their nutritional base; k_6: regulation of air quality; k_12: noise reduction; k_15: protection from snowdrifts; k_20: strengthening social bonds; k_21: places of recreation; k_23: monuments of nature; k_24: business benefits.

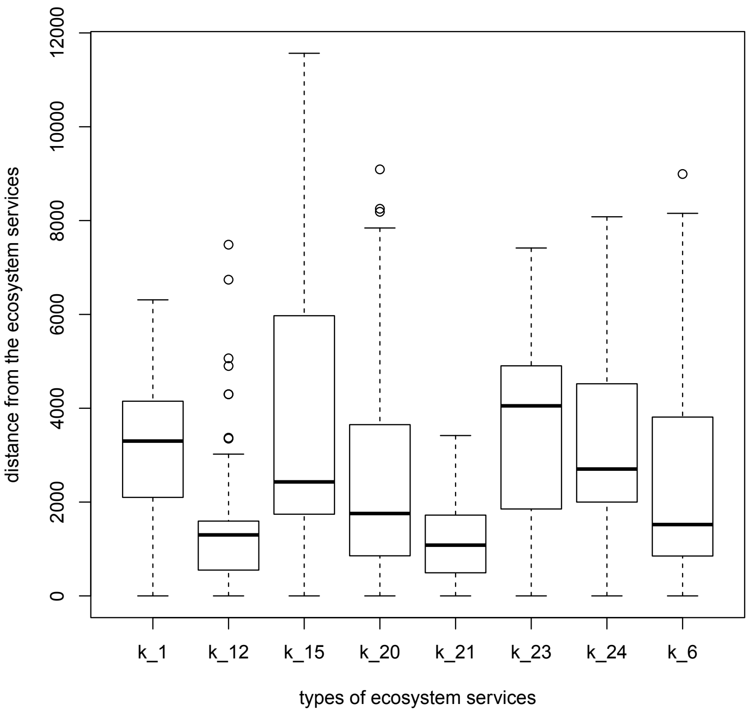

Figure 2. Distance from each type of ecosystem services related to trees and shrubs. The figure presents: median, first and 3rd quartile, minimum and maximum of values and outliers

Codes of ecosystem services: k_1: habitat for animals and their nutritional base; k_6: regulation of air quality; k_12: noise reduction; k_15: protection from snowdrifts; k_20: strengthening social bonds; k_21: places of recreation; k_23: monuments of nature; k_24: business benefits.

Although only a few cut off trees/shrubs were located within the identified areas of ecosystems services, cut offs done further also have certain impact. Euclidean distance from the areas where ecosystem services were indicated was measured for each tree or shrub. Only a distance to the closest area was taken if more than one areas of a particular an ecosystem service were identified. The results of distance analysis is presented in figure 2.

The analysis shows that each type of ecosystem services is influenced by trees/shrubs, that were cut off near their locations. However, average distance from the ecosystem services locations differs. Cutting off trees/shrubs has the biggest impact on areas dedicated to recreational purposes (K_21) as the median distance of the cut off trees to that area is the shortest one (1081,7 meters). Although only two trees were cut off in the very area of influence of the ecosystem services, 44 cut off trees were located in the vicinity (within 500 m).

The least influenced service is the cultural one related to monuments of nature (K_23), with the distance median of 4051 meters. For this service the distances are more dispersed compared with the recreational services.

Two services, noise reduction (K_12) and protection from snowdrifts (K_15) present peculiar characteristics. Both are related to roads, and therefore they are concentrated and linear in space. Noise reduction (K_12) has significant number of outliers, meaning several cases do not fit the model. For protection from snowdrifts (K_15) there is no outliers but the distance between the minimum and maximum distances is the biggest compared with all other ecosystem services.

Summary

The study enabled to identify and map ecosystem services provided by trees and shrubs in the Municipality of Czerwonak. Trees and shrubs cut off in accordance with the administrative decisions in the Municipality of Czerwonak do not affect all the ecosystem services equally. The felling have the biggest impact on places for of recreation in the municipality, and the smallest one on the areas with cultural ecosystem services, such as monuments of nature. The overall impact for all identified ecosystem services can be however assessed as small and felling trees and shrubs do not affect a particular ecosystem service.

This research has an exploratory character, and its limitation is related to the assumption that the influence scopes of all ecosystem services are the same. The results show however that this assumption requires refining. Two services which are spatially concentrated and of relatively short distance impact (noise reduction, and protection from snowdrifts) are either having significant number of outliers (noise reduction) or are more dispersed in term of distances compared with other services. It suggests that spatial scope of ecosystem services impact requires scrutiny in further studies.

Conclusions and recommendations

Conducted research enabled to identify spatial distribution of ecosystem services provided by woody plants in the Municipality of Czerwonak. Dominant services identified with experts during participatory mapping can help in understanding management of municipal green areas, taking into account ecosystem services in particular areas of a municipality and adjust conservation actions to requirements. Our study contributes to a knowledge of municipality green areas' management, by consideration of trees and shrubs felling on the ecosystem services. Location of ecosystem services can enhance the actions to raise local society's awareness of the role of municipal green areas.

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Hanna Krzyżyńska, B.Sc. – 5%

Literature

Artmann M., *Assessment of soil sealing management responses, strategies, and targets toward ecologically sustainable urban land use management*, "Ambio" 2014 no. 43(4), p. 530–41

Baró F. et al., *Contribution of ecosystem services to air quality and climate change mitigation policies: the case of urban forests in Barcelona*, "Ambio" 2014 no. 43(4), p. 466–79

Baro F. et al., *Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities,* "Ecological Indicators" 2015 no. 55, p.146–158

Beil K., Hanes D., *The influence of urban natural and built environments on physiological and psychological measures of stress – A pilot study*. "International Journal of Environmental Research and Public Health" 10(4), 2013, p. 1250–1267

Bolund P., Hunhammar S., *Ecosystem services in urban areas*, "Ecological Economics" 1999 no. 29(2), p. 293–301

Bowler D.E. et al. , *Urban greening to cool towns and cities: a systematic review of the empirical evidence*, "Landscape and Urban Planning" 2010 no. 97, p. 147–155

Giergiczny M., Kronenberg J., *How to assess the value of nature? Valuation of street trees in Lodz city center*, "Sustainable Development Applications" 2012 no. 3, p. 73–88

Haase D. et al., *A quantitative review of urban ecosystem service assessments: concepts, models, and implementation*, "Ambio" 2014 no. 43(4), p. 413–33

Hunhammar B., *Ecosystem services in urban areas*, "Ecological Economics" 1999 no. 29(2), p. 293–301

Kronenberg J., *Barriers to preserving urban trees and ways of overcoming them*, "*Sustainable Development Applications" 2012 no.* 3, p. 31–49

Kronenberg J., *Urban ecosystem services*, "Sustainable Development Applications" 2012 no. 3 (Special Issue: Polish TEEB for Cities), p. 14–28

Kronenberg J., *Why not to green a city? Institutional barriers to preserving urban ecosystem services*, "Ecosystem Services" 2015

Larondelle N., Haase D., Kabisch N., *Mapping the diversity of regulating ecosystem services in European cities*, "Global Environmental Change" 2014 no. 26, p. 119–129

Larondelle N., Haase D., *Urban ecosystem services assessment along a rural–urban gradient: A cross-analysis of European Cities*, "Ecological Indicators" 2013 no. 29, p. 179–190

Pietrzyk-Kaszyńska A. et al., *Usługi ekosystemów na obszarach cennych przyrodniczo z perspektywy różnych grup interesariuszy: podsumowanie wyników projektu*, 2016

Szczepanowska H.B., *Wycena wartości drzew na terenach zurbanizowanych*, Warszawa 2007

Takács Á. et al., *Microclimate modification by urban shade trees an integrated approach to aid ecosystem service based decision-making*, "Procedia Environmental Sciences" 2016 no. 32, p. 97–109

Thompson C.W., *Activity, exercise and the planning and design of outdoor spaces.* "Journal of Environmental Psychology" 34, 2013, p. 79–96

Ustawa z dnia 14 czerwca 1960 r. Kodeks postępowania administracyjnego (Dz.U. z 2016 poz. 23)

Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody (Dz.U. z 2015 poz. 1651)

Watson R.T., Zakri A.H. (eds), *Ecosystems and human well-being, Millennium Ecosystem Assessment*, 2005

Sylwia **KULCZYK** • Edyta **WOŹNIAK** • Marta **DEREK**

HOW MUCH IS THE "WONDER OF NATURE" WORTH? THE VALUATION OF TOURISM IN THE GREAT MASURIAN LAKES USING TRAVEL COST METHOD

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ILE JEST WART "CUD NATURY"? WYCENA TURYSTYKI W REGIONIE WIELKICH JEZIOR MAZURSKICH METODĄ KOSZTÓW PODRÓŻY

STRESZCZENIE: W artykule przedstawiono wycenę turystyki jako usługi ekosystemowej w regionie Wielkich Jezior Mazurskich. Wycenę przeprowadzono metodą kosztów podróży, wykorzystując wyniki badania kwestionariuszowego (n=499) i dane statystyczne. Uwzględniono szerokie spektrum elementów: koszty dojazdu, koszt czasu dojazdu, koszty noclegu, koszty podejmowanych aktywności oraz koszt zakupu spożywczych wyrobów regionalnych. Uzyskane wyniki pozwoliły na opracowanie mapy zróżnicowania przestrzennego przyrodniczej wartości turystyki w omawianym regionie. Wyrażona wydatkami turystów wartość Wielkich Jezior Mazurskich to ok. 277 mln PLN na sezon letni.

SŁOWA KLUCZOWE: wycena usług ekosystemowych, turystyka, metoda kosztów podróży, Wielkie Jeziora Mazurskie

Introduction

Although natural values are crucial for most of outdoor activities, they are rarely included into tourism accounts. Balmford et al.[1] estimate the global value of tourism in natural protected areas as USD 600 billion per year in direct expenditure. These calculations describe just a part of all nature based activities, that embrace both variety of natural settings and different tourism activities.

Tourism & recreation, recognized as a type of cultural services, are frequently assessed and mapped ecosystem services (ES)[2]. This paper concerns mapping of ES monetary value of nature, which recently has become a hot research topic[3].

We focus on the use value. The revealed preferences method has been chosen as this type is claimed to be more reliable[4]. As far as tourism and recreation are concerned, Travel Cost Method (TCM) is widely applied. In Poland, TCM has been used for valuation of protected areas including Białowieski[5], Pieniński[6] and Wielkopolski[7] national parks.

TCM is based on the assumption, that the consumption of non-marked good (visiting natural area) corresponds to buying some market goods. It assumes that users are rational in their decisions, and that a benefit from visiting natural area is always higher than a cost of the visit[8]. Consequently, the total costs of visits to the area can be identified as its value.

1 A. Balmford et al., *Walk on the Wild Side: Estimating the Global Magnitude of Visits to Protected Areas*, "PLoS Biol" 2015 no. 13(2), www.journals.plos.org [29-09–2016].

2 K.M. Chan et al., *Where are cultural and social in ecosystem services? A framework for constructive engagement*, "BioScience" 2012 no. 62(8), p. 744–756.

3 A. Troy, M.A. Wilson, *Mapping ecosystem services: practical challenges and opportunities in linking GIS and value transfer*, "Ecological Economics" 2006 no. 60(2), p. 435–449; J. Maes, M.L. Paracchini, G. Zuliani, *A European assessment of the provision of ecosystem services*, JRC Scientific and Technical Reports, Luxembourg 2011, p. 81; J.P. Schägner et al., *Mapping ecosystem services' values: Current practice and future prospects*, "Ecosystem Services" 4, p. 33–46.

4 T. Żylicz, *Valuating ecosystem services*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 18–38.

5 M. Giergiczny, R*ekreacyjna wartość Białowieskiego Parku Narodowego*, "Ekonomia i Środowisko" 2009 no. 2(36), p. 117–127.

6 D. Panasiuk, *Wycena środowiska metodą kosztów podróży w praktyce. Wartość turystyczna Pienińskiego Parku Narodowego,* w: F. Piontek (ed.) *Ekonomia a rozwój zrównoważony*, *Teoria i kształcenie*, Białystok 2001, p. 264–277.

7 A. Zydroń, O. Pruchlat, *Określenie społecznej wartości Wielkopolskiego Parku Narodowego metodą kosztów podróży*, "Barometr Regionalny. Analizy i prognozy" 2014 no. 4, p. 155–164.

8 T. Żylicz, *Ekonomia środowiska i zasobów naturalnych*, Warszawa 2004.

This study aims to estimate the value of tourism in the Great Masurian Lakeland using TCM. The second goal is to map spatial diversity of this value, pointing out the parts of the region that should be a priority for tourism management.

Study Area

The study has been realized in northern Poland, in the Great Masurian Lakeland (GML), (figure 1). The post-glacial landscape of the region features numerous lakes, including the largest lake in Poland, Śniardwy (113.8 km^2). The region consists of ten municipalities (2811 km^2). Forestry, agriculture and fisheries, the primary economic industries of the region, are supported by tourism. This is highly seasonal. July and August are the peak season: more than a half of total number of visits is realized in these months[9].

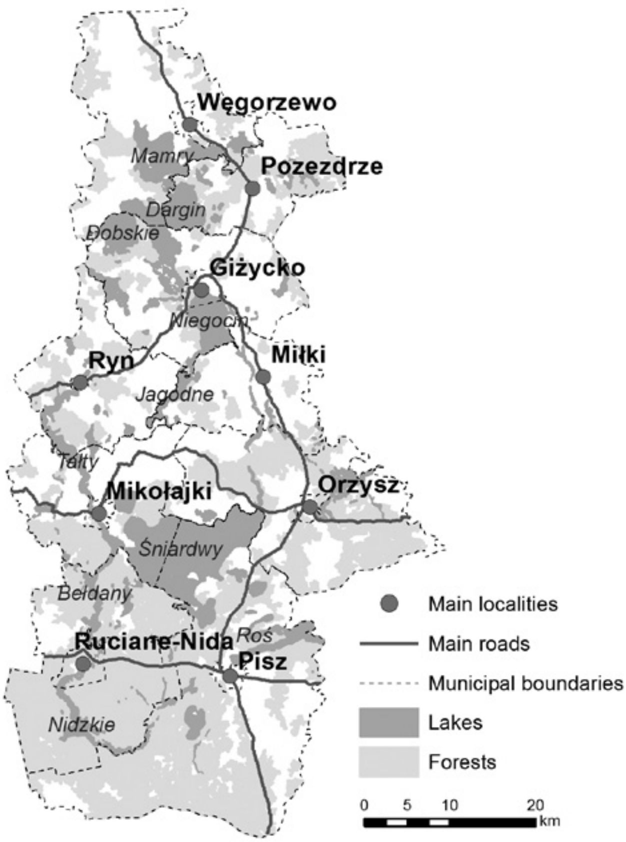

Figure 1. Study Area

9 Central Statistical Office of Poland.

The GML is commonly perceived as an attractive destination for nature based tourism. From 2007 to 2011, the region competed in the global New 7 Wonders of Nature Competition held by the Switzerland-based foundation New7Wonders and was highly ranked as one of the final group of 28 sites[10].

Methods

General overview

TCM analysis is based on survey data. There are two possible approaches: zonal one, where results are calculated for zones and individual, where cost of journey of every respondent is calculated separately. The Individual TCM has been chosen as this approach is concerned to give more precise results[11] than the zonal one. In this study the expanded formula has been applied and not only transportation costs, but also costs that are substantial for different outdoor activities as well as costs of accommodation and regional food have been taken into account in order to improve valuation results. Therefore the tourism value has been calculated as:

$$TV = JC + AC + UC + FC$$

where:
TV – Tourism value
JC – Journey cost
AC – Accommodation cost
UC – Use cost (cost of activities undertaken by tourists)
FC – Food cost (cost of regional food purchased during visit)

The individual costs were mapped by assigning them to places of overnight stays given in the survey. If any tourist was accommodated in more than one place the total sum has been divided proportionally. On this basis the density of all variables has been calculated and mapped.

Finally, the Total Tourism Value has been estimated taking into account all travelled distances, accommodation types, undertaken activities and regional food purchased related to the total number of tourists visiting the region.

In the following paragraphs we describe the procedure in details.

10 www.world.new7wonders.com [20-08–2016].

11 T. Żylicz, *Ekonomia środowiska …*, op. cit.

Survey

499 interviews were conducted with tourists in 9 locations throughout the area. The survey was conducted in the centre of each municipality in front of convenience stores. Using this approach, we hoped to get a sample representative in terms of the activities undertaken by tourists and their spatial distribution.

The survey was conducted simultaneously in all locations during two weekends and two working days in the summer of 2014, regularly throughout the day. The survey was limited to the Poles, as they constitute the majority of visitors in the region. The questionnaire's topics included type and location of accommodation, outdoor activities and regional food purchases, in addition to general questions about the tourist. The analysis has been conducted using SPSS 22 and ArcGis 10.1. All given accommodation places were mapped and the information about respondents has been assigned to these points. Also places where the tourists carried out different outdoor leisure activities were mapped and the information about the frequency of the realization of the activity was adjusted to these points.

Individual Travel Cost Method: calculating partial costs

The cost of the journey (JC) was calculated for each respondent as:

$$JC = D \times Fp + T \times Jc$$

where:
D – Travelled distance
Fp – Cost of fuel
T – Time of journey
Jc – Cost of journey time

The distances and times of travels were taken from Google Maps. Travelled distance was measured as the shortest road distance [km] between the respondent's place of origin and his accommodation in the GML. If the place of accommodation had been changed during a respondent's stay in the region, the mean distance to all overnight places of the respondent within the region was calculated. It was assumed that the travel was made by car and that the average use of fuel was 8 l per 100 km[12]. The mean price of unleaded petrol (PB95) for July and August 2014 (5,45 PLN) was taken for account[13]. Apart from distance the cost of time spent in travel was also calculated.

12 M. Giergiczny, op. cit., p. 124.
13 Bank of Local Data, Statistical Office of Poland, www.bdl.stat.gov.pl [12-08–16].

The cost of an hour of journey was described as fraction of mean wage in Poland in 2014 (4 003,99 PLN[14] / 160 hours).

The cost of accommodation (AC) was calculated as:

$$AC = P_{ac} \times Ls$$

where:

P_{ac} – mean accommodation price per type based on authors' own estimation (see table 1)

Ls – respondent's length of stay.

The use cost (UC), understood as a cost of activities undertaken by tourists, was estimated on the basis of costs of equipment rentals.

$$UC = \sum \sum_{n=1}^{15} (f\, x\, P\, x\, Ls)$$

where:

n – Number of undertaken activities

f – Frequency of undertaken activity[15]

P – Price of equipment rental per person (see table 1)

Ls – Length of stay

Table 1. Prices of goods and services purchased by tourists. Own field research

Accomodation		Equipment rentals		Regional Food	
type	price [PLN/person/night]	type	Price [PLN/person/day]	type	Price [PLN/kg or one pot]
Hotel	200	Windsurfing	150	Fish	50
Bed&Breakfast	50	Motor boat	100	Honey	30
Resort	50	Sailing yacht	87,5	Mush-rooms	30
Camping site	20	Horse	50	Wild berries	15
Port	20	Kayak, rowing boat, pedalo	17,5		

14 Ibidem.

15 The respondents declared the frequency at which they undertook the activity using a 5-point Likert scale, ranging from 1 (never) to 5 (very often). The following assumptions were made: rarely: once during a stay; from time to time: 0.2 × length of stay (at least one); often: 0,75 × length of stay, very often: every day during the visit.

Cost of purchase of regional food (FC) was estimated according to the information on type of food purchased by respondents. (see table 1). Therefore:

$$FC = \sum_{1}^{n=4} P$$

where:
n – Number of food types
P – Price per unit

Total number of tourists

In order to transform individual results to the total value for the region it was necessary to estimate the total number of tourists in the GML. The existing statistics are underestimated as they do not include all the accommodation located in the region.

We assume, that as the World Tourism Organization defines tourist as a person who stay out of home at least one night, accommodation and its level of use is a good measure of the number of tourists. Consequently

$$NT_n = \frac{A \times U^{VII} \times 31 + A \times U^{VIII} \times 31}{Ls}$$

where:
NT_n – number of tourists per accommodation type
A – accommodation (number of beds in the region) by types[16]
U – occupancy rate: mean for July (VII) and August (VIII) by types of accommodation[17]
LS – average length of stay: sailors – 7 days (charter time unit), others – 3,3 days[18]

$$TNT_{public} = \sum_{n=1}^{5} NT_n$$

where:
TNT_{public} – number of tourists in public access accommodation places
n – type of accommodation (hotel, B&B, resort, port, camping site)
NTn – number of tourists per accommodation facility type

$$TNT = TNT_{public} \times (1 + \%TNT_{private})$$

where:
TNT – total number of tourists
TNT_{public} – number of tourists in a public access accommodation places
$\%TNT_{private}$ – percent of tourists visiting friends and relatives and staying in second homes[19]

16 Own research.
17 *Tourism in Warmińsko-Mazurskie Voivodeship in 2014*, Olsztyn 2015, p. 22
18 Ibidem, p. 32.
19 Estimation based on survey data.

Total tourism value

The total tourism value was calculated as:

$$\mathrm{TTV} = \sum_{dc=1}^{n} JC_{dc} \times \%TN_s \times TNT + \sum_{at=1}^{5} AC_{at} \times \%TN_s \times TNT + \sum_{ut=1}^{5} UC_{ut} \times \%TN_s \times TNT + \sum_{at=1}^{4} FC_{ft} \times \%TN_s \times TNT$$

where:
TTV – total tourism value
TNT – total number of tourists
$\%TN_s$ – percent of tourists per category according to the survey
JC_{dc} – journey cost in distance category
AC_{at} – accommodation cost per accommodation type
UC_{ut} – use cost per activity
FC_{ft} – regional food cost per type per unit

The estimated value was mapped taking into account area's diversity of use identified by the realized survey.

Results

Sample profile

The sample profile was slightly dominated by men (56%). The majority of respondents was between 25 and 44 years old (54.9%) and most of the sample possessed university degrees (48.3%). Most of the respondents came from big towns and cities. They visit the region regularly and spend there one or two weeks of their holidays on average. Natural features are highly appreciated by the tourists, with special emphasis on the proximity to water and forest.

Individual travel value

Visitors cover on average 274 km to reach the destination. The most numerous group travel the distance between 201 and 300 km. A significant part of tourists (20%) travel from 501 to 600 km to reach the area. This two zones correspond to distances between the GML and the most urbanized areas in Poland. It takes on average 4 hours and 14 minutes to reach the destination.

A significant group of respondents don't pay for their accommodation. These are people who stay by friends and relatives, in their second homes or who moor their yachts outside of ports. The most of tourists who use accommodation services stayed in resorts and bed & breakfast. Resorts were usually chosen for longer holiday stays and consequently influenced significantly total accommodation costs.

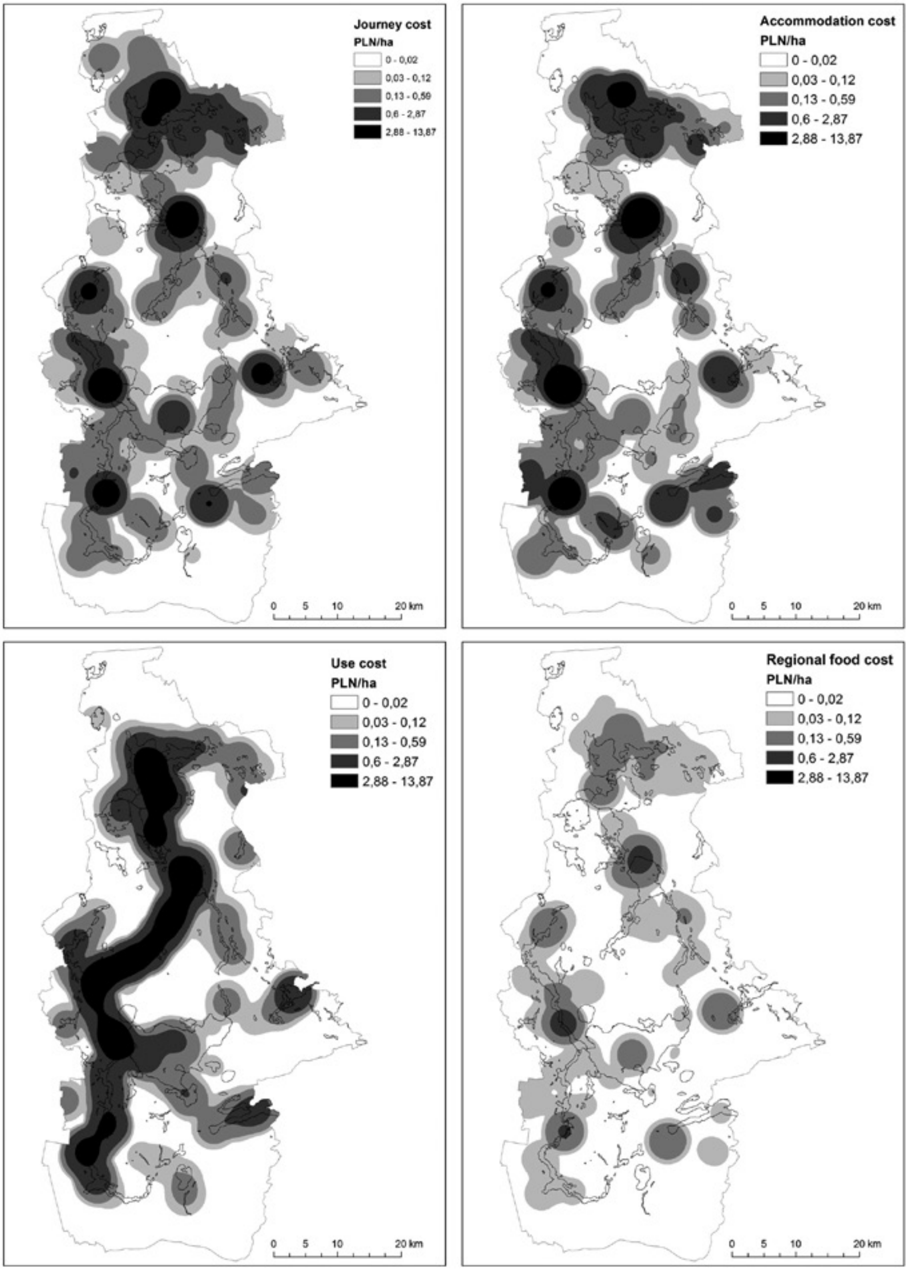

Figure 2. Individual travel cost – spatial diversity of partial costs

As far as equipment rentals are concerned, sailing generates the highest cost. Due to the high maintenance costs, the majority of Polish sailors tend to charter a yacht. Riding a horse is the least popular activity, possibly because of small number of studs.

Fish is the most often purchased regional food and its price is also the highest. Consequently, fish purchase is the most significant of all food costs.

The partial costs differ not only in their value, but also in spatial pattern. Figure 2 presents the spatial diversity of the journey cost, accommodation cost, use cost and regional food cost of the respondents. All the highest values are concentrated along the shores. Whereas journey and accommodation costs are more dispersed, the areas of highest use extend along the main sailing trail. Comparing to other costs, that of regional food is less significant. Also it is needed to mention that this value is ascribed to the place of the purchase not to the place of the production.

Total travel value

Our estimations give 305 563 tourists who visited the region in July and August of 2014. This number was used to calculate the total value of tourism in the region, which is 276 820 523 PLN per summer season. The diversity of elements that influence the value of respondent's travel is described by table 2.

Table 2. Travel costs of tourists in the GML region

Good / service	% of users	Estimated sum spent by respondents [PLN]
TRAVELLED DISTANCE		
≤ 100 km	5.6	545 603
100.1 – 200 km	19.0	4 026 093
200.1 – 300 km	29.7	9 784 289
300.1 – 400 km	12.4	5 766 785
400.1 – 500 km	7.6	4 530 178
500.1 – 600 km	20.4	15 171 102
More than 600 km	5.2	5 256 911
TOTAL COST OF TRAVELLED DISTANCE	100	45 080 961
JOURNEY TIME		
≤ 60 minutes	1.4	82 622
60.1–120 minutes	9.6	1 126 059

Good / service	% of users	Estimated sum spent by respondents [PLN]
120.1–180 minutes	11.2	2 193 121
180.1–240 minutes	22.4	6 011 608
240.1–300 minutes	17.2	5 793 496
300.1–360 minutes	9.0	3 758 596
360.1–420 minutes	15.2	7 586 533
>420 minutes	13.8	8 430 119
TOTAL COST OF JOURNEY TIME	100	34 982 155
ACCOMODATION		
Accommodation	9.02	24 800 174
Bed & Breakfast	16.03	11 022 300
Resort	18.64	28 474 274
Camping site	5.41	1 488 010
Mooring in port	7.21	4 408 920
Free of charge	42.28	0
Not identified	1.4	964 451
TOTAL COST OF ACCOMMODATION	100	71 158 130
EQUIPMENT FOR ACTIVITIES		
Sailing yacht	36.8	84 839 659
Rowing boat, pedalo	28.7	6 317 967
Kayak	21.7	6 797 246
Motor boat	6.8	12 902 229
Windsurfing	1.2	3 954 255
Horse	0.2	956 798
TOTAL COST OF ACTIVITIES	100	115 768 153
REGIONAL FOOD		
Fish	39.1	5 972 178
Honey	28.1	2 572 630
Wild fruits	14.0	643 158
Mushrooms	7.0	643 158
TOTAL COST OF REGIONAL FOOD	100	9 831 124
TOTAL COST OF SUMMER TOURISM IN THE GML		276 820 523

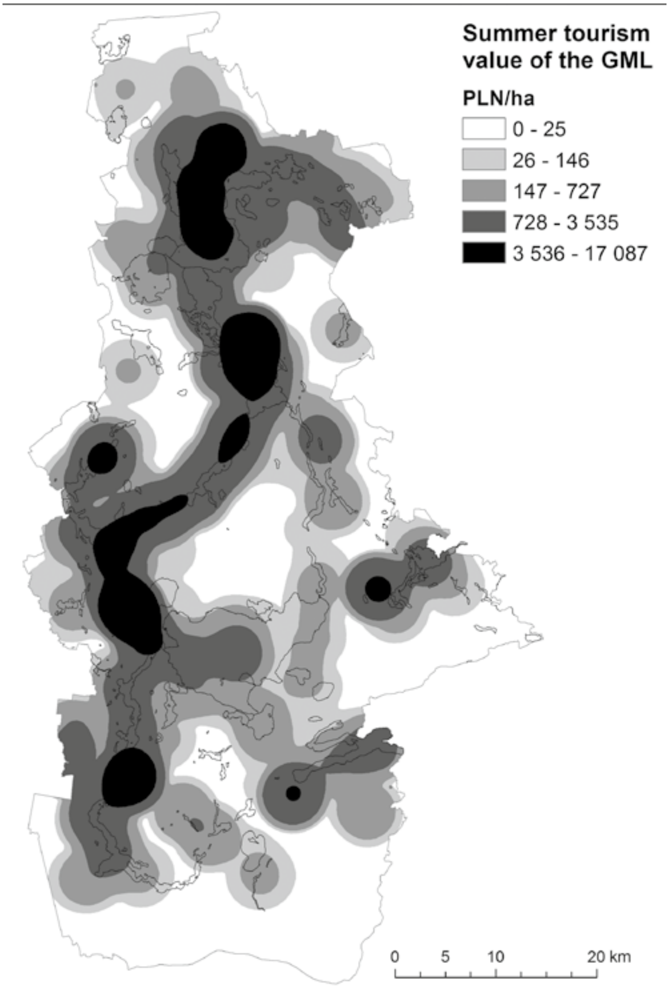

Figure 3. Total tourism value of GML

From all of the considered types of costs, equipment rental remains the highest (41,8% of all costs payed by the respondents). This cost is mainly generated by charter of sailing yachts. Although inshore sailing is rather unimportant part of the whole tourism industry, it remains the key activity in the GML. Because sailors sleep on their yachts, in their case rental costs cover also (when not mooring in ports) accommodation costs. As for all tourists, accommodation is 25,7% of their expenses. It is only slightly less then journey costs (distance and time), which make 28,8% of the total sum.

Figure 3 presents spatial diversity of the total travel value. It remains the highest along the main sailing trail. The hot spots are located in regional tourist hubs. Despite their urbanized status, nature remain easily accessible there, as towns are located by lakes, remain relatively small and encompass many green areas. Surprisingly, Śniardwy lake, commonly considered as a significant tourist attraction, has a relatively low value. This reflects the low level of its real use by tourists. Due to unsuitable natural conditions the shores of Śniardwy are difficult to access and lack tourism infrastructure. The lake itself is known to sailors as potentially unsafe. Another area whose value remains unexpectedly low is Piska woodland. This big forest in the south of the region has high potential for tourism, but lack accommodation.

Discussion and conclusions

The total value of summer tourism for the GML was estimated on around 277 million PLN. It must be emphasized that it is not the money that tourists leave in the region (some costs, such as travel costs, are incurred outside of the destination).

In comparison to other economically important activities in the GML, the calculated tourism value is high. The value of wood production in the areas is estimated on 88 042 107 PLN and the value of sold wild fruit and mushrooms on 173 638 PLN[20].

The tourism value is spatially diversified; the biggest lakes and their shores are up to 27 times more valuable than agricultural areas out of shoreline. The described diversity proved the importance of water to tourists. They not only declare, but also actively use the GML water bodies. The high value of water and shores is the regularity found worldwide[21], but to our knowledge detailed spatiality of the phenomenon has not been studied. In GML, the value of waters is the highest near towns that provide infrastructure and for the lakes that are not only big but also connected to the others. The use value of forest is not only lower than water bodies, but also spatially limited to more densely populated areas, where accommodation is available.

The study shows clearly, that the tourism value and its spatial pattern are driven by many different factors. As many factors as possible should be included in valuation process in order to obtain reliable results. Such calcula-

20 Values for warmińsko-mazurskie region recalculated by forest area in GML region. Source of the data: Bank of Local Data, Statistical Office of Poland, www.bdl.stat.gov.pl [12-08–16].

21 C.M. Fleming, A. Cook, *The recreational value of Lake McKenzie, Fraser Island: An application of the travel cost method*, “Tourism Management” 2008 no. 29(6), p. 1197–1205; I. Maharana, S.C. Rai, E. Sharma, *Valuing ecotourism in a sacred lake of the Sikkim Himalaya, India,* “Environmental conservation” 2002 no. 27(03), p. 269–277; N.H. Lansford Jr, L.L. Jones, *Recreational and aesthetic value of water using hedonic price analysis,* “Journal of Agricultural and Resource Economics” 1995, p. 341–355.

tions can help to improve the management of an area. For example a land tax for tourism infrastructure could be lowered in areas of lower value to tourism.

The realized analysis has some limitations. Firstly, only use value has been included. The existence and bequest values are surely important in the GML region, which is iconic Polish landscape. Secondly, the presented valuation is limited to summer season. If not as busy as in summer, winter season in the GML should not be neglected. Still, due to totally different character of winter tourism, the method should be significantly modified.

The presented study is the first attempt to estimate how precious this area is, what is the impact of particular groups of costs, and how much tourism is important for the region. This, in turn, should result in appropriate tourism management.

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The contribution of the authors in the article:

Sylwia Kulczyk, Ph.D. – 40%
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Marta Derek, Ph.D. – 25%

Literature

Balmford A. et al., *Walk on the Wild Side: Estimating the Global Magnitude of Visits to Protected Areas*, "PLoS Biol" 2015 no. 13(2)

Chan K.M. et al., *Where are cultural and social in ecosystem services? A framework for constructive engagement*, "BioScience" 2012 no. 62(8), p. 744–756

Fleming C.M., Cook A., *The recreational value of Lake McKenzie, Fraser Island: An application of the travel cost method*, "Tourism Management" 2008 no. 29(6), p. 1197–1205

Giergiczny M., R*ekreacyjna wartość Białowieskiego Parku Narodowego*, "Ekonomia i Środowisko" 2009 no. 2(36), p. 117–127

Lansford N.H. Jr, Jones L.L., *Recreational and aesthetic value of water using hedonic price analysis,* "Journal of Agricultural and Resource Economics" 1995, p. 341–355

Maes J., Paracchini M.L., Zuliani G., *A European assessment of the provision of ecosystem services*, JRC Scientific and Technical Reports, Luxembourg 2011, p. 81

Maharana I., Rai S.C., Sharma E., *Valuing ecotourism in a sacred lake of the Sikkim Himalaya, India,* "Environmental conservation" 2002 no. 27(03), p. 269–277

Panasiuk D., *Wycena środowiska metodą kosztów podróży w praktyce. Wartość turystyczna Pienińskiego Parku Narodowego,* w: F. Piontek (ed.) *Ekonomia a rozwój zrównoważony*, *Teoria i kształcenie*, Białystok 2001, p. 264–277

Schägner J.P. et al., *Mapping ecosystem services' values: Current practice and future prospects*, "Ecosystem Services" 4, p. 33–46

Tourism in Warmińsko-Mazurskie Voivodeship in 2014, Olsztyn 2015

Troy A., Wilson M.A., *Mapping ecosystem services: practical challenges and opportunities in linking GIS and value transfer*, "Ecological Economics" 2006 no. 60(2), p. 435–449

www.bdl.stat.gov.pl

www.world.new7wonders.com

Zydroń A., Pruchlat O., *Określenie społecznej wartości Wielkopolskiego Parku Narodowego metodą kosztów podróży*, "Barometr Regionalny. Analizy i prognozy" 2014 no. 4, p. 155–164

Żylicz T., *Ekonomia środowiska i zasobów naturalnych*, Warszawa 2004

Żylicz T., *Valuating ecosystem services*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 18–38

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

PROBLEMATYKA OGÓLNOEKOLOGICZNA I SPOŁECZNA

Małgorzata STĘPNIEWSKA • Dawid ABRAMOWICZ

SOCIAL PERCEPTION AND THE USE OF ECOSYSTEM SERVICES ON MUNICIPAL POST-MINING LANDS. AN EXAMPLE OF SZACHTY IN POZNAN

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SPOŁECZNA PERCEPCJA I KORZYSTANIE ZE ŚWIADCZEŃ EKOSYSTEMOWYCH MIEJSKICH TERENÓW POEKSPLOATACYJNYCH. PRZYKŁAD SZACHT W POZNANIU

STRESZCZENIE: Zagospodarowywanie obszarów poeksploatacyjnych w miastach stwarza możliwość kształtowania struktury i poziomu świadczeń ekosystemów. Zarządzanie takimi obszarami powinno uwzględniać potrzeby mieszkańców miast i służyć podniesieniu jakości ich życia.
Celem artykułu jest ukazanie społecznej percepcji i wykorzystania świadczeń ekosystemowych Szacht w Poznaniu. W badaniach wykorzystano kwestionariusz internetowy, skierowany do użytkowników obszaru badań. Zebrane informacje pozwoliły określić cechy społeczno-ekonomiczne respondentów, przyczyny, dla których odwiedzają oni Szachty oraz poziom zadowolenia z obecnego zagospodarowania terenu. Uzyskane wyniki pozwoliły na sformułowanie rekomendacji dla decydentów w zakresie dalszego wzmacniania potencjału Szacht do dostarczania świadczeń.

SŁOWA KLUCZOWE: świadczenia ekosystemów, tereny zurbanizowane, tereny poeksploatacyjne, ankieta internetowa, podejmowanie decyzji

Introduction

Built-up areas – as cities, towns and suburbs – provide a home to almost three-quarters of the European Union population and this number will further grow[1]. The creation of a healthy, resilient and safe living environment for all citizens is the key task of urban policy and planning[2]. To make cities more sustainable and better places to live, increasing urbanization should go hand in hand with attention to the proper design of the urban green infrastructure[3]. Significant opportunities for enriching cities with green infrastructure are created by development of post-industrial areas, especially post-mining ones. *If managed properly,* these areas can provide a broad bundle of ecosystem services (ES), such as *remediation of pollutants,* reducing noise, educational and aesthetic values, space for recreation and maintenance of social relations[4].

The subject of this article is social perception and the use of ES by visitors of the post-mining Szachty area in Poznan. The inspiration for the research was a growing interest in the site from citizens and decision makers. This is expressed by a more and more intensive use of the Szachty area by inhabitants, which is accompanied by increasing public spending on site arrangement.

The main objectives of the study included:

- identification of ES in the Szachty area used by citizens;
- determination of the users satisfaction with the site's arrangement;
- provision of recommendations to decision-makers towards further strengthening of the ES potential of the site.

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1 Eurostat, *Statistics on European cities*, www.ec.europa.eu/eurostat [30-09–2016].

2 European Commission, *Mapping and Assessment of Ecosystems and their Services – Urban Ecosystems*, Technical Report–2016–102, May 2016.

3 A. Chiesura, *The role of urban parks for the sustainable city*, "Landscape and Urban Planning" 2003 no. 68, p. 129–138; S. Buchel, N. Frantzeskaki, *Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands*, "Ecosystem Services" 2014 no. 12, p. 169–177; C. Bertram, K. Rehdanz, *Preferences for cultural urban ecosystem services: Comparing attitudes, perception and use*, "Ecosystem Services" 2015 no. 12, p. 187–199.

4 e.g. K. Fagiewicz, *Obszary pogórnicze jako typ krajobrazu recepcyjnego turystyki,* "Problemy Ekologii Krajobrazu" 2009 no. XXV, p. 95–103; N. Larondelle, D. Haase, *Valuing post-mining landscapes using an ecosystem services approach – An example from Germany*, "Ecological Indicators" 2012 no. 18, p. 567–574; S.G. Popović et al., *Models of Landscape Shaping in Exploited Quarries of Urban Area*, "Procedia Engineering" 2015 no. 117, p. 609–615.

Study area

The study area (Szachty) covers 114.1 ha and nearly all of it (113.8 ha) is located in the southern and western part of the city of Poznan in the valley of the Junikowo Stream (figure 1). A small fragment of the study area (0.3 ha) is situated within the boundaries of the town of Lubon. In Poznan, the study area is located within the boundaries of the Fabianowo-Kotowo, Świerczewo and Górczyn housing estates.

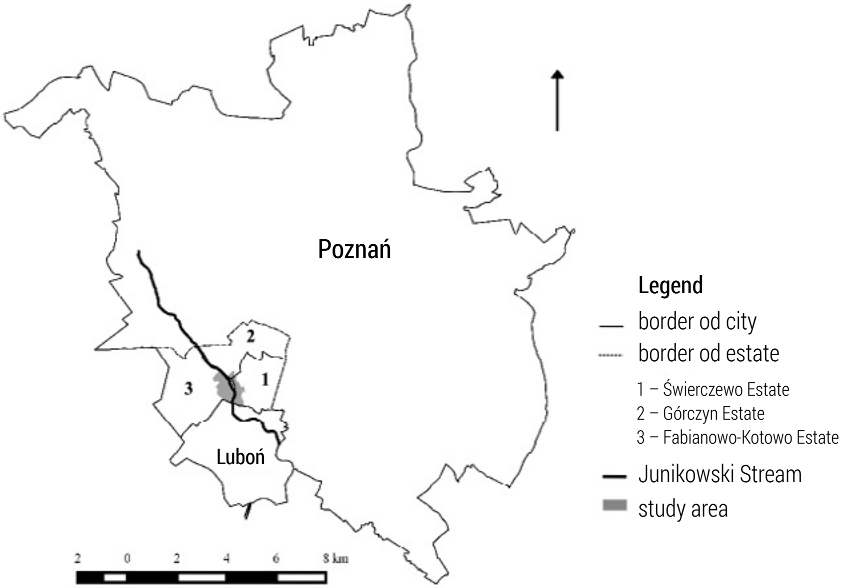

Figure 1. The location of the study area

The name Szachty comes from the German language in which the word “der Schacht” means “a shaft”. For over 100 years – from the 1830s to the end of the 1960s and the beginning of the 1970s – the extraction of ceramic materials, especially varved clays and tills, occurred[5]. Traces of former mining activities, determine the contemporary landscape of Szachty. Former clay pits, which have become filled with rainwater and ground water, are an

5 I. Markuszewska, *Funkcjonowanie oraz zagospodarowanie obszarów poprzemysłowych związanych z eksploatacją surowców ilastych ceramiki budowlanej*, “Krajobrazy Przemysłowe i Poeksploatacyjne” 2007 no. 6, p. 115–125.

important element of the land cover[6]. After the discontinuation of aggregate mining, the Szachty area was not subjected to reclamation actions. Instead, the natural succession of vegetation occurred here. The renaturalization process led to positive landscape changes, which are reflected by a mosaic of bodies of water, wetlands, grass vegetation and trees.

At present, the study area is a significant element of the green infrastructure in Poznan, which is one of five green wedges formed in river valleys[7]. It is mostly the city's inhabitants that cause changes in the landscape, as the Szachty area is for them a place where various forms of open-air rest and recreation are undertaken.

Methods

In order to achieve the adopted objectives, we conducted an online survey using local websites that gather the users of the Szachty area[8]. Studies on ES using surveys were conducted by numerous researchers[9]. Survey studies using the Internet are more and more popular due to their advantages such as easy distribution and completion of the questionnaire and lower costs[10].

The survey was conducted from December 16th through 31st, 2015 and responses were obtained from 204 respondents. The survey covered the social and economic characteristics of respondents, the reasons why they visit the Szachty area, the ES used and the degree of satisfaction with the current site arrangement. While ordering the ES of Szachty identified by citizens, we used the Common International Classification of Ecosystem Services (CICES version 4.3[11]). The selection of CICES resulted from its coherence with

6 I. Matuszyńska, *Zmiany użytkowania tereny jako element transformacji środowiska przyrodniczego na obszarze wybranych zlewni Poznania i jego strefy podmiejskiej*, Poznań 2001.

7 L. Poniży, *Tereny zieleni na obszarze miasta Poznania,* in: I. Piotrowska, M. Cichoń (eds) *Człowiek w krajobrazie miasta Poznania*, Poznań 2010.

8 www.facebook.com/szachty; www.swierczewo.poznan.pl [20–10–2016].

9 A. Chiesura, op. cit.; P. Lupa, *Ecosystems' local recreational services valuation. Krajenka municipality case study*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 209–222; S. Buchel, N. Frantzeskaki, op. cit.; C. Bertram, K. Rehdanz, op. cit.

10 D. Nulty, *The adequacy of response rates to online and paper surveys: what can be done?,* "Assessment & Evaluation in Higher Education" 2008 no. 33, p. 301–314; L. Peña, I. Casado-Arzuaga, M. Onaindia, *Mapping recreation supply and demand using an ecological and a social evaluation approach*, "Ecosystem services" 2015 no. 13, p. 108–118; S. Willcock et al., *Do ecosystem service maps and models meet stakeholders' needs? A preliminary survey across sub-Saharan Africa*, "Ecosystem Services" 2016 no. 18, p. 110–117.

11 European Environmental Agency, *Common International Classification of Ecosystem Services v. 4.3*, www.cices.eu [30-09–2016].

recognized categorizations and concepts and the possibility of making future comparisons with results from other EU member states.

Results

Profile of the respondents

204 respondents took part in the study – 111 men and 93 women. With regard to age groups, persons aged 18–29 were the most numerous (89 respondents), and next were those aged 29–45 (68 respondents). Over a half of the respondents taking part in the study declared higher education (108 persons) and a further 70 respondents – secondary education (figure 2).

There are no data that would make it possible to assess the representativeness of the sample. The lower number of elderly respondents undoubtedly results from the fact that it is the age that most strongly determines the online presence and digital exclusion*.* D*espite that fact,* two-thirds of adult Poles regularly use the Internet (i.e. at least once a week)[12]. For this reason, in the authors' opinion, the research conducted can be treated as a source of precious information about social perception and the use of ES in the study area.

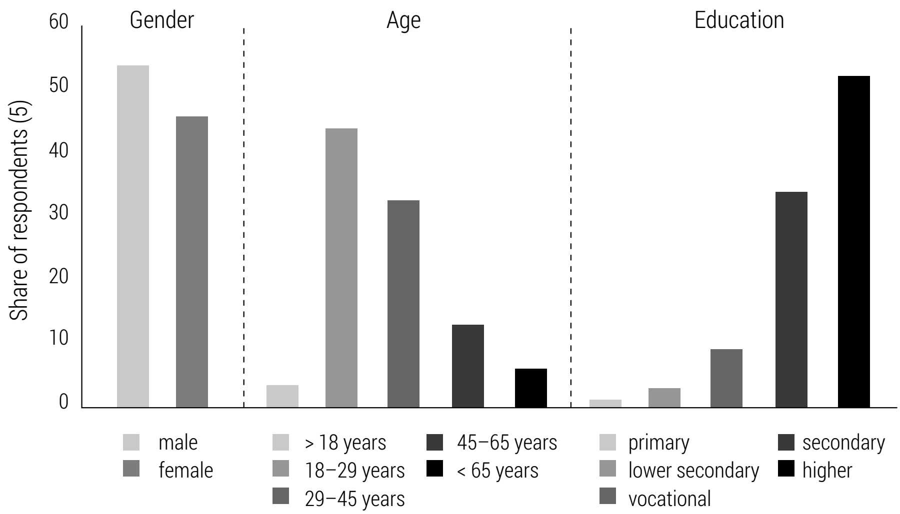

Figure 2. The structure of respondents according to the sex, age and education

12 Centrum Badania Opinii Społecznej, *Internauci 2015*, www.cbos.pl [30-09–2016].

Reasons for choosing the Szachty area as a place of recreation

As the reason for choosing the Szachty area as a place of rest and recreation, the respondents usually quoted proximity to the place of residence (180 persons). It should be noticed that a total of 28.3 thousand people live in Poznan housing estates that are directly adjacent to the study area, and the Szachty area itself is relatively easy to reach owing to a well-developed network of roads, including bike paths and the proximity of public transport stops.

Very important reasons for the users of the Szachty area include its wild plants and animals (154 responses), the presence of water (138 responses) and less polluted air as compared to the surrounding area (96 responses). These values result from renaturalization of the landscape, which occurred after the discontinuation of aggregate mining. The presence of small infrastructure objects facilitates the exploration of the ecosystem (96 responses). Every fourth respondent indicated the importance of actions promoting Szachty undertaken by the housing estate council for their choice, while every fifth respondent mentioned the absence of alternative places for rest and recreation in the neighborhood. Furthermore, 16 respondents indicated other reasons including semi-natural landscape, space for meeting family and friends, peace and quiet as well as the sentiment mostly related to spending one's time in the Szachty area in the past.

The ecosystem services used by users

Respondents were asked to provide information about the manner and frequency of using the services listed in the questionnaire. The authors used closed questions. The selection of services proposed in the questionnaire resulted from the previous field reconnaissance, pilot study, conversations with users, scientific discussions and analysis of relevant literature[13].

The responses show that the respondents use two classes of provisioning services, one class of regulating services and four classes of cultural services. The frequency of using particular ES is varied (figure 3). With regard to provisioning services, the respondents most often declared that during their visits to the Szachty area they catch fish, pick herbs, flowers and fruits (54 persons). This activity is seasonal. Nearly all respondents (201 persons) notice regulating service connected with improving the quality of air. However, respondents observe varied forms of cultural services to the greatest extent. This is related to the fact that inhabitants of nearby areas use Szachty as a place for rest and recreation. Respondents usually declared engaging in activities such as walking, socializing, admiring the landscape, observing

13 e.g. A. Chiesura, op. cit.; S. Buchel, N. Frantzeskaki, op. cit.; C. Bertam, K. Rehdanz, op. cit.

nature, drawing inspiration from nature, photographing, doing sports (e.g. cycling, jogging). From among cultural services, users more rarely undertook those that require certain infrastructures (e.g. barbecue, making a campfire) or pertain to activities undertaken by a specific group of users (e.g. recreational angling).

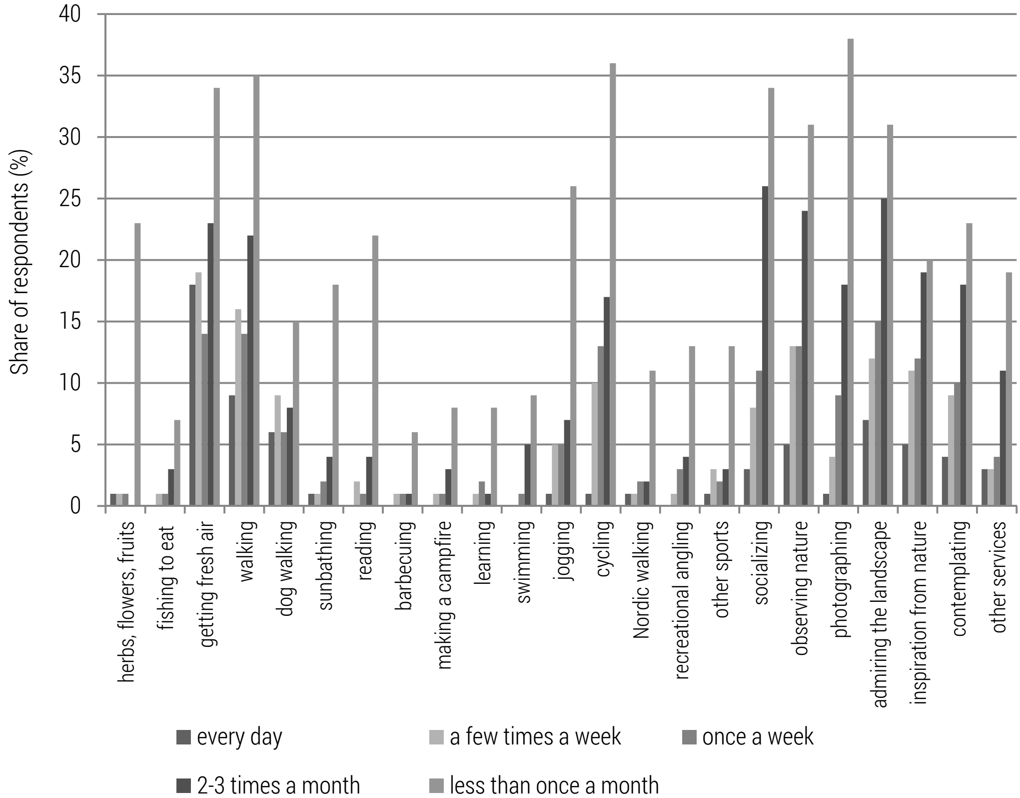

Figure 3. Ecosystem services of Szachty perceived by respondents

The range of impact of ecosystem services

The questionnaire contained a question about the place of residence of the respondents, assuming that it will indicate the range of impact of the identified ES.

The data concerning the distance of the respondents' place residents from the Szachty area is presented in figure 4. Nearly ¾ of the respondents live at a distance that is no more than 1 kilometre from the research area. In total, slightly more than 90% cover the distance of 3 kilometres or less to reach the Szachty area. Slightly over 95% of the respondents live in areas situated at a distance of 5 kilometres or less from the study area.

The results presented show that the Szachty area provides ES mostly on a local scale. Szachty users mostly reside in the southeastern part of Poznan, especially in the following housing estates: Świerczewo, Górczyn, Fabianowo-Kotowo, Grunwald Południe, Wilda and Zielony Dębiec (in total 137 respondents). The local range of impact of the Szachty services results from its small surface area, its peripheral location in the city and also the availability of other green areas, which are attractive for other inhabitants of Poznan, and its surrounding areas.

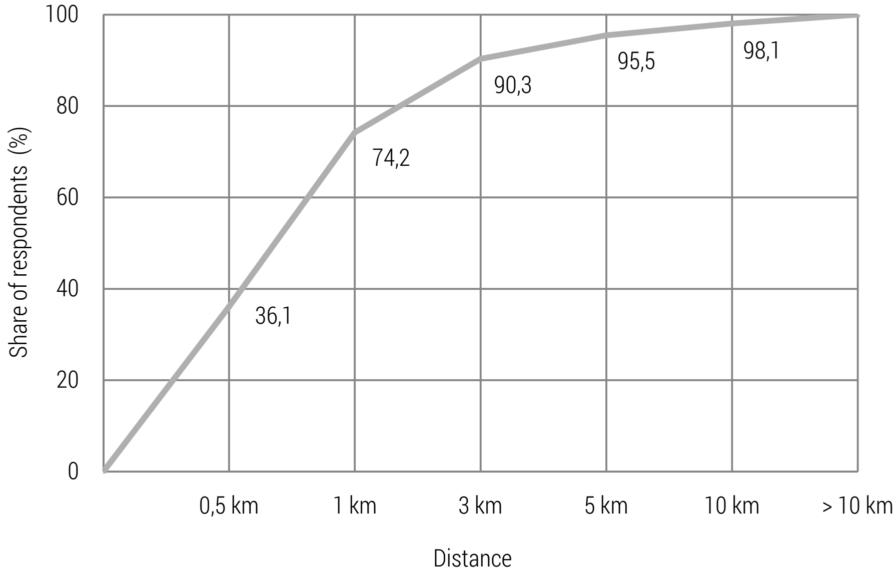

Figure 4. Distance from the place of residence of respondents to Szachty area

Current site's arrangement in the eyes of users

Ecosystem services do not flow directly from ecosystems to human well-being – their production takes place through interactions between the natural capital and the built environment (built capital)[14]. The existing infrastructure makes it possible to use ecosystems and thus draw benefits from them. In the presented research, respondents were asked to assign a positive, negative or neutral mark to the elements of the Szachty area development that have been created so far. The results show how highly the respondents value elements of small architecture such as waste bins, benches, signposts,

14 R. Constanza et al. *Changes in the Global Value of Ecosystem Services*, "Global Environ. Change" 2014 no. 26, p. 152–158.

paths (figure 5). Users attach less importance to investments enhancing regulating services, which include the construction of culverts between ponds. The lowest number of respondents marks positively the creation of a skatepark in the former brickyard and a private fishing ground at Nowakowski Pond. In the authors' opinion, this results from the fact that these last undertakings are targeted at a relatively narrow group of users.

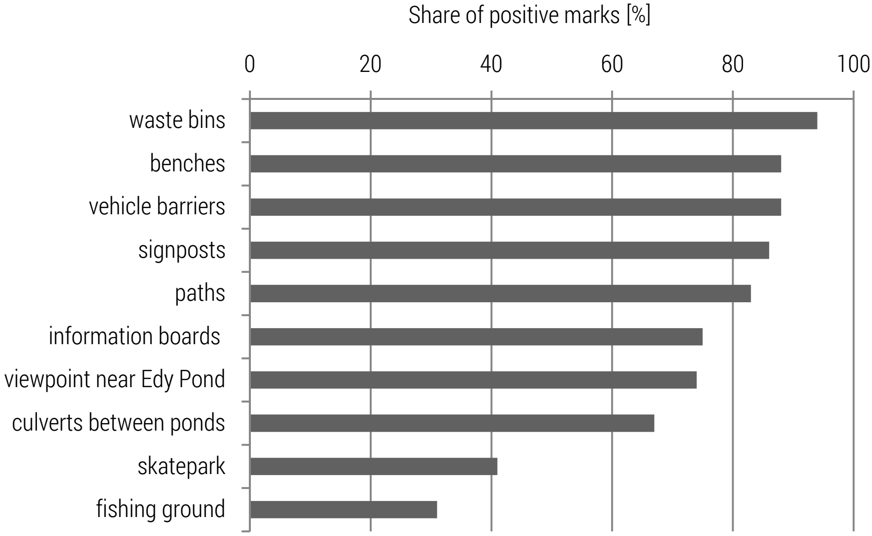

Figure 5. The percentage of positive marks for particular elements of the Szachty area development

Conclusions

The study shows that users of the Szachty area in Poznan perceive and use mainly cultural ES. Consequently, citizens appreciate these *elements of site arrangement,* which improve the place of rest and recreation. In turn, *less attention is paid* to investments enhancing the regulating services. The results allow us to provide recommendations to decision-makers towards further strengthening of the ES potential of the area. Fulfilling the demand for cultural ES should be addressed in the site's management. However, the enhancement of cultural ES could weaken the ecological benefits provided by the Szachty area; at present, regulating ES are overlooked by users. Therefore, *according to the authors,* the strengthening of the cultural ES should be accompanied by the safeguarding of regulating ES, both at the planning and project implementation stages. In particular, we recommend the implementation of tasks that enhance cultural services, but do not weaken regulating services (e.g. keeping the area clean on an ongoing basis, trimming trees, protecting the places of entry to Szachty against the entry of cars). With regard to tasks that enhance cultural services, and at the same time weaken regulating services, one must guarantee protection of the site's potential to provide the latter. For example, the construction of pedestrian and cycling paths or an observation tower should be accompanied with the care to maintain services such as life-cycle maintenance, habitat and gene pool protection, *mediation of pollutants.* We also recommend implementation of tasks that directly enhance regulating services. J. Borysiak & J. Markiewicz (2005)[15] and A. Kaniecki (1995)[16] drew attention to the necessity of reclamation of some ponds to regulate the trophy and eliminated the internal burden. It is also necessary to protect hydrotechnical devices that regulate the level of water in ponds. Last, but not least, strengthening of the cultural ES should be accompanied with education, which would increase the perception of ecological benefits from this area. The construction of educational paths will make it possible to inform users about regulating services provided by urban green infrastructure. Moreover, the organization of classes in Szachty by local schools and other educational institutions may play an important educational role.

The contribution of the authors in the article:

Małgorzata Stępniewska, Ph.D – 60%
Dawid Abramowicz, M.Sc – 40%

Literature

Bertram C., Rehdanz K., *Preferences for cultural urban ecosystem services: Comparing attitudes, perception and use*, "Ecosystem Services" 2015 no. 12, p. 187–199

Borysiak J., Markiewicz J. (eds), *Weryfikacja granic terenów cennych przyrodniczo – byłych użytków ekologicznych Kopanina I i Kopanina II w celu wyróżnienia terenów predysponowanych do objęcia ochroną, z uwzględnieniem wprowadzenia w ich sąsiedztwie (teren ZKO) funkcji sportowej*, Poznań 2005

Buchel S., Frantzeskaki N., *Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands*, "Ecosystem Services" 2014 no. 12, p. 169–177

Centrum Badania Opinii Społecznej, *Internauci 2015*, www.cbos.pl

15 J. Borysiak, J. Markiewicz (eds), *Weryfikacja granic terenów cennych przyrodniczo – byłych użytków ekologicznych Kopanina I i Kopanina II w celu wyróżnienia terenów predysponowanych do objęcia ochroną, z uwzględnieniem wprowadzenia w ich sąsiedztwie (teren ZKO) funkcji sportowej*, Poznań 2005.

16 A. Kaniecki, *Problem podpiętrzenia* wód w dolinie Strumienia *Junikowskiego,* in: A. Kaniecki (ed.), *Dorzecze Strumienia Junikowskiego. Stan obecny i perspektywy*, Poznań 1995.

Chiesura A., *The role of urban parks for the sustainable city*, "Landscape and Urban Planning" 2003 no. 68, p. 129–138

Constanza R. et al. *Changes in the Global Value of Ecosystem Services*, "Global Environ. Change" 2014 no. 26, p. 152–158

European Commission, *Mapping and Assessment of Ecosystems and their Services – Urban Ecosystems*, Technical Report–2016–102, May 2016.

European Environmental Agency, *Common International Classification of Ecosystem Services v. 4.3*, www.cices.eu

Fagiewicz K., *Obszary pogórnicze jako typ krajobrazu recepcyjnego turystyki,* "Problemy Ekologii Krajobrazu" 2009 no. XXV, p. 95–103

Kaniecki A., *Problem podpiętrzenia wód w dolinie Strumienia Junikowskiego,* in: A. Kaniecki (ed.), *Dorzecze Strumienia Junikowskiego. Stan obecny i perspektywy*, Poznań 1995

Larondelle N., Haase D., *Valuing post-mining landscapes using an ecosystem services approach – An example from Germany*, "Ecological Indicators" 2012 no. 18, p. 567–574

Lupa P., *Ecosystems' local recreational services valuation. Krajenka municipality case study*, "Ekonomia i Środowisko" 2012 no. 2(42), p. 209–222

Markuszewska I., *Funkcjonowanie oraz zagospodarowanie obszarów poprzemysłowych związanych z eksploatacją surowców ilastych ceramiki budowlanej*, "Krajobrazy Przemysłowe i Poeksploatacyjne" 2007 no. 6, p. 115–125

Matuszyńska I., *Zmiany użytkowania tereny jako element transformacji środowiska przyrodniczego na obszarze wybranych zlewni Poznania i jego strefy podmiejskiej*, Poznań 2001

Nulty D., *The adequacy of response rates to online and paper surveys: what can be done?,* "Assessment & Evaluation in Higher Education" 2008 no. 33, p. 301–314

Peña L., Casado-Arzuaga I., Onaindia M., *Mapping recreation supply and demand using an ecological and a social evaluation approach*, "Ecosystem services" 2015 no. 13, p. 108–118

Poniży L., *Tereny zieleni na obszarze miasta Poznania,* in: I. Piotrowska, M. Cichoń (eds) *Człowiek w krajobrazie miasta Poznania*, Poznań 2010

Popović S.G. et al., *Models of Landscape Shaping in Exploited Quarries of Urban Area*, "Procedia Engineering" 2015 no. 117, p. 609 – 615

Statistics on European cities, www.ec.europa.eu/eurostat

Willcock S. et al., *Do ecosystem service maps and models meet stakeholders' needs? A preliminary survey across sub-Saharan Africa*, "Ecosystem Services" 2016 no. 18, p. 110–117

www.facebook.com/szachty

www.swierczewo.poznan.pl

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POPULATION OF COMMON SWIFT IN POZNAN (POLAND) AND ECOSYSTEM SERVICES PROVIDED BY IT

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POPULACJA JERZYKA ZWYCZAJNEGO W POZNANIU I ŚWIADCZONE PRZEZ NIĄ USŁUGI EKOSYSTEMÓW

STRESZCZENIE: Celem badań było określenie skali zmian populacji jerzyka zwyczajnego (Apus Apus) zasiedlającej bloki mieszkaniowe w Poznaniu oraz ustalenie zmian w zakresie świadczonych przez nie usług ekosystemów. W artykule wskazano, że termodernizacja budynków często prowadzi do likwidacji siedlisk, a tym samym do zmniejszenia populacji ptaków je zamieszkujących. Wykazano, że w Poznaniu pozostało tylko 15% bloków mieszkalnych nie poddanych termomodernizacji. Tylko 4% z budynków po renowacji posiada zainstalowane skrzynki lęgowe dla ptaków. Szacuje się, że utracono ok. 86% populacji jerzyka na Osiedlu Mlodych – największej spółdzielni mieszkaniowej w Poznaniu. Utracono również usługi ekosystemów w postaci zjadania przez ptaki blisko 2,5 tony lub 25 tys. latających insektów na sezon z obszaru Poznania i okolic.

SŁOWA KLUCZOWE: jerzyk zwyczajny, apus apus, usługi ekosystemów, usługi regulacyjne, ptaki na budynkach

Introduction

A common swift (*Apus apus*[1]) is one of most common birds in big Polish cities[2], currently swifts in Poznan mainly nesting on residential blocks. An intensive process of thermo-modernization of residential blocks is carried out in Poland since nineties. This modernization is often made incorrectly and is causing the loss of habitats of birds breeding on buildings, which in turns causes a reduction of their population in cities. Meanwhile, the birds provide ecosystem services to residents of cities among which one of the most important is the regulation of insect populations.

The first aim of this study was to determine the scale of population change of common swift colonizing residential blocks made in the concrete panels technology in Poznan. The second aim was to quantify ecosystem services provided by birds which exist nowadays and potentially if their habitats would still exist.

Regulating services provided by birds in Polish cities were studied by Kamiński[3], Luniak[4], Zimny[5] but mainly as part of urban ecology or zoology studies. Abroad researches include also studies in small cities[6] and agricultural areas[7]. None of these studies were dedicated to common swift. Additionally many researchers on ecosystem services provided by birds use only descriptive methods[8]. As Wenny et al.[9] states there is the need to quantify

1 Species authority: C. Linnaeus, *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis,* Holmiæ 1758.

2 W. Nowicki, *Ptaki Śródmieścia Warszawy*, Warsaw 2001.

3 P. Kamiński, *Bioenergetische Untersuchungen zur Jugendentwicklung der Dohle Corvus monedula*, "Journal of Ornithology" 1986 no. 127, p. 315–329.

4 M. Luniak, *Awifauna miasta – jej skład, zróżnicowanie oraz udział w procesach ekologicznych*, in: H. Zimny (ed.), *Funkcjonowanie układów ekologicznych w warunkach zurbanizowanych,* Warszawa 1990.

5 H. Zimny, *Ekologia miast*, Warszawa 2005.

6 P. Mikula, M. Hromada, P. Tryjanowski, *Bats and Swifts as food of the European Kestrel (Falcotinnunculus) in a small town in Slovakia,* "Ornis Fennica" 2013 no. 90, p. 178–185.

7 M.R. Abdar, *Seasonal Diversity of Birds and Ecosystem Services in Agricultural Area of Western Ghats, Maharashtra State, India*, "Journal Of Environmental Science, Toxicology And Food Technology" 2014 no. 8(1), p. 100–105.

8 CCI and BirdLife International, *Measuring and monitoring ecosystem services at the site scale*, Cambridge 2011; J. Kronenberg et al., *The importance of White Stork Ciconia ciconia for society: an analysis from the perspectve of ecosystem services*, "Chrońmy Przyrodę Ojczystą" 2013 no. 69(3), p. 179–203; Z. Brzozowska, *Situation in Poland p 1 In: The 1st Common swift Seminars, Berlin 8th – 11th April 2010 Summaries of the presentations*, 2010; E. Smeets, R. Weterings, *Environmental indicators: Typology and overview, Technical report No 25/1999*, Copenhagen 1999.

9 D.G. Wenny et al., *The need to quantify ecosystem services provided by birds*, "The Auk" 2011 no. 128(1), p. 1–14; G. Kruszewicz, *Ptaki Polski*, Warszawa 2005, p. 352.

ecosystem services provided by birds, and this research is part of this trend. There is also a wide range of international literature about behavioural studies of common swift, including amount of consumed insects[10]. But none of studies mentioned above were quantitative research on regulating services provided by common swift population in a given area like presented in this paper.

About common swift and their habitat

A common swift (*Apus apus*) is a medium-sized bird, similar to a barn swallow or a house martin but it is larger. Swifts have very short legs which they use primarily for clinging to vertical walls and they never settle voluntarily on the ground. Except when nesting, swifts spend their lives in the air, they drink, feed, and often mate and sleep on the wing. Swifts are insectivores, they feed on flying insects while airborne such as aphids, flying ants, mosquitoes, hoverflies and small beetles, catching huge numbers of them every day. This birds could travel long distances in search for food (the longest recorded distance was 200 km), but when there are good weather conditions they usually do not depart far from the nesting sites. Swifts are one of the fastest-flying birds found in Europe[11].

Swifts build their nests of airborne material caught in flight, bonded with their saliva. They used to breed in holes of caves or hollows of trees, but nowadays they mostly use building's hollows. In panel buildings they occupy mainly ventilation holes in attics and crevices between panels. Swifts, contrary to pigeons, make little or no mess (depositon of feces etc.)[12].

The common swifts return to the breeding places in their old colony approximately the same time each year, around the 1st of May in Europe. They are faithful to its breeding place so the pairs may breed together for many years. At the end of July the young fly out and around the 1st of August the parents leave Europe for Africa[13].

10 T.L.F. Martins, J. Wright*, Cost of reproduction and allocation of food between parent and young in the swift (Apus apus)*, "Behavioral Ecology" 1993 no. 4, p. 213–223; T.L.F. Martins, *Fledging in the common swift, Apus apus: weight-watching with a difference*, "Animal Behaviour" 1997 no. 54(1), p. 99–108; B. Sicurella et al., *Weather conditions, brood size and hatching order affect Common Swift Apus apus nestlings' survival and* growth, "Bird Study" 2015 no. 62, p. 64–77.

11 D. Graszka-owski, *Ptaki. Profesjonalny przewodnik dla początkujących obserwatorów*, Warszawa 2005, p. 177.

12 D. Zyskowski, D. Zielińska, *Przewodnik do inwentaryzacji oraz ochrony ptaków i nietoperzy związanych z budynkami*, Szczecin 2014.

13 W. Nowicki, op. cit.

Figure 1. Main places in panel buildings where swifts build nests: ventilation holes in attics (left) and crevices between panels (right)

Source: Jakub Kotnarowski (CPSD).

Decline in population

During the second half of the twentieth century when ideology of communism was dominating in Central and Eastern Europe construction of panel buildings took place on a mass scale. This process also reached Poznan. Since nineties these panel building has been undergoing modernization to be more energy efficient and to refresh their appearance. This process has led to removal of hollows used by birds for breeding. Research on 58 buildings in Warsaw[14] showed that after thermo-modernization there is at least loss of 74% of such places on building.

A similar process has been taking place all over the Europe. Authors from different countries report that there is about 50% decline in common swift population across Europe (table 1).

There is lack of detailed data on population of swifts in Poland. But most of authors agree that there is decline in population of swifts living in cities since nineties[15]. Brzozowska[16] estimated decline in Szczecin on 85%.

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14 M. Luniak, *Ochrona ptaków a modernizacja budownictwa*, in: P. Indykiewicz, L. Jerzak, T. Barczak (ed.), *Fauna miast. Ochronić różnorodność biotyczną w miastach*, Bydgoszcz 2008, p. 90–95.

15 P. Kamiński, op. cit.; L. Tomiałojć, T. Stawarczyk*, Awifauna Polski, rozmieszczenie, liczebność i zmiany,* t. 2, Wrocław 2003; G. Kruszewicz, op. cit., p. 352.

16 Z. Brzozowska, op. cit.

Table 1. Decrease in population of common swift in the Europe

Country	Decrease in population
The United Kingdom	1995–2011 declines of 39% in England and 57% in Scotland
Slovakia	average of 50–60% in last 15 years (from 2012)
East Germany	57% since 1990

Source: K. Risely et al., *The Breeding Bird Survey 2012,* Thetford 2013; M. Cel'uch, et al*., Will the Common Swift survive in Slovakia?,* in: *Report and summaries of the presentations, and additional contributions, given to The Second Commonswift Seminars Berlin,* 10th–12th April 2012, p. 6; D. Zyskowski, D. Zielińska*, Przewodnik do inwentaryzacji oraz ochrony ptaków i nietoperzy związanych z budynkami,* Szczecin 2014.

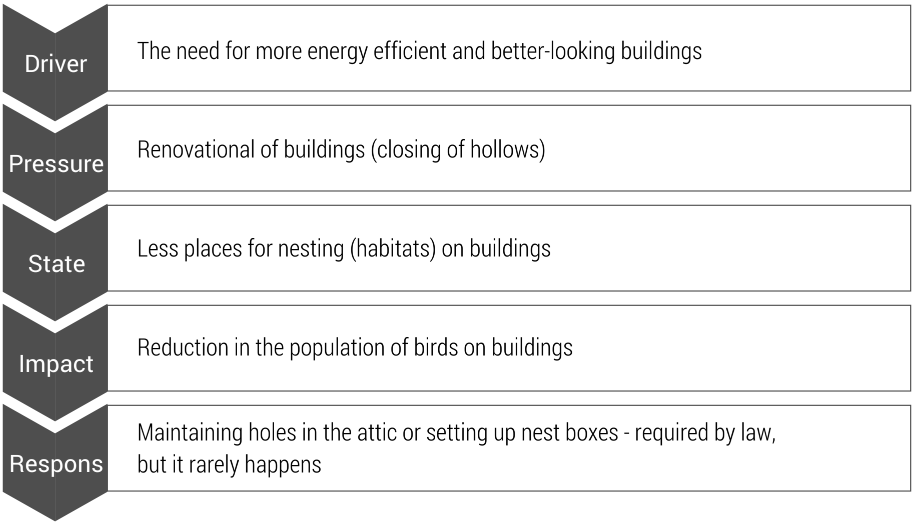

Figure 2. Processes described with DPSIR methodology

This process could be described with DPSIR methodology[17] (figure 2). The driver of thermo-modernization is the need of more energy efficient and better-looking buildings. This leads to renovation of buildings which causes a reduction of hollows on this buildings. As a resulting state there are less places for birds to breed. This state has an impact on birds population which is decreasing. The response to such loss should be maintaining the hollows or setting up nesting boxes, but in Poland, despite the law which obliges to make such compensation, this process occurs rarely. The main cause of this is, on one hand, costliness of such process and, on other hand, ineffectiveness of state offices to supervise implementation of law in this matter.

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17 E. Smeets, R. Weterings, op, cit.

Ecosystem services provided by birds

Birds provide many ecosystem services for people and other organisms (table 2). Services like supporting and provisioning are not of great importance in cities. Also, nowadays most of provisioning services lose their importance like clothing, tools (e.g. quill pen) and others (e.g. stuffing beddings).

In cities the most important ones are regulating and cultural services. The most noticeable regulating service is pest control (rodents and insects). This service is usually acknowledged in ornithological literature as the most important and often is only one mentioned[18].

As for cultural services provided by birds, they are often one of a few possibilities for people living in the cities to experience contact with nature. Most of birds except species like pigeons and aquatic birds are usually difficult to spot, but sounds of birds can be heard almost everywhere in cities.

Table 2. Ecosystem services provided by birds

Supporting	Ecosystem engineering (nests and tree holes)
	Pollination and seed dispersal
Provisioning	Cultivated and harvested food
	Natural medicines
	Clothing
	Tools
Regulating	Pest control (insects and rodents)
	Carcass removal
	Pollination and seed dispersal
Cultural	Nature-based recreation/ tourism
	Aesthetic benefits /inspiration /mental health
	Spiritual / religious experience

Source: based on D.G. Wenny, et al., *The need to quantify ecosystem services provided by birds,* "The Auk" 2011 no. 128(1), p. 1–14; J. Kronenberg et al., *The importance of White Stork Ciconia ciconia for society: an analysis from the perspectve of ecosystem services,* "Chrońmy Przyrodę Ojczystą" 2013 no. 69(3), p. 179–203; CCI and BirdLife International, *Measuring and monitoring ecosystem services at the site scale,* Cambridge 2011.

[18] M. Cel'uch, J. Gúgh, J. Kaľavský, K. *Staples, Will the Common Swift survive in Slovakia?, in: Report and summaries of the presentations, and additional contributions, given to The Second Commonswift Seminars Berlin, 10th–12th April 2012*, p. 6; L. Tomiałojć, T. Stawarczyk, op. cit.

Studies on residents of residential blocks in Rzeszow[19] showed that despite these ecosystem services, only small group (12%) of people notice impact of birds on improving the welfare of themselves.

As for regulating services provided by swifts there could be found two data in literature about the amount of food gathered by pair of birds to feed nestlings during one day. The first is average weight – 50 g[20] and the other one is the number of flying insects – 20 000[21]. Flying insect if are not eaten by swifts could be nuisance for inhabitants of cities (e.g. by biting) and also negatively affect plants (e.g. by feeding on them).

Project and methodology

The project "Birds in the city" (Polish: *Ptaki w mieście*) was managed by Centre for Promotion of Sustainable Development (CPSD), which is a non-governmental organization based in Poznan (the author is a member of the board). The project was founded by a grant from Department of the Environment in Poznan Municipal Office.

The main aim of this project was to protect common swifts remained in Poznan on residential blocks by determining number of nesting sites and scales of ecosystem services.

The only comprehensive study about birds in Poznan[22] is outdated and analyse common swift population only on smart part of city. To take a successful watchdog activity CPSD had to make a geolocalized database of buildings and determine if they are inhabited by birds.

The first part of this project took place in 2015. During this period volunteers checked residential blocks in Poznan if their elevation had been renewed and hollows had been closed. Data from this phase is freely available on the project webpage – www.mapaptakow.pl.

Next year the same team made ornithological observations in the biggest housing association in Poznan – Osiedle Mlodych. The area of this housing association is 359 ha and there are 375 residential blocks placed there. They checked if remaining nonrenovated blocks and nesting boxes were colonized by birds.

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19 J. Kostecka, *Edukacyjne znaczenie pojęcia świadczenie ekosystemów dla ochrony awifauny miast*, "Inżynieria Ekologiczna" 2010 no. 22.

20 U. Tigges, *Common swift*, www.commonswift.org [10-08–2016].

21 P. Kamiński, op. cit.; M. Grzeniewski, M. Kowalski, *Ochrona ptaków gniazdujących w budynkach*, Siedlce 2010.

22 J. Ptaszyk, *Ptaki Poznania – stan jakościowy i ilościowy oraz jego zmiany w latach 1850–2000*, Poznan 2003.

Based on data from literature it was estimated how much of this birds usually were breeding on residential blocks in Poland before renovation. Bocheński et al.[23] estimated about 40 birds pairs per 10 ha in Koszalin (a city with the lowest result in study). Luniak[24] took another approach and estimated that there were average 4,12 birds pairs per building in Warsaw. This data was compared with a size of swift population on Osiedle Mlodych.

The last part of the project was to quantify a pest control service provided by birds. To achieve this, literature data on how much of flying insects a swifts eats every day, was used. These amounts were multiplied by the number of observed pairs and the number of pairs estimated before renovation of buildings (the lowest one). It was assumed that feeding of nestlings lasts about 40 days.

Results

During the first part of the project (2015) 1324 residential blocks were surveyed in Poznan. Only 205 (15%) were not renovated. Nesting boxes were identified only on 47 blocks (4%), there were 530 boxes observed.

The second part of this project (2016) took place on Osiedle Mlodych in Poznan. Volunteers observed 202 pairs of swifts.

Two studies about a number of birds nesting on residential blocks in Poland before renovation were found, there was lack of such data for Poznan. Using this data it was estimated that there should be from 1436 (based on per ha data) to 1545 pairs of swifts (based on per building data) on Osiedle Mlodych. Taking the lowest quantity (1436) there is 86% decline in swift population.

The next step in this research was to estimate the quantity of .cosystem services provided by swifts on Osiedle Mlodych. Currently occurring birds catch around 0,40 t and 4 040 000 of flying insect during one season, while estimated population should eat around 2,9 t or 28 720 000 of insects. This data is based on the number of birds so the difference is the same – we probably lose 86% of possible ecosystem services. This is around 2,5 t and 25 000 of flying insect which are not removed by swifts every season and could be nuisance for people of Poznan and surrounding areas.

23 M. Bocheński et al., *Ochrona ptaków w mieście*, Gorzow Wielkopolski 2013.

24 M. Luniak, *Bogactwo gatunkowe i liczebność fauny wielkiego miasta – przykład Warszawy*, in: P. Indykiewicz, L. Jerzak, T. Barczak (ed.) *Fauna miast. Ochronić różnorodność biotyczną w miastach*, Bydgoszcz, 2008, p. 17–26.

Discussion

This loos in population is a significant and similar to the one estimated by Brzozowska[25] in Szczecin. The difference between two methods of estimating how much birds were living on Osiedle Mlodych was very low (7%), so it could be close to the actual number of birds living on this area before renovations took place.

In this study only breeding pairs of swifts were taken into consideration, real benefits could be much bigger because there are also many birds which do not breed (e.g. young swift which reaches sexual maturity after 3 years). In this case, the proportion of such birds in present population of swifts should be similar in the population that has been occurring. So estimated proportion of loss should be also valid in this case. There is need of research to estimate how many there are nonbreeding birds and how much they eat while they do not feed nestlings.

It is very likely that the similar decline in population and ecosystem services occurred on other residential blocks in Poznan. Also, the situation of other birds which use building to breed should be similar, especially for sparrows (*Passer domesticus*), jackdaws (*Corvus monedula*) and kestrels (*Falco tinnunculus*).

There are many positive examples of activities undertaken by local authorities in cities like Amsterdam, Aylesbury, Basel, West Sussex and Zurich which lead to maintaining their swifts populations[26]. CPSD hopes that it will be also possible in Poznan thanks to using ecosystem services provided by these birds to promote their protection.

Ecosystem services provided by big colony of common swifts seems to significantly reducing population of flying insect. This service should be similar in other cities in the same climate zone as Poznan.

Conclusions

The substantial decline in population of swift occurred in Poznan and this is also a significant amount of lost benefits in reduction of bothersome insect population. The reason of this seems to be an unsupervised process of thermo-modernization which leads to not introducing compensation of lost habitats.

Till now CPSD was using ecosystem services without quantifiable values and it did not cause any change in actions of authorities and housing associations in Poznan. Now we have such data and we will be testing how this knowledge will affect their decisions.

25 Z. Brzozowska, op. cit.

26 E. Mayer, *Swift Facts*, www.swift-conservation.org [10–10–2016].

Literature

Abdar M.R., *Seasonal Diversity of Birds and Ecosystem Services in Agricultural Area of Western Ghats, Maharashtra State, India*, "Journal Of Environmental Science, Toxicology And Food Technology" 2014 no. 8(1), p. 100–105

Bocheński M. et al*., Ochrona ptaków w mieście*, Gorzow Wielkopolski 2013

Brzozowska Z., *Situation in Poland p 1 In: The 1st Common swift Seminars, Berlin 8th – 11th April 2010 Summaries of the presentations*, 2010

CCI and BirdLife International, *Measuring and monitoring ecosystem services at the site scale*, Cambridge 2011

Cel'uch M. et al*., Will the Common Swift survive in Slovakia?, in: Report and summaries of the presentations, and additional contributions, given to The Second Commonswift Seminars Berlin*, *10th–12th April 2012*, p. 6

Graszka-owski D., *Ptaki. Profesjonalny przewodnik dla początkujących obserwatorów*, Warszawa 2005

Grzeniewski M., Kowalski M., *Ochrona ptaków gniazdujących w budynkach*, Siedlce 2010

Kamiński P., *Bioenergetische Untersuchungen zur Jugendentwicklung der Dohle Corvus monedula*, "Journal of Ornithology" 1986 no. 127, p. 315–329

Kostecka J., *Edukacyjne znaczenie pojęcia świadczenie ekosystemów dla ochrony awifauny miast*, "Inżynieria Ekologiczna" 2010 no. 22

Kronenberg J. et al., *The importance of White Stork Ciconia ciconia for society: an analysis from the perspectve of ecosystem services*, "Chrońmy Przyrodę Ojczystą" 2013 no. 69(3), p. 179–203

Kruszewicz G., *Ptaki Polski*, Warszawa 2005

Linnaeus C., *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis,* Holmiæ 1758

Luniak M., *Awifauna miasta – jej skład, zróżnicowanie oraz udział w procesach ekologicznych*, in: H. Zimny (ed.), *Funkcjonowanie układów ekologicznych w warunkach zurbanizowanych,* Warszawa 1990

Luniak M., *Bogactwo gatunkowe i liczebność fauny wielkiego miasta – przykład Warszawy*, in: P. Indykiewicz, L. Jerzak, T. Barczak (ed.) *Fauna miast. Ochronić różnorodność biotyczną w miastach*, Bydgoszcz 2008

Luniak M., *Ochrona ptaków a modernizacja budownictwa*, in: P. Indykiewicz, L. Jerzak, T. Barczak (ed.), *Fauna miast. Ochronić różnorodność biotyczną w miastach*, Bydgoszcz 2008

Martins T.L.F., *Fledging in the common swift, Apus apus: weight-watching with a difference*, "Animal Behaviour" 1997 no. 54(1), p. 99–108

Martins T.L.F., Wright J*., Cost of reproduction and allocation of food between parent and young in the swift (Apus apus)*, "Behavioral Ecology" 1993 no. 4, p. 213–223

Mayer E., *Swift Facts*, www.swift-conservation.org

Mikula P., Hromada M., Tryjanowski P*., Bats and Swifts as food of the European Kestrel (Falcotinnunculus) in a small town in Slovakia,* "Ornis Fennica" 2013 no. 90, p. 178–185

Nowicki W., *Ptaki Śródmieścia Warszawy*, Warsaw 2001

Ptaszyk J., *Ptaki Poznania – stan jakościowy i ilościowy oraz jego zmiany w latach 1850–2000*, Poznan 2003

Risely K. et al., *The Breeding Bird Survey 2012*, Thetford 2013; M. Cel'uch, et al., *Will the Common Swift survive in Slovakia?,* in: *Report and summaries of the presentations, and additional contributions, given to The Second Commonswift Seminars Berlin*, 10th–12th April 2012

Sicurella B. et al., *Weather conditions, brood size and hatching order affect Common Swift Apus apus nestlings' survival and* growth, "Bird Study" 2015 no. 62, p. 64–77

Smeets E., Weterings R., *Environmental indicators: Typology and overview, Technical report No 25/1999*, Copenhagen 1999

Tigges U., *Common swift*, www.commonswift.org

Tomiałojć L., Stawarczyk T., *Awifauna Polski, rozmieszczenie, liczebność i zmiany,* t. 2, Wrocław 2003

Wenny D.G. et al., *The need to quantify ecosystem services provided by birds*, "The Auk" 2011 no. 128(1), p. 1–14

www.mapaptakow.pl

Zimny H., *Ekologia miast*, Warszawa 2005

Zyskowski D., Zielińska D., *Przewodnik do inwentaryzacji oraz ochrony ptaków i nietoperzy związanych z budynkami*, Szczecin 2014

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POTENTIAL OF PROVISIONING AND REGULATING ECOSYSTEM SERVICES IN POSTGLACIAL LANDSCAPE

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POTENCJAŁ EKOSYSTEMÓW DO ŚWIADCZENIA USŁUG ZAOPATRZENIOWYCH I REGULACYJNYCH W KRAJOBRAZIE MŁODOGLACJALNYM

STRESZCZENIE: W niniejszym artykule zaprezentowano wyniki badań nad przestrzennym zróżnicowaniem potencjału ekosystemów do dostarczania wybranych usług zaopatrzeniowych i regulacyjnych. Każde z wybranych do prezentacji świadczeń (cztery usługi zaopatrzeniowe – plony zbóż, miód, biomasa zwierząt kopytnych, zapas drewna na pniu; jedna usługa regulacyjna –sekwestracja węgla w glebie) jest przykładem innego podejścia do definiowania i obliczania wskaźników określających potencjał do świadczenia usług. Wyniki zróżnicowania przestrzennego potencjałów przedstawiono na mapach, obejmujących trzy gminy z Polski północno-wschodniej.

SŁOWA KLUCZOWE: potencjał ekosystemów, plony zbóż, miód, zwierzęta łowne, zapas drewna na pniu, sekwestracja węgla, usługi ekosystemowe

Introduction

The general objective of the study was to present different methods for identification and assessment of ecosystem services provided by various ecosystems in postglacial landscape. Our study focused on ecosystem-oriented approach in which the potential of ecosystems to deliver goods and services was analyzed. Other approaches, e.g. society-oriented (dealing with goods and services demands) or process-oriented (focused on uptake of goods and services) were applied only additionally.

Five ecosystem services were selected for the analysis: four provisioning services (harvested crops, honey, ungulate biomass, timber standing crop) and one regulating service – carbon sequestration in soils. Each of them represents different approach for defining and calculating measures and indicators of ecosystem potential. The place of chosen services in the scheme of Common International Classification of Ecosystem Services (CICES)[1] is presented in table 1. Results of estimation of spatial differentiation of ecosystem potential are presented on maps covering three communes in north-eastern Poland.

Table 1. Place of chosen ecosystem services in Common International Classification of Ecosystem Services (CICES)

Section	Division	Group	Class	Ecosystem service
Provisioning	Nutrition	Biomass	Cultivated crops	Cereals (eg. wheat, rye, barely)
			Reared animals and their outputs	Honey
			Wild animals and their outputs	Game
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Timber
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by ecosystems	Filtration/ sequestration/ storage/ accumulation by ecosystems	Carbon sequestration

Ecosystem potential is understood as an ecosystem capacity to deliver (supply) goods and services[2]. The individual ecosystem capacities to supply services are strongly linked to:

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1 R. Haines-Young, M. Potschin, *Common International Classification of Ecosystem Services (CICES): Consultation on version 4, August-December 2012*, EEA Framework Contract No EEA/IEA/09/003, 2013.

2 B. Burkhard et al., *Mapping ecosystem service supply, demand and budgets*, "Ecological Indicators" 2012 no. 21, p. 17–29.

- natural conditions; e.g. natural land cover (vegetation foremost), hydrology, soil conditions, fauna, elevation, slope and climate;
- human impacts; mainly land use but also emissions, pollution, etc.

Flow of ecosystem services is influenced not only by the capacity of a certain ecosystem, but also by human needs and the desired level of provision for this service by society, which connects inseparably supply and demand of ecosystem services[3]. Ecosystems provide the necessary structures and processes, which in turn define the capacity or potential to deliver services. Ecosystem supply is the full of potential ecological functions or biophysical elements in an ecosystem to provide a potential service, irrespective of whether humans currently use or value that function or element[4].

Study area

The survey was carried out in three rural communes – Giby, Nowinka and Suwałki in north-east Poland (Podlaskie voivodeship) (figure 1). Study area encompasses 796 km^2. Relief and morphology were shaped by glacial and peri-glacial geomorphologic processes. Forests cover over 54% of the area, while arable lands about 13% and grasslands over 17%. Lakes cover about 5%. Lands of great natural value comprise a significant part of the study (e.g. Wigry National Park, Natura 2000 sites). The average population density of the studied communes accounts for 12 inhabitants/km^2 [5].

Three communes differ in the structure of land use and in the intensity of anthropogenic changes. The Giby commune, dominated by forests (approx. 75 %), is characterized by a large number of lakes, and almost lack of industry. The large coverage of Natura 2000 sites (over 80%) confirms the high nature value in the commune.

The Nowinka commune is characterized by the predominance of forests (approx. 60%) that are part of the Wigry National Park and the Augustów Forest. Farmland comprise approx. 27% of the commune. A significant area is occupied by waters here. The commune is dominated by protected natural ecosystems, which occupy 84% of the area. Natura 2000 sites cover 78%. The biggest advantage of the commune is the beautiful landscape, tourism and rich peat deposits.

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3 O. Bastian et al., *The five pillar EPPS framework for quantifying, mapping and managing ecosystem services*, "Ecosystem Services" 2013 no. 4, p. 15–24.

4 H. Tallis et al., *A Global System for Monitoring. Ecosystem Service Change*, "BioScience", 2012 no. 62 (11), p. 977–986; J. Maes et al., *Mapping ecosystem services for policy support and decision making in the European Union*, "Ecosystem Services" 2012 no.1(1), p. 1–122.

5 Bank Danych Lokalnych (Local Data Bank), 2016, www.bdl.stat.gov.pl [20–10–2016].

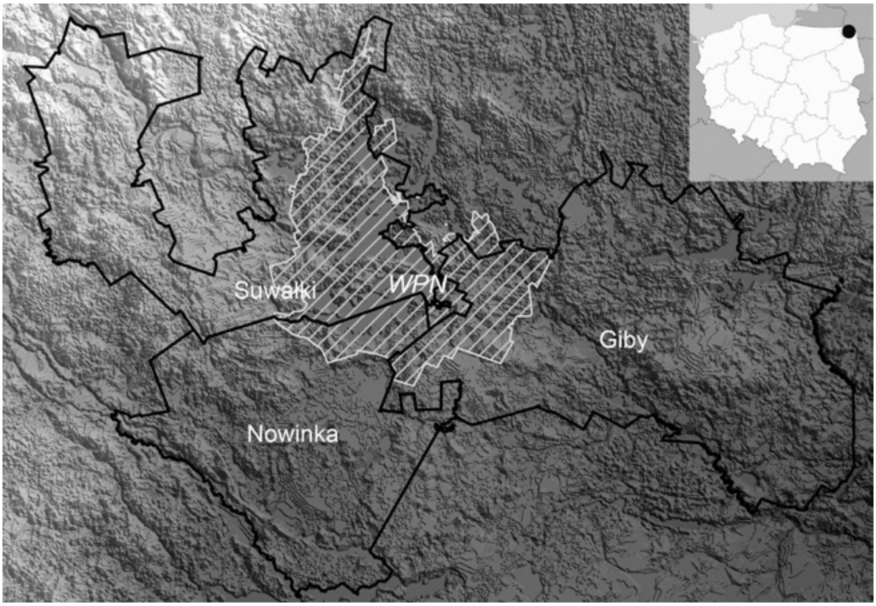

Figure 1. Study area

Source: elaborated by B. Kruczkowska.

The Suwałki commune has an agro-forest character. Farmlands constitute approx. 55%, while forests – 29%. Agriculture, successfully developed on the plains, play a dominant role in the economy of the commune. Farmlands are managed mostly (approx 84%) by individual farmers. The characteristic feature of agriculture in the Suwałki commune is the diversity of production, and the dominance of dairy cattle and pigs.

Data and Methods

Basic spatial units

Two types of basic spatial units were used for presentation of results:

- the hunting units (official spatial division specified for breeding, protecting and obtainment of wild animals) – for analysis for the potential provision of ungulates biomass;
- ecosystems and ecosystem types – for the rest of analysed services[6].

[6] The final map includes 3146 separate patches (ecosystems) belonging to 44 ecosystem types of which 25 are different categories (age and habitat) of forests, three categories of grassland, three types of arable fields, four categories of wetlands, six classes of lakes, one category represents rivers and the last one – built-up areas (B. Kruczkowska et al., *Map of ecosystems – concept and realization,* "Geographia Polonica" (in preparation).

Potential harvested crops from agro-ecosystems

Cultivation of edible plants used for human nutrition is a basic provisioning service from agro-ecosystems that is usually quantified using harvested crops[7]. In this research potential supply of agro-ecosystem services was estimated employing the indicator of agricultural production spatial valorisation IAPSV[8], which is based on the assessment of soil quality, climate, relief and water conditions. These factors are considered to have the greatest influence on yields on the local scale (a commune level). Each natural factor was defined using adequate parameter and was weighted reflecting its influence on agro-ecosystem productivity[9]. To calculate the indicator data from soil maps, slope maps based on DEM, maps of soil water retention and statistical data on cereal crops from the Local Data Bank of Central Statistical Office were used. In theory, the indicator can range from 19.5 to 119 points (below 30 means very poor arable lands, 30–59 – poor, 60–79 – good, above 80 – very good). The final cereal crops' potential from each agro-ecosystem was quantified using the indicator value substituted into one of the regression equations (y = -0,339 + 0,541x) developed for different regions in Poland[10].

Potential honey production

To construct an indicator and then to map the potential honey production a more detailed definition of potential was proposed. It this understanding, ecosystem potential refers to a maximum theoretical honey supply from a given type of ecosystem and in the particular regional context, calculated for environmental setting (e.g. plant species composition, soil qualities, water balance etc.) best suited for honey production. This means that, for instance, to calculate honey potential of cropland located on fertile soil one needs to pick a crop (cultivated in the region on such a soil) that has the highest honey potential (bees can produce the largest amount of honey out of a hectare of a given crop).

7 R. Haines-Young, M. Potschin, *Common International Classification of Ecosystem Services (CICES): Consultation on version 4, August-December 2012*, EEA Framework Contract No EEA/IEA/09/003, 2013; M. Kandziora et al., *Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution*, "Ecosystem Services" 2013 no. 4, p. 47–59.

8 T. Witek (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski wg gmin*, Puławy 1981; T. Witek (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski wg gmin. Suplement*, Puławy 1994.

9 T. Witek, T. Górski, *Przyrodnicza bonitacja rolniczej przestrzeni produkcyjnej w Polsce*, Warszawa 1977.

10 K. Filipiak, *Ocena wykorzystania rolniczej przestrzeni produkcyjnej w Polsce w ujęciu regionalnym,* "Pamiętnik Puławski" 2003 no. 132, p. 73–79.

To estimate ecosystem potential for honey production, we took into account the quality of a bee pastures, namely, the abundance and accessibility of honey sources (nectar and honeydew) and pollen (a necessary nutrition for a bee family to function properly)[11].

The amount of nectar and pollen potentially produced by an ecosystem is directly linked to the actual floral resources of a plant community and its melliferous potential. This, in turn, is determined by plant species composition and honey potential of single species. The honey potential of individual plants was taken from The Great Atlas of Melliferous Plants [in Polish][12], which includes information on nectar secretion and pollen production for over 250 melliferous plants in temperate climate. Recognition of key honey species within types of ecosystems was based on the available phytosociological relevés (frequency of species established according to Braun-Blanquet[13]) taken in the study area and the general typologies of plant communities presenting species composition and dominance structure for Central Europe[14]. Crane and Walker[15], based on Haragsim work[16], listed trees that are important sources of honeydew, along with the information on the honey potential available in terms of yield per hectare.

For the indicator of potential honey production an ordinal scale from 0 to 5 was applied, where 0 means no relevant capacity to deliver a service, and 5 means very high relevant capacity. The scale corresponds to the maximum possible annual honey yields per hectare of a given ecosystem [kg/ha].

Potential ungulate biomass

Hunting data (number of animals) from the annual hunting reports (2011–2014), covering 14 hunting units and the Wigry National Park served as basic material research to assess ungulate biomass. The detailed data we obtained from four forest districts (Suwałki, Szczebra, Pomorze, Głęboki Bród) and the Wigry National Park. Four species of big game animals were taken into account: moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and wild boar (*Sus scrofa*).

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11 E. Crane, *Bees and beekeeping: science, practice and world resources*, Oxford 1990; P. Westrich, *Habitat requirements of central European bees and the problems of partial habitats*, in: A. Matheson et al. (eds)*, The Conservation of Bees*, London 1996, p. 1–16.

12 Z. Kołtowski, *Wielki Atlas Roślin Miododajnych,* Warszawa 2006.

13 J. Braun-Blanquet, *Pflanzensoziologie*. "Grundzüge der Vegetationskunde, Pflanzensoziologie Grundzüge der Vegetationskunde" Wien 1964.

14 W. Matuszkiewicz, *Przewodnik do oznaczania zbiorowisk roślinnych Polski*, Warszawa 1981.

15 E. Crane, P. Walker, *Important honeydew sources and their honeys,* "Bee World" 1985 no. 66, p. 105–112.

16 O. Haragsim, *Medovice a včely*. "Státní zemědělské nakl", Praha 1966.

Ungulate biomass was calculated as the total biomass (kg / 100 ha) of the moose, red deer, roe deer and boar, according to the formula: ∑ (species density * unit weight). The following assumptions were adopted: (a) each population is evenly divided into males and females; (b) the unit weight (kg) of an animal is: for moose – male 400, female 300; for red deer – male 120, female 80; for roe deer 25; for boar – male 120, female 90.

Timber standing crop

We define timber standing crop as thickness (volume in cubic meters) of wood in the stands (merchantable timber) in a given area. The basic material research to assess volume of timber standing crop was derived from administrative units of four forest districts (Suwałki, Szczebra, Pomorze, Głęboki Bród) and the Wigry National Park. It covered approx. 16 000 records originally addressed to local forest sites showing volume of timber standing crops. Data of age of tree species allowed to calculate the volume of timber in five age stand categories (0–40; 40–60; 60–80; 80–120; >120) in each site in forest communities corresponding to the legend presented on the map of ecosystems. Spatial differentiation of the volume of timber crop is presented on the map of ecosystems in five types of forest communities: alder forest, riparian forest, oak-hornbeam forest, pine and mixed pine forest and swamp/bog forest.

Carbon sequestration in the soils

Forty nine undisturbed soil samples were collected from 18 points in different ecosystem types. Total organic carbon content (TOC) in mineral and organic-mineral samples was analysed using the Tiurin method, while that in organic samples was assessed using the Alten method. TOC capital in the soils to the depth of 50 cm was calculated by the formula:

$$TOC_{(capital)} = \frac{h \cdot D \cdot TOC}{10} \cdot (1-q)$$

where:
$TOC_{(capital)}$ – capital of TOC in soils,
h – thickness of soil horizon,
D – bulk density,
TOC – content of TOC in soil horizon,
q – soil skeleton [%]/ 100

Map of soils was adapted to the scale of the map of ecosystems. To determine the content of TOC in soils of each of studied ecosystems, calculation results were counted into areas occupied by each ecosystem type.

Results

Spatial differentiation of indicator values for the provisioning ES

Potential harvested crop from agro-ecosystems

In the research, the indicator of agricultural production spatial valorisation takes the values from 25 to 93. Over 55% of cropland belongs to very poor arable lands category, associated with soils formed from sands, poor in nutrients and usually permanently too dry. Only 26% of cropland constitutes good and very good arable lands with soils rich in nutrients and organic matter, with regulated water conditions. Potential harvested cereal crops from the studied agro-ecosystems amount to 13.2–50 dt ha^{-1} year^{-1} (figure 2), with the average crop 26.5 dt ha^{-1} year^{-1}.

Figure 2. Potential harvested cereal crops [dt/ha/year]

Source: elaborated by A. Kowalska.

Potential honey production

The highest potential to produce honey was achieved by cropland located on fertile soils, assuming that the selected crop would be most suited for honey production (e.g. phacelia – *Phacelia tanacetifolia* or buckwheat – *Fagopyrum esculentum*). Those plant species can give up to 300 kg of honey per hectare when forming continuous monocultures. According to our estimations, grassland on dry and fresh mineral substrate along with young swamp pine forests have also one of the highest capacity to provide honey. The lowest capacity was assigned to alder forest, riparian forest and wetlands, as they constitute, apart from water bodies and other non-vegetated areas, the poorest bee pasture. Honey potential of forest ecosystems was differentiated in relation to forest age in such a way that the youngest and the oldest tree stands were assigned higher values than middle age and mature forests (see Taki et al.[17]).

Higher honey potential could be found in the north-western part of the area, were grassland and cropland are dominant ecosystem types (figure 3).

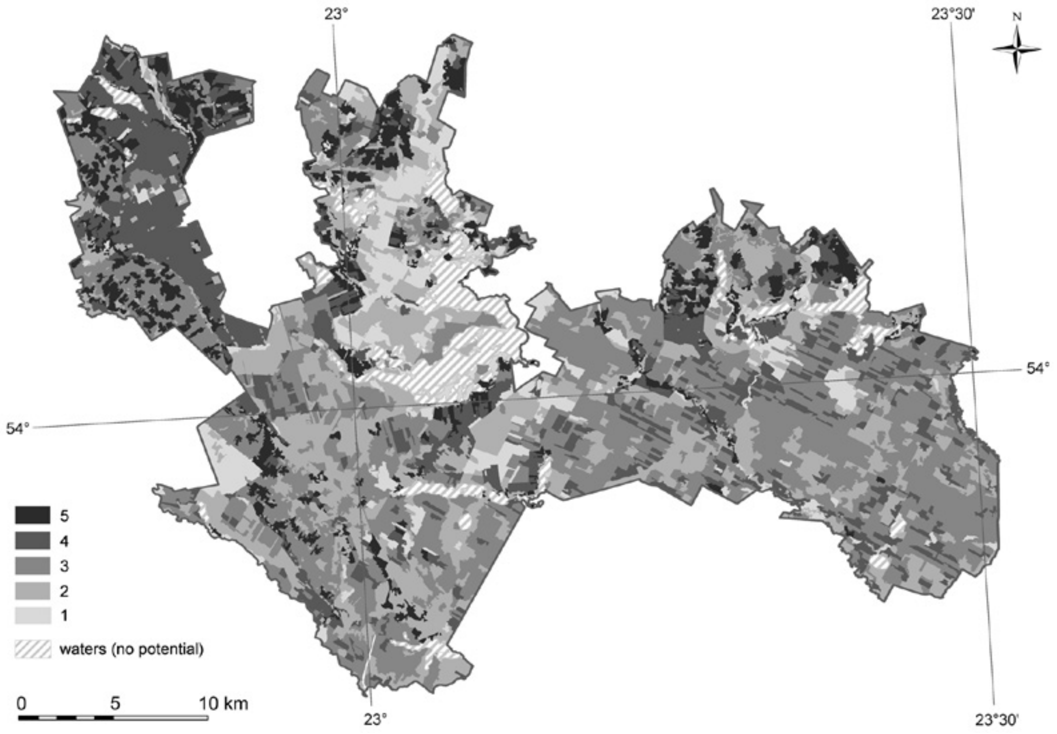

Figure 3. Potential honey production [kg/ha]

The value of 5 means high relevant capacity [approx. 300 kg/ha], whereas 1 – low relevant capacity. Waterbodies and other non-vegetated areas were assigned 0 Source: elaborated by A. Affek.

17 H. Taki et al., *Succession influences wild bees in a temperate forest landscape: the value of early successional stages in naturally regenerated and planted forests*, "PLoS ONE" 2013 no. 8.

Apart from fertile grassland in the eastern part of Wigry NP, the rest of the Park, being covered by mature forest, has relatively low potential for honey production. In contrast, patches of young forest stands and clearings within vast areas of managed pine forests (outside WNP) may provide considerable amount of nectar and pollen.

Potential ungulate biomass

Ungulate biomass varies from approx. 40 kg to about 600 kg/100 ha among hunting units. The greatest resource of wild ungulates is in the units with the proportion of forests between 60% and 80%, mainly in the forest hunting units of Giby and at some of the hunting units of Nowinka. The lowest value of biomass was reported in hunting units in the Suwałki commune and in northern part of Giby with a small proportion of forests (approx. 6 to 15%), (figure 4).

Figure 4. Potential ungulate biomass [kg/100 ha]

Source: elaborated by B. Grabińska and J. Solon.

From the point of view of land cover structure, the last one have mainly open-space character with dominance of fields, meadows and pastures.

The majority of game animal species are associated with various forest habitats. The percentage shares of habitat types in forests and the density of the animals constitute two closely interrelated elements. The greatest potential to deliver wild ungulate biomass is in the area with the highest proportion of forests. In contrast, the lowest resource of ungulates was reported on farmland and grassland. That spatial diversity of ungulate biomass in most cases is linked with the diversity of habitats and types of ecosystems.

3.1.4. Timber standing crop

The results of calculation of timber standing crop in each age category show that the smallest supply of wood is in youngest forests (0–40 years) and gradually increases with age stand. Maximum potential to deliver timber was achieved for the d-age category of stands (80–120 years). The Wigry National Park appeared to have significantly larger average volume of timber compared to four forest districts. That trend is observed in four types of forest communities: alder forest, riparian forest, oak-hornbeam forest and in pine and mixed pine forest. The last one is selected to illustrate the trend described above (figure 5).

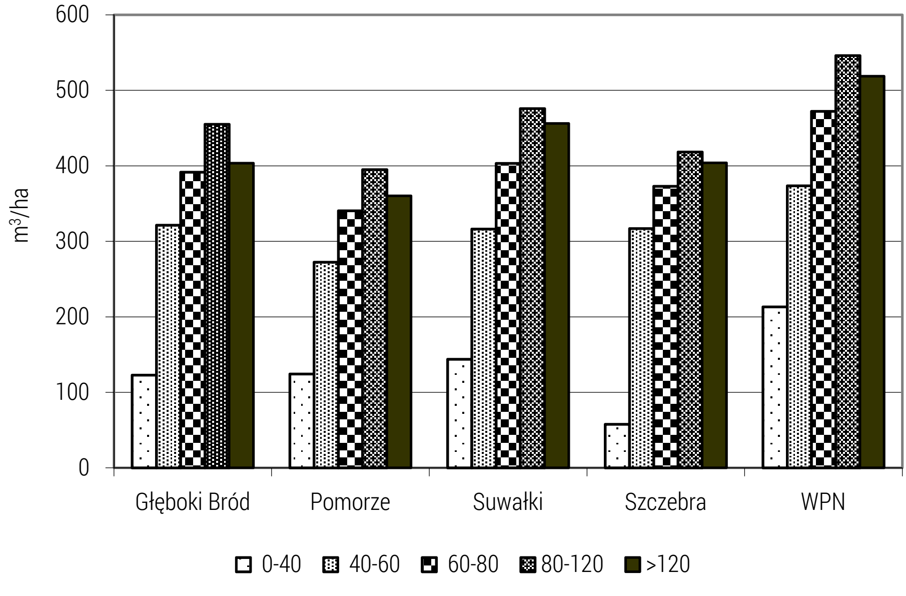

Figure 5. Volume of timber in different age categories of pine and mixed pine forests in four forest districts and in the Wigry National Park

Source: elaborated by E. Roo-Zielińska.

Spatial differentiation of the volume of timber standing crop presented on the map shows very clearly almost lack of potential to deliver timber in Suwałki (especially in the north part), which is mostly farmland. In turn, much higher values of timber volume was reported in the majority of the Wigry National Park and in the highly forested Giby commune, where we can find forests with more than 500 m^3/ha of timber volume. Some parts of Nowinka commune, especially adjacent to the Wigry National Park, are characterized by a rather big volume of timber standing crop (400–500 m^3/ha), (figure 6).

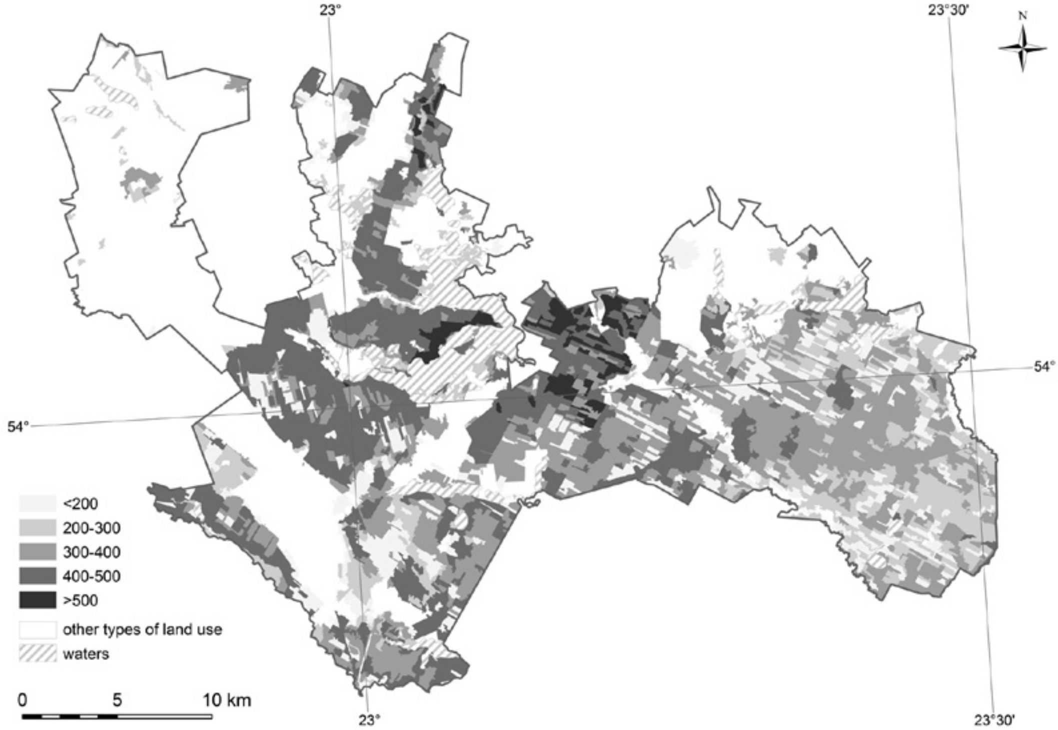

Figure 6. Volume of timber standing crop [m^3/ha]

Source: elaborated by E. Roo-Zielińska and J. Wolski.

Spatial differentiation of indicator values for regulating ES

The study area is located in post-glacial landscape, which is characterized by the occurrence of many land forms developed as a result of glacier waters and ice-sheet impact. The soils of the study area developed from post-glacial sediments – glacial and fluvioglacial sands and tills, which influenced soil texture diversity – one of the main factors essential for the development of the particular soil type. Each type of ecosystem is characterized by different content of TOC.

The highest values are observed mainly in Histosols and Haplic Luvisols (WRB 2014) of wet habitats, both forest, grassland and arable, what is also correlated with at least sandy loam soil texture (mineral soils) and organic substrate. High content of TOC is characterized especially for swamps-swards, reedbeds, sedges (5478 t/ha), eutrophic mire (5250 t/ha), all categories of alder carr, riparian alder-ash forests and swamp coniferous forests and mixed swamp coniferous forests (2184–4683 t/ha). The low values (minimum 313 t/ha) are characteristic for all age categories of coniferous forests and mixed coniferous forests, grasslands and crop fields on mineral habitats (figure 7).

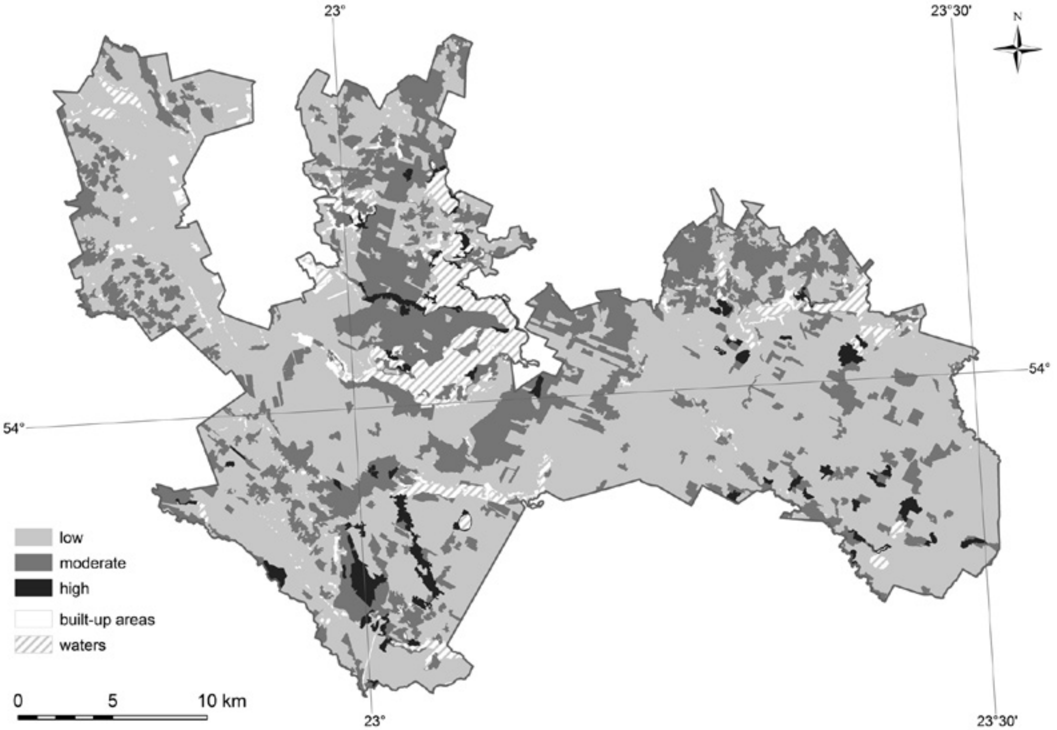

Figure 7. Content of Total Organic Carbon (TOC) in soils [t/ha]

Source: elaborated by B. Kruczkowska.

Final Remarks

Methods applied for calculation of ecosystems' potential for delivering goods and services, described in this paper, represent wide spectrum of methodical approaches. The differences between them are shown in table 2 in s shortened form. It is worth to underline that we use simple direct method (as for timber standing crop), compound direct indicators (as for potential ungulate biomass), as well as compound indirect approaches resulting in surrogate indicators (as for potential honey production).

Table 2. Comparison of approaches to calculate indicators of chosen ecosystem services

Ecosystem service	Input data	Calculation steps
Potential crop yield from agro-ecosystems	Abiotic data derived from detailed maps (soil quality, relief and water conditions) and general maps (climate), crop yield taken from regional statistical data	Abiotic valorisation of patches according to predefined formulas, calculation of potential yield from regression equation (formulas from literature), generalisation of results for ecosystem types
Potential honey production	Optimal plant species composition of ecosystem types (model based on field data and literature data), maximal supply of nectar, honeydew and pollen by plant species (literature data)	Recalculation of potential honey precursors supply to honey production (formulas and coefficients from literature), separately for ecosystem types
Potential ungulate biomass	Detailed field censuses of number of animals by species and hunting units (data completed by Forest Service and national park)	Recalculation from numbers of animals of different species into total biomass with the help of coefficients derived from literature
Timber standing crop	Treestand volume detailed data for each forest patch (field measurements completed by Forest Service)	Simple averaging by ecosystem types
Carbon sequestration in the soils	Own field data from chosen points, additional data from literature	Spatial extrapolation of point data values based on soil map, generalisation to ecosystem types

Source: elaborated by J. Solon.

The analysis of the spatial differentiation of evaluated or measured services show that each of them represents a unique spatial pattern, which depends of distribution of several elements of the natural environment and/or types of human activities. Depending on the service, there are: abiotic conditions (e.g. harvested crop, carbon sequestration in the soils), land cover structure on the landscape level (e.g. ungulate biomass), type and age categories of forests as well as forest management direction (e.g. timber standing crop), species composition of plant communities, which – in turn – depends on abiotic conditions and land use (e.g. honey).

Simple reclassification of indicators' values (see table 3) and summing up of newly established values made it possible to evaluate the the joint potential of ecosystems for delivering the analysed five services (figure 8).

Table 3. Reclassification of variables' values

New Classes	Original scales				
	crop [dt/ha]	honey [points]	game [kg/100 ha]	timber [m³/ha]	TOC [t/ha]
0	0	0	0	0	0
1	13–15	1	40–100	1–200	1–500
2	15–20	2	100–200	200–300	500–1000
3	20–30	3	200–300	300–400	1000–2000
4	30–40	4	300–400	400–500	2000–4000
5	40–50	5	400–500	500–600	4000–10000

Source: elaborated by J. Solon.

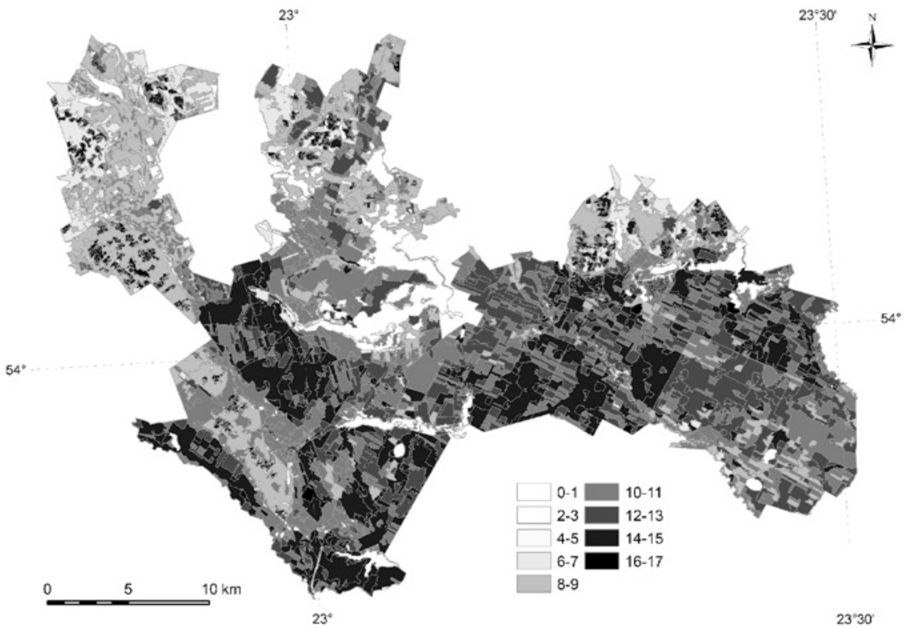

Figure 8. Joint valorization of the ecosystem potential for delivering five analyzed services (original values as on Figs. 2–4 and 6–7 recalculated according to the scheme presented in table 3 and summed up)

Source: elaborated by J. Solon.

The highest possible rank of total potential for a patch is 20 (not 25, as potential crop yield and timber standing crop were calculated for mutually excluding areas), but in fact the real highest rank equals to 17 and occurs on less than 0.2% of the total area. It is worth to notice than ca. 80 % of the analysed area represents ranks between 8 and 15, what means that almost all types of ecosystems have the meaningful potential for delivering more than one service. The highest potential is characteristic for mixed and pine forests, as well as for older age classes of boggy pine forests (13–15 points), while the lowest for meadows (7–9 points) and pit bogs and swamps (9–10). The other types of ecosystems (alder carrs, riparian forests, oak-hornbeam forests, arable fields) are of intermediate character (the sum of ranks is in the range from 8 to 12). This results show clearly that for all theoretical and practical purposes ecosystems (and their landscape complexes) should be treated as multifunctional entities.

At the end it is necessary to underline that our study was conducted in a local scale, what influenced all the methodical approaches. The choice of methods for identification, estimation and evaluation of the ecosystems' potential for selected services, their indicators and measures depends on the geographical scale (local, regional, general). First of all, the following elements should be taken into account to determine the proper spatial unit (ecosystem / hunting unit / landscape) for the evaluation of a particular service: (1) land cover structure, (2) biotic factors (vegetation and fauna), (3) abiotic factors (type of soils, climatic conditions) and (4) anthropogenic pressure (intensity of forest management, silviculture, forest practices and forest policy).

Methodical approaches adopted in our study as well as results obtained may serve as a roadmap for other studies conducted in similar spatial scales.

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Literature

Bank Danych Lokalnych (Local Data Bank*)*, 2016, www.bdl.stat.gov.pl

Bastian O. et al., *The five pillar EPPS framework for quantifying, mapping and managing ecosystem services*, "Ecosystem Services" 2013 no. 4, p. 15–24

Braun-Blanquet J., *Pflanzensoziologie*. "Grundzüge der Vegetationskunde, Pflanzensoziologie Grundzüge der Vegetationskunde" Wien 1964

Burkhard B. et al., *Mapping ecosystem service supply, demand and budgets*, "Ecological Indicators" 2012 no. 21, p. 17–29

Crane E., *Bees and beekeeping: science, practice and world resources*, Oxford 1990

Crane E., Walker P., *Important honeydew sources and their honeys,* "Bee World" 1985 no 66, p. 105–112

Filipiak K., *Ocena wykorzystania rolniczej przestrzeni produkcyjnej w Polsce w ujęciu regionalnym,* "Pamiętnik Puławski" 2003 no. 132, p. 73–79

Haines-Young R., Potschin M., *Common International Classification of Ecosystem Services (CICES): Consultation on version 4, August-December 2012*, EEA Framework Contract No EEA/IEA/09/003, 2013

Haragsim O., *Medovice a včely*. "Státní zemědělské nakl", Praha 1966

Kandziora M. et al., *Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution*, "Ecosystem Services" 2013 no. 4, p. 47–59

Kołtowski Z., *Wielki Atlas Roślin Miododajnych,* Warszawa 2006

Kruczkowska B. et al., *Map of ecosystems – concept and realization,* "Geographia Polonica" (in preparation)

Maes J. et al., *Mapping ecosystem services for policy support and decision making in the European Union*, "Ecosystem Services" 2012 no.1(1), p. 1–122

Matuszkiewicz W., *Przewodnik do oznaczania zbiorowisk roślinnych Polski*, Warszawa 1981

Taki H. et al., *Succession influences wild bees in a temperate forest landscape: the value of early successional stages in naturally regenerated and planted forests*, "PLoS ONE" 2013 no. 8

Tallis H. et al., *A Global System for Monitoring. Ecosystem Service Change*, "BioScience", 2012 no. 62 (11), p. 977–986

Westrich P., *Habitat requirements of central European bees and the problems of partial habitats*, in: A. Matheson et al. (eds)*, The Conservation of Bees*, London 1996

Witek T. (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski wg gmin*, Puławy 1981

Witek T. (ed.), *Waloryzacja rolniczej przestrzeni produkcyjnej Polski wg gmin. Suplement*, Puławy 1994

Witek T., Górski T., *Przyrodnicza bonitacja rolniczej przestrzeni produkcyjnej w Polsce*, Warszawa 1977

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CULTURAL SERVICES PROVIDED BY URBAN ALLOTMENT GARDEN ECOSYSTEMS

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KULTUROWE ŚWIADCZENIA EKOSYSTEMOWE MIEJSKICH OGRODÓW DZIAŁKOWYCH

STRESZCZENIE: Zidentyfikowano 64 kulturowe świadczenia ekosystemowe dla miejskich ogrodów działkowych, na podstawie własnych studiów terenowych i literatury przedmiotu. Wpasowano je w ramy klasyfikacji CICES v.4.3. Reprezentują najniższy poziom tej klasyfikacji – typ klasy. Należą do jednej sekcji (kulturowych), dwóch działów, trzech grup i ośmiu klas. Wszystkie zestawiono w tabeli i przedyskutowano w świetle najnowszych publikacji naukowych.

SŁOWA KLUCZOWE: ekologia miasta, ekosystem miasta, ogród działkowy, świadczenia ekosystemów, zielona infrastruktura

Introduction

Among the quality of life factors in cities, the availability of the green infrastructure and possibility of the passive or active using it are of growing importance. Urban allotment gardens (UAGs) are a significant element of the green infrastructure. They are characterized by a high level of biodiversity, native species predominate in their spontaneous flora. The basic part of the biotic structure are cultivated plants[1], thus in this respect, UAGs are similar to urban home gardens. The common features of these two types are green sites is the similar level of provisioning and regulating ecosystem services. UAGs are positive distinguished, however, by specific cultural ecosystem services (CES). This results, amongst other things, from their location outside the permanent residents of users. J. Breuste[2] paid attention to the position of UAGs that indicated their intra-urban locations and the tradition of usage for growing fruits and vegetables. Recently, several papers use ecosystem services approach for consideration of benefits, which UAGs provide to their holders. J. Langemeyer et al.[3] gave an overview of the services offered by allotment gardens in Europe. A. Speak et al.[4] discussed the differences between the services provided by UAGs and parks in Manchester and Poznań. Camps-Calvet et al.[5] reported on the perception of services delivered by UAGs in Barcelona from the allotment users' point of view.

An attempt at summarizing the position of allotment gardens in the social-ecological system is the monograph by S. Bell et al.[6] It presents results of the multidisciplinary research carried out in the framework of the COST Action TU1201 Urban Allotment Gardens in European Cities – Future, Chal-

1 J. Borysiak, A. Mizgajski, A. Speak, *Floral biodiversity of allotment gardens and its contribution to urban green infrastructure*, "Urban Ecosystems" 2016, pp. 1–13.

2 J. Breuste, *Allotment gardens as part of urban green infrastructure: Actual trends and perspectives in Central Europe*, in: N. Müller, P. Werner, J.G. Kelcey (eds), *Urban Biodiversity and Design*, 2010, pp. 463–476.

3 J. Langemeyer, M.J. Latkowska, E.N. Gómez-Baggethun, *Ecosystem services from urban gardens*, in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016, pp. 115–141.

4 A. Speak, A. Mizgajski, J. Borysiak, *Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity*, "Urban Forestry and Urban Greening" 2015 no. 14, pp. 772–781.

5 M. Camps-Calvet, J. Langemeyer, L. Calvet-Mir, E. Gómez-Baggethun, *Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning*, "Environmental Science and Policy" 2016 no. 62, pp. 14–23.

6 S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016, p. 384.

lenges and Lessons Learned. Polish experience in this area can be particularly valuable as this is a country with the highest number of allotments sites in Europe in relation to population[7].

The existing research findings make it possible to conclude that cultural benefits are of key importance for UAGs holders and this importance has been growing recently.

Cultural benefits are inherent linked to their subjective perception by receivers, hence their different specification in publications. It would be of importance to adopt more or less uniform classification to increase the comparability of diverse studies. The aim of this paper is to present the set of CES provided by UAGs and to attribute the identified categories to the Common International Classification of Ecosystem Services (CICES).

Cultural benefits of UAG ecosystems as an object of research

According to the definition in the Millennium Ecosystem Assessment[8], cultural ecosystem services signify the psychosocial aspects of people-nature interactions. R. Russell et al.[9] reported that CES represent '*intangible dimensions of the links between people and ecosystems that are psychological, philosophical, social, and spiritual and are at the very core of human preferences and values*'. Cultural services constitute one of three sections in the CICES v.4.3[10]. While accepting this classification, one should notice the statement by K.M.A. Chan et al.[11] that most of cultural benefits are produced not only through cultural services but also through provisioning services. D. La Rosa et al.[12] emphasized that '*CES are directly experienced and appreciated by people through ecosystems, thus, unlike other services*'. Publications devoted to ecosystem services provided by UAGs[3,4,5,6] use various approaches to the classification of CES. From the point of view of the CES diagnosis, the ethno-

7 B. Wycichowska, *Przesądzona zmiana polityki państwa w zakresie ogrodnictwa działkowego*, "Przegląd Komunalny" 2013 no. 2, pp. 44–48.

8 *The Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis*, Washington 2005.

9 R. Russell, A.D. Guerry, P. Balvanera et al., *Humans and nature: how knowing and experiencing nature affect well-being*, "Annual Reviews Environment and Resources" 2013 no. 38, pp. 473–502.

10 R. Haines-Young, M. Potschin, *CICES. Towards a common classification of ecosystem services. CICES v.4.3* (January 2013), www.cices.eu [28-09–2016].

11 K.M.A. Chan, T. Satterfield, J. Goldstein, *Rethinking ecosystem services to better address and navigate cultural values*, "Ecological Economics" 2012 no. 74, pp. 8–18.

12 D. La Rosa, M. Spyra, L. Inostroza, *Indicators of cultural ecosystem services for urban planning: A review*, "Ecological Indicators" 2016 no. 61, pp. 74–89.

graphic monograph[13] is particular valuable. It takes into account the main CES included into three groups of interactions between the person and the allotment garden, namely, physical, intellectual and spiritual ones. R. Shelton[14] presented motives that guided him in the arrangement of the plot in a personal account. A.E. van den Berg and M.H.G. Custers[15] indicated the importance of gardening for alleviating stress. M. Ferres and T.G. Townshend[16] have described the current benefits (social, health and well-being) and future opportunities of allotments in the UK. J. Breuste and M. Artmann[17] described the cultural benefits from allotmenteers' perspectives. A few CES from UAGs were characterized by J. Langemeyer et al.[3] Similar research was conducted in Barcelona[6]. Several papers concern the role of gardening activities in an individual's emotional, physical and spiritual renewal[18,19,20,21,22].

Study procedure

The paper presents the results on the identification of cultural benefits provided by UAGs. The investigations base on the expert knowledge of authors, own field study in Poznań's UAGs, scientific papers as well as publications addressed to a wide audience.

13 M. Szczurek, M. Zych (eds), *Dzieło-działka*, Muzeum Etnograficzne im. Seweryna Udzieli w Krakowie 2012, Kraków, p. 382.

14 R. Shelton, *Allotted time, two blokes, one shed, no idea*, Robin Shelton 2006, p. 372.

15 A.E. van den Berg, M.H.G. Custers, *Gardening promotes neuroendocrine and affective restoration from stress*, "Journal of Health Psychology" 2011 no. 16, pp. 3–11.

16 M. Ferres, T.G. Townshend, *The social, health and well-being benefits of allotments: five societies in Newcastle*, "Global Urban Research Unit, Electronic Working Paper" 2012 no. 47, p. 47.

17 J. Breuste, M. Artmann, *Allotment garden contribute to urban ecosystem service: Case study Salzburg, Austria*, "Journal of Urban Planning and Development" 2015 no. 141(3), pp. 1–10.

18 N. Dunnett, M. Qasim, *Perceived benefits to human well being of urban gardens*, "Hort Technology" 2000 no. 10, pp. 40–45.

19 C. Milligan, A. Gatrell, A. Bingley, '*Cultivating health*'*: therapeutic landscapes and older people in northern England*, "Social Science and Medicine" 2004 no. 58, pp. 1781–1793.

20 J.L. Hawkins, K.J. Thirlaway, K. Backx et al., *Allotment gardening and other leisure activities for stress reduction and healthy ageing*, "Hort Technology" 2011 no. 21, pp. 577–585.

21 S.A. Park, K.S. Lee, K.C. Son, *Determining exercise intensities of gardening tasks as a physical activity using metabolic equivalents in older adults*, "Hort Science" 2011 no. 46, pp. 1706–1710.

22 B. Kabiri, L. Balilan, *The analysis of the Iranian garden-therapy process based on the perceptual ecologic theory*, "Journal of Art and Architecture" 2015 no. 1, pp. 5–13.

The presented work follows the research on biodiversity (J. Borysiak et al.[1]) and study on ecosystem services (A. Speak et al.[5]) carried out for UAGs in Poznań. One part of that studies was a questionnaire interview completed by 110 allotment garden users with the help of the researchers. Some questions concerned gardeners opinion to the importance of CES. The results of discourses on CES with members of the management boards of 11 UAGs have been also considered as a significant source of knowledge. We analysed related records in garden chronicles. The identified cultural ecosystem services have been attributed to the Common International Classification of Ecosystem Services CICES v.4.3.

Cultural benefits of UAGs ecosystems

Sixty four cultural ecosystem services on the most detailed level 'class type' of the CICES v.4.3 were identified. They represent 2 divisions, 3 groups and 8 classes (table 1). Numbers of recognized services in the classes are very diverse. This reflects the different detailed perception of individual cultural benefits.

'Intellectual interactions' as the dominating group occurs in 45 class types of benefits clustered in 5 classes. Seeing urban allotment gardens as the subject of research is the largest class, which consists of 14 benefit class types. The class 'Allotment gardening heritage …' contains 12 class types. Similarly extended (10 benefits) is the class 'Enhancing and building family ties and relations with society …'. Former two classes in this group are less numerous: place of gaining and providing knowledge on the nature and allotmenteering (6) and objects of cultural creativity (3). The other smaller two groups: 'Physical and experiential interactions' and 'Spiritual interactions' comprise respectively 10 and 9 class types.

While the table 1 reflects a general state of knowledge, the table 2 illustrates the spread of users real opinions concerning the significance of some CES provided by UAGs in Poznań.

Discussion of results

One of the CES groups provided by UAGs is the physical and experiential interactions between the allotment garden holder and the used ecosystem. Mostly activities performed at the plot are treated as the source of recreation: composting, cutting trees and shrubs, digging, fertilizing, harvesting and processing fruits or vegetables, mowing, raking, sowing and planting, watering, weeding, and also 'do-it-yourself' tasks. They are a simple way of harnessing the healing power of nature and an opportunity for an individual's emotional, physical and spiritual renewal. Hawkins et al.[20] found that allotment gardeners showed significantly lower stress level than other urban inhabitants, who only performed indoor activities. Similarly, A.E. van den Berg and M.H.G. Custers[15] reported that passive relaxation releases the stress more slowly than working in one's allotment. The mental health benefits from private gardens are highly appreciated by people[18]. Fifty percent of allotmenteers in Salzburg would like to reduce the maintenance gardening to have more time to relax[23].

Physical activities in gardens help to fight the dementia syndrome[24]. J.N. Davis et al.[25] documented a positive influence on blood pressure, cholesterol synthesis and body mass. Regular gardening is effective in improving diabetes care[26]. J. Langemeyer et al.[3] quoted the results of study by A. Taylor et al., which document healthy child development under the influence of contact with nature. J.L. Hawkins et al.[20] and S.A. Park et al.[21] concluded that gardening is an excellent motivation to undertake physical activities by older adults. C. Milligan et al.[19] demonstrated that the positive influence of gardening on the quality of life and emotional well-being of older people is greater when these activities are performed in allotments than in home gardens. Such actions in communal gardening sites are called the cultivation of 'therapeutic landscape'[22]. As many as 99% allotmenteers in Poznań found physical well-being benefits to be very important for them (table 2), while psychological well-being benefits were important for 95%. The demographic burden ratio in Poznań increases dynamically, which means society's ageing and an increased demand for healthcare services[27]. Such a demographic change exposes the role of allotmenteering for older adults as a way to actively spend time.

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23 J.H. Breuste, M. Artmann, *Cultural benefits from allotment gardens in Salzburg, Austria*, in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016, pp. 133–134.

24 D. Gębka, K. Kędziora-Kornatowska, M. Podhorecka et al., *Activation of the elderly with dementia syndrome,* "Medical and Biological Sciences" 2015 no. 29, pp. 5–9.

25 J.N. Davis, E.E. Ventura, L.T. Cook et al., *LA Sprouts: A gardening, nutrition, and cooking intervention for Latino youth improves diet and reduces obesity*, "Journal of the American Dietetic Association" 2011 no. 111, pp. 1224–1230.

26 D.L. Armstrong, *A community diabetes education and gardening project to improve diabetes care in a Northwest American Indian tribe*, "Diabetes Educator" 2000 no. 26, pp. 113–120.

27 T. Kaczmarek, M. Walaszek, *4.1. Rozmieszczenie, dynamika i struktura ludności*, in: T. Kaczmarek (ed.), *Koncepcja kierunków rozwoju przestrzennego metropolii Poznań*, Poznań 2015, pp. 63–85.

The level of social cohesion is also related to CES provided by UAGs. Such a social contacts are stronger in Polish than in Austrian AGs[23]. For example (table 2), problems connected with cultivating plants are solved by Poznań allotment holders by looking for help from other allotment users (72% of respondents, including 66% from others gardeners in the same UAGs estate) more often than by searching in specialist publications (24%). Some people (28%) gained knowledge from older family members. A significant part of respondents (42%) gained knowledge through their own experience. Advice was sought from gardening specialists of the UAG District Management only occasionally (4%). In Salzburg, only a half of those surveyed (48%) learned gardening from other gardeners, but they used published information more often[23]. The majority of Poznań gardeners (68%) concluded that allotmenteering requires continuous learning. S. Barthel et al.[28] found that the allotment gardens function as communities-of-practice. Knowledge in allotment gardens are retained and transmitted by imitation of practices, oral communication and collective rituals and habits.

Conclusions

The analysis conducted, systematizes the knowledge about cultural ecosystem services provided by UAGs. The frequent practise of using the CICES as a framework motivated authors to apply it for ordering cultural benefits for people resulting from processes and functions of allotment gardens. Considering that CICES is a general classification, an adjustment to this specific type of urban ecosystem has been implemented.

The completed catalogue of UAGs' CES facilitates to compare the results of studies from different cities with various social-ecological conditions. One can see the presented approach as a reference point for other inventories of cultural services provided by various types of urban ecosystems.

[28] S. Barthel, C. Folke, J. Colding, *Social-ecological memory in urban gardens-Retaining the capacity for management of ecosystem services*, "Global Environmental Change" 2010 no. 20, pp. 255–265.

Table 1. Cultural services provided by urban allotment garden ecosystems

Section	Division	Group	Class	Class type
Cultural services	Physical and intellectual interactions	Physical and experiential interactions	Physical experience of the nature of an allotment garden in situ	Physical experience of: [13,14; and authors' recognition] 1. natural rhythms of nature and their manifestations in the condition of cultivated plants and spontaneous vegetation 2. climate change and its consequences visible in the habits of plant cultivation 3. developmental biology of cultivated plants and spontaneous flora species 4. biodiversity of fauna and flora 5. developmental biology of oppressive weeds 6. developmental biology of cultivation pests and the damage caused 7. taste and nutritional values of cultivated fruits and vegetables
			Using the nature of an allotment garden for recreation: physical and mental, individual and collection, intensive and relaxation	Recreation by: [13,15,23,29,30,31; and authors' recognition] 8. physical activity during gardening: digging, watering, weeding etc. 9. physical activity during: competitions, dances, games, festivals etc. 10. relaxation while: contemplating nature, walking etc.
		Intellectual interactions	Allotment gardens as an object of scientific research	Scientific subjects in publications:[1,28,30,31,32,33,34,35,36,37,38,39] 11. biology and autecology of flora and fauna species

29 E. Duś, *Recreational use and health functions of allotments gardens in the Katowice conurbation,* Poland, "Environmental and Socio-economic Studies" 2014 no. 2.2, pp. 16–25.

30 R. Szkup, *Użytkowanie rodzinnych ogrodów działkowych (ROD) przez społeczność wielkomiejską*, Łódź 2013.

31 A. Adamczewska, J. Janowska, *Występowanie zagrożonych gatunków flory segetalnej na terenie pracowniczych ogrodów działkowych w północnej części Łodzi,* "Acta Universitatis Lodziensis" 1998 no. 13, pp. 165–168.

32 W. Biaduń, *Winter avifauna of Lublin – species composition, distribution and numbers,* "Berkut" 2005 no. 14, pp. 1–23.

33 E. Andersson, S. Barthel, K. Ahrné, *Measuring social-ecological dynamics behind the generation of ecosystem services*, "Ecological Applications" 2007 no. 17, pp. 1267–1278.

34 E. Domene, D. Sauri, *Urbanization and class-produced natures: Vegetable gardens in the Barcelona Metropolitan Region*, "Geoforum" 2007 no. 38, pp. 287–298.

35 D. Figurska-Ciura, K. Łoźna, M. Styczyńska*, Cadmium, lead, zinc and copper contents in selected vegetables and fruit from garden allotments of the South-Western Poland,* "Polish Journal of Food and Nutrition Sciences" 2007 no. 57, pp. 137–143.

36 A.E. van den Berg, M. van Winsum-Westra, *Manicured, romantic, or wild? The relation between need for structure and preferences for garden styles,* "Urban Forestry and Urban Greening" 2010 no. 9, pp. 179–186.

37 A.E. van den Berg, M. van Winsum-Westra, S. de Vries, S.M.E. van Dillen, *Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment,* "Environmental Health" 2010 no. 9: 74.

38 R.S. Matos, D.S. Batista, *Urban agriculture: the allotment garden as structures of urban sustainability,* "Advances in Landscape Architecture" 2013, http://dx.doi.org/10.5772/55892. [03–10–2016]

39 B.B. Lin, S.M. Philpott, S. Jha, *The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps,* "Basic and Applied Ecology" 2015 no. 16, pp. 189–201.

Section	Division	Group	Class	Class type
				12. biodiversity of fauna and flora 13. invasive plant and animal species 14. agrodiversity as a genetic resource of cultivation plants 15. physicochemical properties of soils, fertilization and yields of cultivations 16. fighting weeds in cultivations 17. protection of cultivations against pests 18. architecture of plots 19. position in urban green infrastructure and spatial planning 20. the influence on the state of human health 21. importance for education 22. role in social cohesion 23. historiography 24. cultural heritage
			Gaining and providing knowledge on the nature of allotment gardens and allotment gardening	Scope of education:[14,15; and authors' recognition] 25. biodiversity of fauna and flora 26. functioning of the natural environment 27. conditions of plant cultivation 28. methods and skills of plant cultivation 29. techniques of fighting weeds and animal pests 30. design plant composition according to the nature of the habitat
			Allotment gardening heritage: of materials, ideals, customs and social behaviours	Heritage of allotment gardening:[30,40,41,42,43,44,45,46,47; and authors' recognition] 31. a complex of family allotment gardens, as a historically-shaped type of urban agriculture landscape and urban green infrastructure 32. long-term development of the allotments network which constitutes a part of the historical urban layout 33. a nearly 100-year-old allotmenteering tradition – a part of the city›s historical identity and its tradition 34. heritage of natural biosphere resources

40 C. DeSilvey, *Cultivated histories in a Scottish allotment garden,* "Cultural Geographies" 2003 no. 10, pp. 442–468.
41 A. Rubino, *The allotment gardens of the Ile de France: a tool for social development,* "Journal of Mediterranean Ecology" 2007 no. 8, pp. 67–75.
42 A. Smrekar, *Allotment keeping in Ljubljana,* "Geographia Polonica" 2009 no. 82, p. 69–86.
43 A. Pawlikowska-Piechotka, *Tradycja ogrodów działkowych w Polsce*, Gdynia 2010.
44 L. Acton, *Allotment Gardens: A Reflection of History, Heritage, Community and Self*, "PIA" 2011 no. 21, pp. 46–58.
45 M. Lorbek, M. Martinsen, *Allotment Garden Dwellings: Exploring Tradition and Legal Framework,* "Urbani izziv" 2015 no. 26 (special issue).
46 J. Spilková, J. Vágner, *The loss of land devoted to allotment gardening: The context of the contrasting pressures of urban planning, public and private interests in Prague, Czechia,* "Land Use Policy" 2016 no. 52, pp. 232–239.
47 M. Drilling, R. Giedych, L. Poniży, *The idea of allotment gardens and the role of spatial and urban planning,* in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016, pp. 35–61.

Section	Division	Group	Class	Class type
				35. multi-generation knowledge about biodiversity of the flora and fauna and the functioning of the natural environment 36. heritage of the cultivation methods of vegetables, fruits and ornamental plants developed by several generations, and also the heritage of rituals 37. refuge for gene plant resources – ancient cultivars of: fruit trees, shrubs and vegetables 38. a symbol of social cohesion 39. *genius loci* in memories and reminiscences of events 40. chronicles of UAGs estates 41. a hall of fame of distinguished activists in the UAGs sector 42. recording the history of UAGs in legal acts
			Culture-forming role of allotment gardening	Culture-forming interactions:[14, and authors' recognition] 43. development of the art of allotment gardening 44. development of culinary culture – creation of recipes for food processing keeping visual, flavour and nutritious characteristics of fruits and vegetables from the allotment garden 45. organising allotment gardens with an artistic style increasing the aesthetics of the urban landscape
			Enhancing and building family ties and relations with society based on interactions with the nature of the allotment garden	Activity for social integration:[19,21,48; and authors' recognition] 46. common garden management and gardening 47. mutual education in the art of allotment gardening 48. sharing knowledge about biodiversity of the flora and fauna and the functioning of the nature 49. joint recreation 50. participation in family ceremonies and ceremonies for the local community 51. economic assistance in the form of donating fruits and vegetables 52. making UAGs available for the local community 53. organisation of harvest exhibitions (vegetables, fruits, ornamental plants), gardening courses, artistic workshops, lectures on healthy lifestyle 54. organisation of public space for recreation with special attention paid to the youngest generation and the elderly 55. conducting the so-called green schools for formal education entities

48 J. Śniadek, A. Zajadacz, *Senior citizens and their leisure activity: understanding leisure behaviour of elderly people in Poland,* "Studies in Physical Culture and Tourism" 2010 no. 17, pp. 193–204.

Section	Division	Group	Class	Class type
	Spiritual and symbolic interactions	Spiritual interactions	Spiritual states related to allotment gardening	Expression of spiritual states:[14,18,20; and authors' recognition] 56. biophilia – positive, emotional reactions to allotment garden nature 57. cheerfulness resulting from physical well-being, psychological well-being and social well-being 58. satisfaction from success in life in the emotional and affiliative dimension, strengthening family relations and establishing social relations with other people 59. no fear of social exclusion – for elderly people, long-term unemployed people, poor people, single mothers etc. 60. satisfaction from self-fulfilment: fulfilling one›s dreams, achievement of the assumed goal, fulfilling ambitions, doing hobby, fully used free time, healthy lifestyle, intellectual and spiritual development 61. a sense of food security resulting from the production of cheap and healthy food processed on one's own 62. reflection on periodicity, change and transience of life 63. responsibility for continuation of allotment gardening traditions and keeping allotment gardens in green infrastructure of the city 64. acceptance of UAGs estate management board initiatives that meet the needs of the local community

Table 2. Significances of cultural benefits from urban allotment gardens based on opinions from a questionnaire interview with allotment gardeners

	% (from 110 respondents)	Average value a)
KNOWLEDGE OF BIODIVERSITY IN ALLOTMENT GARDENS		
– recognition of the majority of weeds and pests without knowing names of plant and animal	94	
– plants and animals known by their names and taxonomy	8	
GAINING KNOWLEDGE ABOUT PLANT CULTIVATION		
– from one's own experience	42	
– from an older member of the family, allotment user	28	
– obtaining information from another allotment user from the same UAGS estate or from outside/only from the same UAGs estate	72/66	
– from scientific and popular science articles	24	
– consultations with a specialist from UAGs estate management board	4	
– seldom/on a regular basis	32/68	
SOCIAL COHESION		
– exchanging plant material with neighbours	94	
– neighbourly help in gardening work	26	
– family meetings at the allotments	87	
– participation in meetings at the allotments with society outside the UAGs estate	2	
IMPORTANCE OF THE ALLOTMENT GARDEN FOR ITS USER		
– physical well-being benefits	99	1.5
– psychological well-being benefits	95	1.8
– social well-being benefits	97	1.3

a) 0 – not important, 1 – important, 2 – highly important

The contribution of the authors in the article

Prof. Janina Borysiak, Ph.D – 70%

Prof. Andrzej Mizgajski, Ph.D – 30%

Literature

Acton L., *Allotment Gardens: A Reflection of History, Heritage, Community and Self,* "PIA" 2011 no. 21, pp. 46–58

Adamczewska A., Janowska J., *Występowanie zagrożonych gatunków flory segetalnej na terenie pracowniczych ogrodów działkowych w północnej części Łodzi*, "Acta Universitatis Lodziensis" 1998 no. 13, pp. 165–168

Andersson E., Barthel S., Ahrné K., *Measuring social-ecological dynamics behind the generation of ecosystem services,* "Ecological Applications" 2007 no. 17, pp. 1267–1278

Armstrong D.L., *A community diabetes education and gardening project to improve diabetes care in a Northwest American Indian tribe*, "Diabetes Educator" 2000 no. 26, pp. 113–120

Barthel S., Folke C., Colding J., *Social-ecological memory in urban gardens-Retaining the capacity for management of ecosystem services*, "Global Environmental Change" 2010 no. 20, pp. 255–265

Bell S., Fox-Kämper R., Keshavarz N. et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016

Biaduń W., *Winter avifauna of Lublin – species composition, distribution and numbers*, "Berkut" 2005 no. 14, pp. 1–23

Borysiak J., Mizgajski A., Speak A., *Floral biodiversity of allotment gardens and its contribution to urban green infrastructure*, "Urban Ecosystems" 2016, pp. 1–13

Breuste J., *Allotment gardens as part of urban green infrastructure: Actual trends and perspectives in Central Europe*, in: N. Müller, P. Werner, J.G. Kelcey (eds), *Urban Biodiversity and Design*, 2010, pp. 463–476

Breuste J., Artmann M., *Allotment garden contribute to urban ecosystem service: Case study Salzburg, Austria*, "Journal of Urban Planning and Development" 2015 no. 141(3), pp. 1–10

Breuste J.H., Artmann M., *Cultural benefits from allotment gardens in Salzburg, Austria*, in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016

Camps-Calvet M., Langemeyer J., Calvet-Mir L., Gómez-Baggethun E., *Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning*, "Environmental Science and Policy" 2016 no. 62, pp. 14–23

Chan K.M.A., Satterfield T., Goldstein J., *Rethinking ecosystem services to better address and navigate cultural values*, "Ecological Economics" 2012 no. 74, pp. 8–18

Davis J.N., Ventura E.E., Cook L.T. et al., *LA Sprouts: A gardening, nutrition, and cooking intervention for Latino youth improves diet and reduces obesity*, "Journal of the American Dietetic Association" 2011 no. 111, pp. 1224–1230

DeSilvey C., *Cultivated histories in a Scottish allotment garden*, "Cultural Geographies" 2003 no. 10, pp. 442–468

Domene E., Sauri D., *Urbanization and class-produced natures: Vegetable gardens in the Barcelona Metropolitan Region,* "Geoforum" 2007 no. 38, pp. 287–298

Drilling M., Giedych R., Poniży L., *The idea of allotment gardens and the role of spatial and urban planning*, in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016

Dunnett N., Qasim M., *Perceived benefits to human well being of urban gardens*, "Hort Technology" 2000 no. 10, pp. 40–45

Duś E., *Recreational use and health functions of allotments gardens in the Katowice conurbation*, *Poland*, "Environmental and Socio-economic Studies" 2014 no. 2.2, pp. 16–25

Ferres M., Townshend T.G., *The social, health and well-being benefits of allotments: five societies in Newcastle*, "Global Urban Research Unit, Electronic Working Paper" 2012 no. 47

Figurska-Ciura D., Łoźna K., Styczyńska M., *Cadmium, lead, zinc and copper contents in selected vegetables and fruit from garden allotments of the South-Western Poland*, "Polish Journal of Food and Nutrition Sciences" 2007 no. 57, pp. 137–143

Gębka D., Kędziora-Kornatowska K., Podhorecka M. et al., *Activation of the elderly with dementia syndrome,* "Medical and Biological Sciences" 2015 no. 29, pp. 5–9

Haines-Young R., Potschin M., *CICES. Towards a common classification of ecosystem services. CICES v.4.3* (January 2013), www.cices.eu

Hawkins J.L., Thirlaway K.J., Backx K. et al., *Allotment gardening and other leisure activities for stress reduction and healthy ageing*, "Hort Technology" 2011 no. 21, pp. 577–585

Kabiri B., Balilan L., *The analysis of the Iranian garden-therapy process based on the perceptual ecologic theory*, "Journal of Art and Architecture" 2015 no. 1, pp. 5–13

Kaczmarek T., Walaszek M., *4.1. Rozmieszczenie, dynamika i struktura ludności*, in: T. Kaczmarek (ed.), *Koncepcja kierunków rozwoju przestrzennego metropolii Poznań*, Poznań 2015

La Rosa D., Spyra M., Inostroza L., *Indicators of cultural ecosystem services for urban planning: A review*, "Ecological Indicators" 2016 no. 61, pp. 74–89

Langemeyer J., Latkowska M.J., Gómez-Baggethun E.N., *Ecosystem services from urban gardens*, in: S. Bell, R. Fox-Kämper, N. Keshavarz et al. (eds), *Urban allotment gardens in Europe*, London and New York 2016, pp. 115–141

Lin B.B., Philpott S.M., Jha S., *The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps*, "Basic and Applied Ecology" 2015 no. 16, pp. 189–201

Lorbek M., Martinsen M., *Allotment Garden Dwellings: Exploring Tradition and Legal Framework*, "Urbani izziv" 2015 no. 26 (special issue)

Matos R.S., Batista D.S., *Urban agriculture: the allotment garden as structures of urban sustainability*, "Advances in Landscape Architecture" 2013, http://dx.doi.org/10.5772/55892

Milligan C., Gatrell A., Bingley A., '*Cultivating health*'*: therapeutic landscapes and older people in northern England*, "Social Science and Medicine" 2004 no. 58, pp. 1781–1793

Park S.A., Lee K.S., Son K.C., *Determining exercise intensities of gardening tasks as a physical activity using metabolic equivalents in older adults*, "Hort Science" 2011 no. 46, pp. 1706–1710

Pawlikowska-Piechotka A., *Tradycja ogrodów działkowych w Polsce*, Gdynia 2010

Rubino A., *The allotment gardens of the Ile de France: a tool for social development*, "Journal of Mediterranean Ecology" 2007 no. 8, pp. 67–75

Russell R., Guerry A.D., Balvanera P. et al., *Humans and nature: how knowing and experiencing nature affect well-being*, "Annual Reviews Environment and Resources" 2013 no. 38, pp. 473–502

Shelton R., *Allotted time, two blokes, one shed, no idea*, Robin Shelton 2006

Smrekar A., *Allotment keeping in Ljubljana*, "Geographia Polonica" 2009 no. 82, p. 69–86

Śniadek J., Zajadacz A., *Senior citizens and their leisure activity: understanding leisure behaviour of elderly people in Poland*, "Studies in Physical Culture and Tourism" 2010 no. 17, pp. 193–204

Speak A., Mizgajski A., Borysiak J., *Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity*, "Urban Forestry and Urban Greening" 2015 no. 14, pp. 772–781

Spilková J., Vágner J., *The loss of land devoted to allotment gardening: The context of the contrasting pressures of urban planning, public and private interests in Prague, Czechia*, "Land Use Policy" 2016 no. 52, pp. 232–239

Szczurek M., Zych M. (eds), *Dzieło-działka*, Kraków 2012

Szkup R., *Użytkowanie rodzinnych ogrodów działkowych (ROD) przez społeczność wielkomiejską*, Łódź 2013

The Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis, Washington 2005

van den Berg A.E., Custers M.H.G., *Gardening promotes neuroendocrine and affective restoration from stress*, "Journal of Health Psychology" 2011 no. 16, pp. 3–11

van den Berg A.E., van Winsum-Westra M., de Vries S., van Dillen S.M.E., *Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment*, "Environmental Health" 2010 no. 9: 74

van den Berg A.E., van Winsum-Westra M., *Manicured, romantic, or wild? The relation between need for structure and preferences for garden styles*, "Urban Forestry and Urban Greening" 2010 no. 9, pp. 179–186

Wycichowska B., *Przesądzona zmiana polityki państwa w zakresie ogrodnictwa działkowego*, "Przegląd Komunalny" 2013 no. 2, pp. 44–48

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FOREST RESOURCES AS A BASIS TO CREATION OF AN INTEGRATED TOURIST PRODUCT OF AN AREA ON THE EXAMPLE OF BIAŁOWIEZA FOREST

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ZASOBY LEŚNE PODSTAWĄ KREOWANIA ZINTEGROWANEGO PRODUKTU TURYSTYCZNEGO OBSZARU NA PRZYKŁADZIE PUSZCZY BIAŁOWIESKIEJ

STRESZCZENIE: Artykuł podejmuje problematykę szeroko rozumianego produktu turystycznego obszaru. Głównym jego celem jest analiza teoretycznych aspektów dotyczących istoty i struktury produktu turystycznego obszaru, ukazanie znaczenia zasobów leśnych w turystyce na przykładzie Puszczy Białowieskiej i przedstawienie koncepcji zintegrowanego produktu turystycznego tego obszaru w oparciu o unikatowe zasoby leśne. Kreowanie nowych leśnych produktów turystycznych (jako produktów cząstkowych), które będą powiązane ze sobą wspólną ideą (pod nazwą Leśne Dziedzictwo Europy) pozwoli lepiej wykorzystać dotychczasowy unikatowy potencjał przyrodniczy regionu.

SŁOWA KLUCZOWE: produkt turystyczny obszaru, zasoby leśne, Puszcza Białowieska, dziedzictwo leśne

Introduction

One of the important aspects of research in the contemporary scientific literature in the field of tourism is the issue of the development of tourist products of an area (region)[1]. The tourist product of an area is a very complex and multidimensional category. It consists of many various elements, among which an important role is held by the heritage (natural, historic, cultural). It is often a basis for the development of the tourism funtions of the region (however it is not the sole and sufficient condition of the development). Tourism is largely based on the resources of the natural capital (including forest resources) and should protect it, to be able to use it in the long perspective. One of the particularly valuable forest areas, both on the scale of Poland and Europe, is the region of the Bialowieza Forest, which has great potential, hitherto poorly used, to create attractive, competitive and innovative tourist products. The issue of the development of tourism in the region of Bialowieza Forest was described among others A Rutkiewicz[2], M. Jalinik[3], K. i E. Janeczko[4].

The aim of the article is a theoretical analysis of aspects regarding the essence and structure of the tourist product of an area, show the importance of forest resources in tourism on the example of the Bialowieza Forest, and to present the concept of the integrated (complex) tourist product of that area, based on unique forest resources. This study concentrates on showing the possibility to create new tourist products of the forest, which will be linked together by a common idea and will create a conceptually coherent whole.

1 J. Borzyszkowski, *Rozwój produktów turystycznych jako sfera działań Destination Management Organizations,* "Zeszyty Naukowe" 2015 no. 19; J. Kaczmarek, A. Stasiak, B. Włodarczyk, *Produkt turystyczny. Pomysł – organizacja – zarządzanie*, wyd. II, Warszawa 2010; A. Panasiuk (ed.), *Markowe produkty turystyczne*, Szczecin 2005; M. Marczak, J. Borzyszkowski, *Region (obszar) jako produkt turystyczny*, "Zeszyty Naukowe Instytutu Ekonomii i Zarządzania" 2014 no. 3; A.E. Szczepanowski, *Markowe produkty turystyczne*, Warszawa 2012; E. Dziedzic, *Obszar recepcji turystycznej jako przedmiot zarządzania strategicznego*, "Monografie i Opracowania" no. 442, Warszawa 1998.

2 A. Rutkiewicz, *Leśne produkty turystyczne Puszczy Białowieskiej*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2013 no.15, vol. 37/4.

3 M. Jalinik, *Obszary leśne w rozwoju turystyki*, "Ekonomia i Środowisko" 2016 no. 3, p. 313–323; M. Jalinik, *Czynniki decydujące o rozwoju sylwanoturystyki na obszarach leśnych*, w: M. Jalinik, S. Bakier (eds), *Turystyka na obszarach przyrodniczo cennych*, Białystok 2016.

4 K. Janeczko, E. Janeczko, *Las jako produkt turystyczny na przykładzie Leśnego Kompleksu promocyjnego (LKP) Puszcza Białowieska*, "Turystyka i Rekreacja" 2005 t. 1.

The concept and essence of the product of a tourist area

The concept of a tourist product is a complex category, hence in the literature there are many different definitions of it. In the narrow approach (in the strict sense – as a product of tourism enterprises) is defined as everything that tourists are buying, so both individual services (e.g. transport, accommodation, catering) as well and the whole package of benefits (which are a complex variety of services). In the broad sense, a tourist product is a composition of what tourists do and the assets and equipment, which they use for this purpose. From the point of view of a tourist, a tourism product constitutes the entire experience, i.e. "the sum of impressions and experiences, which a tourist had since leaving the place of residence until returning home"[5].

Tourist products can be variously categorized (classified). Especially interesting is the division proposed by Kaczmarek, Stasiak and Wlodarczyk[6] into simple (a thing, service) and complex (an event, performance, object, trail, area) products. In this study a broad view of the tourist product, seen spatially, is adopted, and the main subject of analysis is the tourist product of the area.

Tourist product of the area is "a special, geographically determined product of a surface nature, composed of selected elements of the tourism potential (or existing products) of a given area and connected with a primary idea, determining its market originality, individuality and attractiveness"[7].

Due to the level of perception of the tourist product (both by the producer and the consumer) the following is distinguished in its structure most often:

- the core of the product (also called the primary product, the main essence of the product) – includes the items that are related to the main theme and purpose of tourist travel, i.e., they determine the choice of the product. It is believed that this level of the product does not have a material nature and is viewed through the prism of the benefits from its purchase;
- the actual product – includes a set of basic services that determine the execution of the tip;
- the expanded product (enriched, enlarged and improved) – includes elements that determine highlighting of the product on the market, its com-

5 S. Wodejko, *Ekonomiczne zagadnienia turystyki*, Warszawa 1997, p. 23.

6 J. Kaczmarek, A. Stasiak, B. Włodarczyk, *Produkt turystyczny. Pomysł – organizacja – zarządzanie*, wyd. II, Warszawa 2010, p. 88–167.

7 Ibidem, p. 159, 167.

petitiveness and attractiveness (i.e. all additional services not included in the standard tourist offer).[8]

This concept is expanded with extra dimensions. From the manufacturers' point of view, additional potential product is distinguished – including the elements which in the future may become a component of the tourism product. However, in the perception of the product by the customer-tourist, besides the core, the actual and expanded product the expected product is distinguished, functioning in the imagination of the tourist, and the psychological product including everything that remains in the consciousness of the individual tourist after an overall assessment of the product[9].

The tourist product of the area has a very complex structure and consists of many different elements. Middleton[10] includes the following among the basic elements of the area tourism product: attractions and the environment at the destination (as one of the basic components, which largely determines the choice of the product by the consumer), infrastructure, and services at the destination, the availability of the destination, the image and perception of the destination, and the price paid by the consumer. A little different classification is show by Kaczmarek, Stasiak and Wlodarczyk[11]. As the main elements of the area tourism product, they mention:

- heritage (natural, historical and cultural of the area) – resources of the area genetically not related to the development of tourism, but forming the part of the area potential, making the development of tourism possible in the first place (e.g. geological structure, topography, water, climate, landscape, natural curiosities, vegetation, culture, history, economy, human potential);
- infrastructure – resources of the area related to the development of tourism, supplementing primary elements (heritage), making the tourist offer of the area more attractive (e.g. accommodation facilities, catering, paratouristic base, external and internal transportation accessibility);
- added value – attributes of the area bringing certain satisfaction to tourists (emotions, impressions, experiences). They are the symbolic elements, such as: the current image of the area existing in the public consciousness and the functioning stereotypes; an idea for a product, which is the main idea uniting all the activities in the field of tourism in the area; elements supporting the identification of the product: name, logo, adver-

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8 G. Gołembski (ed.), *Kompendium wiedzy o turystyce*, Warszawa-Poznań 2002, p. 69–70; J. Altkorn, *Marketing w turystyce*, Warszawa 1994, p. 100–102.

9 J. Kaczmarek, A. Stasiak, B. Włodarczyk, *Produkt turystyczny, albo jak organizować poznawanie świata*, Łódź 2002, p. 89–91.

10 V.T.C. Midleton, *Marketing w turystyce*, Warszawa 1996, p. 89–90.

11 J. Kaczmarek, A. Stasiak, B. Włodarczyk, 2010, op. cit., p. 160–162.

isement slogan; brand identity – unique values, traits that should be permanently associated with the area, and ultimately to become a part of the image of the whole area. In the absence of a unique heritage or infrastructure, they allow for distinguishing the area from other areas that have a similar offer.

- organization and management – all structures and activities allowing the above elements to function as a tourist product[12].

Generally, heritage is the core of the area tourism product, as a primary element, which enables the development of tourism (however, it is not a condition, which is necessary and sufficient for creating new products). The process of creating new tourist products in most cases starts with the diagnosis of the tourist resources and valuables of the region.

The importance of forests in tourism and forest heritage of the Bialowieza Forest

Forest areas, which in Poland occupy 29.4% of the country[13], represent a huge natural capital for the development of tourism. Forest is an attractive place to engage in various forms of tourism and recreation, demand for which has been increasing in recent years (the so-called forestry tourism is developing). In Poland, making the State Forests available for the society is a statutory obligation, regulated by the rules of the Forest Act of 28 September 1991[14]. Forests have a variety of functions: natural (safety), social and productive (economic)[15]. Forest resources, and the tourism space associated with them, are on the one hand a consumer good (suitable for direct use by tourists), and on the other hand, a production good (for purposes of investment and production, used by other entities operating in tourism). Limitation of the space and its resources is a primary cause of the need to apply the principles of rational and sustainable forest management, including sustainable tourism development, and nature and woodland education. The main objective of this education is to disseminate knowledge about the forest environment, about multifunctional and sustainable forest management, raising awareness on the rational and responsible use of the forests, and the need to protect their resources for future generations).

12 Ibidem, p. 160.

13 *Środowiska 2015*, *Informacje i opracowania statystyczne*, Warszawa 2015, p. 315.

14 The Act of 28 September 1991 on forests (Journal of Laws of 1991 No. 101, item 444, as amended).

15 *Lasy Państwowe w Liczbach 2015*, Warszawa 2015, p.16, www.lasy.gov.pl [20–11–2016].

So far, the State Forests, which are the main entity managing forest areas owned by the State Treasury, have undertaken many valuable initiatives aiming at making forests accessible to tourists (including reduction of the anthropo-pressure by directing tourism in forest areas), and the implementation of various forms of nature and woodland education. An example of good practice in this area can be the own LP program entitled "Aktywne udostępnianie lasu" [Active sharing of the forest], which includes specific solutions for construction of tourism and recreation infrastructure in the forest areas[16], or "Las bez barrier" [Forest without barriers], which includes solutions for adapting tourism and educational facilities to the needs of people with disabilities. In spite of the many activities in this area, tourist infrastructure in the Polish forests is still poorly developed[17].

The problem of the tourist use of forests is being increasingly undertaken also in the literature. A number of papers published by the Centre for Nature and Forest Education in Rogow[18] may be an example.

One of the most valuable, unique on the national and European level, is the Bialowieza Forest. Its forest resources are an important natural capital for the development of tourism in the region, generating the potential for creating attractive and competitive tourism products, particularly forest products. The Bialowieza Forest includes the last primeval forest fragments at the Central European Plain, hence it represents the model object for forest ecosystems of Poland and Europe. The woodland of the Forests includes mixed, multi-level and centuries-old stand (an average age calculated for the entire Promotional Forest Complex "Bialowieza Forest" is one of the highest among all the administrative units of the LP[19]). The Bialowieza Forest region has a very high biological diversity, both at the gene, species, and ecosystem as well as landscape levels.

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16 M. Hyży, *Aktywne udostępnianie lasu – program własny Lasów Państwowych*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie" 2011 no. 13, vol. 4(29), p. 144–149.

17 M. Smoleński, *Turystyka w Lasach Państwowych*, w: R. Ziółkowski (ed.), *Praktyczne aspekty rozwoju turystyki i rekreacji na obszarach przyrodniczo cennych*, Białystok 2006, p. 16.

18 E.g. A. Perlińska, M. Rothert, *Działania Lasów Państwowych w zakresie turystycznego udostępniania lasu*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie" 2013, no. 15, vol. 37/4, p. 245–247; M. Pigan, *Rola Lasów Państwowych w propagowaniu turystyki przyrodniczo-leśnej*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2009 no. 11, Vol. 4(23); *Turystyka w lasach i na obszarach przyrodniczo cennych*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2015 no. 17, Vol. 45/4.

19 M. Ksepko, J. Dawidziuk, *Analiza założeń i realizacja planów urządzenia lasu sporządzonych dla nadleśnictw Puszczy Białowieskiej na lata 2002–2011 i 2012–202,* in: *Stan ekosystemów leśnych Puszczy Białowieskiej,* Warszawa 2016, p. 10, www.lasy.gov.pl [20–11–2016].

The most valuable natural fragment of the Bialowieza Forest is managed by the Bialowieza National Park (BNP). The rest of the forest is managed by three forest inspectorates: Hajnówka, Browsk and Bialowieza. In 1976 BNP was recognized by UNESCO as a World Biosphere Reserve M & B ("Man and Biosphere"), and in 1979 it was entered onto the UNESCO World Heritage List – (since 1992 the status of the object was extended to include the adjacent from the east fragment of the Belarusian national park "Bieławieżskaja Forest", and in 2014 the entire Bialowieza Forest was included on the list). The result was the creation of one of seven in the world and three European cross-border World Heritage objects. "Bialowieza Forest and Bialowieza National Park, therefore, constitute a kind of a brand of the region, recognized on the domestic and foreign markets. Unfortunately, there are still too few varied tourist products in the region (e.g. on the basis of forest resources), which would be competitive on the domestic, European, or global tourist market, and could hold tourists in the area for longer. Currently such a product is the Bialowieza National Park (and its facilities – the Nature and Forest Museum in Bialowieza, the Bison Exhibition Reserve, Palace Park, Protective Area of the Reserve). Currently, actions are needed, which would lift the burden of tourism traffic from BNP, for which excessive anthropo-pressure has become a serious threat.

Creating integrated tourist products of the Bialowieza Forest

The natural and cultural heritage of the region and, above all, the rich and unique tourist attractions of the forest environment constitute a great potential to create new products. Forest and its functions (promoted by various forms of education concerning the environment and forestry) may be the core of the integrated tourist product of the Bialowieza Forest.

An important element of any product is its brand (name), under which the product will be introduced to the market, which often determines its commercial success (it should be associated with the characteristics possessed by the product)[20]. Creating a tourist product of an area it is necessary to focus on the activities in which a given area would be best. In the case of the Bialowieza Forest, the name of such an integrated tourist product of the region could be "Forest Heritage of Europe". In 2015, within the framework of the implementation of the "Bialowieza Forest – Forest Heritage of Europe" programme (involving the State Forests, the National Fund for Environmental Protection and Water Management, Bialowieza National Park, and local governments), a concept of such a product was developed, consisting of a

20 M. Molenda, *Regionalny przemysłowy produkt turystyczny*, Warszawa 2015, p. 52.

wide variety of "tourist products' (mainly in the segment of environmental-educational tourism)[21]. The idea is to create new partial products, which will be linked thematically by a common idea.

As part of an integrated tourist product of the Bialowieza Forest, one of the main partial products could be the creation of the European Centre for Nature and Forest Education in the region (e.g. following the example of the Copernicus Science Centre), which will allow for active engagement of the visitors with learning about the nature and function of the forest, and will constitute an attractive form of environmental education. The forest resources of the region should constitute huge natural capital, not only of the region, but also Europe as a whole and should be the basis for the creation of new, innovative forest products. In the region, the field educational offer should also be developed. As an example of such products it is possible to mention eco-museums, which means objects scattered around the region, which will present the advantages of the natural and cultural heritage of the Bialowieza Forest, right in the place of its occurrence. Objects of this type allow for the participation of the visitors in the created offer (e.g. Through a tasting of local culinary products made of berries, wood carving workshops, gardening lessons). A new forest tourist product constituting a part of the integrated tourist product of the of the region of the Bialowieza Forest, which in the future could be a major tourist attraction of the region, would be the path in the treetops. In Europe, there are examples of good practices in this area, e.g. Lipno on the Vltava River in the south of the Czech Republic and in Bavaria, Germany.

When expanding the field educational offer, which would relieve the tourism traffic in the Bialowieza National Park, there is a need to create Theme Parks in the forest districts, concerning, for example, the refuges for animals (including for the bison – since the "Bialowieza Forest is being promoted as the European Capital of the Bison), as well as forest traditions. Theme villages, the creation of which should actively involve local authorities, which will show different ways of using and processing forest resources, could constitute a supplement to such an offer, integrated with the activities of forest districts. Ultimately, one may consider creating a forest arboretum in the region, which would present the advantages of "The Forest Heritage of Europe".

In the region of the Bialowieza Forest, there is also a need to enrich the offer of natural-forest tracks, which constitute one of the main forms of forest education of society. This should be accomplished both through the modernization of the existing tracks as well as laying out and attractive development

21 J. Ejdys et al., *Koncepcja organizacji ruchu turystycznego w regionie Puszczy Białowieskie*j, Białystok 2015.

of the new ones, e.g. through the use of small wooden architecture, educational playgrounds for children and parents, and the development of quests. Environmental education for children should be achieved through play to a greater extent, because the paths and information boards alone are not a very attractive form of sightseeing. Such products can be developed by laying out similar path e.g. Mushrooms, herbs, Birds, Insects, phonological tracks in the Bialowieza Forest or the paths of animals (showing changes in nature occurring in different seasons). In the region of the Bialowieza Forest, there is a need to create various, mutually complementary forest products, integrated with each other, which will exhibit the various functions of the forests. The idea is to create a complementary tourist product that would complement the natural offer of the Bialowieza National Park (relieving the park's excessive concentration of tourist traffic), as well as to develop attractions in the towns constituting the so-called "Gates" to the forest. Tourism in this area, through the development of a wide educational offer, should constitute an important element of active conservation. The so-called fitness trails in different parts of the forest habitat (for children and adults), which will present the impact of individual trees, or habitats on the human body, can constitute a supplement to the offer.

Ultimately, it is important to strive for the creation of a tourist attraction on a European scale in the region, e.g. a forest sanatorium (exposing the health functions of the forest), around which other services will develop (e.g. in the field of aromatherapy, hippotherapy, rehabilitation, medical). New tourism products can be an important impulse for the development of the local tourist economy.

Conclusions

The conducted analysis of the conditions for the development of tourism in the region of the Bialowieza Forest showed that the region outside of the Bialowieza National Park lacks attractive and diverse tourist products that would be competitive on the domestic, European, or global tourist market, that would entice the tourists to stay longer and encourage them to return in the future.

The supply of the tourist services of the region of the Bialowieza Forest should be transformed into a coherently functioning whole – the integrated tourist product of the region, which will create a bundle of benefits for tourists. This requires an integrated development of many different, partial tourism products, created mainly on the basis of unique forest resources and other resources of the natural and cultural heritage of the region. These products should be connected with a specifically defined thematic line ("The Forest Heritage of Europe"), determining its originality, individuality, and attractiveness on the market. The qualities of the forest's natural heritage should be at the core of the integrated tourism product.

The main feature of this tourism product would its dynamic nature. Its size – qualitative and quantitative structure – will be subject to change through the activities of various entities operating in the local tourism economy.

Creating a complementary, integrated tourism product of each area requires the cooperation and coordination of the actions of multiple entities within local and regional tourism economy. In the Region of the Bialowieza Forest, the main entities creating the integrated tourist product of the forests - "Forest heritage of Europe" will be the units of the National State Forests (forest districts), Management of the Bialowieza National Park, and local governments, in cooperation with the tourist companies and local tourist organizations. The process of creating products, building the brand and image of the Bialowieza Forest should also include local communities, which are an important component of an integrated tourist product of an area, affecting various components of its structure[22].

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Literature

Altkorn J., *Marketing w turystyce*, Warszawa 1994

Borzyszkowski J., *Rozwój produktów turystycznych jako sfera działań Destination Management Organizations,* "Zeszyty Naukowe" 2015 no. 19

Dziedzic E., *Obszar recepcji turystycznej jako przedmiot zarządzania strategicznego*, "Monografie i Opracowania" no. 442, Szkoła Główna Handlowa, Warszawa 1998

Ejdys J., Glińska E., Godlewska J., Gorbacz W. J., Kiryluk H., Łaszczewska U., Panfiluk E., Szpilko D., Znaniecki P., *Koncepcja organizacji ruchu turystycznego w regionie Puszczy Białowieskie*j, Białystok 2015

Glińska E., Kiryluk H., *The role of local community in creating tourism products*, in: *Researching destination management, policy and planning: linking culture, heritage and tourism*, Leeds 2007

Gołembski G. (ed.), *Kompendium wiedzy o turystyce*, Warszawa-Poznań 2002

22 E. Glińska, H. Kiryluk, *The role of local community in creating tourism products*, in: *Researching destination management, policy and planning: linking culture, heritage and tourism*, Leeds 2007.

Hyży M., *Aktywne udostępnianie lasu – program własny Lasów Państwowych*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie" 2011 no. 13, vol. 4(29), p. 144–149

Jalinik M., *Czynniki decydujące o rozwoju sylwanoturystyki na obszarach leśnych*, w: M. Jalinik, S. Bakier (eds), *Turystyka na obszarach przyrodniczo cennych*, Białystok 2016

Jalinik M., *Obszary leśne w rozwoju turystyki*, "Ekonomia i Środowisko" 2016 no. 3, p. 313–323

Janeczko K., *Las jako produkt turystyczny na przykładzie Leśnego Kompleksu promocyjnego (LKP) Puszcza Białowieska*, "Turystyka i Rekreacja" 2005 t. 1

Kaczmarek J., Stasiak A., Włodarczyk B., *Produkt turystyczny, albo jak organizować poznawanie świata*, Łódź 2002

Kaczmarek J., Stasiak A., Włodarczyk B., *Produkt turystyczny. Pomysł – organizacja – zarządzanie*, wyd. II, Warszawa 2010

Ksepko M., Dawidziuk J., *Analiza założeń i realizacja planów urządzenia lasu sporządzonych dla nadleśnictw Puszczy Białowieskiej na lata 2002–2011 i 2012–2020,* in: *Stan ekosystemów leśnych Puszczy Białowieskiej,* Warszawa 2016, www.lasy.gov.pl

Lasy Państwowe w Liczbach 2015, Warszawa 2015, www.lasy.gov.pl

Marczak M., Borzyszkowski J., *Region (obszar) jako produkt turystyczny*, "Zeszyty Naukowe Instytutu Ekonomii i Zarządzania" 2014 no. 3

Midleton V.T.C., *Marketing w turystyce*, Warszawa 1996

Molenda M., *Regionalny przemysłowy produkt turystyczny*, Warszawa 2015

Panasiuk A. (ed.), *Markowe produkty turystyczne*, Szczecin 2005

Perlińska A., Rothert M., *Działania Lasów Państwowych w zakresie turystycznego udostępniania lasu*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie" 2013, no. 15, vol. 37/4

Pigan M., *Rola Lasów Państwowych w propagowaniu turystyki przyrodniczo-leśnej*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2009 no. 11, Vol. 4(23)

Rutkiewicz A., *Leśne produkty turystyczne Puszczy Białowieskiej*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2013 no.15, vol. 37/4

Smoleński M., *Turystyka w Lasach Państwowych*, w: R. Ziółkowski (ed.), *Praktyczne aspekty rozwoju turystyki i rekreacji na obszarach przyrodniczo cennych*, Białystok 2006

Szczepanowski A.E., *Markowe produkty turystyczne*, Warszawa 2012

Środowisko 2015, *Informacje i opracowania statystyczne*, Warszawa 2015

Turystyka w lasach i na obszarach przyrodniczo cennych, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" 2015 no. 17, Vol. 45/4

Wodejko S., *Ekonomiczne zagadnienia turystyki*, Warszawa 1997

DISCUSSION AND REVIEWS

RECENZJE OMÓWIENIA, PRZEGLĄDY

Leszek Preisner, PhD, MA, Assoc. Professor

President of the Polish Association of Environmental and Resource Economists

Origins and History of the Polish Association of Environmental and Resource Economists, 1991–2016

The European Association of Environmental and Resource Economists – Polish Division was setup in 1991 as a branch of the European Association of Environmental and Resource Economists (EAERE) which was originally founded, in the mid-1980s. In 1990, EAERE commenced formal activities as an Academic Association after the registration of its Articles of Association in Siegen, Germany. The main aims of the Association, as written down in the Articles of Association, are to raise the level of academic research on the environment and act as a pressure group on environmental policy at a European and Global level as well as in the particular countries.

EAERE is organising annual meetings to discuss environmental issues which is always combined with an academic conference. The first conference entitled: "*Environmental Cooperation and Policy in the Single European Market*" took place in 1990 in Venice, Italy. This was followed in 1991, by one in Stockholm, Sweden discussing: "Economics of International Environmental Problems and Policies". EAERE's third annual conference, titled: "Institutions and Environmental Protection", took place between 16-19th Jun. 1992 in Krakow, Poland at the Cracow Academy of Economics. From this time on, conferences have been held on an annual basis in a number of European countries. During conference in Krakow participated the following Distinguished Professor and EAERE's members: Domenico Siniscalco, Henk Folmer, Ignazio Musu, Frank J. Convery, Rudiger Pethig, H. Landis Gabel, Karl J. Mäler, Ekko C. van Ierland, Alessandro Lanza, Karine Nyborg, Jan van der Straaten, Eamonn J. Judge, Thomas Sterner, Ger Klaassen, Clara Costa Duarte.

Since 1998, together with its U.S. sister organisation AERE (Association of Environmental and Resource Economists), EAERE organises a global conference (the World Congress of the Association of Environmental and Resource Economists) which takes place every three years. Without doubt, this is a realisation of one of the main statutory aims of the Association being the integration of environmental policy on a global level.

Shortly after the official founding of EAERE, there was an initiative in Poland led by Professor Tomasz Żylicz (at the time Director of the Economics Department of the Polish Ministry of Environmental Protection, Natural Resources, and Forestry), to create the **European Association of Environmental and Resource Economists – Polish Division (Europejskie Stowarzyszenie Ekonomistów Środowiska i Zasobów Naturalnych – Oddział Polski,** ESESiZN – OP**).** This initiative was followed up in June 1990 with an invitation from Dr. Bronisław Kamiński (Minister of Environmental Protection, Natural Resources, and Forestry at the time) inviting a group of around 60 senior academics to a meeting in Krakow. During this meeting it was decided to setup the Association in Poland and the Founding Committee consisted of: President – Professor Kazimierz Górka (Cracow Academy of Economics), Professor Tadeusz Borys (Wroclaw Academy of Economics), Professor Stanisław Mestwin Kostka (University of Warsaw – Affiliate in Bialystok) and Professor Bazyli Poskrobko (Bialystok University of Technology).

The Founding Committee then organised the first meeting of the European Association of Environmental and Resource Economists – Polish Division in Krakow on 9th Mar. 1991 attended by 98 economists representing all the major Research and Higher Education Establishments in Poland.[1]

The first President of EAERE – Polish Division was Professor Kazimierz Górka from the Cracow Academy of Economics who served from 1991 to 1994. Professor Górka was followed by Professor Anna Jankowska-Kłapkowska from the Academy of Mining and Metallurgy (AGH), Krakow who served from 1994 to 1998. The next President was Dr. Leszek Preisner two terms: 1998-2002 and 2002–2006, followed by Dr. Tadeusz Pindór from 2006 to 2010. Professor Leszek Preisner was then re-elected for his third term 2010-2014 and again for the current (fourth) term from 2014 to 2018.

A fact worth noting is that since 1994, the Registered Office and Secretariat of EAERE – Polish Division is in Krakow. It was initially affiliated with the AGH Department of Economics and Natural Resource Management then, from 2006 to 2018, with the AGH Department of Economics, Finance, and Environmental Management. Bearing this history in mind, it should be stressed that from the very beginning of the Association's activities in Poland, the Polish (former European) Association of Environmental and Resource Economists is very closely linked with the Department of Economics, Finance, and Environmental Management, Faculty of Management, AGH University of Science and Technology, Krakow. These connections have existed for as long as 22 years and are for two main reasons: firstly, because members of Department (Professor Anna Jankowska-Kłapkowska, Professor Leszek Preisner and Professor Tadeusz Pindór) have been or are currently officers of PSESiZN and secondly,

1 M. Banach, *Europejskie Stowarzyszenie Ekonomistów Środowiska i Zasobów Naturalnych w Polsce*, in: „Ekonomia i Środowisko", Vol. I, Paper 1, Białystok 1992, p. 195-197.

because this is the physical location of the Association's Secretariat, which organises the PAERE General Assemblies, conferences and academic seminars.

Currently, the Association has around 230 members who are mainly Lecturers or Professors holding senior office at the major Polish Higher Education Establishments. The largest number of members (39) is based in Krakow, followed by Warsaw (27), Wroclaw (24), Bialystok (19) then Katowice and Olsztyn (both with 12). Other cities represented are: Szczecin, Bydgoszcz, Poznan, Torun, Opole, Rzeszow, Zielona Gora, Lublin and Zamosc. This geographical spread results in a good representation of Teaching Establishments across almost the whole country which is significant in ensuring a more national coverage. Inspite of this, despite numerous efforts by the PAERE Board, Gdansk and the Pomerania region are still under-represented in the Association membership although this is a region with a strong academic background and a significant role in the economy of Poland.

Recently, the Association's Articles of Association were aligned to current legal requirements in Poland in requiring the PAERE General Assembly to take place annually. Prior to this, the General Assembly took place once every two years. For this reason upto now, 16 General Assemblies have taken place without including the Founding Meeting in Krakow on 9th Mar. 1991.

Decisions as to the location for a specific General Assembly are based on practical considerations and on a recognition of the academic contribution of the Higher Education Establishments in the region or city chosen to host the General Assembly. General Assemblies are normally organised as part of an Academic Conference and the range of geographic locations where the General Assemblies have taken place has without doubt had a very positive influence on the degree of integration of both individuals and groups working on environmentally related topics in the academic world or in various institutions.

Members of the Association are also very active in various environment related organisational bodies and, as well as this activity, carry out numerous analyses and provide input and opinion on issues related to ecology or environmental policy.

A significant aspect underlining the commitment of Association members to realising the statutory goals is the organisation of new courses in Environmental Economics, Environmental Management and Environmental Policy at a number of universities. This includes the organisation of post-graduate courses covering various aspects of Natural Resource Economics.

There are however other activities carried out by Association members which may be worth mentioning. These include:

- Providing „expert opinion" on a number of significant aspects regarding the implementation of sustainable development in Poland.
- Participation by Association members in advisory boards and consultative councils.
- Preparation of technical and expert evaluations with regard to environmental protection.

On 4th Oct. 2007, as a result of a resolution by the PAERE Board, a new section was founded within the framework of the Association to deal with the Economics of Water Supply Safeguarding, Water Utilisation and Protection. This section was headed by Professor Rafal Milaszewski who was appointed by the PAERE Board. In 2008, the PAERE Board passed a resolution authorising this section to be located within the Department of Environmental and Resource Economics at Warsaw Business School. However, from 2014 this Section is now located at the AGH Department of Economics, Finance, and Environmental Management in Krakow. Since it was founded, the section has organised five academic seminars.

The Association is also very active in publishing and, in collaboration with the Foundation of Environmental and Resource Economists in Bialystok, issues the following:

- Conference Proceedings – "*Economics and Environment*" (widely known in Poland as the "Green Library Series"): collection of conference materials, proceedings and publications edited by Professor Kazimierz Górka (currently 35 volumes).
- Journal of the Polish Association of Environmental and Resource Economists – "Ekonomia i Środowisko" ("Economics and Environment"): Academic Journal edited by Dr. Elżbieta Broniewicz, Chief Editor (currently 59 Research Papers).
- Books and other materials published by the "Ekonomia i Środowisko" ("Economics and Environment") Publishing House under the auspices of the Foundation of Environmental and Resource Economists in Bialystok.

As many of the persons working in the Foundation of Environmental and Resource Economists are also members of the PAERE, the relationship between the two organisations is very close and from the start of the Foundation members of our Association formed the Foundation's Editorial Board and the Programme Advisory Panel. Moreover, many of the PAERE members have entrusted the publication of their books and academic papers to the "Ekonomia i Środowisko" ("Economics and Environment") Publishing House run under the auspices of the Foundation of Environmental and Resource Economists in Bialystok.

From the start of its activities, the Polish Division was the only representative of EAERE in Poland. This is because the EAERE Articles of Association, as a matter of principle, do not anticipate the creation of separate country affiliations.[2]

Over the many years in which the European Association of Environmental and Resource Economists – Polish Division has been active here have never been any issues raised with this name which was officially registered in the Business Register in Krakow. Problems appeared when the name EAERE – Polish Division, as a faithful reflection of the mother organisation, appeared in English on its web-site. The EAERE Board in Milan, Italy explained that the Articles of Association do not envisage the creation of national entities and therefore approached the Board of the EAERE – Polish Division with a request to change the name. The purpose was to try to avoid public confusion or problems of a formal nature due to the names of both organisations.

2 K. Górka, G. Peszko, *Krakowski szczyt ekonomistów środowiska i zasobów naturalnych*, in: "Ekonomia i Środowisko", Vol. I, Paper 2, Białystok 1992, p. 176.

The subject of the name of our Association was discussed on a number of occasions at meetings of the Management Committee as well as at Annual General meetings (for instance in Supraśl on 11th Nov. 2012 and on 6th Dec. 2012 at the Wroclaw University of Economics).

On 9th Jul. 2014, the XI Commercial Law Department of the Company Registration Court in the Krakow-Śródmieście District Court in Krakow, authorised the registration of the new name of the European Association of Environmental and Resource Economists – Polish as being the: **Polish Association of Environmental and Resource Economists** and from 16th Jul. 2014, this new name has become the exclusive name of our Association. Appropriate steps have been taken by the PAERE Board to ensure all relevant documents are modified and to inform all appropriate institutions.

Significant contributions to environmental protection can be attributed to very many of our members but inspite of this, the 20th Anniversary of the European Association of Environmental and Resource Economists was celebrated in a fairly subdued manner and was combined with the first *Convention of Faculties incorporating Environmental Economics, Environmental Management and Sustainable Development* which was organised on 26th Sep. 2011 by the Department of Economics, Finance, and Environmental Management, Faculty of Management, AGH University of Science and Technology in Krakow[3]. The Convention was attended by representatives of 9 University Faculties which carry out environmentally related activities in Poland. These representatives presented reviews of the activities and contribution of their faculties in this area. The reviews were then published by the "Ekonomia i Środowisko" ("Economics and Environment") Publishing House in Bialystok[4].

During the current term 2014–2018 following members are officers at the PAERE Board and Revision Committee:

The Board PAERE: Professor Leszek Preisner (President), Professor Adam Budnikowski (Vice-President), Professor Bogusław Fiedor (Vice-President), Professor Małgorzata Burchard-Dziubińska (Secretary General), Professor Tadeusz Pindór (Treasurer), and as Board Members: Dr. Elżbieta Broniewicz, Professor Kazimierz Górka, Professor Andrzej Graczyk, Professor Barbara Kryk, Professor Elżbieta Lorek, and Professor Rafał Miłaszewski.

The PAERE Revision Committee: Professor Ryszard Janikowski (Chairman), Professor Mariusz Plich (Vice-Chairman), Dr. Paulina Szyja (Vice-Chairman), and two Members: Dr. Paweł Bartoszczuk and Dr. Ksymena Rosiek.

The Jubilee of the 25th Anniversary of the Polish (former European) Association of Environmental and Resource Economists took place on 19th Sep. 2016 in Krakow and was supported by the Department of Economics, Finance, and Environmental Management, Faculty of Management, AGH University of Science and Technology

[3] *Badania naukowe i działalność dydaktyczna w zakresie ekonomii i zarządzania środowiskowego – Pierwszy Zjazd Katedr Ekonomii i Zarządzania Środowiskowego*, L. Preisner (ed.), Wyd. Ekonomia i Środowisko, Białystok 2012.

[4] L. Preisner, *20-lecie Europejskiego Stowarzyszenia Ekonomistów Środowiska i Zasobów Naturalnych*, in: "Ekonomia i Środowisko", No. 3(43), Białystok 2012, p. 226-235.

and was followed by the two-days conference on: Natural Resources and Sustainable Development, 20–21 Sep. 2016 in Krakow.

The Board of the Polish Association of Environmental and Resource Economists would, within the framework of our Association, appreciate the development of strong relationships between the Academic Community and individuals who find the aims of the Association to be relevant and important. Therefore, persons interested in membership of our Association are kindly requested to contact us via the following address:

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Authors are invited to submit Academic Papers on theoretical and empirical aspects of Sustainable Deve¬lopment and Environmental Management as well as on Environmental Economics and Natural Resources. Papers submitted for review should be in the form of Articles, Research Reports, Discussions or Reviews of Books, information on Academic Conferences, Symposia or Seminars.

Submissions should have up to 20.000 chars, with a clearly defined structure (Introduction, Chapters, Sub-chapters, Ending/Conclusions). They should include an Abstract and "Key-words" in Polish and English.

Articles should be sent by e-mail to: czasopismo@fe.org.pl, in compliance with the official form published on the website of the journal (www.ekonomiaisrodowisko.pl). A model form can be found in Template (file: Template.docx). The references cited have to be in alphabetical order, unnumbered. Plans, Drawings and Schemas (black & white only) should be prepared using Microsoft Word with all elements grouped in a single element group. Graphic Elements (e.g. JPG) and schemas (e.g. in Excel) should be submitted additionally as separate files.

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