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Czasopismo Polskiego Stowarzyszenia
Ekonomistów Środowiska i Zasobów Naturalnych

THEORETICAL AND METHODOLOGICAL PROBLEMS

ENVIRONMENTAL POLICY AND MANAGEMENT

STUDIES AND MATERIALS

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

THEORETICAL AND METHODOLOGICAL PROBLEMS

PROBLEMY TEORETYCZNE I METODYCZNE

Piotr **LUPA** • Małgorzata **STĘPNIEWSKA**

THE STRUCTURE OF POLISH RESEARCH ON THE MAPPING AND ASSESSMENT OF ECOSYSTEMS AND THEIR SERVICES

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ABSTRACT: Ecosystem services (ES) concept has been popular among researchers in the last several years. In this paper, we assessed the development and trends in Polish ES research in the period 2010-2016 using the content analysis of 84 scientific papers – the outcome of ECOSERV Symposia. We analysed such attributes as the type, dimension and scale of the study, ecosystems and ES investigated, the system used to name or classify ES, data used, as well as the considered policy and business questions. In addition, we compared the Polish studies with the European research in the database developed in the ESMERALDA project. The conducted study provides insight into the major achievements as well as challenges that the Polish ES research community will have to face. The findings may serve a discussion on how future directions of the research can be shaped in order to mainstream ES into environmental management.

KEY WORDS: ecosystem services; literature review; content analysis; Poland

Introduction

Twenty years ago, the ground-breaking publications of Costanza et al. (1997) and Daily (1997) kicked off an explosion of research, policy, and applications of the ecosystem services (ES) concept. A group of Polish scholars undertook research on the mapping and assessment of ecosystems and their services quite early (e.g. Ryszkowski, 1995; Żylicz, 2000; Mizgajski, 2004; Zalewski, 2004). The uptake of the ES approach by the community of Polish researches have accelerated since 2010, which was reflected in the organisation of conferences concerning this subject, launching of diverse research projects, as well as in the growth of the number of publications (Stępniewska et al., 2018).

In this paper, we conducted a literature review to examine the development and trends in ES research in Poland. The analysis covered scientific papers being the outcome of Symposia ECOSERV – "Ecosystem services in transdisciplinary approach". ECOSERV Symposia have been taking place every two years in Poznan since 2010, playing an important role in the dissemination of the ES approach in Poland as well as for levering the research quality (Mizgajski et al., 2014; Solon et al., 2017). These meetings allow to present new research on ES, including, among others, case studies, methods, tools, models and implementation. About 100 participants – scientists, as well as representatives of environmental protection authorities and non-governmental organisations – take part in the meetings each time.

Research methods

To understand the nature of the Polish ES research, we used the content analysis method, which is popular for the analysis of trends in ES-related documents (e.g. Piwowarczyk et al., 2013; Kabisch, 2015; Mączka et al., 2016; Jiang, 2017). We analysed 84 scientific papers – outcomes of Symposia ECOSERV 2010, 2012, 2014 and 2016; papers published by authors affiliated in Poland were taken into consideration, with the omission of single papers written by foreign participants (ECOSERV Symposia gained international format in 2018). The investigated conference papers were published in the issues no. 37, 42, 51, 59 and 60 of the "Ekonomia i Środowisko" ("Economics and Environment") Journal.

The content analysis was conducted with the use of criteria developed in the multilateral project ESMERALDA – Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking within the Horizon 2020 Programme

(Burkhard et al., 2018). The scope of the criteria is a result of a long consultation process within the ESMERALDA consortium. Hence, we analysed such attributes as the type, dimension and scale of the study, ecosystems and ES investigated, the system used to name or classify ES, data used, as well as the considered policy and business questions (figure 1). It should be noted that the analysis did not cover all the important ES aspects, e.g. ecosystem conditions, ES accounting, monitoring aspects and supply-demand issues. However, the use of the adopted criteria made it possible to compare the structure of the Polish research with the collection of European studies on the mapping and assessment of ecosystems and their services, recorded in the database developed in the ESMERALDA project (Santos-Martin et al., 2018); the database from April 2018 that we used contained 855 entries from 28 countries.

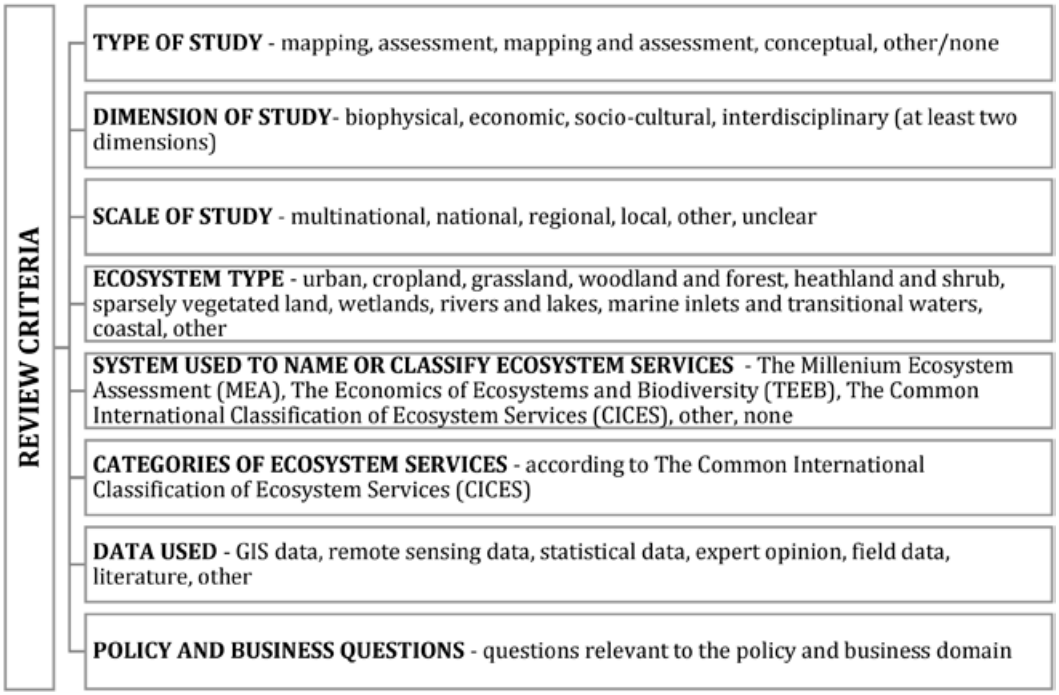

Figure 1. An overview of the criteria used in analysing the research on ecosystem services

Source: author's own work based on Santos-Martin et al., 2018.

We are aware of the fact that the source material insufficiently shows the existing collection of studies on the topic of ES. The ECOSERV proceedings constitute ¼ of ES-related documents indexed by Google Scholar and published by the authors affiliated in Poland in the years 2010-2016 (Stęp-

niewska et al., 2018). Whereas, the ESMERALDA database contains studies arbitrary selected by ESMERALDA project partners, according to their recognition of the state of ES research in individual countries. Therefore, the results should be interpreted with some caution. Nonetheless, in the authors' opinion, the conducted research provides a valuable insight into the major achievements as well as current challenges that the ES research community will have to face. The findings may serve a discussion on how future directions of the research can be shaped in order to mainstream ES into policy and decision-making.

Results of the research

Type of study

The distributions of papers due to the type of study in ESMERALDA and ECOSERV samples were varied (figure 2A). Very characteristic for ECOSERV sample were: a high share of assessment studies (45%), the absence of papers related to mapping only and the presence of theoretical and general works, which we considered as conceptual studies. However, the share of the latter was decreasing in time from 44% in 2010 to 19% in 2016 in favour of case studies related to the mapping and assessment of ecosystems and their services.

Whereas, in the case of the ESMERALDA database, mapping and assessment studies were the most common (56% of total entries). They were followed by studies related to assessments only (33%). The shares of mapping works only as well as other types of studies were quite low.

Dimension of study

Regarding this criterion, the structures of the given samples were quite similar. Most papers had an interdisciplinary character; the second most numerous group included studies on biophysical dimension. The papers focused only on economic or socio-cultural aspects were identified less frequently (figure 2B).

Taking the ECOSERV proceedings into consideration, a significant increase in the share of biophysical studies can be observed in the years 2010-2016 (from 10 to 36%). We noticed also the decrease of the share of economic works (by 10 percentage points). With reference to interdisciplinary studies, the share of three-dimensional studies was decreasing in favour of biophysical-economic and biophysical-socio-cultural ones. This should be

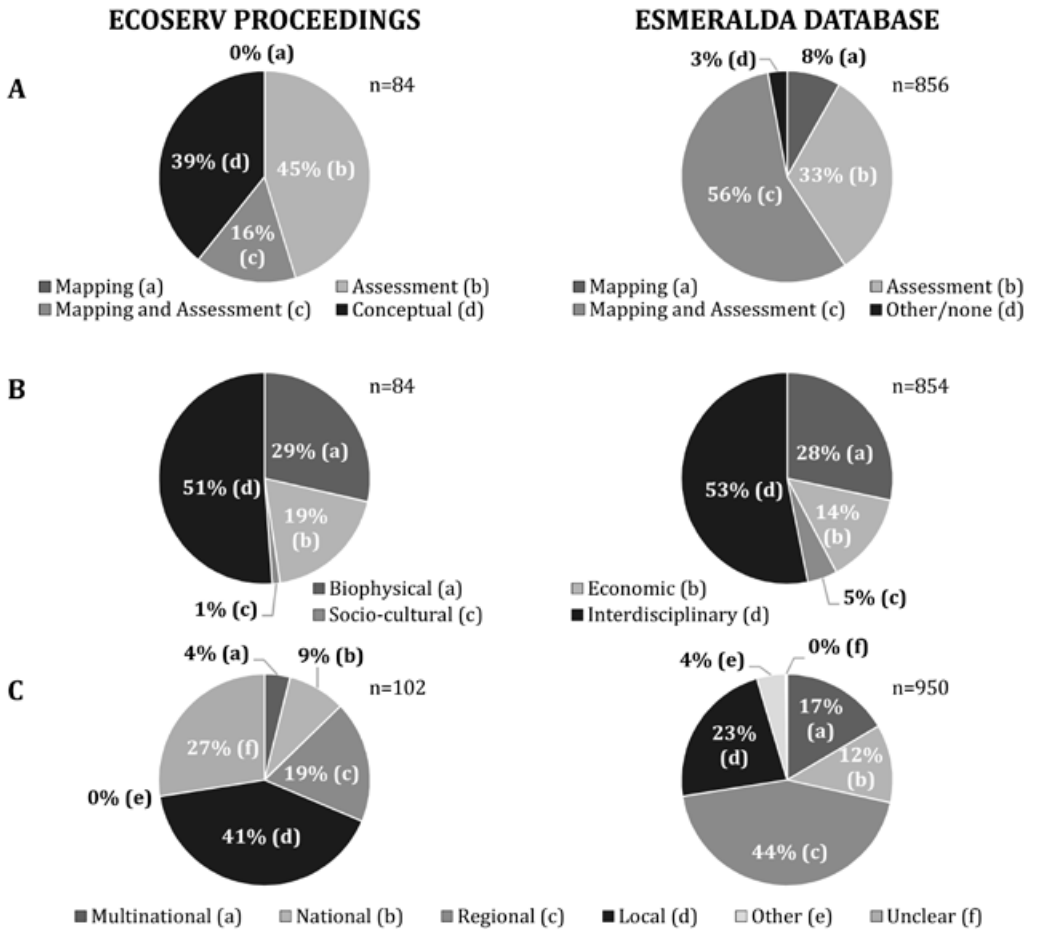

Figure 2. The analysed studies by type of study (A), dimension (B) and scale (C)
Source: author's own work.

combined with a decreasing number of conceptual studies, which had mostly a three-dimensional character.

Scale of study

Another criterion implemented in our analysis was the scale of study. Regarding this, the distributions of works in both samples were varied (figure 2C). Compared to the ESMERALDA database, in the ECOSERV sample we identified a much higher share of local scale studies (by 18 percentage points); we also noticed lower shares of the regional and multinational stud-

ies (by 25 and 11 percentage points). Characteristic for ECOSERV papers was also a relatively high share of studies carried out at an unclear level of scale (27%). However, it must be emphasised that most of them had a conceptual character.

Ecosystem type considered

We review the studies taking into account the main ecosystem types, which are considered by them. In the case of the ECOSERV sample, the "other" ecosystem types were mainly represented in papers (40% of studies). We included in this group the research in which ecosystem types were not pointed out directly by authors. In this kind of studies, ES was considered mostly in relation to the nature protection areas or geographic regions without reference to the particular ecosystem types (e.g. ES provided by a given national park).

The urban ecosystems (26% of studies), rivers and lakes (25%), woodlands and forests (23%), grasslands (20%), and croplands (19%) were taken into account in the other ECOSERV papers. Remaining ecosystem types were investigated by authors very rarely (sparsely vegetated land, heathland and shrub, coastal ecosystems, wetlands) or not present in analysed set of studies at all (marine inlets and transitional waters). These ecosystem types have a low share in the total structure of ecosystems in Poland (Mizgajski, Stępniewska, 2012), which can be the reason for a smaller interest of Polish researchers. Nevertheless, a lack of or a small number of studies on the above-mentioned ecosystem types can be considered as gaps in the research on ES in Poland.

In the ESMERALDA sample, all considered ecosystem types were present in at least fifty studies. Urban ecosystems, woodland and forests, croplands and grasslands were studied most frequently. The research on coastal ecosystems and water bodies – rivers and lakes, marine inlets and transitional waters – were among the least popular.

System used to name or classify ecosystem services

Regarding this criterion, both samples were quite similar in terms of using the Millennium Ecosystem Assessment classification (MEA) and Common International Classification of Ecosystem Services (CICES) (figure 3A). The biggest difference referred to the use of the Economics of Ecosystems and Biodiversity (TEEB) classification; it was used in 10% of studies regis-

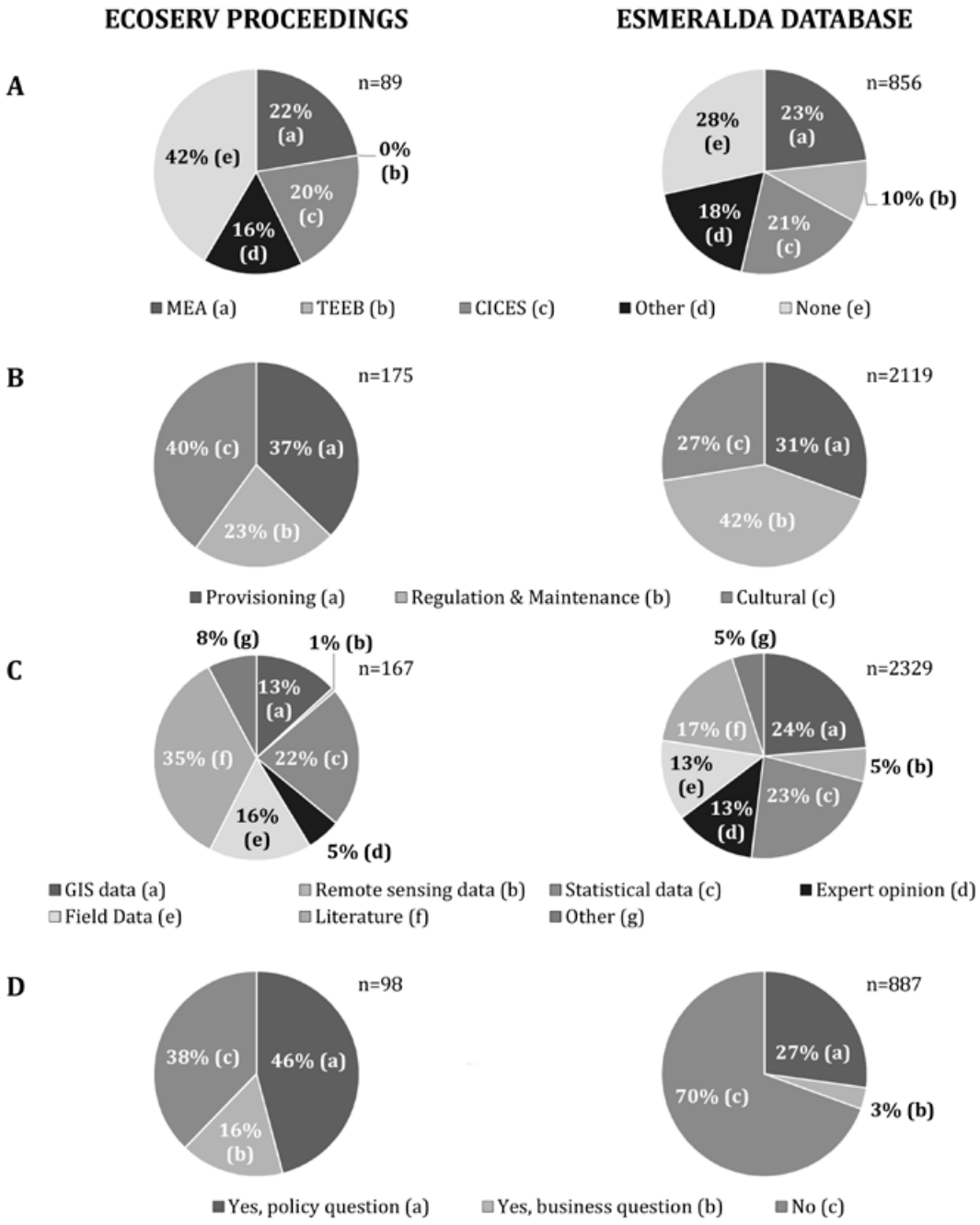

Figure 3. The analysed studies by system used to name or classify services (A), services investigated (B), data used (C) and considered policy and business questions (D)

Source: author's own work.

tered in the ESMERALDA database, but not even in one paper from the ECOSERV sample. In addition, a lot of Polish researchers were not using a concrete system to name and classify ES. In the case of these studies, the authors often used their own terms to define benefits from ecosystems or used very general terms, e.g. leisure and recreational opportunities.

It is important to note the changes in the popularity of particular systems in the subsequent years. In 2010, Polish researchers did not apply any classification (48% of ECOSERV papers) or applied MEA (26%) or other systems (26%). Whereas, the works from 2016 often referred to the CICES classification (36% of papers); the share of the papers, in which no system for naming or classifying ES was used has decreased (by 7 percentage points).

Ecosystem services categories

In this case, we categorised the benefits from ecosystems considered by the authors according to Common International Classification of Ecosystem Services (CICES). Although CICES version 5.1 was published in January 2018, we used version 4.3 from January 2013, which allowed us to compare the Polish studies with the European research from the ESMERALDA database. CICES has a hierarchical structure with five levels of generality (section – division – group– class – class type). We considered the level of section (i.e. provisioning, cultural, and regulation & maintenance ES) and class (forty eight). Because in the ECOSERV sample only 20% of works used the CICES classification, for remaining papers, we re-named the ecosystem benefits considered by authors according to CICES terminology (to ES section or ES classes, depending on the level of detail of an article).

It can be observed that in ECOSERV sample, the cultural (40%) and provisioning (37%) ES were investigated more often than regulation & maintenance ones (23%). This is in opposition to the ESMERALDA sample, where the regulation & maintenance ES were most frequently analysed (42%) (figure 3B).

In the case of provisioning ES, distribution between ES classes was relatively similar in both ECOSERV and ESMERALDA samples. The services related to crops and fibers were studied most frequently, followed by reared and wild animals with their outputs. In both samples, animal-based energy and resources, as well as plants, algae and animals from in-situ aquaculture were not examined often.

Taking regulation & maintenance ES into account, the ECOSERV papers were focused mainly on global climate regulation, hydrological cycle and water flow, and flood protection. The number of studies related to other

regulation & maintenance ES was very limited. In addition, we have not found any work related to bio-remediation, filtration by micro-organisms, storm protection, pest control, disease control, weathering processes, and the chemical condition of salt waters. In turn, studies registered in the ESMERALDA database usually investigated services related to filtration by ecosystems, global climate regulation, mass stabilisation and control of erosion, maintaining nursery populations, as well as hydrological cycle and water flow. Every other regulation & maintenance service was included in at least several dozen studies.

Regarding cultural ES, the ECOSERV papers were centered around the physical use of land-/seascapes and experiential use of plants, animals, and land-/seascapes (commonly called recreational services). The number of works related to other cultural ES was low. Entertainment and symbolic services were not included in any study in this sample. In contrast, papers from the ESMERALDA database covered all classes of cultural ES. However, attention was paid mainly to the physical use of land-/seascapes, aesthetic services, existence services, experiential use of plants, animals and land-/seascapes, heritage and educational services.

Data used

The distributions of data types used were different in both samples. In ECOSERV papers, the most important sources of data were literature (35%), statistics (22%), field data (16%), and GIS data (13%). For comparison, in the ESMERALDA sample, the most frequently used were GIS data (24%), statistics (23%), literature (17%), field data (13%) and expert opinions (13%). We also noticed the difference in the use of remote sensing data, which were more common in studies registered in the ESMERALDA database (figure 3C).

The changes in the sources of data used by Polish researchers in the years 2010-2016 should be highlighted. The first ECOSERV papers (from 2010) were based mostly on the literature and statistical data. In the next few years, the share of these sources of data was gradually decreasing in favour of field data, GIS datasets, and high-resolution remote sensing data. This process is characteristic not only of Polish research – the dynamic uptake of advanced technologies like GIS, as well as more accurate data acquisition methods and tools, stimulate the worldwide development of innovative research, including the ES field (Palomo et al., 2017). Technological changes allow for work on increasingly large datasets (Vihervaara et al., 2018). On the other hand, interpreting the values and comparing the results obtained on the basis of data from various sources requires particular attention to avoid errors (Lupa,

Mizgajski, 2014). The errors may also be result of using only secondary information (Maes, 2016), which still prevail as a source of data in ECOSERV papers; also, the review of Seppelt et al. (2011) covering 153 ES studies from around the world showed that less than 40% of the papers had derived their results on primary data from observations or measurements. This highlights the need for more efforts to collect the primary data of ES (Maes et al., 2012; Stępniewska et al., 2017).

Policy and business questions

The inclusion of policy and business (P&B) questions in the study was another criterion used in our analysis. The specific P&B questions being researched guide the scope and methodological approach for particular ES analysis (Kruse, Petz, 2017). The sets of P&B questions were presented by e.g. Stępniewska (2016), Albert et al. (2017), Maes et al. (2018). The examples of P&B questions can also be found in case studies collected on a thematic webpage developed in the ESMERALDA project (http://www.maes-explorer.eu/page/1). Based on the list of questions from the above materials, we investigated whether the analyzed papers contain a reflection on the practical use of ES research in policy and business.

We found that P&B questions were included more often in ECOSERV studies (56%) than in the ESMERALDA ones (28%) (figure 3D). However, these results should be interpreted with due caution. From the beginning, one of the goals of ECOSERV Symposia is to strengthen the application potential of the ES concept, hence many conference papers consider the issues of result operationalisation. We did not, however, analyze the quality of these P&B links, which differs same as their thematic scope. The latter ranged from studies indicating the significant role of ES for society and entrepreneurs to general discussions on how to include ES valuation in the national accounting. It should be noticed the identification of P&B questions in papers was causing difficulties for many ESMERALDA partners; therefore, the data collected in the ESMERALDA database may be somehow incoherent.

Conclusions

The study provide an overview of the research on the mapping and assessment of ecosystem and their services (MAES) in Poland. The results show the gradual development of competences of Polish researchers within the scope of the ES analysis. It is confirmed in the growing number of publi-

cations, including papers that refer, apart from theoretical deliberations, to case studies related to MAES. We also noticed the increase in use of primary sources of data, as well as presenting research results based on classifications and terminology recognized internationally, and referring the findings to environmental management issues. Our work helps to identify the gaps, which are still an obstacle in mainstreaming ES into policy and practice. They include the concentration of research on a relatively small number of ecosystems and ES, the application of an interdisciplinary approach mainly in theoretical and general studies, and only local perspective in many works. One can say that to overcome the gaps mentioned above, increased cooperation between scientists representing different disciplines is necessary. This would facilitate the mapping and assessment of key ES for all main ecosystem types, as well as the identification of significant ES synergies, trade-offs and bundles, and cross-cutting analysis of the ecological, cultural and economic values of ES.

The contribution of the authors

Piotr Lupa – 50%.

Małgorzata Stępniewska – 50%.

Literature

Albert C. et al. (2017), *Map interpretation/end-user issues*, in: B. Burkhard, J. Maes (eds), *Mapping Ecosystem Services*, Sofia, p. 290-293

Burkhard B. et al. (2018), *Mapping and assessing ecosystem services in the EU – Lessons learned from the ESMERALDA approach of integration,* "One Ecosystem" No. 3: e29153

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

Daily G.C. (1997), *Nature's Services: Societal Dependence on Natural Ecosystems*, Washington

Haines-Young R., Potschin M. (2013), *Common International Classification of Ecosystem Services (CICES) V4.3*., www.cices.eu [29-11-2018]

http://www.maes-explorer.eu/page/1 [29-11-2018]

Jiang W. (2017), *Ecosystem services research in China: A critical review*, "Ecosystem Services" No. 26, p. 10-16

Kabish N. (2015), *Ecosystem service implementation and governance challenges in urban green space planning – The case of Berlin, Germany*, "Land Use Policy" No. 42, p. 557-567

Kruse M., Petz K. (2017), *Mapping provisioning services*, in: B. Burkhard, J. Maes (eds), *Mapping Ecosystem Services*, Sofia, p. 189-198

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

Maes J. et al. (2018), *Which questions drive the mapping and assessment of ecosystems and their services under Action 5 of the EU Biodiversity Strategy?* "One Ecosystem" No. 3: e25309

Maes J. (2016), *Mapping and assessment of ecosystems and their services (MAES): highlights and uncertainties of a science-policy interface on biodiversity and ecosystem services*, "Ekonomia i Środowisko" No. 4(59), p. 52-64

Maes J. et al. (2012), *Mapping ecosystem services for policy support and decision making in the European Union*, "Ecosystem Services" No. 1(1), p. 31-39

Mączka K. et al. (2016), *Application of the ecosystem services concept in environmental policy – a systematic empirical analysis of national level policy documents in Poland*, "Ecological economics" No. 128, p. 169-176

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

Mizgajski A. (2004), *Problemy percepcji idei zrównoważonego rozwoju w naukach przyrodniczych,* in: A. Graczyk (ed.), *Zrównoważony rozwój w teorii ekonomii i w praktyce*, Prace Naukowe Akademii Ekonomicznej we Wrocławiu, p. 171-180

Mizgajski A., Stępniewska M. (2012), *Ecosystem services assessment for Poland – challenges and possible solutions*, "Ekonomia i Środowisko" No. 2(42), p. 54-73

Palomo I. et al. (2017), *Tools for mapping ecosystem services*, in: B. Burkhard, J. Maes (eds), *Mapping Ecosystem Services*, Sofia, p. 72-76

Piwowarczyk J. et al. (2013), *Marine ecosystem services in urban areas: Do the strategic documents of Polish coastal municipalities reflect their importance?* "Landscape and Urban Planning" No. 109, p. 85-93

Ryszkowski L. (1995), *Managing ecosystem services in agricultural landscapes*, "Natural Resources" No. 31, p. 27-36

Santos-Martin F. et al. (2018), *Creating an operational database for Ecosystems Services Mapping and Assessment Methods*, "One Ecosystem" No. 3: e26719

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

Solon J. et al. (2017), Świadczenia ekosystemowe w krajobrazie młodoglacjalnym. *Ocena potencjału i wykorzystania*, Warszawa

Stępniewska M. et al. (2018), *Drivers of the ecosystem services approach in Poland and perception by practitioners,* "Ecosystem Services" No. 33, p. 59-67

Stępniewska et al. (2017), *Possibilities of using the concept of ecosystem services at the regional level in experts' opinions*, "Ekonomia i Środowisko" No. 1(60), p. 81-91

Stępniewska M. (2016), *Ecosystem Service Mapping and Assessment as a Support for Policy and Decision Making,* "CLEAN – Soil, Air, Water" No. 44(10), p. 1414-1422

Vihervaara et. al. (2018), *Biophysical mapping and assessment methods for ecosystem services*, Deliverable D3.3 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007, http://ESMERALDA-project.eu/getatt.php?filename= ESMERALDA%20D3.3_14966.pdf [29-11-2018]

Zalewski M. (2004), *Ecohydrology as a system approach for sustainable water biodiversity and ecosystem services*, "Ecohydrology & Hydrobiology" No. 4, p. 229-235

Żylicz T. (2000), *Costing Nature in a Transition Economy. Case Studies in Poland*, Chelthenham

ENVIRONMENTAL POLICY AND MANAGEMENT

POLITYKA EKOLOGICZNA I ZARZĄDZANIE ŚRODOWISKIEM

Barbara KRYK

PROVIDING SUSTAINABLE ENERGY IN POLAND IN COMPARISON TO THE EUROPEAN UNION IN LIGHT OF THE SEVENTH GOAL OF THE 2030 AGENDA

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ABSTRACT: Purpose – is to answer the research question: what is the speed of ensuring access to sustainable energy in Poland in comparison to the average speed in the EU-28 in the context of the seventh goal of the 2030 Agenda, as well as an analysis of Poland's accomplishments in this field. The study made use of available statistical data related to the eight primary indicators of the Sustainable Development Goals (SDGs) reported by Eurostat and established by the UN. The time frame considered was 2010-2016. Methodology – analysis of dynamic indicators, analysis of real variables or percentages depending on the available data, comparative analysis, and a scale of positive assessments reflecting accomplishments. Implications – the speed of change in Poland is slower than in the rest of the EU. In light of the speed and level of achievements in providing sustainable energy in Poland and the EU, one can indicate tasks/areas requiring more intensive action in the context of the seventh goal of the 2030 Agenda.

KEY WORDS: sustainable development; sustainable energy; society; Poland; European Union

Introduction

It is likely that no one still needs to be convinced of the importance of energy security for society (creating access to varied energy sources for all people) and increasing energy efficiency in all economic sectors (including the domestic sector) in the European Union, in individual countries, and on a global scale. The level of the problem is highlighted by the fact that, in December 2011, the United Nations General Assembly declared the year 2012 to be the International Year of Sustainable Energy for All. It was declared thus because access to modern energy services at affordable prices in developing countries is imperative for achieving the Millennium Development Goals and the concept of sustainable development. During the assembly, the Secretary-General, with the support of UN-Energy and the United Nations Foundation, took charge of the new global initiative entitled "Sustainable Energy for All". Ensuring energy supply was not a separate goal in the Millennium Declaration, but it was stated that its contribution is key to achieving most of its objectives (there is a strong correlation between energy and human development), which is why its importance was raised by taking this initiative (The Energy…, 2005, p. 1-17; The Future…, 2012; Nilsson et al., 2013, p. 4124-4151). Within this initiative, governments, the private sector, and representatives of civil societies around the world would cooperate to realize three main goals relating to general access to sustainable energy by the year 2030. These goals are (Kryk, 2012, p. 151; The Millennium, 2015):

- providing general access to affordable, reliable, and modern energy services,
- considerably increasing the use of renewable energy in the global energy mix (actions in this area are conducted very unevenly, and their effects are also smaller and slower than expected) (Miłek, 2012, p. 19-40; Wamsted, 2013, p. 22-29),
- doubling the speed of improving energy efficiency (the underlying meaning of this goal through the use of the word "doubling" should be noted, as it means that the speed of increasing energy efficiency up until this point was insufficient in comparison to expectations, and actions leading to this increase should be intensified).

These goals, because they were not realized (Sachs, 2012, p. 2206-2211; EC, 2013; UN, 2015), were reiterated as goal 7 of the 2030 Agenda (seventh goal is to "ensure access to affordable, reliable, sustainable and modern energy for all") – they were indicated in order as tasks 7.1, 7.2, and 7.3. Two more tasks were also added, namely:

- 7a. To increase, by 2030, international cooperation allowing access to research on clean energy and technology related to renewable energy and energy efficiency, and advanced and cleaner fossil fuel technology, as well as promoting investment in energy infrastructure and cleaner energy technologies,
- 7b. To expand infrastructure and modernize technology allowing access to modern and sustainable energy services for all residents of developing countries by 2030, especially the least developed countries, small developing island countries, and developing inland countries, according to their development programs.

The tasks of the seventh goal of the 2030 Agenda are convergent with the energy politics goals of the European Union, both from 2007 (EC, 2007) and the current one presented in Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy (EC, 2015), the Europa 2020 Strategy (EC, 2010) and in a document *Clean Energy For All Europeans* (EC, 2016), containing a package of measures to maintain the competitiveness of the European Union at a time when the transition to clean energy is changing global energy markets, which promotes their realization in EU countries. Poland, as a member of the EU and a signatory of the New Agenda, is obliged to realize them as well. It follows, then, that it is worth examining what the current situation in this regard is. Thus, the aim of this article is to answer the research question: what is the speed of ensuring access to sustainable energy in Poland in comparison to the average speed in the EU-28, as well as an analysis of Poland's accomplishments in this field, in the context of the seventh goal of the 2030 Agenda. In order to answer this, statistical data related to the eight indicators of the SDG 7 reported by Eurostat and established by the UN were analysed. The beginning of the considered time period was 2010, when, in the UN report "The Global Partnership for Development: Time to Deliver" (UN, 2011, p. 8-10), information was provided on the difficulties in supplying energy to a large portion of the Earth's population. This information was the basis for formulating the above-mentioned opinion of the UN in 2011 regarding the necessity for increasing efforts to provide greater access to energy, as well as the seventh goal of the New Agenda, which is the topic of discussion of this article. The end of the considered time period (2016) is marked by the end of the available data. Because of the relative newness of the Agenda, the following article stands as a supplement to the perceived research gap, and the analytical method used broadens the spectrum of experimental methodology. The conducted research allowed conclusions to be formulated regarding the current achievements of Poland in this field and the necessary directions of change.

Research methods

Objective 7 of Agenda 2030 – providing everyone with access to stable, sustainable and modern energy at an affordable price – reflects a new multi-faceted view on the issues of energy supply and the energy sector. According to the aforementioned document, ensuring sustainable energy does not only refer to increasing the share of energy from renewable sources in final gross energy consumption, but to treat this issue and the energy sector in a broader perspective than before. It is necessary to take into account other economic and social variables determining the implementation of the objective, which is why the number of indicators to illustrate this has been increased.

In order to monitor achievements in the realization of the seventh goal of the 2030 Agenda of the UN, eight indicators were used (primary energy consumption, final energy consumption, final energy consumption in households *per capita*, energy productivity, share of renewable energy in gross final energy consumption by sector, energy dependence by product, population unable to keep home adequately warm by poverty status, greenhouse gas emissions intensity of energy consumption). For most of these indicators, no reference levels or benchmarks were set, but rather it was established, that the levels of these indicators should be improved. Firstly, in order to identify the state of Polish achievements in comparison to the EU regarding access to sustainable energy, dynamics and actual or percent values of the measured indicators were analysed, and then– taking into account the speed and direction of changes– a synthetic evaluation of achievements toward the seventh goal thus far was performed. For this evaluation, the following scale was used: unsatisfactory (+), moderately satisfactory (++), sufficiently satisfactory (+++), fully satisfactory (++++). The higher the level of indicators accomplished and the faster the speed of these changes, the higher the evaluation (tables 1-8).

Results of the research and Discussion

The realization of the SGDs requires primary energy consumption, which is also one of the significant goals of the 2007 energy and climate package (the so-called "3×20%") in the EU. Although the data from Table 1 reveals that this has occurred rather slowly in Poland. Periods of decline intertwined with periods of growth (this trend was similar to the EU trend), which is likely linked to the economic situation. Altogether, over six years, the use of this energy decreased by 1.5 percentage points (pp) and was 5.4 pp lower than the EU average. The speed of decreasing the use of primary energy also

decreased fourfold: in Poland, it was 0.3 pp/year, and in the EU it was 1.2 pp/year. Although in percentages the effects on a national scale were not satisfactory, they were moderately satisfactory on the scale of the entire EU. However, the actual values should be noted. In Poland, a change of 1 pp = 0.93 million TOE, and in the EU 1 pp = 16.64 million TOE. Thus, it can be said, that the overall amount of unused energy – 1.4 million and 114.8 million TOE respectively – led to a saving of energy. A rise in energy productivity added to this (in Euro/KGOE – table 4), which led to an increase in energy efficiency both in Poland and in the EU (Energy, 2017, p. 17-18). In the end, the synergetic effect was more satisfactory, but still less than expected. Indeed, in economic forecasts (The EU..., 2014) and scientific studies it was determined that in order to achieve the goal, it would be necessary to reduce primary energy consumption by an average of 6.3% per year (Skoczkowski, Bielecki, 2016, p. 5-20; Pach-Gurgul, 2015, p. 75-90). With the current rate of change, the goal may not be reached.

Table 1. Primary energy consumption [million tonnes of oil equivalent – TOE]

Specification	2010	2011	2012	2013	2014	2015	2016	Dynamic 2016/2010	Change	Evaluation
EU 28	1657,5	1595,4	1586,1	1571,2	1508,6	1531,9	1542,7	93,1	-6,9 pp Average -1,2/r	++
Poland	95,7	95,8	92,7	93,0	89,2	90,0	94,3	98,5	-1,5 pp Average -0,3/r	+

Source: author's own work based on Eurostat.

The limitations also require final energy consumption, which in Poland decreased between 2010-2014, what was related to the then economic crisis, but in 2015 it began to rise again, and in 2016 it was 0.6 pp greater in comparison to the beginning of the studied time period (table 2). This was connected to a large extent to an increase in economic activity, improvement of living conditions and lifestyle (a majority of appliances and products require the use of electric energy, a few runs on batteries), and to a lesser extent of structural changes (the "structure effect") and weather conditions (Energy, 2017). This trend confirms economic forecasts indicating an increase in energy consumption in the EU in the perspective up to 2030 and beyond. The average annual speed of increase was 0.1 pp, and the direction of change was the opposite of the intended direction, so the effect was unsatisfactory. Simultaneously, this indicates the necessity for finding new solutions for decreasing energy intensity, which would satisfy energy requirements without

a greater energy expenditure. In the EU, the final energy consumption decreased between 2010-2015 and only rose in 2016. This resulted in an overall decrease of 4.8 pp from 2010. The annual average decreased by 0.8 pp. Considering percentages, the overall change in the EU was nine times greater than in Poland, which is a rather satisfactory result in the context of the SDGs.

Table 2. Final energy consumption [million tonnes of oil equivalent – TOE]

Specification	2010	2011	2012	2013	2014	2015	2016	Dynamic 2016/2010	Change	Evaluation
EU 28	1163.2	1109.2	1108.5	1108.2	1063.1	1086.2	1107,7	95.2	-4,8 pp Average -0,8/r	+++.
Poland	66.3	64.7	64.4	63.3	61.6	62.3	66.7	100,6	0.6 pp Average 0.1/r	+

Source: author's own work based on Eurostat.

Poland had better results in the area of final energy consumption in households *per capita*, which decreased by 9.9 pp over six years (table 3). The annual average dropped by 1.6 pp, which is equivalent to 35.6 kg of oil, and was 2.5 kg of oil equivalent less than 1 pp in the EU (38.1 kg). In a situation where the level of final energy consumption in households *per capita* was consistently lower than the EU average, this could be considered a satisfactory result in the context of the SDGs, although the speed of change in Poland was 0.6 pp slower than in the EU.

Table 3. Final energy consumption in households *per capita* [kg of oil equivalent]

Specification	2010	2011	2012	2013	2014	2015	2016	Dynamic 2016/2010	Change	Evaluation
EU 28	635	565	589	595	522	543	558	87,9	-12,1 pp Average -2,02/r	+++
Poland	577	528	545	537	498	498	520	90.1	-9.9 pp Average -1.6pp	+++

Source: author's own work based on Eurostat.

The indicator of energy productivity shows how many euros are earned by saving 1 kilogram of oil equivalent (KGOE). The higher this indicator, the better. In Poland, as in other countries which joined the EU in the twenty-first

century, energy productivity was lower than the EU average (around 3.9 euro/KGOE) during the entire time period considered (table 4). The average speed of increase was higher than the EU, as it reached 3.2 pp/year, whereas the EU's was 2.5 pp/year (this could have been linked to the weaker impact of the last financial-economic crisis on the Polish economy). Thanks to this, energy productivity rose by 19.4 pp and was 4.3 pp higher than the EU average (15.1 pp). Despite this, there is still almost two times higher of a value generated by 1 KGOE in the EU (8.4 euro) than in Poland (4.3 euro in 2016), therefore the results were evaluated as moderately satisfactory in the context of the seventh goal of the 2030 Agenda. This also indicates the necessity of finding new ways to increase energy productivity. This is even more important because it affects energy efficiency.

Table 4. Energy productivity

Specification	2010	2011	2012	2013	2014	2015	2016	Dynamic 2016/2010	Change	Evaluation
EU 28	7.3	7.7	7.7	7.8	8.3	8.3	8.4	115.1 Average 2.5/r1.1 Average 2,5/r	15.1 pp Average 2.5/r	++
Poland	3.6	3.8	4.0	4.0	4.3	4.4	4.3	119.4	19.4 pp Average 3.2/r	++

Source: author's own work based on Eurostat.

A vital role in providing sustainable energy is played by renewable energy sources (RES), which should largely replace traditional sources. The indicator of shares of renewable energy in gross final energy consumption by sector is used for monitoring this, and this indicator rose both in the EU and in Poland during the considered time period, although at different speeds (table 5). In Poland, the indicator rose from 9.3% in 2010 to 11.3% in 2016, in other words, by 2 pp in six years. The average rose by 0.3 pp in a year, although the yearly increases were lower. The change in direction in Polish energy policy in the field of energy supply has hindered the development of RES (the Polish government assumed that hard coal mining is and will be the basis for the energy balance of the state in the coming years) (Bojanowicz, 2017, p. 6-7; Uznański, 2018, p. 6-7; Energy Policies, 2017), which could lead to a failure to achieve a 15% share of renewable energy in the final energy consumption, originally planned for 2020. This also has a negative impact on the realization of the Europa 2020 Strategy, 2030 Agenda goals and Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy (EC, 2015).

This is all the more disadvantageous because at all times the indicator of shares of renewable energy in gross final energy consumption by sector in Poland was at a lower level (on average, 4.2 pp lower) than in the EU. The average speed of change of this indicator in the EU was 0.8 pp/year and was 2.7 times higher than in Poland, thanks to which the amount of RES in the final energy consumption by sector rose by 17% in 2016 (by 5% pp). If the rate of change of this indicator does not decrease, the planned level of the examined indicator in the EU will be achieved – 20% in 2020 and 27% in 2030 thanks to the positive effects of actions of other community members in this regard (EC, 2016). The RES share is projected to even increase to 30% in the EU. The reason for this is the recent decline in the costs of renewable technologies. EU commissioner Maroš Šefčovič estimates that achieving the 30% target by 2030 will cost almost as much as 27% previously adopted (EC, 2017). Summing up, in the context of Poland's goal 7, Poland's achievements in this respect are unsatisfactory and the EU quite satisfactory.

Table 5. Share of renewable energy in gross final energy consumption by sector [%]

Specification	2010	2011	2012	2013	2014	2015	2016	Changes	Evaluation
EU 28	12.0	13.2	14.4	15.2	16.1	16.7	17.0	5 pp Average 0.8 pp/r	+++
Poland	9.3	10.3	10,9	11.4	11.5	11.7	11.3	2 pp Average 0.3pp/r	+

Source: author's own work based on Eurostat.

Providing access to clean, sustainable, and modern energy, along with energy security, is not always possible based only on a country's own natural resources or energy production. Some of the EU member states (including Poland) must import appropriate fuel (less harmful to the environment) or energy in order to limit pollution of the natural environment (Sakowska, 2017, p. 11-19). Thus, it is important to research the level of energy dependence by-product, which reflects the impact of importing on overall energy usage. In 2010, the EU reached 52.7% of this indicator, and over six years, it rose by 0.9 pp to 53.6%, for an average of 0.15 pp annually–which could be considered to be not very much (table 6). This is certainly the case from an environmental perspective: increasing the importing of more ecological fuels or buying pre-generated energy is less harmful to the environment. However, for the country's economy, importing requires more reliance on external sources, which could lead to risks related to punctual delivery or an increase in energy supply prices due to using less polluting fuels not owned by the

country. These arguments are cited by the Polish government in answer to their use of national fossil fuel resources. This could be one of the reasons for the decline in the share of fuel imports in total energy consumption in Poland from 31.3% in 2010 to 30.3% in 2016, which may be detrimental to the environment. One cannot, however, discard the relationship of this indicator to the increase in energy efficiency caused by technological changes, and this is precisely what occurred. Increasing energy efficiency is determined by a decrease in energy usage as well as a decrease in energy import. Regardless of the causes, the decrease in energy dependence by-product in Poland by 1 pp over 6 years (on average 1.17 pp/year) is not satisfactory. Moreover, it should be noted that over the entire time period studied, this indicator was lower in Poland than the EU average (around 23.6 pp), which means less dependence of the country on external providers, and the direction of change of the indicator is appropriate from the perspective of ensuring energy security.

Table 6. Energy dependence by-product [% of imports in total energy consumption]

Specification	2010	2011	2012	2013	2014	2015	2016	Changes 2016/2010	Evaluation
EU 28	52.7	54.0	53.4	53.1	53.4	53.9	53.6	0,9 pp Average 0.15/r	+
Poland	31.3	33.4	30.6	25.6	28.6	29.2	30.3	-1 pp Average -0.17/r	+

Source: author's own work based on Eurostat.

Another indicator reflecting the implementation of SDG 7 is the indicator of the population unable to keep home adequately warm by poverty related to the measurement of fuel poverty and reflects the percentage of all residents who are not able to maintain an adequate level of heat in their homes. According to the World Health Organization, the temperature of 21°C in the living room and 18°C in the other rooms can be considered as comfortable (Ormandy, Ezratty, 2012, p. 116-121). The concept of fuel poverty relates to the problem of maintaining an appropriate (comfortable) temperature in the home. The causes of this are three key factors: high energy costs, energy inefficient homes, and relatively low household income. Thus, poverty is associated with a lack of financial resources, for the purchase of energy and energy services (in the UK it is assumed that it occurs when the household spends more than 10% of its income on heating the house to the appropriate temperature) (Moore, 2012, p. 19-26; Liddella et al., 2012, p. 27-32; Waddams,

2012, p. 19-26). The result of this state is a cold and damp home, which has a negative impact on the health and well-being of its residents (sick building syndrome). From the definition, it can be stated that not all "impoverished" homes are also "energy impoverished", although the probability of fuel poverty rises in correlation with decreasing income. Often, the victims of fuel poverty are the poorest families who live in buildings using the most energy. These families are punished twice over: by a poor standard of living, and by high energy bills. However, belonging to non-impoverished households does not automatically eliminate such a household from fuel poverty. This results from one simple fact–fuel poverty occurs not only where income is low, but also where a combination of three factors occur: low income, low housing quality, and high energy costs" (Szamrej-Baran, 2013, p. 151-152; Darby, 2012, p. 98-106; Thomson, Snell, 2016, p. 101-118).

In Poland, at the beginning of the studied time period, 14.8% of the population were living in fuel poverty, which was 5.3 pp more than in the EU, whereas in 2016 it affected only 7.1% of residents (table 7). Over six years, the indicator of the population unable to keep home adequately warm by poverty was constantly decreasing: whereas by 2013 it was higher than the EU (on average by 3.1 pp), in 2014 it was the opposite case. In 2016, it was lower in Poland by 1.7 pp than in the EU, and 52% lower than in 2010. The decrease in this indicator was linked to, among others, the improvement of the Polish economy, which impacted the increase in wealth of the population and limited the amounts of extreme and relative poverty in all social groups. In the EU–due to the inclusion in 2007 of Bulgaria and Romania (the poorest countries in the group)–this indicator initially rose, and only started to decrease in 2013, when the average speed of change was around -0.13 pp/year, and was almost 10 times lower than the average speed of change in Poland (-1.28 pp/year). In effect, this indicator decreased in the EU by 1.1 pp overall (unsatisfactory – the results of research in this respect in relation to the EU coincide with the results presented in the literature on the subject) (Tirado Herrero et al., 2012, p. 60-68; Świerszcz, Grenda, 2018, p. 211-230), and in Poland by 7.7 pp (which was 52%), a sufficiently satisfactory result. Thanks to this, the number of people in Poland living in fuel poverty decreased by 48%.

Implementation of SDG 7 also requires reduction of greenhouse gas emissions. According to the EU climate and energy policy, Member States are obliged to reduce greenhouse gas (CO_2) emissions by 40% by 2030 and by as much as 80% by 2050 compared to 1990 levels (EC, 2013; EC, 2011). The proposed target for Poland (reduction of CO_2 by 7%) is one of the lowest in the EU (the same is to be achieved by Croatia and Hungary, with lower reduction targets only for three countries – Latvia (6%), Romania (2%) and Bulgaria (0%).

Table 7. Population unable to keep home adequately warm by poverty status [% of the population]

Specification	2010	2011	2012	2013	2014	2015	2016	Changes 2016/2010	Evaluation
EU 28	9.5	9.8	10.8	10.7	10.3	9.4	8.7	-0.8 pp Average -0.13 pp/r	+
Poland	14.8	13.6	13.2	11.4	9.0	7.5	7.1	-7.7 pp Average -1.28 pp/r	+++

Source: author's own work based on Eurostat.

In the studied time period, the indicator of greenhouse gas emissions intensity of energy consumption decreased in both Poland and the EU, but at different speeds (table 8). In the EU, it decreased on average by 0.78 pp/year, which resulted in a decrease in greenhouse gas emissions by 4.7 pp. The rate of change of this indicator was not significantly higher than in the years 2000-20009 (0.71 pp/year) (author's calculations based on Eurostat data), but despite this, the realization of one of the EU's climate policy goals by 2030 – the limiting of at least 40% of greenhouse gas emissions based on the levels from 1990 – is questionable. Thus, the achieved result is moderately satisfactory. In Poland, the indicator decreased by an average of 0.45 pp/year, or 1.7 times slower than in the EU. This allowed for a decrease in greenhouse gas emissions by only 2.7 pp, and this is not a satisfactory result. What is worse, the situation may not improve, as it is predicted that fossil fuels will dominate the energy market until 2035 or even until 2050. This could lead to an increase in greenhouse gas emissions through energy usage. Therefore, accomplishing the EU energy policy goals and the 2030 Agenda requires taking appropriate steps in order to increase the speed of limiting greenhouse gas emissions.

Table 8. Greenhouse gas emissions intensity of energy consumption

Specification	2010	2011	2012	2013	2014	2015	2016	Changes 2016/2010	Evaluation
EU 28 index (2000 = 100)	92.6	92.4	92.0	90.7	89.3	89.1	87.9	-4.7 pp Average -0.78pp/r	++
Poland index (2000 = 100)	93.0	91.9	93.9	91.9	91.4	91.4	90.3	-2.7 pp Average -0.45 pp/r	+

Source: author's own work based on Eurostat.

Taking into account the individual evaluations of achievements for each indicator, a synthetic evaluation was performed, summing up the amount of (+) awarded. Table 9 presents the amount of possible (+) that could be gained, and table 10 presents the evaluation of the effects so far.

Table 9. Number of pluses possible to achieve

Evaluation	Possible amount of points to be gained
Unsatisfactory (+)	1-8
Moderately satisfactory (++)	9-16
Sufficiently satisfactory (+++)	17-24
Satisfactory (++++)	25-31

Source: author's own work based on Eurostat.

Table 10. Synthetic evaluation of achievements in the context of the SDGs

Specification	Sum (+)	Sum (++)	Sum (+++)	Sum (++++)	Total sum of (+)
Poland	6	0	6	0	12
EU 28	3	4	9	0	16

Source: author's own work based on Eurostat.

Based on the findings above, conclusions were drawn, which are presented below.

Conclusions

During the studied period:

- The combined effects of Poland and the EU as measured by the SDGs were assessed as moderately satisfactory, and the achievements of Poland were smaller than the EU's.
- In Poland, the speed of change of five of the goals (1, 2, 5, 6, 8) was unsatisfactory, and two were sufficiently satisfactory (3, 7), whereas, in the EU, the speed of change of three of the goals (4, 6, 7) was unsatisfactory, two were moderately satisfactory (1, 8), and three were sufficiently satisfactory (2, 3, 5).

In summary, Poland's effort to realize the seventh goal of the 2030 Agenda must increase in the speed of change in almost all areas measured by the aforementioned indicators. This will require not only a search for new solu-

tions or instruments allowing them but also an increase in the level of education regarding sustainable development and changes in the development of sustainable energy. In the EU, the situation in this area is better, but specific actions are still needed, which are formulated in the A framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy of 2015.

Poland as an EU member is obliged to participate in the implementation of energy goals. The EU objectives that should be achieved by 2030 are: reduction of greenhouse gas emissions by 40% (as already mentioned – for Poland only a 7% reduction is foreseen in this case), share of energy from renewable sources in total energy consumption – 27% (20% for Poland), improvement of energy efficiency by 27-30%, 15% of energy in interconnections (i.e. 15% of electricity generated in the EU can be sent to other EU countries). Their achievement is to be supported by new regulatory proposals related to the new vision of the energy market contained in the mentioned Clean Energy For All Europeans package (EC, 2016), accompanying the strategy for the Energy Union, which, inter alia, they assume equal treatment of energy sources, efficient management of energy demand and supply, shaping energy prices on an arm's length basis, guaranteeing the possibility of producing and storing energy for prosumers and energy cooperatives, strengthening competitiveness of the energy market. Most of the proposed solutions have not yet been included in Polish legal regulations, as the last strategic document called Energy Policy of Poland until 2030 comes from 2009, and the draft "Energy Policy of Poland until 2040" developed by the previous Government since 2015 has not yet been finalized (Projekt..., 2018). The Act on Renewable Energy Sources adopted by the new Government (Ustawa, 2015), pointing to a change in national energy policy (return to hard coal as a basis for energy security) adversely affected the RES development, resulting in a slowdown in the development of renewable energy and a threat of failure to achieve in this regard. It can also determine the implementation of other goals. The International Energy Agency (IEA) pointed out this in the Report on the energy situation in Poland (Energy Policies of IEA, 2017). However, it should be emphasized that according to the IEA report, Poland does not fully support the "transformation of the energy system", putting still on fossil fuels as the basic element of the energy system in the long-term perspective. Nevertheless, it places great emphasis on reducing greenhouse gas emissions (GHG) and air pollution, improving energy efficiency, meeting renewable energy targets, decarbonising the transport system and introducing nuclear energy.

Literature

Bojanowicz J. (2017), *Węgiel pozostanie podstawowym paliwem dla energetyki*, „Przegląd Energetyczny" No. 4(88), p. 6-7

Darby S.J. (2012), *Metering: EU policy and implications for fuel poor households*, "Energy Policy" No. 49, p. 98-106, doi.org/10.1016/j.enpol.2011.11.065 [10-10-2018]

Energy (2017), GUS, Warsaw, Poland

Energy Policies of IEA Countries Poland 2016 (2017), http://www.danfoss.pl/news-stories/cf/raport-iea-o-sytuacji-energetycznej-w-polsce/?ref=17179918848#/ [10-10-2018]

EC (2015), *A framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy*, Brussels, COM/2015/080 final

EC (2016), *Clean Energy For All Europeans*, COM/2016/0860 final/2, Brussels

EC (2007), *Communication "An energy policy for Europe",* COM(2007) 1 final – Not published in the Official Journal, Brussels

EC (2011), *Energy Roadmap 2050*, Brussels, COM(2011) 885 final

EC (2010), *Europe 2020: A strategy for smart, sustainable and inclusive growth*, Brussels, COM (2010) 2020 final

EC (2013), *Green Paper. A 2030 framework for climate and energy policies*, Brussels, 27.3.2013 COM(2013) 169 final

EC (2013), *Report Implementation of the Communication on Security of Energy Supply and International Cooperation and of the Energy Council Conclusions of November 2011*, Brussels, COM(2013) 638 final

EC (2017), *Third Report on the State of the Energy Union*, COM(2017) 688 final, Brussels, https://ec.europa.eu/commission/publications/third-report-state-energy-union_pl [10-10-2018]

Energy Policies of IEA Countries Poland 2016 (2017), http://www.danfoss.pl/news-stories/cf/raport-iea-o-sytuacji-energetycznej-w-polsce/?ref=17179918848#/ [10-10-2018]

Kryk B. (2012), *Wzrost efektywności energetycznej – wyzwanie inwestycyjne dla polskiego sektora energetycznego*, in: Ł. Dymek, K. Bedrunka (eds), *Kapitał ludzki i społeczny w rozwoju regionalnym*, Opole, p. 151

Liddella Ch., Morrisa Ch.S.J.P., Mc Kenzieb G.R. (2012), M*easuring and monitoring fuel poverty in the UK: National and regional perspectives*, "Energy Policy" No. 49, p. 27-32, doi.org/10.1016/j.enpol.2012.02.029 [10-10-2018]

Miłek M. (2012), *Problemy z pakietem klimatyczno-energetycznym*, Izba Gospodarcza Energetyki i Ochrony Środowiska, Warszawa, p. 19-40

Moore R. (2012), *Definitions of fuel poverty: Implications for policy*, "Energy Policy" No. 49, p. 19-26, doi.org/10.1016/j.enpol.2012.01.057 [10-10-2018]

Nilsson M. Lucas P., Yoshida T. (2013), *Towards an Integrated Framework for SDGs: Ultimate and Enabling Goals for the Case of Energy*, "Sustainability" No. 5(10), p. 4124-4151, doi:10.3390/su5104124 [10-10-2018]

Ormandy D., Ezratty V. (2012), *Health and thermal comfort: From WHO guidance to housing strategies*, "Energy Policy" No. 49, 116-121, doi.org/10.1016/j.enpol.2011.09.003

Pach-Gurgul A. (2015), *The energy-climate package and realisation of its objectives within the context of the sustainable development of the European Union*, "Central European Review of Economics & Finance" Vol. 10, p. 75-90

Projekt Polityka energetyczna Polski do 2040 roku (2018), Warszawa, https://www.gov.pl/web/energia/projekt-polityki-energetycznej-polski-do-2040-roku [16-10-2018]

Sachs J.D. (2012), *From millennium development goals to sustainable development goals*, "Lancet" Vol. 379, p. 2206-2211, https://www.thelancet.com/ [10-10-2018]

Sakowska A. (2017), *Diversification of sources of supply in the Polish energy resources as determinants of national energy security*, "Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach" No. 113, p. 11-19

Skoczkowski T., Bielecki S. (2016), *Efektywność energetyczna – polityczno-formalne uwarunkowania rozwoju w Polsce i Unii Europejskiej*, "Polityka Energetyczna – Energy Policy Journal" Vol. 19 No. 1, p. 5-20

Świerszcz K., Grenda B. (2018), *Poziom ubóstwa energetycznego w wybranych regionach kraju jako miernik poziomu bezpieczeństwa energetycznego w wymiarze społecznym*, "Przedsiębiorczość i Zarządzanie" Vol.19**,** p. 211-230

Szamrej-Baran I. (2013), *Komu zagraża ubóstwo energetyczne?*, "Ekonomia i Środowisko" No. 3(46), p. 151-152

The Energy Challenge for Achieving the Millennium Development Goals (2005), UN Energy Paper, No. June 22, p. 1-17

The Future We Want (2012), in: Proceedings of the Rio+20 United Nations Conference on Sustainable Development, UN, Rio de Janeiro, p. 20-22

The EU in the world 2015 (2014), A statistical portrait, Eurostat

The Millennium Development Goals Report (2015), New York

Thomson H., Snell C. (2016), *Definitions and indicators of energy poverty across the EU*, in: T. Meszerics (ed.) *Energy poverty*. *Handbook*, European Union, Brussels and Budapest, p. 101-118, doi: 10.2861/094050 [10-10-2018]

Tirado Herrero S., Ürge-Vorsatz D. (2012), *Trapped in the heat: A post-communist type of fuel poverty*, "Energy Policy" No. 49, p. 60-68, doi.org/10.1016/j.enpol.2011.08.067 [10-10-2018]

UN (2011), *The Global Partnership for Development: Time to Deliver*, New York, p. 8-10

UN (2015), *Transforming our World: the 2030 Agenda for Sustainable Development*, Resolution adopted by the General Assembly on 27 July 2015, A/RES/69/313. 12, New York

Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii, Dz.U. 2015, poz. 478

Waddams C., Brazier P.K., Wang W. (2012), *Objective and subjective measures of fuel poverty*, "Energy Policy" No. 49, p. 19-26, doi.org/10.1016/j.enpol.2011.11.095 [10-10-2018]

Wamsted D. (2013), *The Outlook for 2013. Using less,* "Electric Perpectives" No. January/February, p. 22-29

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THE INFLUENCE OF NEW LEGAL REGULATIONS ON THE METHOD OF DETERMINING THE AMOUNT OF FEES FOR DISCHARGING RAIN WATER AND SNOW WATER TO WATER

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ABSTRACT: In article was analyzed procedure of determining fees for water services connected with discharging rain water and snow water to water, as a result of the new Water Law, which came into force on the 1st of January 2018. First of all, authors compare the scope of water law permits – connected with the aforementioned matter – issued under the Water Law of 2001 (currently not in force) to those issued under the new Water Law of 2017 (currently in force since the 1st of January 2018). Authors indicate that – within the new Water Law – water law permit issued before the 31st of December 2017 is the fundamental source of information related to determining fees for discharging rain water and snow water to water. Such situation can lead to interpretational doubts of legal provisions related to the aforementioned matter. Results of the analysis conducted by the authors of this paper indicate crucial differences within amounts of fees for discharging rain water and snow water, paid by the obliged entities. Such differences result from the method of determining certain amounts of fees and also from the interpretation of the new Water Law and implementing regulations.

KEY WORDS: water services, water law, rainwater, fees for water services, rain fee

Introduction

Following Poland's accession to the European Union (EU), national provisions related to the management of water are formed mainly by regulations issued within EU. Policy of EU – while considering environment – contributes to achieving a reasonable and rational method of using natural resources. Such policy is aimed at reaching a high level of nature preservation, including differences within certain regions (Białek et al., 2018). While considering the usage of water and management of water resources, Directive 2000/60/WE of European Parliament and Council of 23rd of April 2000 is of fundamental importance. The Directive sets the scope of community activities within water policy. Art. 9 point 1 of the Directive shows that EU Member States – within provisions of their national law, which are currently in force – should take into consideration the rule related to refunds of fees for water services, including economic fees and expenses connected with materials (in other words "the one who pollutes has to pay"). What is more, the aforementioned Directive introduces legal definition of "water services": *"water services mean all services allowing households, public institutions or any other economic activity to: a) consume, dam up, store, treat and distribute surface or underground water; b) receive and treat waste, which is drained off to surface water afterwards"* (EU, 2000).

The issue of the water management and water services in the EU has been the subject of many publications (among others: Jekel, 2005; Unnerstall, 2007; Miłaszewski, Rauba, 2010; Gawel, 2015), but the system of water services in Poland is new, that is why the literature connected with the subject matter is poor and insufficient. Economic analysis (required by the aforementioned Directive and conducted by Białek et al., 2018) shows that in the years 2016-2017 the refund of fees for water services reached only 22-24%. Such situation caused introducing a new system of fees for water services in the new Water Law. The main issue was related to the rule of refunding fees for water services. Fees for water services were recognized as one of the five instruments related to management of water resources (art. 11 point 3 of the new Water Law) and as one of the nine economic instruments connected with water management (art. 267 point 1 of the new Water Law).

Introducing the new system of fees is a crucial change, especially for entrepreneurs, because now they must analyze the entire previous scope of water management. Decision-makers must choose how resources are allocated for rain water management and decide among the options available to reduce the impact of rain water to the receivers. At the same time, decision-makers must face problems related to costs and benefits of managing rain water including maintenance costs, and how the cumulative effects of

many decentralized and distributed projects across the city will impact rain water flows (Cousins, 2017). Until now, in many cities of Poland as well as abroad, it was required to pay fees for rain water for property under the impervious cover of land parcels (Burszta-Adamiak, 2014; McPhillips, Matsler, 2018). Establishment of such rain water fees was aimed at mitigating losses in the overall fee base and thus funds for maintaining and upgrading rain sewer infrastructure (Keeley et al., 2013). This provided additional revenue to fund maintenance of existing rain water control measures as well as to support development of new ones.

On the 1st of January 2018 the new Water Law (2017) came into force, introducing a reform of the water administration and management system. Amendment to the Water Law (the new Water Law, 2017) was the final step leading to implementation of the aforementioned Directive (EU, 2000) to Polish law.

As far as management of rain water and snow water is concerned, significant changes were introduced. Under the old Water Law, rain water and snow water were defined as wastewater, contained in open or closed drainage systems, coming from contaminated areas with permanent surface, in particular:

- cities, ports, airports,
- areas of industrial, commercial, service and warehousing purpose,
- transport bases,
- roads and parking lots (Art. 9, item 1, point 14 (c), old Water Law, 2001).

On the other hand, under the new Water Law, rain water and snow are no longer included in the wastewater category. They became a part of water services, defined as: *"discharging rain water and snow water to water, contained in open or closed rain sewage systems used for draining off rainfalls or contained in collective sewage systems within administrative borders of cities"* (Art. 35, item 3, point 7, the new Water Law 2017).

The new Water Law introduces a system of fees for water services, including, among others: discharging rain water and snow water to water, contained in open or closed rain sewage systems used for draining off rainfalls or contained in collective sewage systems (Art. 268, item 1. point 3 (a), the new Water Law, 2017). Under the new Water Law, fees for water services connected with discharging rain water and snow water, consist of a fixed fee and variable fee dependent on the existence of facilities for water retention from the sealed areas (Art. 270, item 11, the new Water Law, 2017). The amount of the fixed fee for discharging rain water and snow water is calculated as the product of the unit fee rate, period in days and maximum quantity of water, which can be consumed (measured in m3/s) – according to legal water permission or integrated permission. (Art. 271, item 4, new Water Law, 2017).

On the other hand, the variable fee is calculated as the product of the unit fee rate, the amount of consumed water expressed in m^3 and period in years, considering the existence of facilities for water retention from the sealed areas and capacity of such facilities (Art. 272, item 5, the new Water Law, 2017). Binding unit fee rates are provided in the Ordinance of the Council of Ministers related to unit fee rates for water services (currently Journal of Laws of 2017, item 2502). The amount of the fee is determined by State Water Holding – Polish Waters (in polish: Państwowe Gospodarstwo Wodne – Wody Polskie), which notifies the entities obliged to pay it in form of annual information containing the method of calculating the fee (Art. 271, item 1, the new Water Law, 2017). Pursuant to art. 271, item 4 of the new Water Law (the new Water Law 2017), the calculation of the fixed fee is based on information included in the water law permit. Under the amended Water Law, the permit for discharging rain water and snow water to water or to soil shall specify the maximum amount of consumed water in m^3/s, the average amount in m^3/year and the actual and reduced surface area of the catchment drained by each outlet, the amount of rain water and snow water, and the average amount of rain water and snow water discharged to the facilities for the retention of water from sealed areas, expressed in m^3 per year (Art. 403, item 1, points 2 and 20, the new Water Law, 2017).

Under the old Water Law, fees for using the environment and discharging rain water and snow water to water and soil, were applicable (Art. 273, item 1, point 2, Law of Environmental Protection, 2001). In the legal situation that existed until the 31st of December 2017, if rain water or snow water was discharged to water or soil, the amount of fee was dependent on the size, type and method of development of the area from which such wastewater was discharged (Art. 274, item 4, point 1, Law of Environmental Protection, 2001). The amount of unit fee per 1 m^2 of contaminated area with a permanent surface was published annually in the announcement of the Minister of the Environment related to fees for the use of environment (Appendix 2, Table D, M.P. of 2016, item 718). Under the old Water Law, the water law permit for discharging rain water and snow water should specify the amount, state and composition of wastewater discharged to water, soil, or sewage systems or the minimum percentage of contamination's reduction in the wastewater treatment process (Art. 128, item 1, point 4, old Water Law, 2001). It should be mentioned that water law permits issued under the repealed Water Law remain in force (Art. 547, item 7, the new Water Law, 2017), which – in extreme cases – may refer to the period until the 31st of December 2027.

Under the old Water Law (2001) fees for discharging the rain water or snow water had to be paid by the owner of the rainfall sewage system's outlet, where the wastewater was discharged to soil, water or to water devices.

Similar situation occurs in the new Water Law, however with one exception – the fee have to be paid only for discharging the rain water and snow water to surface water. In most of the cases, communes are the owners of the sewage systems' outlets. Earlier, the communes could include collecting of the wastewater – coming from the rain or snow – in the fee tariff for water and wastewater, but today they can't do it, because rain water and snow water are no longer defined as a wastewater.

Sustaining the old water law permits in force cause problems related to the rights – expressed under the old Water Law and under the new Water Law – which are not the same in both of those cases. The main difference is connected with the information about the maximum and annual amount of rain water and snow water which has been discharged. Another problem is related to facilities used for retention of rain water and snow water: under the old Water Law, possession of such facilities wasn't required in water law permits or it was required, but only to the extent specified in the old Water Law; whereas under the new Water Law, water law permit must include possession of the aforementioned facilities. This may cause difficulties related to proper calculation of fees for water services connected with discharging rain water and snow water to water or soil, pursuant to water law permits issued under the old Water Law (old Water Law, 2001).

The main purpose of this article is to show the need to unify methods of calculating fees for rain water and snow water. Such need is connected with interpretational doubts related to the new Water Law, especially, while considering water law permits, issued before the 1st of January 2018.

Research methods

The authors analysed 50 water law permits for discharging rain water to water or to soil, issued under the repealed Water Law (old Water Law, 2001), selected randomly from publicly disclosed decisions on water law permit. They specify the scope of rights, which was systematised according to the adopted categories (table 1). The share of water law permits containing information that enables directly or indirectly to calculate the fixed fee (i.e. maximum transient runoff – Q_{max} maximum hourly discharge – $Q_{max.h}$, or maximum annual discharge – $Q_{max.yr}$ and the variable fee (i.e. maximum annual discharge – $Q_{max.yr}$, average annual discharge – Q_{yr}, average daily discharge – Q_d) was determined. The analysed decisions were issued by starostes of county, presidents of towns with county rights, voivodeship Marshalls and the Director of the Regional Water Management Authority in the years 2004-2017. The paper is based on the legal status of the new Water Law (new Water Law, 2017) as of May 31st, 2018.

Table 1. Categories adopted for the analysis of water law permits in terms of the contained information about the data characterizing the quantity of discharged wastewater (rainwater and snow water)

Category	Unit	Type of discharge according to water law permits	Characteristics of the category
Q_c	m^3/s	calculated	This category includes water law permits that specified the amount of discharged water, without providing the maximum, hourly, average daily or annual values, etc.
	m^3/s	total/cumulative	
	m^3/s	Unit	
Q_{max}	m^3/s	maximum [1, 3]	This category includes water law permits that specify the maximum transient quantity of discharged water and unit-based or calculated discharge, but do not specify the maximum hourly and annual values and average daily values.
	m^3/s	calculated	
Q_4	m^3/s	calculated	This category includes water law permits that specify the value of maximum hourly and annual discharge, average daily discharge and calculated discharge.
	m^3/h	maximum hourly [4]	
	m^3/d	average daily [5]	
	m^3/r	maximum annual [4]	
Q_{3C}	m^3/h	maximum hourly [4]	This category includes water law permits that specify the value of maximum hourly and annual discharge and the average daily discharge.
	m^3/d	average daily [5]	
	m^3/r	maximum annual [4]	
Q_{4C}	m^3/s	maximum	This category includes water law permits that specify the value of maximum transient, hourly and annual discharge and the average daily discharge.
	m^3/h	maximum hourly [4]	
	m^3/d	average daily [5]	
	m^3/r	maximum annual [4]	
Q_{other}	m^3/s	calculated	This category includes water law permits that do not qualify to the other categories.
	m^3/h	maximum hourly [4]	
	m^3/d	average daily [5]	
	m^3/r	annual [2, 3]	
Q_w	-	-	The water law permit does not specify the quantity of discharged waters.

1 amount required to calculate fixed fee under the new Water Law
2 amount required to calculate variable fee under the new Water Law
3 information required in the water law permit under the new Water Law
4 amount used for calculating fixed fee under the new Water Law, by converting indirectly into seconds
5 amount used for calculating variable fee under the new Water Law, including the amount of rainy days

Source: author's own work.

Pursuant to the water law permit (Decision of 2016) and the statement of water management conditions (Siwulski, 2016) for discharging rain water from the area of the city Strzelin to the Oława River – outlet W-IV, the authors conducted a simulation of the calculation of the fee, considering different interpretations of the method of determining input data for calculating the fee. The amounts of fixed and variable fee were calculated separately. The analyzed variants are presented in table 2, while table 3 presents the characteristic data of the drained area and the input data for calculations. The calculation of fixed and variable fee was based on the formula specified in the new Water Law (new Water Law, 2017). However, it was presented as a total annual fee, without dividing it into quarterly payment instalments. The basic rate of fee per unit was estimated, as the statements of water management conditions issued under the repealed Water Law (old Water Law, 2001) did not specify the volume of water retained in dedicated facilities. Comparative analyses, related to the amount of fee, included basic variant, which constituted variant 1 – for the fixed fee, variant 4 – for the variable fee and the sum of variants 1 and 4 – basic variant for the entire amount of annual fee.

$$FF - UR \cdot T \cdot Q_{max}, \quad (1)$$

where:
FF – fixed fee [PLN],
UR – unit rate determined pursuant to the Ordinance of the Council of Ministers (Journal of Laws of 2017, item 2502),
T – time [days],
Q_{max} – maximum transient quantity of discharged rainwater and snow water [m^3/s].

$$VF = UR \cdot T \cdot Q_{v.yr}, \quad (2)$$

where:
VF – variable fee [PLN],
UR – unit rate determined pursuant to the Ordinance of the Council of Ministers (Journal of Laws of 2017, item 2502),
T – time [years],
$Q_{v.yr}$ – annual quantity of discharged water [m^3].

Table 2. Analysed variants of the simulation of the amount of fixed and variable fee for discharging rainwater and snow water to water

Variant	Type of fee	Characteristics of the manner of calculating the fee
1	Fixed fee	Calculated directly from the Q_{max} specified in water law permit
2		Calculated indirectly: Q_{max} calculated basing on $Q_{max.h}$ specified in the water law permit or statement of water management conditions. $(Q_{max} = Q_{max.h}/3600^*)$
3		Calculated indirectly: Q_{max} calculated basing on $Q_{max.yr}$ specified in the water law permit or statement of water management conditions. $(Q_{max} = Q_{max.yr}/31536000^*)$
4	Variable fee	Calculated directly, based on the assumption that Q_{yr} correspond to the annual quantity of water discharged pursuant to the permit obtained or as specified in the statement of water management conditions. $Q_{v.yr} = Q_{yr}$
5		Calculated indirectly, as the product of the average daily quantity of discharged water and the number of rainy days (DP) specified in the statement of water management conditions. $Q_{v.yr} = Q_d \times DP$
6		Calculated as the product of the average total rainfall from the long-term period (Hm) and the drained surface area (F). (Filipek et al., 2018). $Q_{v.yr} = H_m \times F$
7		Calculated as the product of the total rainfall from the preceding year (H) and the drained surface area (F). (Filipek et al., 2018). $Q_{v.yr} = H \times F$
8		Calculated as the product of the average total rainfall from the long-term period (Hm), the drained surface area (F) and the runoff coefficient (φ) (Filipek et al., 2018). $Q_{v.yr} = H_m \times F \times \varphi$
9		Calculated as the product of the total rainfall from the preceding year (H), the drained surface area (F) and the runoff coefficient (φ) (Filipek et al., 2018) $Q_{v.yr} = H \times F \times \varphi$
10	Marshall's fee	Fee for the use of environment binding until the 31st of December, 2017, based on the unit fee rate (M.P. of 2016, item 718) and the size of the drained surface area.

* conversion per second: day, year.

Source: author's own work.

Table 3. Input data necessary for calculating the fixed and variable fee for discharging rainwater and snow water to water

Item	Parameter	Unit	Value	Data source
1.	Q_{max}	m^3/s	3.094	Decision of 2016
2.	Q_d	m^3/d	689.9	Siwulski, 2016
3.	$Q_{max.h}$	m^3/h	378.97	Siwulski, 2016
4.	$Q_{max.yr}$	m^3/r	1385757.7	Siwulski, 2016
5.	Q_{yr}	m^3/r	111588	Siwulski, 2016
6.	$Q_{v.yr} = H_m \times F$	m^3	548020	Own calculations based on data by Siwulski, 2016
7.	$Q_{v.yr} = H \times F$	m^3	574340	
8.	$Q_{v.yr} = Hm \times F \times \varphi$	m^3	137693	
9.	$Q_{v.yr} = H \times F \times \varphi$	m^3	144306	
10.	Long-term period rainfall (meteorological station Wrocław*)	m	0.583	Siwulski, 2016
11.	Rainfall in preceding year (meteorological station Wrocław*)	m	0.611	GUS, 2017
12.	Number of rainy days	-	160	Siwulski, 2016
13.	Drained area	ha	94.00	Siwulski, 2016
14.	Average weighed runoff coefficient	-	0.25	Own calculations based on data by Siwulski, 2016
15.	Green areas	ha	37.76	Siwulski, 2016
16.	Developed areas	ha	50.3	Siwulski, 2016
17.	Roads	ha	5.94	Siwulski, 2016
18.	Runoff coefficient – green areas	-	0.1	Siwulski, 2016
19.	Runoff coefficient – developed areas	-	0.3	Siwulski, 2016
20.	Runoff coefficient – roads	-	0.8	Siwulski, 2016
21.	Rate per unit FF (equation 1)	PLN per m^3/s	2.5	Journal of Laws of 2017, item 2502
22	Rate per unit VF (equation 2)	PLN per m^3	0.75	Journal of Laws of 2017, item 2502
23	Rate per unit – Marshall's fee	PLN per m^2	0.057	M.P. of 2016, item 718

* – meteorological station Wrocław was used in the statement of water management conditions (Siwulski, 2016) as characteristic for Strzelin

Source: author's own work.

Results and discussion

The fees for water services connected with discharging rain water and snow water should be charged only for discharging it to water. Pursuant to art. 268, item 1, point 3 (a) of the amended Water Law (the new Water Law, 2017), discharging rain water and snow water to soil is free of charge. On the other hand, Białek et al. (2018) claim that the provisions of Art. 268, item 1, point 3 (a), Art. 270, items 3 and 11, Art. 272, item 5, Art. 274, item 5 (the new Water Law, 2017) may be interpreted as a lack of obligation to pay the fees for water services connected with discharging rain water and snow water to water units, as the cited provisions on charges do not list the water units, although according to the definition of water services rain water and snow water is discharged to water units. Capturing rain water or snow water with the use of water melioration units is also exempt from charge, as it does not constitute a water service and is an example of using water which does not require obtaining a water law permit (Art. 395, item 13, new Water Law, 2017). However, one should bear in mind that not every ditch or reservoir is classified as a water melioration unit, because pursuant to Art. 195 of the amended Water Law (new Water Law, 2017), water melioration units consist in regulating water relations in order to improve the production capacity of soil and to facilitate its cultivation, and not every ditch or reservoir serves that purpose.

The analysis of water law permits issued under the repealed Water Law demonstrates that they are not homogenous in terms of the scope of the rights provided therein connected with discharging rain water or snow water to soil (figure 1).Water law permits that only specify the Q_{max} value, which enables to determine the fixed fee directly, had the highest share (28%), while permits specifying the Q_c value that does not allow the calculation of fixed fee accounted for 24%. On the other hand, permits specifying the values of $Q_{max.h}$, $Q_{max.yr}$, Q_d, which may constitute the basis for calculating the fixed fee indirectly, by converting $Q_{max.h}$ and $Q_{max.yr}$ into Q_{max} represented 26% of all permits. 2% of the permits did not specify the amount of discharged rain water and snow water at all. Altogether, 36% of the water law permits contained information about Q_{max} value that enabled to calculate the fixed fee directly, while 36% specified the $Q_{max.h}$, and 38% decisions specified $Q_{max\ yr}$, which may be converted to Q_{max} to calculate the fixed fee indirectly (figure 2). It should be noted that only 8% of the water law permits contained any information about the annual amount of discharged waters (Q_{yr}), which would enable to determine the amount of variable fee. On the other hand, 40% of the permits contained information about the daily amount of discharged

waters (Q_d), which may constitute the basis for calculating the annual amount of such waters indirectly (table 2).

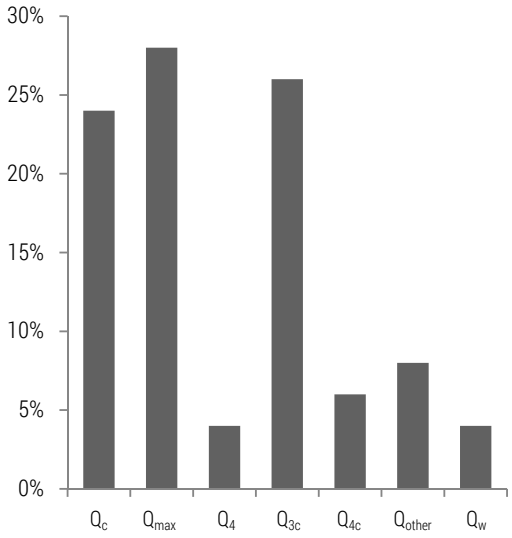

Figure 1.
Share of water law permits belonging to a category defined in Table 1 for the purposes of analysing the amount of discharged wastewater (rain water and snow water)

Source: author's own work.

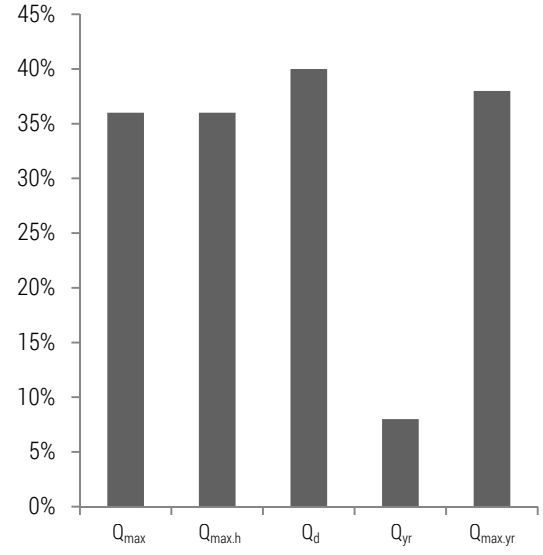

Figure 2.
Share of water law permits specifying a value characterising the amount of discharged rainwater that enables to determine the fee for discharging rain water and snow water to water

Source: author's own work.

Among all analysed water law permits, 30% contained all information (Q_4 and Q_{3C} categories) required for the determination of fixed and variable fee, provided that the Q_{max} and $Q_{v.yr}$ values may be calculated indirectly,

by converting them, respectively, from $Q_{max.h}$ or $Q_{max.yr}$ and Q_d. 6% of the water law permits (Q_{4C} category) specified Q_{max} thus enabling to calculate the fixed and variable fee indirectly, by converting Q_d into $Q_{v.yr.}$ 8% of them ($Q_{other\ category}$) contained information that enable to determine the fixed fee indirectly (by converting $Q_{max.h}$ into Q_{max}) and to calculate the variable fee indirectly or directly, respectively by converting Q_d and Q_{yr} into $Q_{v.yr}$. 44% of the water law permits altogether contained information that enable to simultaneously calculate the data required for the determination of fixed and variable fee, directly or indirectly, without the need to use additional information from the statement of water management conditions. It should be noted that none of the water law permits provided information about facilities for water retention in sealed areas or their capacity, which is necessary to determine the amount of unit rate for discharging rain water and snow water to water. In such event, the maximum rate is applied.

Depending on the adopted calculation variant (table 2), the amount of fixed fee may range from PLN 40 to PLN 2823 (figure 3). The highest fixed fee is charged if the Q_{max} specified in the water law permit (Decision of 2016) is applied directly, while the lowest one is obtained if $Q_{max.yr}$ is converted into Q_{max}. In the analysed case it is obligatory to apply the Q_{max}, as it is specified in the water law permit constituting the basis for calculation of the fee for discharging rain water and snow water to water (Art. 271, item 4, new Water Law, 2017). If the permit does not specify the Q_{max} value, only the $Q_{max.h}$ and/or $Q_{max.yr}$ instead, one may consider determining the Q_{max} value indirectly by converting $Q_{max.h}$ or $Q_{max.yr}$ (Filipek et al., 2018). However, this may result in a significant underestimation of the fixed fee, which might not reflect the fixed costs of discharging rain water and snow water to water. The amount of fixed fee calculated by converting $Q_{max.h}$ or $Q_{max.yr}$ may constitute, respectively, 3.4% and 1.4% of the fixed fee calculated basing on Q_{max}.

The judgments of administrative courts will become an important element in determining the fixed fees for water services. In the case concerning the fixed fee for using water services, the Voivodeship Administrative Court in Szczecin (II SA/Sz 514/18) stated that the legislator had not specified, which of the indicators provided in water law permits issued pursuant to the repealed Water Law ($Q_{max.h}$, $Q_{max.d}$ or $Q_{max.yr}$) should be used to calculate the fixed fee. According to the Court, the application of the $Q_{max.h}$ indicator is incorrect, as its use of waters is not constant, because it is limited by the value of $Q_{max.yr}$. The application of $Q_{max.h}$ results in charging a fee that does not reflect the costs of the actual, permitted and legal use of water services. Additionally, the water management authority, which calculated the fixed fee for using water services based on the $Q_{max.h}$ indicator of such use, as foreseen in the water law permit, contrary to the provisions of Art. 7a § 1 of the Code of

Administrative Procedure – "If the subject of administrative proceedings consists in imposing an obligation on a Party or depriving it from an entitlement or limiting the scope of its rights, and the case leaves any doubts regarding the content of the legal standard, these doubts shall be settled to the benefit of the party (...)", (Code of Administrative Procedure, 1960) failed to settle the doubts concerning the interpretation of the provision of Art. 271 item 2 of the amended Water Law (new Water Law, 2017) to the benefit of the party obliged to pay the fee and assumed a result that does not reflect the costs of actual, permitted and legal use of waters on an annual scale. However, in a similar case, the Voivodeship Administrative Court in Kielce (I SA/Ke 134/18) expressed a different opinion, arguing that the fixed fee is a subscription fee, payable for the Q_{max}, which is assumed to be the maximum value in m^3/s, converted, respectively, from $Q_{max.h}$, $Q_{max.d}$ or $Q_{max.yr}$, and the fact that $Q_{max.yr}$ was exceeded, is insignificant, as the fixed fee is by definition a permanent, lump-sum fee, i.e. a fee in a predefined amount and it is not related to the actual extent of use of waters.

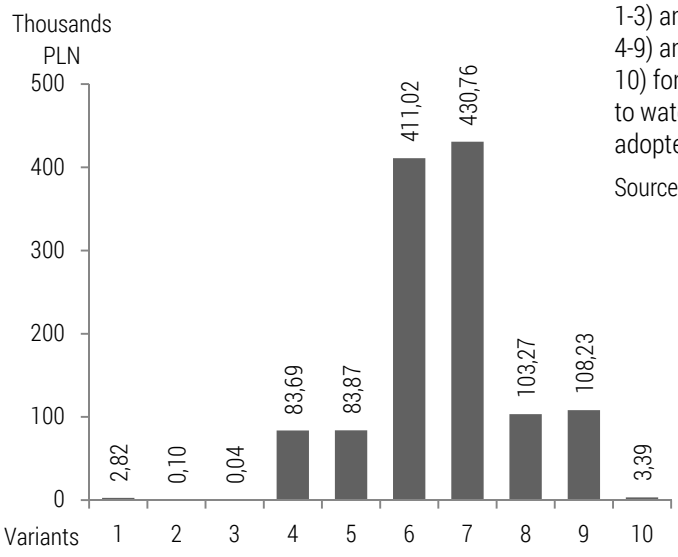

Figure 3.
Amount of fixed fee (variants 1-3) and variable fee (variants 4-9) and Marshall's fee (variant 10) for discharging rainwater to waters, according to the adopted calculation

Source: author's own work.

The authors prefer the interpretation adopted by the Court in Szczecin, because applying hourly indicator ($Q_{max.h}$) during calculatinos leads to increasing the amount of fee, whereas annual indicator ($Q_{max.yr}$) reflects the real level of the usage of water service. Moreover, exceeding annual (as well as hourly) level of usage is liable to a fine (art. 476 item 1 of the new Water

Law 2017, II SA/Sz 514/18). However, the absence of a uniform jurisdiction of the Voivodeship Administrative Courts and interpretation of Art. 271 of the amended Water Law (new Water Law, 2017) may lead to a chaos in the interpretation of the amount of the fixed fee calculated basing on the Q_{max} specified in water law permits issued under the repealed Water Law. Due to that, the judgments of the Supreme Administrative Court will be decisive.

The analysis of the amount of variable fee for discharging rain water to water depending on the adopted calculation variant (table 2) demonstrates that the fee may vary to a significant extent, falling into the range from PLN 83 691 to PLN 430 755.

The base variant adopted for the purposes of this study was the case, in which the amount of variable fee is calculated basing on the average amount of rain water discharged to water annually (table 4). As not all water law permits issued pursuant to the repealed legislation contain such information (which is missing, e.g. in the analysed case of Strzelin (Decision of 2016)), it became necessary to use the water low documentation (Siwulski, 2016). The lowest values of the variable amount were obtained when it was determined basing on the annual average (variant 4) and daily average (variant 5) amount of discharged rain water and snow water, although the difference between variants 4 and 5 is only 0.2%. On the other hand, definitely the highest variable fee was obtained for variants 6 and 7, where it was calculated basing on the rainfall intensity and the actual surface of the drained area (table 2). For variants 6 and 7, the amount of the variable fee exceeds PLN 410 thousand/year, and it is, respectively, 4.5 and 5.1 times higher than in the base variant. Still, it seems that these variants should not be applied, as only some of the rainwater from the total area will be discharged to the collector, while the rest will infiltrate to the ground or evapotranspirate (Liu et al., 2010; Walsh et al., 2012; Hasenmueller, Criss, 2013; Tokarczyk-Dorociak et. al., 2018; Zhang et al., 2018). Using the actual size of the total area at a specific rainfall volume for calculations results in an amount of the fee for discharging rain water and snow water to water that is disproportionately high in comparison to the amount of water that is actually discharged.

A better solution consists in using the reduced size of the total area (variants 8 and 9) that takes into account the runoff coefficient depending on the type of the drained area (Thompson, 2006; Królikowska, Królikowski, 2011; Kim et al., 2016; Szewrański et. al., 2018; Wang, Wang, 2018), and the amount of discharged water calculated in this way is more similar to the actual amount. In the analysed case, the amount of the variable fee calculated with the use of reduced area (variants 8 and 9) will be approx. 4 times lower than the fee based on the actual area (variants 6 and 7), but, respectively, 23.4% and 29.3% higher than the base variant 4. For variants 6-8, the volume of

rainfall plays a smaller, but still important role. The use of long-term period rainfall (variants 6 and 8) result in a value of fixed fee that may be lower than in the event of using the rainfall from the preceding year (variants 7 and 9) if it was higher than the long-term average. For variants 6 and 7 the difference is 23.6%, and for variants 8 and 9 by 5.9%.

It should also be noted that variants 6 and 8 refer to average long-term data, which results in the fact that the variable fee will remain constant for the whole validity period of the water law permit. What is important is the fact that the variable fee should not remain the same for the whole period of the water law permit. Such situation will occur as a result of applying variants 4, 5, 6 and 8, as they are based on the average values (variant 5 – Q_d, variant 4 – Q_{yr}) or on the average long-term precipitation (variants 6 and 8). These variants should be put aside because they do not meet the "variability" criterion. Additionally, it seems problematic to determine the number of rainy days, which are not specified in the water law permit, and are often missing from the statement of water management conditions as well. The free choice of the relevant (closest) meteorological station to determine the rainfall volume also seems questionable. The analyzed statement of water management conditions for the city Strzelin used data from the Wrocław station, although station IMGW No. ID 95341 is located in Strzelin (Jawecki, Burszta-Adamiak, 2014; IMGW-PIB, 2018). It seems more justified to use the rainfall from the preceding year to calculate the amount of variable fee, as it allows to set the fee for a near to actual amount of rain water and snow water discharged to water, and the fee will vary in the subsequent years of validity of the water law permit.

Table 4 presents the total annual amount (sum of the fixed and variable fee) for discharging rain water and snow water to water. The intersection of each column and row contains the total amount of fee constituting the sum of the calculation variants. The total fee varies significantly in the range from PLN 83731 (variant 3 + wariant 4) to PLN 433578 (variant 1 + wariant 7). The comparison of the sum of base variants (1+4) with the amount of the Marshall's fee paid until 2017 allows to determine that the value of the latter accounts for only 3.9% of the sum of base variants.

According to the analysis of the adopted base variants (table 2), the availability and scope of input data (table 3), the potential amount of the fee for discharging rain water (table 4) and the statutory requirements concerning the necessity of using data from water law permits (Art. 271, item 4, new Water Law, 2017), it seems that some of the calculation variants should be put aside. Variants 2 and 3 that constituted the basis for determining the Q_{max} value and the amount of the fixed fee result in significantly underestimated fee amounts. However, if it is impossible to apply Q_{max} directly, it is recom-

Table 4. Sum of the fixed and variable fee for discharging rain water and snow water to water in the analyzed variants

Fixed fee / Variable fee	Variant 1	Variant 2	Variant 3
Variant 4	PLN 86514	PLN 83787	PLN 83731
Variant 5	PLN 86691	PLN 83964	PLN 83908
Variant 6	PLN 413838	PLN 411111	PLN 411055
Variant 7	PLN 433578	PLN 430851	PLN 430795
Variant 8	PLN 106093	PLN 103366	PLN 103310
Variant 9	PLN 111053	PLN 108326	PLN 108270
Variant 10		PLN 3386	

Source: author's own work.

mended to calculate this value indirectly from $Q_{max.yr}$, according to the interpretation of the Voivodeship Administrative Court in Szczecin (II SA/Sz 514/18). On the other hand, variants 6 and 7 lead to a significant overestimation of the variable fee, as they do not take into account the infiltration and evapotranspiration of some of the rainwater. On the other hand, variants 4 and 5 calculate the amount of variable fee based on the average daily (Q_d) or annual (Q_{yr}) volume of discharged water, and as a result, the variable fee becomes "fixed" for the whole period of the water law permit, losing its "variable" characteristics. Variants 6 and 8 may be criticized similarly, as they use the average long-term rainfall to determine the amount of rain water and snow water discharged to water. Basing on the conducted analyses it seems reasonable to suggest that the optimum method of calculating the fee for discharging rain water and snow water to water will be the method specified in variants 1 and 9, where, for the analyzed facility, the total annual amount being the sum of fixed amount in variant 1 and the variable amount in variant 9 equals PLN 111053. It should be noted that in the analyzed case the amount of the fee due for water services connected with discharging rain water and snow water to water will be 33 times higher than the Marshall's fee paid until the end of 2017 for discharging wastewater from rain and snow to the environment.

Conclusions

The conducted research allowed the Authors to formulate the following conclusions:

1. The water law permits issued under the repealed Water Law do not contain all the information required by the amended Water Law that is necessary to calculate the fee for discharging rain water and snow water to water. Due to that, pursuant to the new legal regulations, there is a need to use data from statements of water management conditions or data of the Institute of Meteorology and Water Management to determine the amount of the fee.
2. Only 36% of the analysed water law permits issued pursuant to the repealed Water Law provided the information about maximum temporary amount of discharged rain water and snow water (Q_{max} in m^3/s) that enables to calculate the fixed fee for such water services directly.
3. 8% of the analysed water law permits issued under the repealed Water Law contained information about the annual average (Q_{yr} in m^3/yr) amount of discharged rainwater and snowmelt, while 40% contained information about the daily average (Q_d, in m^3/d) amount of discharged waters, which enables to determine the variable amount for this type of water services indirectly.
4. The analysis of variants, which were used for calculations, showed crucial meaning of those variants while considering evaluation of aggregate fee for discharging rain water and snow water. This may lead to underestimating or overvaluing the amount of fee or – in extreme cases – the amount of the fixed fee can constitute 1,4% of a base variant or the amount of the variable fee can be 5,1 times as big as the base variant.
5. As a result of using average values (Q_d, Q_{yr}, H_m) to calculate the annual amount of discharged rain water and snow water, the variable fee will remain constant for the whole period of validity of the water law permit, losing its "variable" characteristics, nevertheless it can change per every year.
6. As a result of the differences in the scope and form of data (m^3/s, m^3/d, m^3/yr) related to the amount of the discharged rain water specified in water law permits issued pursuant to the repealed Water Law will have to develop a uniform methodology of calculating the fee for discharging rain water and snow water to water for the whole country.
7. In the opinion of authors, it seems reasonable to use the method that uses Q_{max} directly (fixed fee – variant 1) and the algorithm considering the rainfall amount for the long-term period from the nearest meteorological station as well as the reduced size of the drained area (variable fee –

variant 9) to calculate the total fee for discharging rain water, because it includes requirements related to the new legal provisions and it doesn't overvalue or underestimate the amount of the fee.

The contribution of the authors

Bartosz Jawecki – 70% (research concept and design, collection and/or assembly of data, data analysis and interpretation, writing the article, final approval of article).

Marcin Sobota – 15% (writing the article, critical revision of the article, final approval of article).

Ewa Burszta-Adamiak – 15% (writing the article, critical revision of the article, final approval of article).

Literature

Białek M., Chojnacki D., Grabarczyk T. (2018), *Opłaty za usługi wodne w nowym Prawie wodnym*, Warszawa

Burszta-Adamiak E. (2014), *The financial mechanisms of urban rain water management*, in: Bergier T., Kronenberg J., Wagner I. (eds), *Sustainable Development. Water in the City*, Kraków, p. 57-69

Cousins J.J. (2017), *Infrastructure and institutions: Stakeholder perspectives of rain water governance in Chicago*, "Cities" No. 66, p. 44-52

Decyzja Starosty Strzelińskiego z dnia 13 września 2016 r. znak. OS.6341.15.2016. WS1.5 w sprawie pozwolenia wodnoprawnego na szczególne korzystanie z wód w zakresie odprowadzania wód opadowych z terenu miasta Strzelin do wód lub ziemi [Decision of the Staroste of Strzelin County of September 13th, 2016 on the water law permit for special use of waters with respect to discharging rain water from the area of the city Strzelin to water or to soil]

EU (2000), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22.12.2000, p. 1-73

Filipek K., Kucharski M., Michalski P. (2018), *Nowe prawo wodne. Najważniejsze zmiany dla gmin i przedsiębiorstw wodociągowo-kanalizacyjnych*, Warszawa

Gawel E. (2015), *Cost Recovery for Water Services in the EU*, "Intereconomics" No. 50(1), p. 40-45, https://doi.org/10.1007/s10272-015-0523-5

GUS (2017), *Rocznik Statystyczny Rolnictwa 2017*, Warszawa

Hasenmueller E.A., Criss R.E. (2013), *Water balance estimates of evapotranspiration rates in areas with varying land use*, open access peer-reviewed chapter, DOI: 10.5772/52811

I SA/Ke 134/18 – Wyrok WSA w Kielcach z dnia 12 lipca 2018 r., orzeczenie nieprawomocne [Decision of the Voivodeship Administrative Court in Kielce of July 12th, 2018, decision invalid]

II SA/Sz 514/18 – Wyrok WSA w Szczecinie z dnia 12 lipca 2018 r., orzeczenie nieprawomocne [Decision of the Voivodeship Administrative Court in Szczecin of July 12th, 2018, decision invalid]

IMGW-PIB (2018), http://danepubliczne.imgw.pl [10-07-2018]

Jawecki B., Burszta-Adamiak E. (2014), *Seasonal variability of basic pollution parameters in atmospheric precipitation in Strzelin*, "Journal of Water and Land Development" No. 20, p. 31-37

Jekel H. (2005), *Sustainable Water Management in Europe – the Water Framework Directiv*e, in: Vogtmann H., Dobretsov N. (eds), *Transboundary Water Resources: Strategies for Regional Security and Ecological Stability*, NATO Science Series, Vol. 46, Dordrecht, p. 121-127, https://doi.org/10.1007/1-4020-3082-7_10

Kim N.W., Shin M., Lee J.E. (2016), *Application of runoff coefficient and rainfall-intensity-ratio to analyze the relationship between storm patterns and flood responses*, "Hydrology and Earth System Sciences", doi:10.5194/hess-2016-194

Kodeks postępowania administracyjnego (1960) (Code of Administrative Procedure), Dz.U. z 2017 poz. 1257 ze zm.

Królikowska J., Królikowski A. (2011), *Analiza wpływu wartości współczynnika spływu na przepływy obliczeniowe w kanałach deszczowych,* „Rocznik Ochrona Środowiska" No. 13, p. 597-606

Liu W. et al. (2010), *Actual evapotranspiration estimation for different land use and land cover in urban regions using Landsat 5 data*, "Journal of Applied Remote Sensing" No. 4, doi: 10.1117/1.3525566

McPhillips L.E., Matsler A.M. (2018), *Temporal evolution of green rain water infrastructure strategies in three US cities*, "Frontiers in Built Environment" Vol. 4(26), doi.org/10.3389/fbuil.2018.00026

Miłaszewski R., Rauba E. (2010), *Określanie opłat za usługi wodne zgodnie z wymaganiami ramowej dyrektywy wodne*, "Ekonomia i Środowisko" No. 2(38), p. 66-80

Nowe Prawo wodne (2017) [New Water Law], Dz.U. z 2017 poz. 1566 ze zm.

Obwieszczenie Ministra Środowiska z dnia 29 czerwca 2016 r. w sprawie wysokości stawek opłat za korzystanie ze środowiska na rok 2017. M.P. 2016 poz. 718 [Announcement of the Minister of the Environment on the rates of fees for using the environment for the year 2017]

Prawo ochrony środowiska (2001) [Law of Environmental Protection], Dz.U. z 2017 poz. 519 ze zm.

Rozporządzenie Rady Ministrów z dnia 22 grudnia 2017 r. w sprawie jednostkowych stawek opłat za usługi wodne, Dz.U. 2017 poz. 2502 [Regulation of the Council of Ministers of December 22 2017 on unit rates of fees for water services]

Siwulski M. (2016), *Operat wodnoprawny na odprowadzanie wód opadowych z kanalizacji deszczowej w Strzelinie*, Wrocław

Stare Prawo wodne (2001) [old Water Law], Dz.U. z 2017 r. poz.1121. ze zm.

Szewrański S. et al. (2018), *A Location Intelligence System for the Assessment of Pluvial Flooding Risk and the Identification of Storm Water Pollutant Sources from Roads in Suburbanised Areas*, "Water" No. 10(4), p. 386, https://doi.org/10.3390/w10040386

Thompson D.B. (2006), *The Rational Method. Engineering Hydrology. Texas Department of Transportation*, http://drdbthompson.net/writings/rational.pdf [21-07-2018]

Tokarczyk-Dorociak K. et al. (2017), *Rainwater Management in the Urban Landscape of Wroclaw in Terms of Adaptation to Climate Changes*, "Journal of Ecological Engineering" No. 18(6), p. 171-184, https://doi.org/10.12911/22998993/76896

Unnerstall H. (2007), *The Principle of Full Cost Recovery in the EU-Water Framework Directive–Genesis and Conten*t, "Journal of Environmental Law" No. 19(1), p. 29-42, https://doi.org/10.1093/jel/eql038

Walsh Ch. J., Fletcher T.D., Burns M. J. (2012), *Urban rain water runoff: a new class of environmental flow problem*, "PLoS One" No. 7(9), doi: 10.1371/journal.pone. 0045814

Wang S., Wang H. (2018), *Extending the Rational Method for assessing and developing sustainable urban drainage systems*, "Water Research" No. 144, p. 112-125, doi:10.1016/j.watres.2018.07.022

Zhang Y. et al. (2018), *Simulation and assessment of urbanization impacts on runoff metrics: insights from landuse changes*, "Journal of Hydrology", p. 560, 247-258, doi.10.1016/j.jhydrol.2018.03.031

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ECOLOGICAL INNOVATIONS AS AN ELEMENT OF THE ORGANIZATION STRATEGY

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ABSTRACT: The aim of the study is to indicate the essence and increasing importance of the eco-innovations in the strategic activity of the enterprises as well as the potential benefits of eco-innovation for a long-term strategic objectives. The study systematize the knowledge on this topic, and indicate the necessity of their continuous development. The applied methodology is based on an analysis of available domestic and foreign literature. The function of innovation is to balance the product portfolio and maintain competitive advantages what enables to secure company's financial inflows and build shareholder value in the long term. This is a new way of looking at the organisation, i.e. that looks at how innovation should be used for strategic advantage.

KEY WORDS: ecological innovations (eco-innovations), organization strategy

Introduction

Changing economic conditions underscore the growing importance of environmental protection. What's more, economic development often means negative consequences for the environment, which with increasing concern for the natural environment contributes to the growing need for eco-innovations. The aim of these innovations is to reduce the burden on the environment by human activities (Oslo Manual: Rules ...). Together with these changes, the natural environment degrades, which in turn leads to the creation of many barriers to economic development, and thus to changes in the organization's strategy. One of such changes is the application of eco-innovations in the context of the organization's strategy. In view of the growing pollution and depletion of natural resources, currently ecological investments are of interest to both researchers and decision-makers. In all (highly) developed countries it is emphasized that without the implementation of eco-innovations in the economy, it is not possible to effectively solve the growing ecological problems.

The aim of the article is to indicate the essence and growing importance of eco-innovations in enterprises' operations as well as the achievable benefits resulting from the use of eco-innovations. The study presents a theoretical review of selected aspects of ecological innovations and their analysis and evaluation.

General characteristics of eco-innovations

The literature on ecological innovations is quite limited. What's more important, due to the greater complexity and different hierarchy of objectives an eco-innovation is largely different from innovation in the general sense. The very concept of innovation is understood as introducing a new commodity, a new production method, opening a new market, acquiring a new source of raw materials or semi-finished products, and introducing a new organization in a specific field of industry (Schumpeter, 1960). The goal of innovation is to enable the dynamic development of the company. Taking into account the ecological context of the management indicates that ecological innovations are one of the key areas of economic activity that meets the requirements of sustainable development.

Some of the exemplary definitions of eco-innovations presented below show that they can take different forms in practice. The term "eco-innovation" is a new concept. The prefix 'eco' comes from the word 'ecology', whereas 'innovation' means everything that is new. By eco-innovation, according to

the classic definition, one should understand a new product that provides value for the client and business, while significantly reducing the negative impact on the environment (James, 2001). Eco-innovations can also be defined as: "creating or modifying processes, products, techniques or methods of operation that are perceived as a new by given company and as being progressive in a given field and leading to increased efficiency in the use of resources at their disposal" (Penc, 1999, p. 102).

The aim of eco-innovations is to develop new products and processes that significantly reduce the negative impact on the environment resulting from human activity. Ecological innovations lead to integrated solutions that aim to reduce the resources and energy inputs, which at the same time improve the quality of the product and service. One of the methods of eco-innovation is technological innovation (Carley, Spapens, 2000). The study assumes that ecological innovations are important for the organization's strategy, which can be understood as a changes in technology, organizational structure and business management that reduce or prevent negative impacts on the natural environment (Witkowski, 2008, p. 319). Ecological innovation (product) is an innovation that integrates ecological features of the product and technology throughout the entire life cycle (from "cradle to grave"), thus distinguishing the product from the competing products. Its aim is to implement the requirements of "ecological quality" (Chodyński, 2003).

The Central Statistical Office examines the benefits of implementing eco-innovation at the time of their introduction. (Activity..., 2010). As benefits that arise during the production of a product or service, it lists:

- reduction in material consumption per unit of product,
- reduction of energy consumption per unit of product,
- reduction of carbon dioxide emissions by the company,
- use of less polluting or less hazardous materials for the environment,
- reducing soil, water, air or noise pollution,
- reduction of the share of energy obtained from fossil fuels in favour of renewable sources,
- re-use (recycling) of waste, water or materials.

During the use of the product or using the service, the use of eco-innovation allows:

- reduce energy consumption,
- reduce soil, water, air or noise pollution,
- improve the recyclables of the product after use.

In the literature, the most popular division of eco-innovations is the division into (figure 1): product, process, organizational and marketing eco-innovations (Matejun, 2009; EIO..., 2013; Oslo Manual, Rules..., 2008).

- Product eco-innovation, like the general category of innovation, is the introduction of products or services that will help to better achieve environmental goals. The main purpose of their introduction is to reduce the consumption of materials throughout the product's life cycle (that is from the process of its production, through use to utilization after the end of its usage life). This is made possible through the ability to repair products, regenerate or use recyclable materials.
- Process eco-innovations involve the improvement or introduction of new production technologies or new devices that serve to limit the negative impact on the environment, e.g. reducing the energy consumption of energy-efficient refrigerators.
- Organizational eco-innovations are changes in the company regarding company organization and management, aimed at increasing ecological awareness and implementation of eco-development, e.g. implementation of the ISO 14000 environmental management system.
- Eco-innovations in marketing concern the introduction of a new marketing method in the company that draws attention to changes in the product or packaging, distribution or promotion with particular emphasis on ecological principles, e.g. eco-labelling.

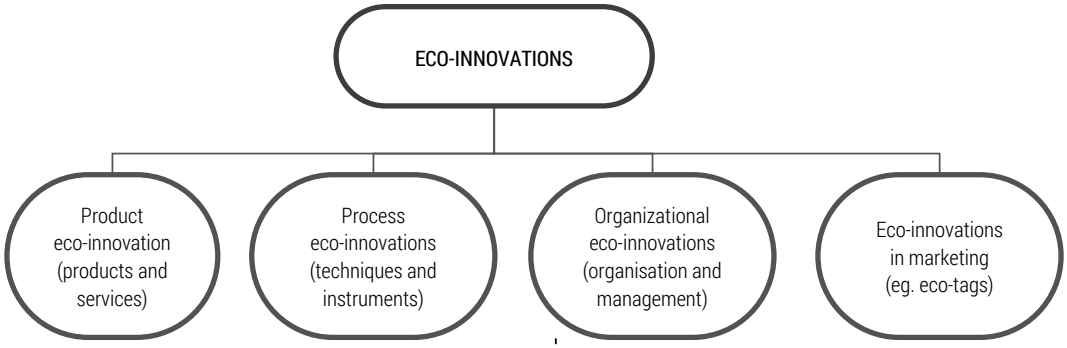

Figure 1. The Division of Eco-innovations

Source: author's own work based on Matejun, 2009.

Innovative Strategies

Sustainable development of an economic entity is based on the premise of strategic thinking. The concept of strategy is used to formulate a set of long-term organizational goals and their modification depending on changes taking place in its environment. The strategy is a set of coherent actions

aimed at achieving a good competitive position. Organizations develop their overall strategy and determine how various functions, such as marketing, finance or R&D, are to support the implementation of this strategy. However, they rarely use the strategy to reconcile innovative activities with their business strategy (Pissano, 2015). The article assumes that the strategy is a management process, consisting of three stages: strategic business analysis, strategic planning and strategy implementation. Implementation of the strategy is "a series of decisions at the tactical and operational level, deciding the key problems in the field of investment, marketing, structures, procedures, finances, which goal is to create conditions for the implementation of the chosen strategy variant and ensuring the efficient course of its implementation" (Romanowska, 1996, p. 3). Organizations that do not have an innovation strategy have little chance of successfully implementing innovations, including eco-innovations.

Often, the reaction of enterprises to the changes taking place in the environment and on the market are innovations. Therefore, they should be considered in various strategic areas, with particular emphasis on the environmental management context, in accordance with the idea of sustainable and long-term development. Currently, due to the growing preoccupation with the protection of the environment and raising social environmental awareness, the implementation of eco-innovation has become important and desired essential and purposeful. Ecological innovations have been distinguished among innovations on the basis of domain and purpose, and, as a result they constitute a specific group of innovations. Ecological innovations are used to achieve the desired environmental effects by the company. From the point of view of the company's strategy, the effect is compliance with regulations, increasing profits (thanks to reduction of fees and environmental fines) as well as improving the image of the company. From the tactical point of view, the goal is to reduce the ecological risk, improve the functioning of production processes, increase environmental efficiency, and better management of resources. However, at the operational level, the quality of the product or the implementation of the project objectives is important, e.g. the development of an environmentally friendly product (Leszczyńska, 2011). Eco-innovations should be implemented in a well-thought-out way in accordance with the company's strategy. They can be an element supporting the greening of management.

The basic division of the innovation strategy has been made on the basis of the amount of expenditure on research and development in a given economic entity. Six types of strategies in the sphere of research and innovation activity are related to this (Freeman, 1982):

- The offensive strategy is aimed at achieving the leading position through innovations consisting of the introduction of a new product and improving the functional features of existing products. The strategy must be based on one of the following factors or a combination of them: contacts with representatives of special knowledge or having their own research facilities.
- A company that uses a defensive strategy does not seek to gain a leading position in the production of a new product or the use of a new method, but at the same time does not lag far behind the wave of technical innovation. A defensive strategy, like an offensive one, has an active attitude towards innovation. A company using this strategy follows the leader with some delay, because he believes that it will keep him from mistakes and allow him to take advantage of the market opening for new products and even take over part of the market by introducing a new product substitute (at least as good as the initiating product).
- The imitating strategy consists in following the producer using the offensive strategy, and often with a long delay, depending on the specific conditions in which the imitating company or the entire industry operates. The activity is based on the relatively quick implementation of other people's solutions. Patents are not an important element as in the previous strategies. The imitator can achieve an advantage with lower costs.
- The dependent strategy is also known as the satellite strategy and stands that the company adopts the function of a cooperative or in some other way subordinated (or satellite) role to the stronger producer. Its own R&D works play here a very minuscule role. A company using this strategy does not try to imitate or initiate changes made by others. The cooperator will use technical services or plan production of his partner.
- The product produced as part of a traditional strategy changes little or no at all. The company usually adopts this strategy when, in his opinion, there is no reason to change the product, because it is neither demanded by customers nor forced by the competition. This situation can only lead to product improvement through innovations that better meet the needs of customers.
- The opportunistic strategy is based on the skilful exploitation of a certain gap which has occurred in the ever changing sphere of production and which has not been yet fulfilled by someone else. The gap allows the first one to discover and fulfil it to prosper for long. The strategy is based on intensive research and development works and striving for product changes or methods of its production, but first of all on good scientific and economic information, long-term planning and entrepreneurship.

Innovative actions, without innovation strategies, will only be a set of activities or best practices. The organization's ability to innovate is closely related to the existence of an innovative and coherent system consisting of processes and structures that define:

- how the company looks for solutions,
- how it turns ideas into a business strategy,
- how he chooses solutions for implementation.

Innovative actions, without innovation strategies, will only be a set of activities or best practices. The organization's ability to innovate is closely related to the existence of an innovative and coherent system consisting of processes and structures that define:

- How will innovation create value for potential customers?
- How will the company capture a share of the value its innovations generate?
- What types of innovations will allow the company to create and capture value, and what resources should each type receive?

The map of innovation can help to create innovation strategies (see figure 2). Innovation is seen here along with two dimensions: the degree to which innovations entail changes in technologies and the extent to which they influence the business model. By creating an innovation strategy, organizations get the choice concerning how much to focus on technological innovation and how much to invest in innovation within their business models.

The Matrix shows how a potential innovation fits the company's business model and its technical capabilities and can help in deciding what categories of innovation to choose. The business model identifies four categories of innovations (Pissano, 2015):

- routine innovation, which is based on the existing technological competences of the company and fits in with the existing business model,
- disruptive innovation, which requires changes in the business model, but does not necessarily demand technological changes,
- radical innovation, which is the opposite of disruptive innovation, thus it does not require changes in the business model, but requires technological changes,
- architectural innovation, which requires changes in both the business model and technology.

One of the significant distinguishing factors of innovative strategies is the Ecological Criterion. This criterion takes into account human values and should be considered together with the other criteria. Since ecological innovations are considered one of the most important elements of the strategy of all enterprises, it is justified to present the typology of innovative development strategies (table 1). It shows that there are specific connections between

particular types of innovation strategies. Including innovation strategies in the company's strategy helps to focus efforts on building the foundations for the future position of the company.

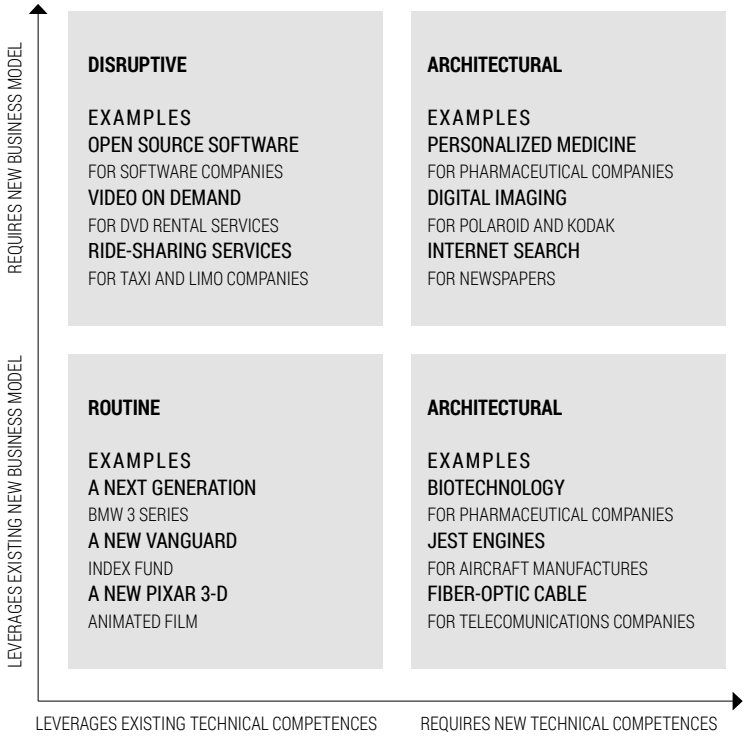

Figure 2. The Innovation Landscape Map

Source: Pissano, 2015.

Conclusions

The ecological management relies on introducing ecological aspects into the management strategy of the enterprise. The complexity and uncertainty associated with the implementation of eco-innovation pose a major challenge to the strategic management of companies involved in the development of environmental innovations. An important element of the business strategy is the selection of strategies for acquiring innovation, because it can determine the result of innovation in the field of environmental protection.

Table 1. Typology of innovative development strategies

Classification criteria	Types of strategies	Characteristics
Innovation objectives	Product, process, organizational	New products, new functional features, new processes, modernisation of old processes, implementation of new organisational systems, increase in management efficiency.
Factors of innovation	R&D	Development of own R&D base, cooperation with external R&D units.
	Purchase of licences	Purchase of domestic and foreign licences.
	Training of workers	Creating one's own intellectual potential, occasional education, shortening the innovation cycle.
Ways of implementing innovation	Pioneering	Insulated, bonded, market leader.
	Imitating	Insulated, bonded, market leader.
Reference to environmental problems	Cost reduction	Reduces costs at the manufacturer's and operating costs at the customer's site.
	Improvement of quality	Production of organic products.
	Ecologization	Ecologization products, processes, packaging.
Market	Customer education	Permanent education, occasional, constant contact with the customer, convenience in purchasing consumer goods, shares of "eco" products.
	Searching for new markets	
	Maintaining old markets	

Source: Białoń, 1999, p. 21.

The dynamic changes currently taking place in the environment and markets, the growing globalization processes and the rising social and ecological requirements result in the more and more frequent involvement of economic entities in pro-ecological activities. Eco-innovations are the response to these changes.

The contribution of the authors:

Jolanta Pakulska – 50% (concept and objectives, literature review, research etc.).
Małgorzata Rutkowska – 50% (concept and objectives, literature review, research etc.).

Literature

Białoń L. (1999), *Typologia innowacyjnych strategii,* in: Jasiński A.H., Kruk M. (eds), *Innowacje techniczne i zmiany strukturalne w procesie transformacji polskiej gospodarki*, t. 1, Białystok

Bönte W., Dienes Ch. (2013), *Environmental Innovations and Strategies for the Development of New Production Technologies*: *Empirical Evidence from Europe*, "Business Strategy and the Environment Bus. Strat. Env." No. 22, p. 501-516

Carley M., Spapens P. (2000), *Dzielenie się światem*, Białystok-Warszawa

Chodyński A. (2003), *Innowacyjność i jakość w strategii rozwoju firmy. Zarządzanie produktowymi innowacjami ekologicznymi*, Sosnowiec

De Marchi V. (2011), *Environmental innovation and R&D cooperation: empirical evidence from Spanish manufacturing firms*, Research Policy

Działalność innowacyjna przedsiębiorstw w latach 2006-2009, GUS (2010), Warszawa

Działalność innowacyjna przedsiębiorstw w latach 2012-2014, GUS (2015), Warszawa

EIO Europe in transition: Paving the way to a green economy through ecoinnovation. Eco-innovation. Observatory Founded by the European commission (2013), Brussels

Freeman Ch. (1982), *Economics of Industrial Innovation*, London

James P. (2001), *Toward sustainable bussines*?, in: Charter M., Tischner U. (eds), Sheffield

Leszczyńska A. (2011), *Absorpcja innowacji ekologicznych w przedsiębiorstwie*, Lublin

Matejun M. (2009), *Zarządzanie innowacjami ekologicznymi we współczesnym przedsiębiorstwie*, in: Grądzki R., Matejun M. (eds), *Rozwój zrównoważony – zarządzanie innowacjami ekologicznymi*, Łódź

Olkiewicz M. (2016), *Ekoinnowacje jako efekt foresightu strategicznego,* „Stowarzyszenie Ekonomistów Rolnictwa i Agrobiznesu, Roczniki Naukowe" No. 6, p. 152-156

Penc J. (1999), *Innowacje i zmiany w firmie*, Warszawa

Pissano G.P. (2015), *You need an innovation strategy*, Harvard Bussiness Review, p. 46-55

Podręcznik Oslo (2005), *Zasady gromadzenia i interpretacji danych dotyczących innowacji*

Podręcznik Oslo (2008), *Zasady gromadzenia i interpretacji danych dotyczących innowacji. Pomiar działalności naukowej i technicznej*, Warszawa

Romanowska M. (1996), *Zarządzanie strategiczne firmą*, Warszawa

Ryszko A. (2016), *Interorganizational Cooperation, Knowledge Sharing, and Technological Eco-Innovation: the Role of Proactive Environmental Strategy – Empirical Evidence from Poland*, "Pol. J. Environ. Stud." Vol. 25 No. 2, p. 753-764

Sharma S., Vredenburg H. (1998), *Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities*, "Strateg. Manage J." No. 19(8), p. 729

Witkowski J. (2008), *Instrumenty wspomagające działalność przyjazną środowisku w przedsiębiorstwie*, in: Kowalczewski W., Matwiejczuk W. (eds), *Aktualne problemy zarządzania organizacjami*, Warszawa

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SELECTION OF OPTIMAL TREE TOP DETECTION PARAMETERS IN A CONTEXT OF EFFECTIVE FOREST MANAGEMENT

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ABSTRACT: In the process of tree stand parameter estimation based on data from airborne laser scanning ALS, the detection of a single tree is an important starting point.
The aim of this work is to develop optimal values of parameters in the process of detection of tops and segmentation of stands on the basis of ALS data analysis. The research was carried out on the basis of ALS data from raids carried out in 2007 and 2017 on a fragment of the Zajma forest district in the Zednia forest inspectorate (north-eastern Poland). Parameters analyzed included: Ground Sampling Distance [m], the level of smoothing of the Canopy Height Model (CHM) with the Gaussian filter (the size of the moving window, the value of standard deviation), the filtration of the output point cloud, as well as the application of the additional interpolation algorithm CHM based on the analysis of raster cells neighborhood.
The research has shown that it is possible to indicate detection parameters that ensure a very high correlation between the number of automatically detected treetops and the number of trunks found during fieldwork. Importantly, the optimal detection parameters developed for remote-sensing materials from the years 2007 and 2017 differ slightly, which ensures generally high accuracy of ALS data and the possibility of implementing the values of these parameters in other research objects.

KEY WORDS: ALS, forest inventory, treetop detections, and crown segmentation parameters

Introduction

Forest management as a field of science deals with the knowledge of environmental and economic features of forest production – combining the achievements and knowledge of forest management, forest protection, and use as well as geomatics, nowadays strongly supported by remote sensing. In the area of practical applications, forest management deals with the organization of the production process in a forest holding and the development of forms that ensure a constant increase in the productivity and social utility of forests. In the area of practical applications, forest management deals with the organization of the production process in a forest holding and the development of forms that ensure a constant increase in the productivity and social utility of forests. Forest management serves to improve the technique of organizing production over usually ten-year periods and includes it synthetically for each forest inspectorate in a project for all economic activities, known as the Forest Management Plan (FMP) (Molenda, 1980).

The key issue in the management planning process, and especially in forecasting the development of resources in a very long period of time, is the accuracy of estimation of several dozen stand parameters, and among them, the most important – forest stand volume and their growth in the period under study. The accuracy of their determination directly influences the results of modeling the development of resources in the planning period and thus the possibility of using forests in the scope safe for their sustainability (Dawidziuk, Zajączkowski, 2013). The current inventory of forest resources supported by remote-sensing techniques is based on the use of traditional methods based on instrumental measurements and visual estimation aimed at collecting information on each stand (stand description) in the basic spatial unit, which is the forest division (or subdivision). In this context, particular importance shall be attached to the obtaining of as precise data as possible on stand volume in any spatial unit e.g. division or forest area (growing stock) or unit of area e.g. 1 ha (volume). Especially in recent years, in the area of instrumental methods of measuring environmental features, technological progress provides modern tools enabling remote and very fast measurement of many features of forest phytocenosis. These include Airborne Laser Scanning (ALS), which makes it possible to collect information in a short time and for very vast areas, which corresponds to the production conditions in the State Forests holding SF and the needs of forest management in Poland. The confirmation of this fact is reflected in the national (Zawiła-Niedźwiecki et al., 2008; Myszkowski, Ksepko, 2010; Zasada et al., 2011; Stereńczak et al., 2018) and foreign literature (Hyyppä et al., 2006; Vastaranta et al., 2011; Yao et al., 2012; Hayashi et al., 2015). At the same time, the availability of tools for

data acquisition, analysis and ready-made sets of data collected for other purposes (IT System of the Country's Protection against extreme hazards, ISOK) is constantly improving on the domestic market. In the current Forest Management Manual (IUL, 2012) there are no provisions regulating the possibility and method of using ALS data for the estimation of selected stand features. Therefore, it is necessary to conduct intensive research on the possibility of using the data obtained remotely in the forest practice in Poland, which allows to optimize the economic aspect of forest management work and to conclude on the impact of the use of objective instrumental data on the planning of human activity and the quality of functioning of the forest environment in the country.

Precise determination of selected stand features allows for more precise planning of their use or protection. This is important for all strategic decisions related to forest environment management in Poland and worldwide, including those directly related to their economic dimensions. The aim of this work is to develop optimal values of parameters in the process of detection of tops and segmentation of stands on the basis of ALS data analysis.

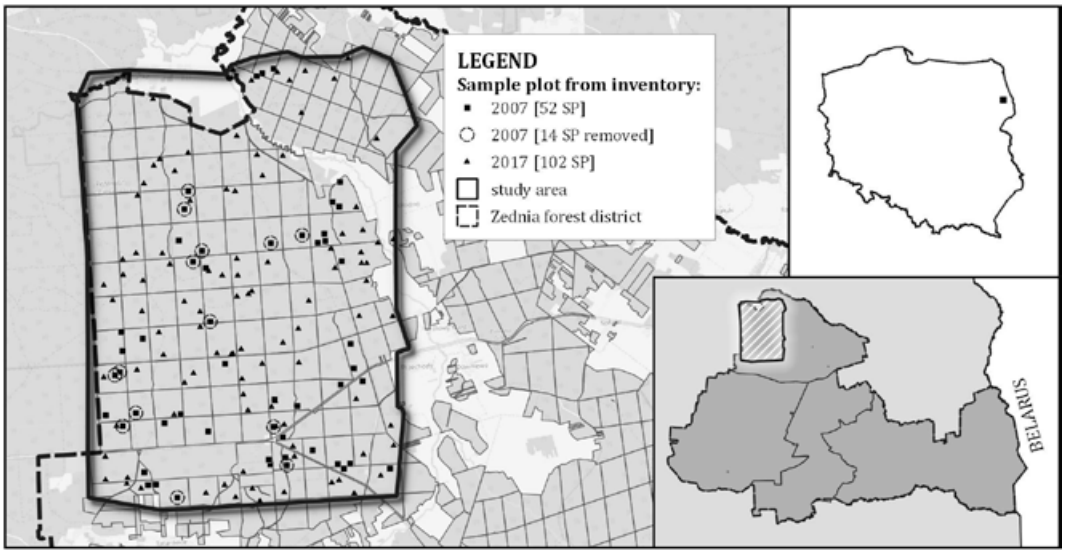

Figure 1. The location of the studied area and location of sample circular surfaces inventoried during field works of stages I and II of the experiment

Source: author's own elaboration based on Open Street Data.

Study area

The research was carried out on a selected fragment of the Zajma forest district in the Zednia forest inspectorate, located in north-eastern Poland and within the range of the Regional Directorate of SF in Bialystok. The research area is located within the range of a large forest complex of the Knyszyn Forest and covers a total area of 51 km^2, which constitutes more than half of the area of the forest district. The location of the research area against the background of the administrative division of the SF is presented in figure 1 together with the location of sample plots SP from field inventory part of experiment. The characterized area was the subject of a 2-stage scientific experiment aimed at determining the possibility of remote acquisition of data on forest environment, including information on the growing stock volume and growth of stands. In 2007 the first stage of the experiment was carried out, which was then continued in 2017 (stage II).

Research methods

The study used remote sensing materials and other spatial data, as well as data collected during the field inventory works carried out within the two stages of the project. The main source material in this analysis were ALS point acquired in 2007 and 2017 (table 1). The remote data acquisition was carried out twice at an interval of ten years and there was a significant technological progress within this period of time, but result point clouds are characterized by similar high density. However point cloud density of remote-sensing material used can have reflection in differences in optimal values of tree detection parameters.

Table 1. The comparison of selected characteristics of ALS data from 2007 and 2017

Feature	Point cloud – 2007	Point cloud – 2017
Flight date	August 2007	August 2017
Scanner model	Optech ALTM 3100	Riegl LMS-Q680i
Plane model	Cessna 404	Cessna 402
Number of registered returns	820,97 mln pts	1178,27 mln pts
Scanning density	14,08 pts/m2	19,64 pts/m2
Number of registered returns	4 discrete returns	Full-waveform registration

Source: author's own work.

In both missions, simultaneously with scanning, aerial photos in the visible and spectro-zone range were obtained, from which orthophoto maps in CIR (ColorInfraRed) and RGB (RedGreenBlue) compositions were generated. The intensity of laser beam reflection (intensity channel) was also recorded and RGB values were assigned to points in the point cloud on the basis of CIR photos. The obtained point clouds, apart from the different character of the return wave recording, also differ in scanning density (table 1). The raw LAS data has been classified using Terrascan software from TerraSolid package in accordance with the ASPRS standard. Apart from remote sensing materials, the study also used data collected in the SILP SF system (LAS module), as well as data from a soil and settlement study by BfFMaG in Bialystok concerning trophic differentiation of habitats and forest soils of the studied area.

In the context of research carried out in this work, reference data collected on SPs during the fieldwork of stages I and II of the experiment are the carrier of, particularly important information. In this respect, a wide range of information has been collected on individual trees located within circular SPs, such as the location of trees (x, y coordinates), species, diameter at breast height DBH, height relative to the ground, height of the base of the crown, visibility, health and other additional information. Among these key parameters for the survey are: GPS stabilized geodetic location of the plot center and coordinates of individual tree trunks, their species affiliation, visibility of the tree top, as well as natural disturbances observed on the sample plot, i.e. tree crowns with multiple tops, which may result in an incorrect number of trees detected by the algorithm on the SP.

In the first stage of the experiment (2007), a total of 52 circular SP with a radius of r=20 m (n=7) and r=25m (n=45) were established. On 47 Sps the dominant species was the pine, while on 5 SPs the dominant component was the spruce. The determinants for the selection of the size of SP were the vertical structure and age of the stand, as well as the possibility of the measuring equipment used, based on the use of the ultrasonic signal. On the analyzed 52 plots a total of 5485 trees were measured, of which 4268 were a component of the upper floor (trees with visible tops) (Myszkowski et al., 2009).

In the period from January to the end of March 2018, field works of stage II of the experiment were carried out. The SPs established during the stage I of the project have been revisited (38 z 52 SPs on which no treatments, e.g. thinning, were carried out in the last 10 years). Pine pine in subclasses IIb to VIIa was the dominant species on 37 SPs, while spruce in the age of VIIa dominated on 1 SP. Apart from the repeated 38 SPs from of stage I of the experiment, additional 102 SPs were selected. The main criteria in the selection of their location were the prevailing species and its bonitation (as an indicator of the use of trophic properties of habitats). The aim was to locate circular

areas in groups of the most numerous stands, characteristic for the Zajma forest district in the Zednia forest inspectorate. Among these areas, the most numerous representations are the areas where the dominant species was pine (53 SPs). The next position is taken by SP with the dominant spruce (24 SPs). The remaining 25 SPs included stands not included in the stage I of the project (with black alde., birch and oak.), including stands typically for hydrogenic habitats (alder trees of I and II class of bonitation). In stage II a reduced radius of SP was adopted (in relation to stage I). The radius was calculated according to the methodology contained in the IUL, by one age class upwards than according to SILP-LAS data.

Out of 38 SPs from the first stage of the experiment with a radius of 20-25 m, a total of 5149 trees were inventoried, of which 929 (18.04%) were removed as a result of economic operations and natural phenomena, while 964 objects (18.72%) are trees which in the last decade reached the minimum DBH of 70 mm, adopted in the IUL (ingrowth). Out of the 4220 trees of the 38 SPs of stage I, 2699 (63,95%) were classified as trees with a visible top. On 102 sample plots established additionally in the second stage of the experiment, a total of 2357 trees were inventoried, of which the most numerous group was spruce in the number of 1159 occurrences (49.17%) and pine in the number of 682 trees (28.94%). In this case of trees with full top visibility, 1425 trees were recorded, which constitutes 60.46% of all observations. To sum up, the total number of trees with top visible in remote sensing, on 140 circular plots of the first stage was 4124 (62.70% of trees).

Selection of optimal (closest to field observations) parameters for tree crown segmentation and tree top detection process depends on selected features of stands, which include the dominant species and its age class. Taking into account the characteristics of data collected during the fieldwork of stages I and II of the experiment, it was decided to list 7 species-age categories for which the optimal range of detection parameters will be indicated:

- category 1 a – pine in age classes up to IIIb (< 60 years),
- category 1 b – pine trees in age classes IV-V (61-100 years),
- category 1 c – pine in age classes VI and above (>100 years),
- category 2 a – spruce in age classes up to IV (< 80 years),
- category 2 b – spruce in age classes V and above (>80 years),
- category 3 a – deciduous species in age classes up to IV (< 80 years),
- category 3 b – deciduous species of age classes V and above (>80 years).

This automatic procedure was performed within 52 SPs of stage I with the use of the point cloud obtained in 2007, while the remote-sensing material from 2017 became the basis for the implementation of the process within 140 SPs of stage II, in accordance with the diagram in figure 2. The selection of optimal parameters consisted in consideration of the influence of various

conditions having a potential impact on the correctness of tree crown segmentation and tree top detection, to which they were included: Ground Sampling Distance GSD [0.3-0.7 m, with a pitch of 0.05 m], the level of smoothing of the Canopy Height Model (CHM) with the Gaussian filter depending on the size of the moving window (1×1, 2×2, 3×3, 4×4 pixels) ang the standard deviation value (1, 2, 3), the filtration of the output point cloud (the filtration of single or first of many returns or all returns), as well as the conducting additional 2-stage interpolation of empty cells within the CHM on the basis of raster cell neighborhood analysis. In the case of Gauss filter smoothing, option 0, assuming no smoothing, was also considered.

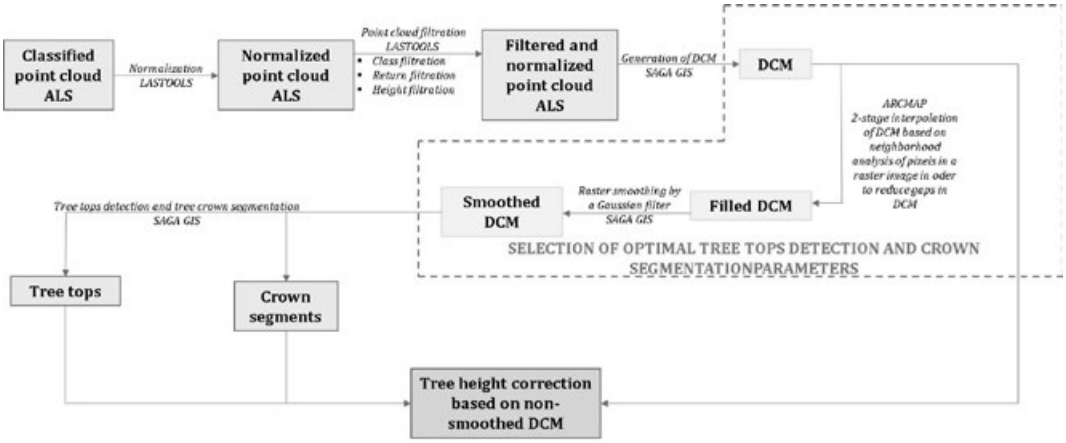

Figure 2. The flow chart of tree tops detection and tree crown segmentation with input data and with the indication of calculation environments

Source: author's own work.

The procedure considered a total of 351 parameter configurations within each species-age category, in three variants:

- Variant I – consideration of all point returns with the use of single empty cell filling within CHM.
- Variant II – consideration of single or first of many point returns with the use of a proprietary algorithm of 2-stage interpolation of empty cells within CHM on the basis of pixel neighborhood analysis.
- Variant III – consideration of all point returns with the use of the proprietary algorithm of 2-stage interpolation of empty cells within CHM on the basis of neighborhood analysis.

The starting point for this analysis was the extraction from a point cloud within the range of SPs. The point cloud was cut with polygons representing circular surfaces with a radius of 1.5 times the radius of individual SPs. This approach was aimed at minimizing the boundary effect and avoiding errors

in the segmentation process in the boundary zone of SPs. Remote sensing material prepared in this way was subjected to the process of normalization of height in relation to the ground surface. The calculations were performed directly on the input point cloud in RapidLasso's LASTOOLS software, which allowed the transformation of above sea level coordinates to relative altitudes (relative to the ground surface, the height of which was reduced to 0) (figure 3).

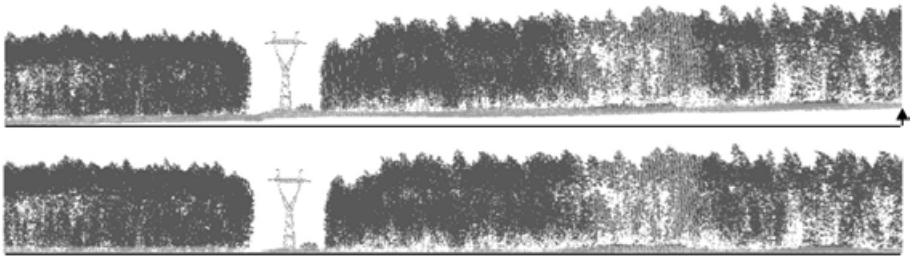

Figure 3. The cross-section through point cloud before (top) and after normalization process

Source: author's own work.

In the next step, the normalized point cloud was filtered in order to optimize the tree detection process by removing the redundant output data for further calculations. It was assumed that the threshold height for distinguishing the tree layer from the lower vegetation layer is 2 m. The remaining points were removed from the cloud.

The next stage was the construction of CHM as a result of the conversion of points height in the cloud to a raster with a spatial resolution appropriate for the considered species-age tree stand category. The resulting picture element value was assigned a relative altitude value based on the point representing the maximum height. In such CHM, empty cells may appear (without altitude value) in the absence of at least one point return. This phenomenon occurs in areas where the point cloud is characterized by a lower density parameter and in stands with visible defoliation due to pathogenic factors. In this paper, two ways of solving this problem have been applied. The first one is to fill single empty cells with the average height of its closest 8 neighbors. The second method is the application of a computational model developed in the Model Builder ESRI environment for the needs of the presented method, consisting of 2-stage interpolation of CHM on the basis of an in-depth analysis of the neighborhood (figure 4). The main assumption in the construction of the calculation model was to avoid the phenomenon of artificial "growth" of tree crowns in the edge zone of the crown. This is particularly

important in the case of the later use of the developed crown models for the analysis of gaps in stands or in the calculation of tree crown biomass for the purpose of forest fire protection (Inan et al., 2017).

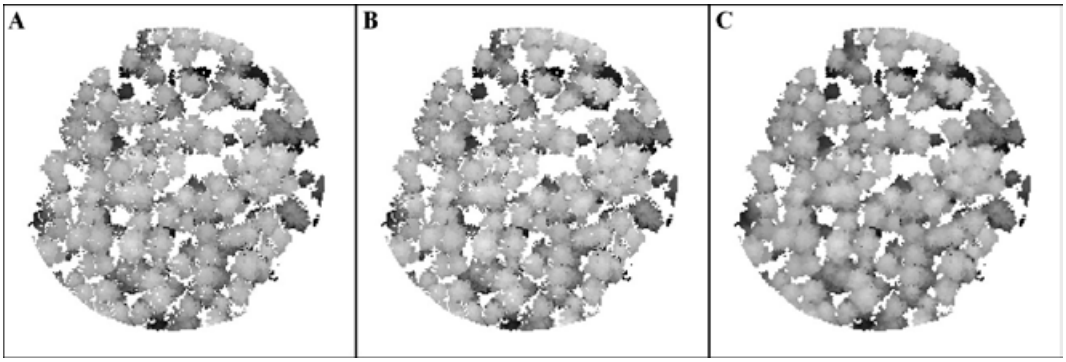

Figure 4. The comparison of CHM on a selected surface: A – non-interpolated model; B – CHM with closed single cells; CHM – subject to 2-stage interpolation

Source: author's own work.

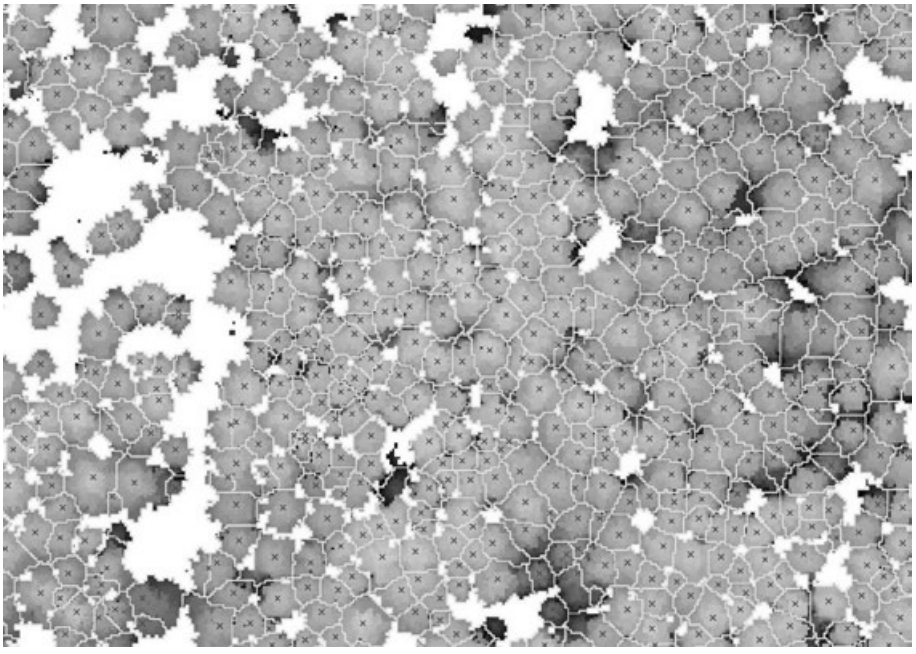

Figure 5. The result of the automatic process of crown segmentation and detection of tops in stands with common pine in age class (IV-V)

Source: author's own work.

Crown models without empty cells were smoothed with a Gaussian filter. They were then subjected to the process of tree crown segmentation and tree tops detection with the use of an inverted watershed algorithm. The result of this operation is a vector layer of local extremes of the height of the crowns model (identified with tree tops) and a raster image presenting the range of crowns. At the final stage, on the basis of the CHM generated directly from the filtered and normalized point cloud, the height values assigned to the tops of trees from the smoothed CHM were corrected. The aim was to avoid underestimation of the height of individual trees in further analyses, e.g. related to estimating the growing stand volume. The result of an exemplary, automatic tree detection and crown segmentation in a stand with pine trees in age classes 60-100 years is presented in figure 5.

Results of the research

The selection of optimal parameters of tree crown segmentation and single tree detection was carried out through comparative analysis of the number of detected treetops in relation to the actual number of trunks in the field inventory. The criteria for the selection of optimal parameters were: the ratio of the number of tree tops identified remotely to the number of tree trunks with a visible top within the range of the sample plots [%], as well as the coefficient of determination of the model of relations between these values within each of the analyzed species-age categories. The analysis assumes that the optimal solution will be characterized by no more than 10% absolute detectability of the number of trees.

Analyzing the results of the automatic detection process on the basis of remote sensing data from stage I of the experiment, where only categories representing coniferous stands were analyzed (categories 1 a, 1 b, 1 c, 2 b), it can be concluded that 15.81% of the detection variants are optimal solutions. The highest number of optimal occurrences was found in categories 1 b (23.08%) and 2 b (17.66%), while the lowest number of such solutions was found in category 1 c (9.40%). Considering the variants including initial filtration of the point cloud and additional interpolation of the crown model, it can be stated that in the case of stands with the prevailing pine trees, automatic detection was the most effective when using variants III (38.13%) and II (36.88%). In relation to stands with the prevailing spruce, the highest number of occurrences of the optimal solution was recorded with the use of variant II (41.94%).

In addition, it can be concluded from the results obtained that, in general, the highest number of optimal solutions occurs in the pixel size range of

0.40-0.55 m (figure 6), although these relations are less pronounced than in the case of stage II data. In the case of the smoothing level with the Gaussian filter, there is a clear decrease in the number of optimal solutions as the size of the smoothing window increases. This trend is particularly noticeable in the case of pine in category 1 a, where optimal solutions are only found in the size range of the smoothing window 1×1 and 2×2 (figure 7).

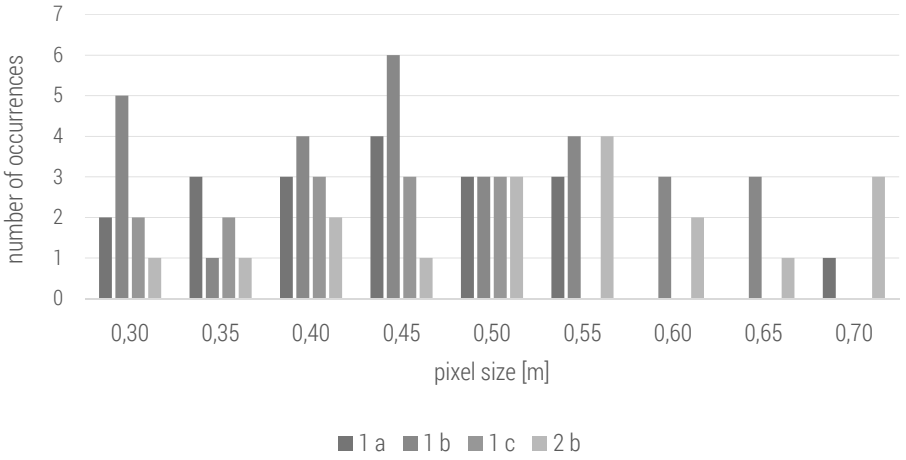

Figure 6. The number of occurrences of the optimal solution in particular species-age categories depending on the pixel size based on data from stage I

Source: author's own work.

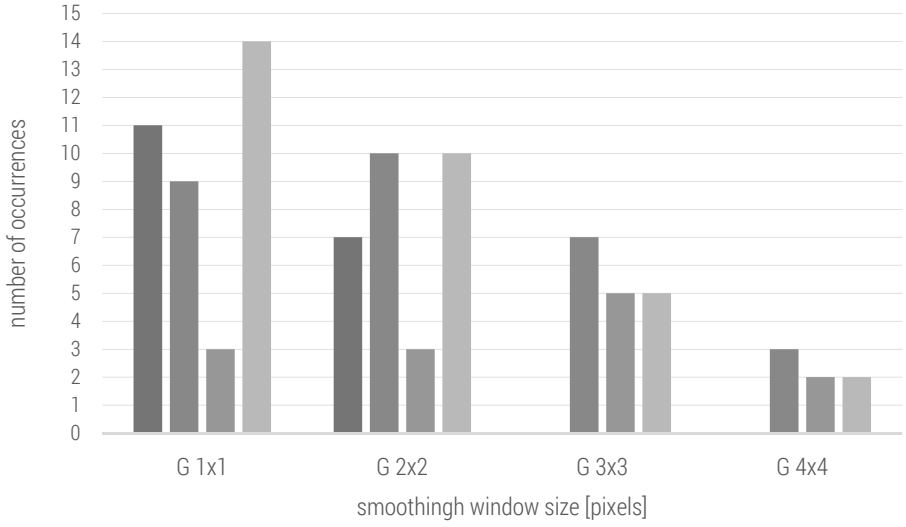

Figure 7. The number of occurrences of the optimal solution in particular species-age categories depending on the smoothing level with the Gaussian filter on the basis of data from stage II

Source: author's own work.

On the basis of the analysis of the results of the segmentation process, carried out on the basis of LiDAR data from stage II of the experiment, it was found that the total number of optimal solutions constitutes 13.31% of all cases. The highest percentage of optimal solution occurrence was recorded in categories 1 b (21.65%) and 3 a (17.09%), while the lowest number of such occurrences was recorded in the case of the category representing younger age classes with the prevailing spruce (category 2 a – 4.84%). On the other hand, comparing three variants related to point cloud output filtration and the application of different approaches to additional interpolation within the CHM, it can be stated that in the context of the applied data, the best results were obtained using the proprietary algorithm of 2-stage CHM interpolation. Of all optimal solutions, 39.14% concern this variant. A large number of occurrences at the level of 34.86% was also noted in the case of the variant assuming no filtration of the reflection character and filling of single empty cells in the crown model. In the case of variant II, assuming filtration of single or first point returns with the use of 2-stage interpolation, 85 optimal solutions (25.99%) were obtained. This can be explained by a lower density of points from which the CHM is built, which results in worse detection results as a result of the presence of empty spaces in the CHM.

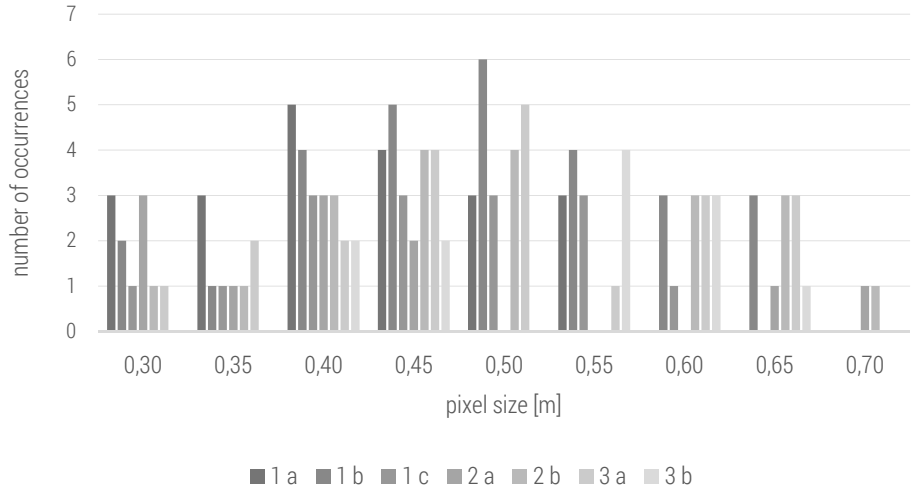

Figure 8. The number of occurrences of an optimal solution in particular species-age categories depending on the pixel size based on data from stage II

Source: author's own work.

Figure 8 presents a comparison of the number of occurrences of the optimal solution in particular species-age categories of the analyzed stands depending on the used pixel size. On the basis of the analysis of the contents

presented in this figure, it can be stated that the highest number of optimal solutions occurs in the pixel size range of 0.40-0.55 m, while characteristic relations can be noticed.

Larger pixel sizes (especially in the case of coniferous stands) cause the underestimation of the total number of trees, which is caused by the over-generalization of CHM. On the other hand, pixels in the 0.30-0.35 m range require a high-density point cloud (>25 points/m2), otherwise, these sizes tend to overestimate the results. Another characteristic feature of the presented distribution is the tendency to increase the pixel size with the age of the stand, as well as the fact that in the case of deciduous stands the use of a larger pixel size gives better results (≥0.60 m), while coniferous stands have different characteristics. On the other hand, when analyzing the influence of the smoothing level with the Gaussian filter on the correctness of detection, it can be stated that the variant assuming no smoothing is definitely not applicable, leading to a significant (max. 400%) overestimation of the obtained results. Moreover, a general tendency can be stated that with the increase in the degree of smoothing expressed by the size of the window in pixels, the quality of detection decreases in the case of coniferous stands. The opposite is true for the analysis of deciduous stands in higher age classes (figure 9).

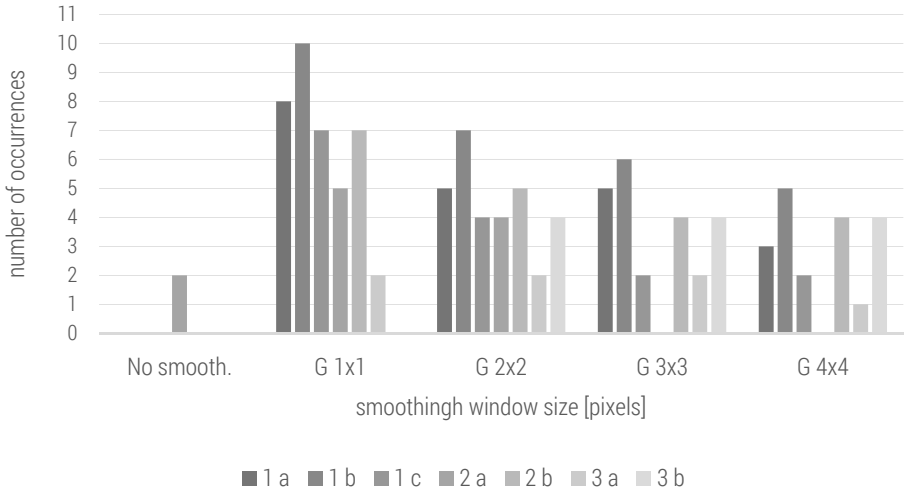

Figure 9. The number of occurrences of the optimal solution in particular species-age categories depending on the degree of smoothing with the Gaussian filter on the basis of data from stage II

Source: author's work.

A total analysis of all variants of automatic detection parameters allowed to indicate proposals for specific sets of parameters on the basis of which the final process of crown segmentation and tree tops detection is the closest to the data obtained directly in the field. When selecting these parameters, apart from the degree of tree detection [%], the values of the determination coefficient determined on the basis of comparison of the number of tops detected automatically to the number of trunks inventoried in the field in the SPs for particular species-age categories (table 2) were also taken into account. The indicated optimal detection parameters reflect the previously indicated conditions concerning the influence of the species (coniferous and deciduous stands) and its age on the selection of these parameters. On the basis of the comparison of the selection of optimal detection parameters developed for the data from the first and second stage of the experiment, it is characteristic that in the case of the data from the stage I, a larger raster cell of the CHM and a lower smoothing level is generally recommended. This trend may be justified by a lower point cloud density in 2007.

Table 2. Summary of proposed (optimal/expected) sets of detection parameters, taking into account the specificity of ALS data from Stage I and II of the experiment

Cat.	Point cloud EI		Point cloud EII	
	Detection parameters	R2/detection of trees [%]	Detection parameters	R2/detection of trees [%]
1 a	Variant I; 0,50 m; G1x1; std 1	0,96/100,06	Variant III; 0,40 m; G2x2; std 1	0,98/100,31
1 b	Variant III; 0,55 m; G1x1; std 2	089/100,07	Variant III 0,45 m; G2x2; std 1	0,98/101,65
1 c	Variant III; 0,50 m; G1x1; std 3	096/101,84	Variant III 0,55 m; G1x1; std 3	0,94/96,26
2 a	-	-	Variant III 0,45 m; G1x1; std 2	0,77/91,43
2 b	Variant III; 0,55 m; G3x3; std 1	0,88/97,06	Variant III 0,45 m; G3x3; std 1	0,78/99,48
3 a	-	-	Variant III 0,45 m; G4x4; std 1	0,79/99,49
3 b	-	-	Variant III 0,55 m; G4x4; std 1	0,21/106,43

Source: author's own work.

Taking into account the data presented in table 2, the process of treetop detection and crown segmentation within 140 SPs on remote-sensing material from stage II was again performed. The results are very promising. On 4124 trunks inventoried on trial surfaces in the field, the automatic segmentation algorithm indicated the occurrence of 4125 tops. Figure 10 compares the number of tops detected remotely with the number of trunks measured in the field.

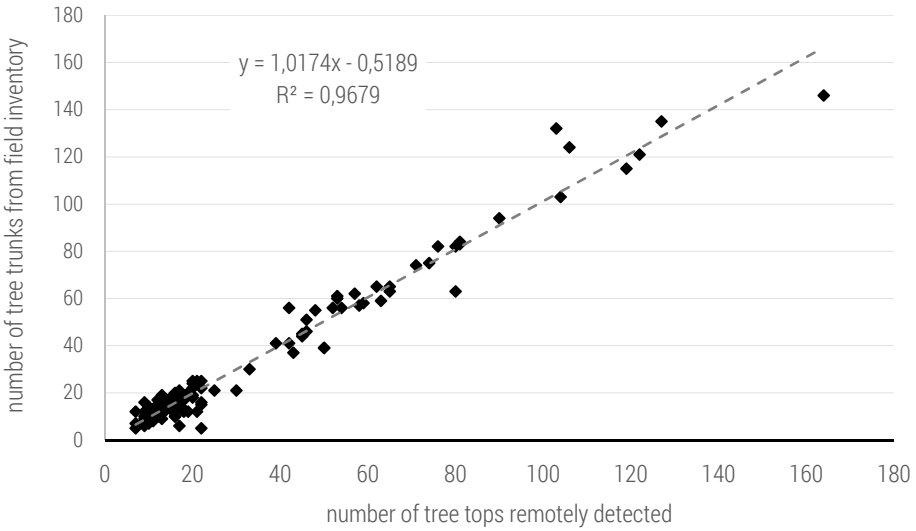

Figure 10. Comparison of the remotely detected number of treetops against the number of tree trunks from field inventory in the spatial extent of 140 circular plots from stage 2 of an experiment

Source: author's own work.

Comparing the results obtained on all 140 SP, the determination coefficient is very high at the level of R2 (0.97), which indicates a very high matching of automatic detection results with empirical data collected on SPs. Slightly weaker relationships were observed within 102 circular surfaces established in the second stage of the experiment (surfaces with a radius r in the range of 5.64-12.62 m). In this case, the determination coefficient R2=0.42 was obtained and after the rejection of areas with the prevailing deciduous species the coefficient increases to 0.49. The mean absolute MAPE (Mean Absolute Percentage Error) was recorded at the level of 22.17% (102 areas of stage II) and 8.26% (38 areas of stage I) (table 3). It can be concluded that the detection algorithm was wrong by an average of 6 tops (with the average number of trees detected in the field at the level of 70) within 38 circular sample plots of stage I and by an average of 3 tops (the average number of trees on the plot – 14 items) in relation to 102 plots.

The highest absolute percentage error was obtained at the level of 340%, (22 tops detected automatically in relation to 5 trunks found in the field) on the circular surface with the prevailing pedunculate oak in the age class Vb. It was a specific area on which spreading crowns formed a heterogeneous, very variable area, extremely difficult for the segmenting algorithm. On other plots with oak (in younger age classes) the results obtained were much better, with an average absolute percentage error of 22.80%.

Table 3. The summary of basic metrics showing the conformity of the automatic detection process in the different trial categories of circular surfaces

Metric	sample plot category					
	all	EI 38	EII 102	E102 (coni-ferous)	coni-ferous	decidious
Minimum absolute percentage error	0,00	0,00	0,00	0,00	0,00	0,00
Maximum absolute percentage error	340,00	28,21	340,00	183,33	183,33	340,00
Mean absolute percentage error	18,39	8,26	22,17	19,48	15,67	29,29
R2	0,97	0,92	0,42	0,49	0,97	0,51
Mean tree count (field inventory)	29,46	69,68	14,48	14,78	33,00	13,68
Mean detection error [tree tops]	5,42	5,75	3,21	2,88	5,17	4,01

Source: author's own work.

Conclusions

On the basis of the results obtained, it can be concluded that laser scanning techniques (LiDAR) are very useful in detecting trees with visible tops (trees of the upper floor and visible trees of the lower floors), which confirms the results of the work of other research teams. Precise determination of the number of trees in the upper floor is a key element in the economic use of stands, as practically the entire volume of wood is concentrated in this part (Stereńczak, 2013). The purpose of this work has been achieved. The results obtained indicate that it is possible to select a set of detection parameters that provides a very high fit to empirical data, with a coefficient of determination greater than 0.90, which in general is a better result compared to similar studies conducted in this field (Hyyppä et al., 2001; Persson et al., 2002; Koch et al., 2006; Kaartinen, Hyyppä, 2008; Tompalski et al., 2009; Wang et al., 2008; Myszkowski et al., 2009; Wężyk et al., 2010; Stereńczak, 2013). It has been shown that there is more than one optimal solution from the point of view of the selection of several important parameters, which reduces the risk of errors resulting from not carrying out earlier calibration works and uncritical assumption of parameter values. The conducted research also indicates that the optimal values of detection parameters differ slightly depending on the characteristics of the remote-sensing material used. In this case, the higher density of the point cloud makes it possible to use a smaller cell size of the raster cell for the construction of CHM. This fact significantly extends the possibility of using laser scanning data in historical analyses (data reanalysis) or in studies based on data of unknown accuracy.

The conducted research also indicates some solutions from the point of view of the problem of selecting the size of the sample area so as to minimize the cost of fieldwork and at the same time ensure the representativeness of the research. It is worth mentioning that apart from increasing the radius of analysis (1.5 radius), no special measures were taken in the study to reduce the impact of the boundary effect. Such a state of affairs may be influenced by several factors of different nature. The first factor is the significantly reduced size of test surfaces (in comparison to the inventory from stage I), which means that the accuracy of the obtained results is more influenced by the boundary effect resulting from the higher values of the ratio of circumference to test surfaces of circular surfaces (figure 11). In addition, on smaller circular areas, far fewer observations are recorded (sample size), due to a drastic increase in the circular area from a radius of approx. 15 m. With a smaller circular area, the effect of the measurement error of the position of the centre of the circular area may be more pronounced.

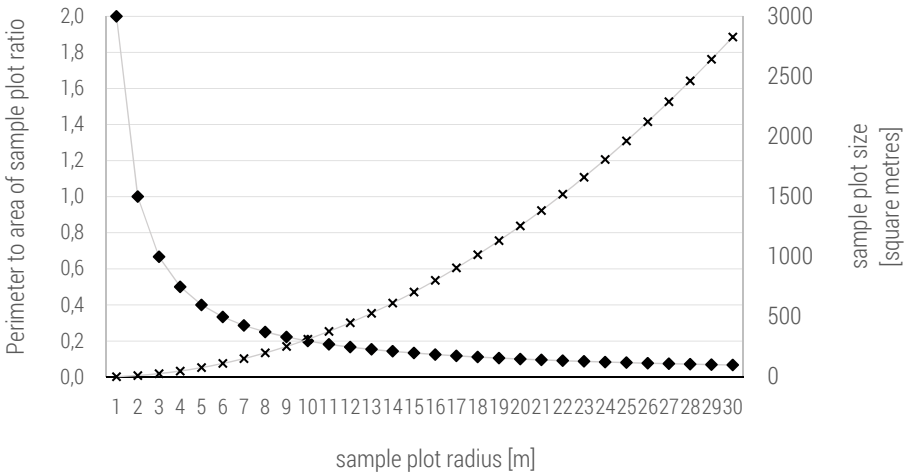

Figure 11. The relationship between the ratio of circumference and surface values on circular surfaces depending on the size of the radius of the circular surface

Source: author's own work.

The proposed methodology can be successfully applied for the automatic detection of treetops and crown segmentation in large areas (e.g. a range of the entire forest inspectorate covered by the forest management plan). The results obtained in this way can be an important starting point for other studies of different aspects of forest management, including those related to its economic, social or protective dimension.

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The contribution of the authors

Łukasz Kolendo – 50%.
Marek Ksepko – 50%.

Literature

ASPRS, The Imaging & Geospatial Information Society, Standards Committee, https://www.asprs.org/committees/standards-committee

Dawidziuk J., Zajączkowski S. (2013), *Znaczenie urządzania lasu w budowie systemu planistyczno-prognostycznego w leśnictwie*, in: Arkuszewska A., Lotz D., Szujecka G. (eds), *Zimowa Szkoła Leśna przy Instytucie Badawczym Leśnictwa,* V Sesja, Planowanie w gospodarstwie leśnym XXI wieku, Sękocin Stary, p. 32-47

Hayashi R., Kershaw J.A., Weiskittel A.R. (2015), *Evaluation of alternative methods for using LiDAR to predict aboveground biomass in mixed species and structurally complex forests in northeastern North America*, "Mathematical and Computational Forestry and Natural-Resource Sciences" No. 7(2), p. 49-62

Hyyppä J. et al. (2001), *A Segmentation–Based Method to Retrieve Stem Volume Estimates from 3–D Tree Height Models Produced by Laser Scanners*, IEEE Transactions on Geoscience and Remote Sensing 39(5), p. 969-975

Hyyppä J. et al. (2006), *Methods of airborne laser scanning for forest information extraction"* in: Koukal T., Schneider W. (eds), *3–D Remote Sensing in Forestry*, Vienna, EARSeL SIG Forestry, ISPRS WG VIII/11, p. 63-78

Inan M., Bilicib E., Akay A.E. (2017), *Using airborne lidar data for assessment of forest fire fuel load potential*, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. IV-4/W4, p. 255-258

Koch B., Heyder U., Weinecker H. (2006), *Detection of Individual Tree Crowns in Airborne Lidar Data*, „Photogrammetric Engineering and Remote Sensing" No. 72(4), p. 357-363

Kaartinen H., Hyyppä J. (2008), *EuroSDR/ISPRS Project, Commission II „Tree Extraction", Final Report, EuroSDR*, European Spatial Data Research 53

IT System of the Country's Protection against extreme hazards (ISOK), http://www.isok.gov.pl /en/

Molenda T. (ed.) (1980), *Mała Encyklopedia Leśna*, Warszawa

Instrukcja Urządzania Lasu (2012), PGL LP, Warszawa

Myszkowski M., Ksepko M., Gajko K. (2009), *Detekcja liczby drzew na podstawie danych lotniczego skanowania laserowego*, „Archiwum Instytutu Inżynierii Lądowej" No. 6, p. 63-72

Myszkowski M., Ksepko M. (2010), *Budowa pionowa drzewostanu w* świetle *przestrzennego rozkładu punktów lotniczego skanowania laserowego*, Polskie Towarzystwo Informacji Przestrzennej, „Roczniki Geomatyki", t. VIII, No. 7(43), p. 39-47

Persson A., Holmgren J., Soderman U. (2002), *Detecting and measuring individual trees using airborne laser scanning*, „Photogrammetric Engineering and Remote Sensing" No. 68(9), p. 925-932

Stereńczak K. (2013), *Określenie zagęszczenia drzewostanów z wykorzystaniem danych z lotniczego skanowania laserowego,* "Sylwan" No. 157(8), p. 607-617

Stereńczak K. et al. (2018), *The influence of number and size of sample plots on modelling growing stock volume based on airborne laser scanning*, "Drewno" Vol. 61

Tompalski P. et al. (2009), *Determining tree number in pine stands using airborne laser scanning data and orthophotos*, "Annals of Geomatics" No. 2(32), p. 133-14

Wang Y. et al. (2008), *LIDAR point cloud based fully automatic 3D single tree modeling in forest and evaluations of the procedure*, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 38 B6b, p. 45-53

Wężyk P. et al. (2010), *Metoda określania liczby drzew w drzewostanie z wykorzystaniem danych ALS oraz ortoobrazów*, "Sylwan" No. 154(11), p. 773-782

Yao W., Krzystek P., Heurich M. (2012), *Tree species classification and estimation of stem volume and DBH based on single tree extraction by exploiting airborne full-waveform LiDAR data,* „Remote Sensing of Environment" No. 123, p. 368-380

Vastaranta M. et al. (2011), *Individual tree detection and area-based approach in retrieval of forest inventory characteristics from low-pulse airborne laser scanning data*, "The Photogrammetric Journal of Finland" Vol. 22, No. 2, p. 1-13

Zawiła-Niedźwiecki T. (2008), *LIDAR w leśnictwie*, „Teledetekcja Środowiska" No. 39, Warszawa

Zasada M., Stereńczak K., Brach M. (2011), *Zależność między pierśnicą a cechami koron uzyskanymi z lotniczego skanowania laserowego*, „Sylwan" No. 155(11), p. 725-735

Andrzej **KOBRYŃ** • Tomasz **TEKIEŃ**

MULTI-CRITERIA MODEL FOR DETERMINING THE URGENCY OF CONSOLIDATION WORKS (ON THE EXAMPLE OF THE MONIECKI COUNTY)

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ABSTRACT: The article proposes the use of one of the methods of multi-criteria decision analysis (AHP method) to determine the urgency of consolidation works in the area of the Moniecki county. To this end, an appropriate set of criteria was adopted for the mutual comparison of precincts in the considered area. The calculations include a non-typical for AHP method, a large number of considered ranges. The analysis covered 201 precincts, and as a result, the areas with the greatest urgency of merging works were indicated.

KEY WORDS: consolidation, planning, multi-criteria decision analysis

Introduction

Very important for the proper development of the agricultural production space and the possibilities of effective management is the development of the proper area structure of farms, as well as the land distribution within these farms. The means leading to this purpose are consolidation and interchange work. In Poland, the related issues are regulated by two legal acts, which are: the Act on Merging and Exchange of Lands and the Act on Real Estate Management.

The rank of problems concerning the shaping of the area structure of agricultural land and the land distribution and their impact on the efficiency of management are perceived by many researchers, which is reflected in various publications on this subject. As examples, mention may be made of such studies as: (Harasimowicz, 2001; Sobolewska-Mikulska, Pułecka, 2007; Szafrańska, 2011; Wierzchowski, 2007; Woch 2007).

In any case, the starting point for planning the consolidation work should be the assessment of the current area structure of farms, which allows assessment of needs and opportunities in this area. This problem was analyzed, among others by the authors of this article at work (Kobryń, Tekień, 2016), the subject of which was to identify the needs and possibilities in the field of consolidation works in the Moniecki county, located in the Podlaskie District. Among other studies dealing with this type of issues, mention may be made in works: (Banat, Janus, 2002; Gniadek, 2013; Jędrzejek et al., 2014; Leń, Noga, 2010; Leń, 2013).

An inseparable element of research aimed at optimization of spatial structures in rural areas are analyses and methodological proposals concerning the development of procedures and tools to facilitate solving problems related to the planning of consolidation and changeover works. Various proposals in this area have been described, among others in the works: (Ayranci, 2009; Cay, Iscan, 2006; Harasimowicz et al., 2009; Janus, 2011; Leń, 2013; Noga, 1990; Woch, 2008).

This study is also part of the above research trend. This work is a development of the threads undertaken by the authors in the study (Kobryń, Tekień, 2016). The area structure of agricultural holdings in the Moniecki county and the merits of changing it through consolidation works were analyzed there. Currently, the authors intend to propose appropriate analytical tools that may be useful at the level of planning of merging and exchange work by facilitating decisions regarding determining the urgency of these works in a given area.

At this point it can be mentioned that similar problems were taken up at work (Leń, 2013). It proposes appropriate solutions for agricultural lands in

the Brzozowski county, located in the Podkarpackie Voivodeship, using tools derived from taxonomic methods in the analysis. In the opinion of the authors of this article, multi-criteria decision analysis (MCDA), also known as multi-criteria decision making (MCDM), can be very useful in solving such problems.

MCDA / MCDM methods constitute a very intensively developing field of research, which is supported by broad application possibilities in solving multi-criteria decision problems in various areas. This is confirmed in many publications describing various practical applications of these methods. Many MCDA / MCDM methods are known from the literature (Figueira et al., 2005; Hwang, Yoon, 1981; Triantaphyllou, 2002; Tzeng, Huang, 2011; Zopounidis, Pardalos, 2010), the most popular ones include the following methods:

- AHP (Analytic Hierarchy Process) (Saaty, 1980, 2005),
- PROMETHEE (Preference Ranking Organisation METHod for Enrichment Evaluations) (Brans 1982; Brans et al., 1984),
- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Hwang, Yoon, 1981).

their popularity is evidenced and developed by (Behzadian et al., 2010, 2012; Sipahi, Timor, 2010), providing an overview of the different uses of these methods.

Below, the proposal of a methodology for determining the urgency of consolidation works using the AHP method will be described, which will be illustrated on the example of the Moniecki county. This choice results from the fact that agricultural activity within the analyzed area is an important production base for Polish dairy moguls, which are „Mlekovita" and „Mlekpol" production cooperatives.

Identification of decision-making criteria

An important role in solving any decision problems is played by the adoption of a coherent set of criteria that should guarantee a comprehensive evaluation of the alternatives considered, and should be characterized by transparency and precise definition of their scope of avoiding redundancy. It should be added that individual criteria can be used to evaluate alternatives in terms of benefits or costs. They are referred to respectively as a stimulant (criterion of the nature of an advantage) or a deterrent (a criterion of a cost nature).

In establishing a set of decision criteria in relation to the analyzed decision problem, which is to determine the urgency of consolidation works in

a given area, the provisions contained in the Instruction No. 1 of the Minister of Agriculture and Food Economy on land consolidation and exchange (dated March 24, 1983) may be helpful. According to them, the classification of villages for consolidation should result first of all from the analysis of the state of land management, and when undertaking consolidation works, the villages which are characterized, among others, should be taken into account:

- a particularly arduous checkerboard of land for both family farms and the inconvenient land development of the Agricultural Property Agency,
- a relatively high average area of farms,
- an extensive checkerboard of land between villages,
- high level of saturation with means of production,
- a wide range of needs and possibilities of making necessary accompanying investments in the field of after consolidation development,
- the need to adjust the holdings to disruptive production conditions of line investments (motorways, express roads, pipelines, gas pipelines, canals, railway lines, windbreaks, anti-erosion devices, etc.),
- a significant possibility of concurrent consolidation of the enlargement of existing family farms at the expense of land of the Agricultural Property Agency or land obtained from persons who agree to sell all or part of their land.

Additional information that may be helpful in adopting the appropriate set of criteria, is included in Appendix 2 to the above instruction, which indicates how to analyze the land integration needs of a given village. Factors of significant importance included:

- total surface area,
- number of farms,
- total number of plots,
- average farm area,
- average plot area,
- average number of plots on the farm.

There is no doubt that – in addition to the substantive correctness of the set of decision criteria – it is important to have the necessary data to assess the decision alternatives in the light of the adopted criteria. Therefore, guided by the possibility of obtaining the necessary data on the basis of public records (such as land and building records), the authors of this study proposed a set of 6 criteria describing the area structure of agricultural land and thus characterizing the quality of agricultural production space. A summary of these criteria is provided in table 1.

Table 1. Decision criteria for determining the urgency of consolidation work

Criteria	Name	Nature
K1	Area of the precinct	stimulant
K2	Number of plots	stimulant
K3	Number of land registry units	stimulant
K4	Average area of the plot	deterrent
K5	Number of the plots per 1 land registry unit	stimulant
K6	Area of the land per 1 land registry unit	stimulant

Source: author's own work.

AHP as analysis method

The description of the AHP method has been included in many studies, including in works (Saaty, 1980; Kobryń, 2014), therefore it will be omitted in this publication. Only the most important issues related to the use of the AHP method will be indicated here. As is known (Saaty, 1980), the AHP method is based on the mutual comparison of the pairs of considered alternatives. The results of pairwise comparisons are determined using the so-called a relative, 9-grade rating scale. An integral part of the AHP analysis is the assessment of the coherence of the pairwise comparison matrix. Obtaining the required level of consistency is quite problematic for a greater number of compared items. Therefore, an important practical recommendation in the AHP method with regard to the compared elements is the Miller rule, according to which the number of these elements should be in the range of 7 ±2 (Miller, 1957). This rule is related to the limited human information processing abilities, and its consequence is the fundamental principle that is in force in the AHP method and is based on the hierarchical structuring of any decision problem.

This does not mean that – using the algorithm of the AHP method – it is not possible to consider a greater number of elements at a given hierarchical level, which is especially true for the compared alternatives. Limitations resulting from the Miller rule become less important if the pairwise pairing procedure is based on the use of appropriate mathematical formulas. The use of the following formulas gives this possibility (Szłapczyńska, 2009):

- in case of stimulant (benefit nature criteria)

$$p_{i,j} = \frac{Q_i^{(k)} - Q_j^{(k)}}{Q_{max}^{(k)} - Q_{min}^{(k)}} \cdot 8 + 1, \quad \text{for} \quad Q_i^{(k)} \geq Q_j^{(k)} \tag{1}$$

and

$$p_{i,j} = \frac{1}{p_{j,i}}, \qquad \text{for} \qquad Q_i^{(k)} < Q_j^{(k)}; \tag{2}$$

- in case of deterrent (costs nature criteria)

$$p_{i,j} = \frac{Q_j^{(k)} - Q_i^{(k)}}{Q_{max}^{(k)} - Q_{min}^{(k)}} \cdot 8 + 1, \qquad \text{for} \qquad Q_i^{(k)} \leq Q_j^{(k)} \tag{3}$$

and

$$p_{i,j} = \frac{1}{p_{j,i}}, \qquad \text{for} \qquad Q_i^{(k)} > Q_j^{(k)}, \tag{4}$$

where:
$Q_i^{(k)}$, $Q_j^{(k)}$ – alternative result (i-th and j-th) in the light of the k-th criterion.

The result of the implementation of the above formulas are the elements of the pairwise comparison matrix **P**, which assume values corresponding to the Saaty scale.

In the assessment of the consistency of the matrix of comparisons in pairs, the so-called Consistency Index *(CI)* and consistency ratio *(CR).* According to (Saaty, 1980), the consistency index is calculated using the formula:

$$CI = \frac{\lambda_{max} - n}{n-1}, \tag{5}$$

where:
n – dimension of the matrix **P** (corresponding to the number of criteria or alternatives being compared),
λ_{max} – the maximum custom value of matrix **P**.

On the basis of the *CI* index, the *CR* is calculated, which is the quotient:

$$CR = \frac{CI}{RI}, \tag{6}$$

where:
RI – is a reflection of the non-conformity rate of assessments, being the average value of *CI* for a large number of randomly generated comparison matrices.

It should be added that few literature sources provide *RI* values for larger comparison matrices (n>15). Such a need may arise when comparing more alternatives using equations (1)–(4). A valuable proposal in this respect is presented in the paper (Alonso, Lamata, 2006). Using the randomly generated values λ_{max}, the following function was determined as a result of the least-squares estimation:

$$\bar{\lambda}_{max}(n) = 2{,}7699n - 4{,}3513, \tag{7}$$

which allows *RI* index circumscribing as:

$$RI = \frac{\bar{\lambda}_{max}(n)-n}{n-1}. \tag{8}$$

Analysis of the urgency of consolidations in the area of the Moniecki county with the use of the AHP method

In the first place, global preferences were defined. The weight of accepted criteria, reflecting their mutual validity. The starting point for calculations was the comparison matrix in pairs of criteria, the elements of which were determined using the relative Saaty rating scale:

$$\mathbf{P} = \begin{bmatrix} 1{,}0000 & 0{,}2500 & 2{,}0000 & 0{,}2000 & 0{,}3333 & 0{,}5000 \\ 4{,}0000 & 1{,}0000 & 5{,}0000 & 0{,}5000 & 2{,}0000 & 3{,}0000 \\ 0{,}5000 & 0{,}2000 & 1{,}0000 & 0{,}1667 & 0{,}2500 & 0{,}3333 \\ 5{,}0000 & 2{,}0000 & 6{,}0000 & 1{,}0000 & 3{,}0000 & 4{,}0000 \\ 3{,}0000 & 0{,}5000 & 4{,}0000 & 0{,}3333 & 1{,}0000 & 2{,}0000 \\ 2{,}000 & 0{,}3333 & 3{,}0000 & 0{,}2500 & 0{,}5000 & 1{,}0000 \end{bmatrix}$$

Based on the above matrix **P**, using the matrix column averaging method, the vector w was determined containing the weights w_j of the adopted criteria:

$$\mathbf{w} = [0{,}0655 \quad 0{,}2488 \quad 0{,}0434 \quad 0{,}3794 \quad 0{,}1604 \quad 0{,}1024].$$

An integral part of this phase of calculations was the control of matrix **P** consistency, which resulted in:

$$\lambda_{max} = 6{,}169,\ CI = 0{,}034,\ CR = 0{,}027.$$

As you can see, this control showed the consistency of the initial pairwise pairing matrix, as the *CR* does not exceed the permissible value 0.10.

As mentioned in the title and in the introduction to this study, the area covered by the analyses in the Moniecki county, located in the Podlaskie District. In this connection, it should be added that the Moniecki county includes seven communes, which are: Goniądz, Jasionówka, Jaświły, Knyszyn, Krypno, Mońki, and Trzcianne.

The entire area is divided into land and building records for a total of 204 precincts. Three of them are urban areas: Goniądz, Mońki, Knyszyn, which were excluded from the analyses presented in this study. Further analysis based on the AHP method covered the remaining registration precincts in the number of 201.

The purpose of these analyses was to determine the urgency of consolidation works in the analyzed precincts, and in other words – the alignment of these enclaves in accordance with the urgency of consolidation works in their area, resulting from AHP obtained synthetic assessments of individual areas. The starting point for the conducted analyses were the parameters of individual precincts in the light of the adopted decision criteria. Due to editorial restrictions regarding the preferred volume of the text, it was not possible to provide these parameters in the article (this would increase the volume of the article by a factor of 2). However, if you are interested in these source data, the authors of the article will be happy to share it.

On the basis of the above data, in relation to each of the criteria, the so-called local preferences that reflect the mutual positions of the analyzed precincts. Appropriate matrices of pairwise comparisons of these ranges in the light of subsequent criteria were created using formulas (1)–(4).

Each of the six pairwise comparison matrices created in this way was subjected to consistency assessment, where formulas (5) and (6) were used to determine the RI. The resulting value for $n = 201$ is $RI = 1{,}7570$. The appropriate values λ_{max}, *CI* and *CR* are shown in table 2. As it results from the performed control, for each of the criteria, the *CR* of the relevant pairwise comparison matrix turned out to be significantly lower than the permissible value.

Table 2. Evaluation of consistency matrix comparisons in pairs

	Criteria					
	K1	K2	K3	K4	K5	K6
λmax	201,1936	203,5657	203,7845	201,0248	206,2895	201,1054
CI	0,00097	0,01283	0,01392	0,00012	0,02645	0,00053
CR	0,00055	0,00730	0,00792	0,00007	0,01505	0,00030

Source: author's own work.

Then, on the basis of local preferences (which were defined in relation to subsequent criteria) and the weights of the criteria, synthetic estimates of individual precincts were calculated. Using synthetic assessments and organizing the analyzed ranges in order from highest to smallest value of the synthetic evaluation, it is possible to indicate the cadastral areas that most urgently require consolidation works. The list of prefabricated areas with the greatest urgency of consolidation works, together with the obtained synthetic assessments, is given in table 3.

Table 3. Listing of precincts with the greatest urgency of merging works

Precint	Synthetic evaluation
200801_5.2101.Wólka Piaseczna-Łąki Różnych Wsi	0,01533
200803_2.0021.Zabiele	0,00997
200805_2.0004.Długołęka	0,00965
200807_2.0006.Giełczyn	0,00947
200802_2.0007.Kalinówka Królewska	0,00886
200807_2.0013.Nowa Wieś	0,00886
200807_2.0131.Nowa Wieś-Bagno-Ław	0,00861
200807_2.0017.Szorce	0,00848
200803_2.0005.Dolistowo Stare	0,00837
200801_5.0006.Klewianka	0,00801
200802_2.0013.Krasne Stare	0,00796
200806_5.0026.Przytulanka	0,00769
200805_2.0005.Góra	0,00762
200806_5.0016.Kulesze	0,00760
200807_2.0418.Budy-Dz.Długołęka	0,00749
200801_5.0311.Olszowa Droga	0,00746
200807_2.0015.Bajki Stare	0,00745
200804_5.0003.Grądy, Poniklica, Wodziłówka	0,00743
200807_2.0019.Wilamówka	0,00724
200803_2.0020.Szpakowo	0,00708
200801_5.2108.Wólka Piaseczna-Kalinówka K.	0,00702

Source: author's own work.

The summary in table 3 shows that the precinct, which most urgently requires taking appropriate actions related to the consolidation and replacement of land, '200801_5.2101.Wólka Piaseczna-Łąki Różnych Wsi'. In the case of this area, the synthetic evaluation, obtained by the AHP method, by over 50% exceeds the assessment of the next three ranges, located at the top positions in the ranking ('200803_2.0021.Zabiele', '200805_2.0004. Długołęka' oraz '200807_2.0006.Giełczyn'). The importance of the problem in the case of the area '200801_5.2101.Wólka Piaseczna-Łąki Różnych Wsi' It also proves that its synthetic evaluation is more than twice as high as the assessment of the thirteenth division in this ranking, which is '200805_2.0005. Góra'.

For similar reasons, as in the case of parameters of individual registers in the light of accepted decision criteria, in this study it was not possible to cite synthetic assessments for all 201 registers of them, as well as their assessments in the light of subsequent criteria. However, as in the previous case, the authors of the article will be happy to share it in case of possible interest.

At this point, you can only pay attention to the synthetic assessment of the area '200801_5.2101.Wólka Piaseczna-Łąki Różnych Wsi'. It is more than five times higher than the estimates of four precincts, which are located at the end of the ranking ('200807_2.0420.Budy-Dz.Koleśniki', '200807_2.0421. Budy-Dz.Guzy', '200801_5.2107.Wólka Piaseczna-Bagno II' and the '200807_ 2.0711.Gugny-Dz.Dług.Roma.') and which obtained synthetic ratings not exceeding the value 0,00300.

Conclusions

One of the reasons that prompted the authors to undertake analyses aimed at implementing the AHP method to determine the urgency of consolidation works in the area of the Moniecki county was the fact that this method is one of the most popular methods of multi-criteria decision analysis. As the review of various applications of the AHP method presented in the study (Sipahi, Timor, 2010) shows, it found many of applications in solving various decision problems. In the opinion of the authors of this study, the AHP method can be also useful in solving problems related to determining the urgency of merging works. The experience of the authors of this work has shown that a very useful tool proves to be an Excel spreadsheet.

The approach adopted by the authors, according to which all reference sections in the area of the Moniecki county were subjected to simultaneous analysis, does not exclude the possibility of performing similar analyses in a smaller area, as for example in any municipality. In this case, the analysis

algorithm used would be analogous. In the case study, presented in this research the sensitivity analysis of the final ranking to the change in the weightings of criteria, which is an integral part of the multi-criteria analysis, was omitted. However, this was not the main goal of the research, because the authors focused on the implementation of the AHP method to solve the decision problem.

Issues that would require additional research are the possible establishment of a universal set of decision criteria so that it can be applied regardless of the location of the analyzed area. There is no doubt that the key issue, which is of crucial importance from the point of view of a possible extension of the set of criteria, should be the availability of data, enabling the comparison of precincts in the light of all criteria.

According to the authors of this study, the subject of further research with regard to determining the urgency of merging works can and should be other methods of multi-criteria analysis, especially the PROMETHEE and TOPSIS methods, which – as mentioned in the introduction – can be considered as popular as the AHP method.

The contribution of the authors

Andrzej Kobryń – 50% (concept and objectives, literature review).
Tomasz Tekień – 50% (concept and objectives, research).

Literature

Alonso J.A., Lamata M.T. (2006), *Consistency in the Analytic Hierarchy Process: A new approach*, "International Journal of Uncertainty, Fuziness and Knowledge Based Systems" No. 1494, p. 445-459

Ayranci Y. (2009), *A Method for the Construction of a New Reallocation Plan in Land Consolidation and its Application, "*Philipp Agric Scientist" No. 92(3), p. 254-264

Banat J., Janus J. (2002), *Automatyzacja uproszczonej oceny rozłogów gospodarstw rolnych*, „Inżynieria Rolnicza" No. 8(41), Warszawa

Behzadian M. et al. (2010), *PROMETHEE: A comprehesive literature review on methodologies and applications*, "European Journal of Operational Research" No. 200, p. 198-215

Behzadian M. et al. (2012), *A state of the art survey of TOPSIS applications*, "Expert Systems with Applications" No. 39, p. 13051-13069

Brans J.P. (1982), *L'ingenierie de la decision; Elaboration d'instruments d'aide a decision. La methode PROMETHEE* in: Nadeu R., Landry M. (eds) *L'aide a la decision: Nature, Instruments et Perspectives d'Avenir*, Quebec

Brans J.P., Mareschal B., Vincke Ph. (1984), *PROMETHEE: A new family of outranking methods in multicriteria analysis*, "Operational Research'84", Amsterdam

Cay T., Iscan F. (2006), *Optimization in Land Consolidation. XXIII International FIG Congress 8-13 October 2006,* Munich

Dytczak M. (2010), *Wybrane metody rozwiązywania wielokryterialnych problemów decyzyjnych w budownictwie*, Opole

Figueira J., Greco S., Ehrgott M. (eds) (2005), *Multiple Criteria Decision Analysis: State of the Art Surveys*, New York

Gniadek J. (2013), *Analiza położenia i ukształtowania rozłogów działek należących do różniczan we wsi Filipowice*, „Acta Scientarum Polonorum – Geodesia et Descriptio Terrarum" No. 11(4), p. 13-26

Harasimowicz S. (2001), *Wpływ podstawowych cech rozłogu pola na koszty jego uprawy*, „Przegląd Geodezyjny" No. 12, p. 10-15

Harasimowicz S., Janus J., Ostrągowska B. (2009), *Optymalizacja wiejskiego układu gruntowego wykorzystująca podział kompleksów projektowania działek na paski elementarne*, „Przegląd Geodezyjny" No. 5, p. 3-11

Hwang C.L., Yoon K. (1981), *Multiple attribute decision making: Methods and applications*, Berlin

Janus J. (2011), *Zintegrowany system kształtowania układów gruntowych wsi*, Komisja Technicznej Infrastruktury Wsi PAN w Krakowie, Kraków

Jędrzejek A., Woch F., Szymański L. (2014), *Ocena rozdrobnienia gospodarstw rolnych do określenia rozmiarów prac scaleniowych w Polsce*, „Przegląd Geodezyjny" No. 10, p. 3-10

Kobryń A. (2014), *Wielokryterialne wspomaganie decyzji w gospodarowaniu przestrzenią*, Warszawa

Kobryń A., Tekień T. (2016), *Potrzeby i możliwości w zakresie prac scaleniowych w powiecie monieckim*, „Wieś i Rolnictwo" No. 3(172), p. 145-162

Leń P., Noga K. (2010), *Analiza rozdrobnienia gruntów indywidualnych we wsiach powiatu Brzozów*, „Infrastruktura i Ekologia Terenów Wiejskich" Vol. 3, Komisja Technicznej Infrastruktury Wsi PAN w Krakowie, Kraków, p. 55-64

Leń P. (2013), *Sposób określenia pilności potrzeb scalania i wymiany gruntów*, Wydział Geodezji Górniczej i Inżynierii Środowiska AGH, Kraków (doctoral thesis)

Miller G.A. (1957), *The magical number seven*, *plus or minus two: Some limits on our capacity for processing information, "*Psychological Review" No. 63(2), p. 81-97

Noga K. (1990), *Metodyka programowania prac scaleniowych i technologia ich wykonywania w terenach górskich, „*Zeszyty Naukowe AR w Krakowie, seria Rozprawy" No. 143, Kraków

Saaty T.L. (1980), The *Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, New York

Saaty T.L. (2004), *Decision making – the Analytic Hierarchy and Network Processes (AHP/ANP)*, "Journal of Systems Science and Systems Engineering" No. 13(1), p. 1-35

Sipahi S., Timor M. (2010), *The analytic hierarchy process and analytic network process: an overview of applications*, "Management Decision" No. 48, p. 775-808

Sobolewska-Mikulska K., Pułecka A. (2007), *Scalenia i wymiany gruntów w rozwoju obszarów wiejskich,* Warszawa

Szafrańska B. (2011), *Scalenia infrastrukturalne jako narzędzie naprawcze przestrzeni planistycznej przeciętej budowana autostradą*, „Czasopismo Techniczne" No. 108(3), p. 151-161

Szłapczyńska J. (2009), *Zastosowanie algorytmów ewolucyjnych oraz metod rankingowych do planowania trasy statku z napędem hybrydowym*, Zachodniopomorski Uniwersytet Technologiczny w Szczecinie, Wydział Informatyki, Szczecin (doctoral thesis)

Triantaphyllou E. (2002), *Multi-criteria decision making methods: A comparative study*

Trzaskalik T. (ed.) (2014), *Wielokryterialne wspomaganie decyzji. Metody i zastosowania*, Warszawa

Tzeng G.H., Huang J.J. (2011), *Multiple attribute decision making: Methods and applications*

Wierzchowski M.W. (2007), *Przestrzenne, ekonomiczne i społeczne problemy scalania i wymiany gruntów,* Kraków

Woch F. (2007), *Organizacja przestrzenna gospodarstw rolniczych oraz jej wpływ na efektywność gospodarowania*, „Studia i Raporty" No. 7, PINB Puławy

Woch F. (2008), *Wytyczne do opracowania programów urządzeniowych*, PING Puławy

Zopounidis C., Pardalos P. (2010), *Handbook of multi-criteria analysis*, Berlin-Heidelberg

Instrukcja nr 1 Ministra Rolnictwa i Gospodarki Żywnościowej o scalaniu i wymianie gruntów z dnia 24 marca 1983 r.

Ustawa z dnia 21 sierpnia 1997 r. o gospodarce nieruchomościami, Dz.U. 1997 nr 115 poz. 741 z późn. zm.

Ustawa z dnia 26 marca 1982 r. o scalaniu i wymianie gruntów, Dz.U. 1982 nr 11 poz. 80 z późn. zm.

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ADAPTATION PLANS TO CLIMATE CHANGE – RANGE AND QUALITY OF INPUT DATA

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ABSTRACT: One of the most important elements of the process of developing the urban plans for adaptation to climate change is a gathering proper data. It will have an influence on the quality of the final work, its accuracy, reliability, determining the adaptation option and decide on its success. In the first part of the paper the experience in collecting data from the English-language literature which were published between 1999-2016 has been presented. A search was carried via scopus.com, webofknowledge.com and springer.com or sciencedirect.com. In the next part of the paper the main information sources which will be referred to when developing MPAs (Miejskie Plany Adaptacji – Urban Adaptation Plan) in Polish cities have been identified. At the end, the requirements for conducting proper and reliable geostatistical analyses have been presented. In the article the main framework of resources required for MPAs was established. This will allow maintaining the level of quality of documents received and avoid the mistakes.

KEY WORDS: urban adaptation plans, climate change, data collection

Introduction

The issues of urban sensitivity to climate change are addressed in numerous expert studies and strategic documents of the European Union (Gorgoń et al., 2014b). They are of various forms and the first time they appeared was in 2007, when during the COP16 conference the framework for adaptation activities was established. In Poland these activities started almost simultaneously, i.e. in 2009 with the implementation of the KLIMADA project. Works carried out in the previous years resulted in the adoption of a „Strategic Adaptation Plan for Sectors and Areas Sensitive to Climate Change by 2020" in 2013 ('SPA', 2013). This most important Polish document points out to the necessity of preparing adaptation plans or strategies addressed to Polish cities. These documents have been referred to by the Ministry of the Environment as Urban Adaptation Plans (MPAs).

In Poland the process of developing Urban Adaptation Plans (MPAs) to climate change in large cities (i.e. cities with more than 100 thousand inhabitants) was launched in 2017. This is the first such a large project covering 44 Polish cities. The aim of these plans is to prepare urban areas for potential impacts related to climate change. This is the result of the European Union's policy, which points out the need to implement adaptation measures at an urban level (Perks, 2013).

The basis for the development of adaptation plans is the analysis of the vulnerability of a given city to potential impacts resulting from climate change. A characteristic of potential impacts to Polish cities was worked out by the Institute for Ecology of Industrial Areas in the document entitled „*Assessment of the sensitivity of urban areas to potential threats posed by climate change*" (Gorgoń et al., 2014b). Together with the above-mentioned assessment „Guidelines for the development of an urban adaptation strategy for cities with more than 100 thousand inhabitants" (Gorgoń et al., 2014a) were prepared. On the basis of this the "Urban adaptation handbook – guidelines for the development of urban adaptation plan to climate change" ('Podręcznik MPA', 2015) was developed. The aim of these documents is to support the process of establishing MPAs in Polish cities.

Although the aforementioned documents have been developed, there is still an urgent need to continue and expand the activities that could significantly influence the effectiveness of the MPA process. One of the very important elements of such activities is to determine the range of data and information necessary for developing MPAs. Their aim is to support the process of raising the awareness and understanding of the potential impact of climate change and the possible adaptation options. The collected data and information will constitute the basis for further analyses related to MPAs. Therefore,

the quality of work, its accuracy and reliability will depend on the proper selection of data. In addition, it may influence the choice of the adaptation options at the final stage of the process, and ultimately its final success.

The main aims of the paper is establish the minimum requirement for gathering data to allow some level of quality of MPAs and to avoid the mistakes.

Material and Method

This section sets out the methods for reviewing literature and conducting research.

Research related to the data collection process was initiated during statutory work titled "Methods of identifying areas of the city's sensitivity to climate change and preliminary assessment of the effectiveness of measures aimed at reducing the city's sensitivity to the above-mentioned changes". The statutory was conducted in 2016. These studies have led to the conclusion that the first step to conduct the sensitivity analysis is to collect and verify the necessary climate data and information. This stage of work on adaptation plans is of great importance to their result.

Than the research about this issue was began. A literature search was carried out using the terms "input data", "climate change", "adaptation plans" via scopus.com, webofknowledge.com and springer.com or sciencedirect.com. The research was conducted in peer-reviewed journals, books, and conference proceedings which were published in English between 1999-2016 mainly. This literature included a European policy, guidelines, methodological papers, best-practice examples and adaptation plans reviews issued by international organizations, donors and development cooperation agencies. The resulting citations were screened in order to isolate 'input data' that pertained to European and urban/cities adaptation plans. In this stage of work The EU-ClimateAdapt (http://climate-adapt.eea.europa.eu) portal was searched for items tagged "urban adaptation plans" and "data collection" also.

The next step was to review Polish experiences in this area. Two items were helpful in creating the data list of source for adaptation plans of polish cities:

- Wytyczne do przygotowania miejskiej strategii adaptacyjnej dla miast powyżej 100 tys. mieszkańców (Gorgoń et al., 2014a),
- Podręcznik adaptacji dla miast wytyczne do przygotowania Miejskiego Planu Adaptacji do zmian klimatu ('Podręcznik MPA', 2015).

As for Polish experience in collecting and using data for adaptation plans, it was in that stage of work rather poor.

In the text was used abbreviation MPA which means Miejskie Plany Adaptacji in Polish language and Urban Adaptation Plan in English.

What data should be collected? Review of English-language literature

The key element is collecting and reviewing the necessary data concerning climate change and the related hazards of potential impacts within the city area. The data obtained will constitute the basis for all further analyses aimed at the city adaptation (Gorgoń et al., 2014a; 'Podręcznik MPA', 2015; Snover et al., 2007). The problem of data collection, selection of their sources and quality control has so far been discussed mainly in foreign language literature. The largest in this area is the experience of American and European countries, regions or cities which have initiated the process of creating documents related to the adaptation of cities. Taking this into account, it is extremely important to use the acquired knowledge and expertise while starting work with the cities (Giordano, Capriolo, Mascolo, 2013). The analysis of the available materials concerning preparation for urban adaptation or the adaptation itself may be the useful step, especially if it is accompanied by similar climate change experiences. However, it should be emphasized here that solutions which are good in one city do not necessarily work in another (Cortekar et al., 2016).

It is obvious that while collecting the data the existing resources will be used (Basher, 1999; Giordano et al., 2013). It is not expected that new databases will be developed because it is a time-consuming and cost-intensive process. It should also be stressed here that the amount of data required for the development of MPAs may have some limitations, i.e. lack of data, their unavailability, low quality or invalidity. It should also be borne in mind that during the work the state-of-the-art should be monitored for new information to supplement those previously collected.

Quoting Snover et al. (2007), the process of collecting data and information will be connected with finding an answer to the following question: how does climate change affect the region and does it pose an impact to the local community? Van de Ven (van de Ven, Buma, Vos, 2014), on the other hand, addresses the issue in the form of four questions:

1. What can be vulnerable to climate change and where (facilities, networks and groups)?
2. What climatic risks appear, where, and to what extent? Where is the highest risk?
3. Where can you find opportunities connected with climate change?

4. Which of the recent extreme weather conditions may be the benchmark in the research analysis?

Adaptation of cities to future climate change will depend on a number of factors, independent or interacting with each other. However, as already mentioned above, the key element in the adaptation of cities to future climate change is to understand and manage the current climate fluctuations so as to make them predictable (Basher, 1999). For this purpose, relevant data and information will be required. They can be divided into several categories (according to Basher, 1999; Burton, Malone, Huq, 2005; Giordano et al., 2013):

- climatic factors (temperature, precipitation, wind, etc.),
- non-climatic factors (environmental and socio-economic conditions i.e. population, land
- use, ecosystem data, etc.),
- sector vulnerability to present climate change and other changes, and their impacts,
- interactions between the various elements of the system and the result of these interactions,
- adaptation actions, plans and policies.

Climate phenomena and their derivatives, which are, in some way, a causative factor that can affect particular sectors of the city and its components. These, are the first from the above-mentioned data categories. Generally, most of foreign language literature focuses on collecting information related to: air temperature, atmospheric precipitation, solar radiation, wind speed and humidity. The availability and quality of this data is relatively better than, for example, than those relating to the environment or socio-economic factors. They have been gathered for many years, if not decades, as this is popular data, which constitutes the basis for many processes and is used in many sites. In addition, their measurement is relatively simple. Monitoring and collection of data related to climatic issues factors is conducted on a global scale, with the cooperation of international and regional centers. Problems connected with meteorology, operational climatology and hydrology are dealt with by the World Meteorological Organization (WMO). It was established, among others, to coordinate the network of meteorological and hydrological stations and to ensure data consistency. In turn, the Global Climate Observing System (GCOS) is responsible for systematic data collection for global monitoring system, prediction and monitoring of the climate change effects.

Collection of data is just the beginning of the process of gaining knowledge on the climatic phenomena. Based on the obtained data, climate trends are identified and estimated. This can be done using statistical methods, i.e.

analysis of time series from meteorological monitoring stations. Such data should meet the following criteria: the data series should cover a longer period of time (at least 40-50 years), should be continuous over time, and tested for completeness and quality. In addition, the series of data is subjected to homogenisation (Aguilar et al., 2003; Kuglitsch et al., 2009) and statistical processing, including the recognition of linear and nonlinear trends (Seidel, Lanzante, 2004; Tomé, Miranda, 2004) in order to provide reliable results. Subsequently, properly prepared data is interpolated in a regular grid to a larger area using geostatistical methods (Giordano et al., 2013).

Another very important step in the development of the database is the review of environmental and socio-economic conditions as they may include elements sensitive to climate change. Proper identification of impacts will contribute to the selection of the best adaptation option. Nowadays, it can be observed that there are cities which have already been struggling with some environmental or socio-economic problems which are not related to climate change. These problems are sometimes so serious that the cities are not willing to solve any other problems. However, it must be borne in mind that the potential climate change may exacerbate the existing „non-climatic" problems or generate new ones. At this stage of research areas systematically exposed to climatic hazards and showing the highest exposure level should be identified. There is also another factor that raises the level of uncertainty, namely the fact that volatility of the so called „non-climatic" data is sometimes much higher than the observed climate change (Basher, 1999).

In most cases at this stage a list of indicators, i.e. parameters characterise a given receptor (sector of the city) (Burton et al., 2005), is prepared. They will help define the sector sensitivity level. The indicators should meet three criteria – they should: a) aggregate, calculate and simplify relevant information, b) capture the key problem, and c) provide relevant information. They may be qualitative, quantitative or mixed. An ideal situation is when the indicators characterise a given receptor in a qualitative manner. There are many publications and there are adaptation tools that offer ready-made lists of indicators, such as, for example THE FUTURE CITIES ADAPTATION COMPASS. Below, an exemplary fragment of the table from the above-mentioned tool is presented (table 1).

When selecting the indicators, one should also refer to the manual: "The Vulnerability Sourcebook. Concept and guidelines for standardized vulnerability assessments", which describes how to identify and select the indicators ('GIZ', 2014).

Table 1. Sample list of indicators for population-related receptors. Fragment of the table from THE FUTURE CITIES ADAPTATION COMPASS tool

	Receptors	Indicators Select one/or more indicators per receptor to describe core areas
Population	Public health/vulnerable groups*	Spatial distribution of vulnerable groups
		Age structure of different groups in the city
		Population density
		Capacity of medical system
		Capacity of emergency system
		Amount of green spaces
		Distribution of air corridors
		Degree of air quality

* (Smit, Wandel, 2006) According to this authors, vulnerability is a function of sensitivity and exposure of a receptor to the hazardous conditions/climate or weather impact and the capacity to adapt towards those conditions. This definition is different than in the IPCC is, which refers to climate change impacts instead of integrating actual and observed climatic or weather related impacts (compare IPCC, 2007)

Source: The future cities..., 2013.

Another very important element of the above-mentioned list of data categories is to understand the impact of current climate changes on the sectors and their vulnerability to these changes. In literature there are a number of variants which propose a proper course of action. In the tool "THE FUTURE CITIES ADAPTATION COMPASS. A guidance tool for developing climate-proof city regions" ('THE FUTURE CITIES...', 2013), starting from the list of receptors, which are a set of local physical properties and socio-economic conditions, their current sensitivity to weather events and their distribution can be investigated. This is one of the methods, and there is not one tried and tested course of action in this case.

Interactions between the various elements of the system and the resultant of these interactions is a category of data that is much more difficult to put into any frame. It requires understanding and combining many scientific disciplines and data (Basher, 1999). It would be advisable here to refer to the IPCC reports (Pachauri, Mayer, Intergovernmental Panel on Climate Change, 2015).

The last step is to review the existing adaptation measures, plans and policies which operate within or on the part of the investigated area, as well as the effects of the actions already taken. The range of the data is limited to the region or city. It largely depends on funds and local policy. Conducting the data analysis on a local scale will be helpful in taking further actions.

Proposed range of data for adaptation of Polish cities

The presented thematic range and principles of procedure at the stage of spatial data collection was developed on the basis of research and development works (including expertise and studies for the Ministry of the Environment), which have been carried out in the Institute for Ecology of Industrial Areas since 2014.

Currently, a lot of information on the environment, urban structure, climate and its influence is available in Poland and worldwide. It can be obtained from various sources, such as:

1. Publicly available web portals, such as those of the European Environment Agency: http://climate-adapt.eea.europa.eu/, https://www.eea.europa.eu/data-and-maps.
2. Institutions dealing with the collection and dissemination of such data, in particular: Geodesic and Cartographic Documentation Center (CODGiK), National Water Management Authority (KZGW), The General Directorate for Environmental Protection (GDOŚ), Chief Inspectorate of Environmental Protection (GIOŚ), and regional representatives of these institutions.
3. City resources, which are an essential element of the knowledge about the city due to their accuracy of details and adequacy (of course, provided that they are updated).

The above mentioned institutions have databases and information which are also available on their web portals. An example may be the KZGW hydroportal where, for example, under the project: "National Information System for Protection against Extreme Hazards (ISOK)" flood hazard and risk maps as well as Flood Risk Management Plans for the Odra and Vistula River Basins have been published. The maps are available on the portal in pdf format, but they are also in the possession of the administrative units.

When collecting data for MPAs, particular attention should be drawn to a few details. The first important thing in creating the MPA document, especially in analyses of the sensitivity of city sectors and their vulnerability, is the data collection date and data quality. The collection date does not, of course, relate to historical data and studies. The validity of data collected nowadays is often different. It is important, especially when dealing with, for example, models related to future climate change. Current data and information take into account the state-of-the-art on climate change in many areas, as well as adaptation methods or complex systems and interactions between particular elements. This knowledge is dynamic and based on the experience gained in this field. As mentioned before, the validity of data can significantly affect the final outcome of the analyses. Data obtained under international projects are generally updated and also reviewed.

Thus, it can be assumed that the quality of both input and output data is quite good. In many cases this quality is determined and known to the user. It should be remembered, however, that they do not always translate into real problems in the city. The situation is different in terms of data coming from the city resources. Planning documents, which are one of the main sources of information about the city, show different validity, and what may become even a bigger problem – they may be of various quality. It depends on the period in which the document was developed and on the applied cartographic tools. Cities updated or created such documents, depending on the needs or changes of the law.

Another important thing to pay attention to in creating the MPA document is the scale and coverage of data and information. Regardless of whether they are statistical, mapping or descriptive, the data usually have a specific coverage and scale. Most often, those from international portals represent a global scale (world, continent or country). The rest are regional (voivodeship) or local (county, municipality, city). For broader context analyses, less accurate global or regional data will be used. However, this will be rather rare and used to support the work, the overwhelming majority of which will concerns the city, i.e. the local scale.

In order to systematize the data and information on urban adaptation to climate change, they were divided into groups. A similar situation is in the case of English-language literature – Basher et al. (1999) Burton et al. (2005) and Giordano et al. (2013) cited above, where the collected data and information are assigned to different categories (groups). As far as MPAs for Polish cities are concerned the following groups of data and information are proposed:

- elements of urban structure and the environment,
- causative factors, i.e. natural climatic phenomena and their derivatives,
- Internet portals, which are a good source of knowledge or basic and complementary information on both climate change and adaptation methods,
- manuals, good practices, and plans for the applied world-wide examples of urban adaptation to climate change,
- own, strategic, spatial planning and other studies developed at a city or municipal level, and other data collected by local or regional institutions,
- reports developed under bilateral and / or international projects,
- research projects and studies.

The first group of data includes information about the elements of the urban structure and the environment, which constitute the receptors potentially vulnerable to natural hazards, exacerbated by climate change. They can be further systematised by dividing into the following thematic subgroups:

- land use pattern,
- administrative units and special borders,
- digital terrain model (DTM),
- hydrography / hydrology,
- technical infrastructure of the city,
- functional structure of the city including development and its structure,
- division of the city into districts, area of the city,
- share of biologically active areas,
- soil sealing degree,
- functional-spatial relationships with the surrounding,
- demography, health and safety of the population,
- habitats and natural areas, protected areas and species,
- historical background,
- natural hazard zones including flood plains,
- soil.

The second group includes data on causative factors, defined as stressors, i.e. natural climatic phenomena and their derivatives, which have a particular influence on the elements of the urban structure and the environment. These phenomena are related to three areas that may pose a potential threat to the city. These are:

- water,
- temperature,
- wind.

The third group covers Internet portals. They are a good source of knowledge, basic and additional information on both climate change and adaptation methods. This group is so large and dynamic that it is difficult to gather all the available portals. However, when using this information to avoid misunderstandings and ambiguities, it is important to pay attention to the purpose for which it was created, who is the recipient and what is the source of funding.

The fourth group of data and information sources includes manuals, good practices and examples of urban adaptation to climate change. It is also a very broad and dynamically developing group. Many cities, especially European and American ones, have already implemented urban adaptation plans. This enables the exchange of experience in adaptation of cities located in different climatic zones in the world.

The fifth, but very important group, consists of the data collected by individual cities, including those which are publicly available but also studies and documents of the municipality. These are their own, strategic, spatial planning and other works developed at the city or municipal level. This group also includes supra-municipal documents, such as city functional areas or studies on a voivodship scale.

A good source of data may also be reports prepared under bilateral and/or international projects. They may address issues related to climate change or urban adaptation. Such projects are often carried out by the municipal offices and other municipal entities. Many studies on urban adaptation to climate change emerged in scientific circles under various research projects and studies. They were developed by universities, scientific and research institutes and state environmental protection institutions. They contribute a lot to the development of the state-of-the art in this field.

As it has already been mentioned at the beginning of this paper, the list of sources should be updated during the work on MPAs immediately after a new document appears. Within the city, however, the list should include additional documents depending on the city specificity. During the work on the MPAs ready and standardised list of data necessary for carrying out analytical and diagnostic work should be used. This can ensure correct and uniform analytical procedure in the carried out city sensitivity and vulnerability assessment. In addition, the use of similar data sources allows obtaining a result of comparable quality and value. It is also important to use adaptive solutions tested in a specific city to avoid errors. This is why it is so important to refer to the experience of other cities having similar problems connected with the urban adaptation.

Conditions ensuring correctness of geostatistical analyzes

In order to ensure that the above-mentioned data provide measurable effects, the method of their processing is also very important. For this purpose, calculations and statistical inference in these research methods should be performed at the significance level of $\alpha = 0.05$ and in the case of short measurement series at $\alpha = 0.01$. Calculations and inferences will take into account the nature of the statistical distribution, and depending on this distribution parametric and / or nonparametric methods will be used. The analyses will cover the latest data collected from the official holders of such data, e.g. Chief Inspectorate for Environmental Protection, Institute of Meteorology and Water Management, Central Statistical Office, etc. In the case of multi-criteria analyses, the correctness of the results should be ensured by conducting the sensitivity analysis.

In the case of map and computational data obtained from various reliable sources, the consistency analysis should be performed. If there is a lack of consistency, the data which are more reliable (i.e. those the accuracy of which is the highest, data error is known and represents the lowest value) should be taken into account. Spatial analyses should be performed wherever possible on large scale materials (local scale) e.g. 1:10 000.

An important element that will improve the transparency of results is "enclosing" the result maps with metadata in a format consistent with the INSPIRE Directive. In the case of Internet portals providing statistical and spatial data (e.g. the European Environment Agency portal), the following data should be taken into account (if possible): data that are reviewed, reliable, possibly the most recent ones, worked out by renowned institutions, foundations or experts and originating from sources recognized by experts. The last element to be highlighted in the case of information sources or tools is the applied methods, which should take into account the current state-of the-art.

Results and Discussion

The article shows haw to develop data base for adaptation plans of polish cities. The knowledge how data we need for adaptation plans has a decisive impact on the result. In the Poland large project covering 44 has just been completed. Therefore, we have some experience in this area but growing knowledge is very desired. It is extremely important to use the experience and knowledge of other countries. In this range, the available literature is impressive. Using this knowledge one should, however, remember about the specificity of Polish cities. In Poland we have a slightly different data resource than it is, for example, in America or in Europe. Largely, of course we can use the data collected by the European Union especially if were created for adaptation purposes, but one should remember that the basic source of data are gathering from Polish institutions and cities.

In this article, we organize knowledge about the collection of data, indicate the source of which to use and on what we should pay special attention to. The information provided in the article will contribute to broadening the knowledge on the data needed to create plans for adapting to climate change in Poland. The purpose of this article is also to draw attention to the aspect of data collection for the plans for adapting Polish cities. Therefore, it aims is not only to systematize knowledge about data collection but also the correctness of data selection and their range. This is one of the key elements in creating such a plans and can not be belittle.

Conclusions

In the first part of this paper experiences in collecting data described in English-language literature have been presented. The topic has been addressed

in a very general way in order to demonstrate the most important branches of knowledge concerning the adaptation of cities to climate change. A set of questions supporting the collection of data has been developed. In addition, the provided data have been presented according to thematic categories. In the case of climatic data, the way in which they are processed before they reach the final user has been described. This method is very important. It helps realize that climate scenarios are based on data already processed in some way in order to eliminate measurement errors. The English-language literature referred to in this paper brings the whole process of data collection together and should be very helpful in the development of MPAs.

In the next part of the paper the sources from which data and information on urban adaptation will come from have been identified. There are also groups that define the thematic range of data and information necessary for the adaptation of Polish cities. The development of a fixed list of sources, defined for cities at the beginning of the document creation process, should ensure high quality and uniformity. This data may be of different character, e.g., statistical, map or descriptive. Their validity may also vary. Particular attention should be paid to the date of their creation, the latest literature and to the current data. Obviously, this does not apply to historical data, which also affects the understanding of future climate change. Their quality, however, may vary. It may also happen that due to their doubtful reliability they will become useless. When new research results on information appear during the studies the data should be updated on a regular basis. Such a "monitoring" of the latest data or information should be carried out until the final stage of the MPA development process.

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The contribution of the authors

Magdalena Głogowska – 90% (concept, research, literature review, all article except chapter "Conditions ensuring correctness of geostatistical analyzes").

Joachim Bronder – 10% (chapter "Conditions ensuring correctness of geostatistical analyzes" and consultations).

Literature

Aguilar E. et al. (2003), *Guidelines on climate metadata and homogenization*, World Meteorological Organization, https://www.wmo.int/datastat/documents/WCDMP-53_1.pdf [12-05-2016]

Basher R.E. (1999), *Data requirements for developing adaptations to climate variability and change.* "Mitigation and Adaptation Strategies for Global Change" No. 4(3-4), p. 227-237

Burton I., Malone E.L., Huq S. (2005), *Adaptation policy frameworks for climate change: developing strategies, policies, and measures*, in: Lim B., Spanger-Siegfried E. (eds), New York, Cambridge, http://www4.unfccc.int/nap/Documents/General/apf%20front%20matter_contents_foreword.pdf [05-10-2016]

Cortekar J. et al. (2016), *Why climate change adaptation in cities needs customised and flexible climate services*, "Climate Services" No. 4, p. 42-51, https://doi.org/10.1016/j.cliser.2016.11.002 [05-10-2016]

Giordano F., Capriolo A., Mascolo R.A. (2013), *Planning for adaptation to climate change. Gudelines for municipalities*, Adapting to Climate change in Time, http://ec.europa.eu /environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=ACT_306-guidelinesversionefinale20.pdf [12-05-2016]

GIZ (2014), *The Vulnerability Sourcebook. Concept and guidelines for standardised vulnerability assessments,* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, http://www.preventionweb.net/files/38849_38849vulnerabilitysourcebookguideli.pdf [12-05-2016]

Gorgoń J. et al. (2014a), *Wytyczne do przygotowania miejskiej strategii adaptacyjnej dla miast powyżej 100 tys. mieszkańców*, https://www.nfosigw.gov.pl/download/gfx/nfosigw/pl/ nfoekspertyzy/858/211/1/2014-425.pdf [12-05-2016]

Gorgoń J. et al. (2014b), *Ocena wrażliwości terenów miejskich na możliwe zagrożenia wynikające ze zmian klimatu*, https://www.nfosigw.gov.pl/download/gfx/nfosigw/pl/nfoekspertyzy /858/211/1/2014-425.pdf [12-05-2016]

Kuglitsch F.G. et al. (2009), *Homogenization of daily maximum temperature series in the Mediterranean*, "Journal of Geophysical Research" No. 114(D15), https://doi.org/10.1029/2008JD011606 [22-06-2016]

Pachauri R.K., IPCC (eds) (2008), *Climate change 2007: synthesis report,* Geneva, https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf [22-06-2016]

Pachauri R. K., Mayer L., Intergovernmental Panel on Climate Change (eds) (2015), *Climate change 2014: synthesis report*, Geneva, Switzerland, https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf [22-06-2016]

Perks J. (2013), *Adaptation Strategies for European Cities. Climate Action in the European Commission, Climate Action in the European Commission*, http://climate-adapt.eea.europa.eu/metadata/publications/eu-cities-adapt-adaptation-strategies-for-european-cities-final-report [22-06-2016]

Podręcznik MPA (2015), *Podręcznik adaptacji dla miast wytyczne do przygotowania Miejskiego Planu Adaptacji do zmian klimatu*, Ministerstwo Środowiska, Warszawa, https://www.mos.gov.pl/fileadmin/user_upload/Podrecznik-adaptacji-dla-miast.pdf [22-06-2016]

Seidel D.J., Lanzante J.R. (2004), *An assessment of three alternatives to linear trends for characterizing global atmospheric temperature changes*, "Journal of Geophysical Research" No. 109(D14), https://doi.org/10.1029/2003JD004414 [22-06-2016]

Smit B., Wandel J. (2006), *Adaptation, adaptive capacity and vulnerability,* "Global Environmental Change" No. 16(3), p. 282-292, https://doi.org/10.1016/j.gloenvcha.2006.03.008 [12-05-2016]

Snover A.K. et al. (2007), *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*, Oakland, CA: University of Washington Climate Impacts Group and King County, Washington, in association with and published by ICLEI – Local Governments for Sustainability, http://cses. washington.edu/db/pdf/snoveretalgb574.pdf [12-05-2016]

SPA (2013), *Strategiczny plan adaptacji dla sektorów i obszarów wrażliwych na zmiany klimatu do roku 2020 z perspektywą do roku 2030*, Ministerstwo Środowiska, Warszawa, https://www.mos.gov.pl/fileadmin/user_upload/SPA_2020.pdf [15-06-2016]

THE FUTURE CITIES… (2013), *THE FUTURE CITIES ADAPTATION COMPASS*, *A guidance tool for developing climate-proof city regions,* FUTURE CITIES, http://www.future-cities.eu/project/adaptation-compass/ [15-09-2016]

Tomé A.R., Miranda P.M.A. (2004), *Piecewise linear fitting and trend changing points of climate parameters: CLIMATE CHANGING TREND POINTS*, "Geophysical Research Letters" No. 31(2), https://doi.org/10.1029/2003GL019100 [15-09-2016]

Van de Ven F., Buma J., Vos T. (2014), *Guide for Stress Testing the Climate Resilence of Urban Areas*, Netherlands Ministry of Infrastructure and Environment, http://www.ruimtelijkeadaptatie.nl/l/library/download/urn:uuid:561ff13d-156b-43aa-9242-b696095ad0a6/summary+of+guideline+for+stress+testing+the+-climate+resilience+of+urban+areas.pdf?format=save_to_disk&ext=.pdf [01-06-2016]

http://mapy.isok.gov.pl [05-10-2016]

http://climate-adapt.eea.europa.eu/ [05-10-2016]

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FISCAL IMPACTS OF ENVIRONMENTAL TAX REFORM IN SELECTED EU MEMBER STATES

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ABSTRCT: The purpose of the article is to analyse if – according to environmental tax reform assumptions – there occurs an increase in environmental taxes and a concurrent reduction of other taxes (especially personal and corporate income taxes) in the selected EU member states. The group of countries was chosen basing on more significant changes in the tax structure as well as "old" and "new" EU membership. The research is based on the European Commission data and covers the period 2003 to 2015 due to the data availability. The significance of changes in taxation structure has been analysed by means of structural change degree measure. The direction of these changes has been examined using structural changes monotonicity measure. A weak trend to shift slightly from income taxes to the environmental ones has been observed only in three out of ten analysed member states.

KEY WORDS: environmental policy, fiscal policy, tax shift

Introduction

Environmental taxes are a primary economic instrument of environmental policy and are widely used in many countries including the European Union (EU) member states. They minimize the total cost of pollution abatement, provide a constant incentive for pollution reduction and are a source of government revenues (Ekonomia środowiska..., p. 231). The cost-effectiveness of environmental taxes is similar to that of tradeable emission allowances and higher than the cost-effectiveness of emission standards.

Environmental taxes, through providing disincentives to consumption, are sometimes called taxes which destroy their own base. According to the European Commission (2018, p. 266-267), environmental taxes are selected by analysing their tax base which has a negative impact on the environment. As a consequence, such taxes should influence prices and costs of products and activities which have a harmful effect on the environment. They are divided into four groups in the category of indirect taxes (excluding VAT, which is selected as a consumption tax in general): energy, resource, pollution and transport (excluding fuels) taxes. The division is conventional as some of the taxes could be classified in two or more groups.

Environmental tax reform (ETR), visible on a larger scale in the 1990s in countries such as Denmark, Finland, Sweden, the Netherlands, Germany and the UK, involves gradual changes in the national tax system, where the fiscal burden shifts from economic functions such as labour (personal income tax), capital (corporate income tax) and consumption (VAT and other indirect taxes) to activities that lead to environmental degradation and the use of natural resources (Withana et al., 2014). Furthermore, environmental tax reform can be defined as the action of state authorities to increase the role of environmental taxes in the tax system of the country.

The purpose of the article is to analyse if – according to ETR assumptions – an increase in environmental taxes and concurrent reduction of other taxes are observed in the EU member states. Conducted research based on selected examples of EU Member States is to lead to general conclusions on the further role of environmental taxes in tax systems.

The environmental tax reform differs from the environmental fiscal one. The latter is a broader term encompassing additionally the removal of environmentally harmful subsidies (Dresner et al., 2006, p. 896). The analysis focuses on environmental tax reform as part of wider measures, i.e. environmental fiscal reform, which also includes public spending to protect the environment, and those contributing to further deterioration of the environment (energy subsidies, environmentally harmful subsidies and wasteful government expenditures). Environmental tax reform is a part of a fiscal reform

package to response to budgetary necessities or to support wider economic, environmental and social objectives (Withana et al., 2014). To date only some member states adopted a real environmental tax strategy while others only minor changes in tax policy.

General assumptions concerning environmental tax reform

The ETR that increases or introduces new environmental taxes is based on three principles (Deroubaix, Lévèque, 2006, p. 940-949; Cottrell et al., 2016, p. 2):

1. tax neutrality connected with shifting the tax burden mainly from personal income tax (or, more broadly, labour costs, i.e. also social insurance contributions paid by the employer) to environmental taxes and, as a result, rewarding the contribution of top earners and boosting low-income employment,
2. the polluter pays principle – through the internalization of external effects in the form of environmental pollution which results in significant costs for society, it contributes to more fairness by pricing in the negative externalities of polluting or other damaging activities and helps to incentivise behavioural change,
3. double dividend – favourable effects from the environmental and economic perspective visible in the improved quality of the environment, economic growth and increased employment (revenues from environmental taxes could be used to reduce distorting taxes on capital and labour and thus reduce the excess burden of the tax system, with positive consequences for employment, investment and innovation).

Environmental policy in the EU is implemented, among others, by supporting market-based instruments (MBI) such as: subsidies, grants, indirect taxes, tradable emission rights. The EU has set clear policy objectives in the areas of energy and climate change and is committed to achieving ambitious targets with respect to energy savings, reductions of greenhouse gas emissions and deployment of renewable energy sources by 2020. Kosonen and Nicodème (2009) note that the main advantage of MBI in relation to regulatory instruments is efficiency. The shift from taxes with a broader tax base to those with narrower tax breaks creates the danger of or rather the need for increasing taxes. As a result, double dividend effect (higher employment and more effective environmental protection) may not occur. It may also be worthwhile to point out the opposite effect of ETR, when a decline in environmental tax revenue is observed due to less environmentally-damaging activities (a tax base will decrease).

Research on the negative consequences of ETR, that is, on income distribution between the households and on the international competitiveness of enterprises, shows that the effect is rather neutral (Kosonen, Nicodème, 2009, p. 7-9). In the COMETR project, authors proved, using mainly macroeconomic modelling and case studies, that in seven EU countries (Denmark, Germany, Netherlands, Finland, Slovenia, Sweden and UK) the shift towards carbon-energy taxes had a positive impact on selected energy-intensive industries.

It should be stressed that the effects of double dividend are quite modest and depend on the specifics of the reforms in a given country (Bosquet, 2000; Patuelli, Pels, Nijkamp, 2002). When ETR is constituted by shifting of the tax burden from conventional taxes to environmental ones, attention should be paid to the issue of social inequalities and possibilities of tax preferences for the poorest taxpayers (Cottrell et al., 2016, p. 2). Social compensation mechanisms should aim to stimulate ecological behaviour, for example by financing the acquisition of low-emission, energy-saving or resource-efficient technologies, such as solar stoves, and exploiting the synergies and benefits of social and environmental policies.

ETR differs in the EU member states also with respect to the use of the environmental tax revenues (ten Brink, Mazza, 2013). Three approaches can be observed (Clinch, Dunne, Dresner, 2006, p. 960-970; Garnier, György, Heineken et al., 2014): first, recycling all the revenue through tax reductions elsewhere, second, using part of the revenue to support environmental initiatives, and the last one, consolidating public finance by reducing a general government deficit. Consequently, in the tax reform, three options can be considered:

- allocation of all additional income to reduce personal income tax (an equivalent decrease in labour taxes, resulting in no overall change in the tax burden),
- earmarking leading to expenditure on environmental protection,
- the choice of an indirect solution, i.e. a partial reduction of personal income tax and a partial allocation for environmental purposes.

The transfer of taxes from labour to environmental or consumption taxes remains a political recommendation of the European Commission at the end of each European semester (country-specific recommendations) cycle, although some member states choose opposing fiscal solutions to increase or reduce environmental taxes (Garnier et al., 2014).

In the literature, there is an increase in social acceptance of raising taxes for environmental protection or other environmental reasons, e.g. improving energy efficiency and developing renewable energy (earmarking). However, a generally accepted view in public economics is that the allocation of income

is a source of potential ineffectiveness in tax decisions (Cottrell et al., 2016). Requiring that environmental tax revenues are earmarked for a given purpose would mean that the amounts spent for these purposes would change over time in line with the trend in environmental tax revenues rather than in line with the cost-benefit estimates associated with the allocation of income.

According to Cottrell et al. (2016) therefore, such taxes should be assessed to a lesser extent on the basis of their specific environmental impact (although they are obviously still valid), and more on their ability to provide public income in the most effective and socially acceptable way. The effectiveness of large taxes related to environmental protection should be less compared to the environmental performance of other environmental regulation instruments, and more so with the effectiveness of income from other types of taxation.

Research methods

The following EU member states were chosen for the analysis of the presumptive shift from income to environmental taxation: Bulgaria, Croatia, Cyprus, Denmark, Estonia, Greece, Italy, Netherlands, Poland and Slovenia. These states were selected by taking into consideration more significant changes in the tax structure and basing on "old" and "new" EU membership. The research is based on the European Commission (Eurostat) data and covers the period 2003 to 2015 due to the data availability.

The significance of changes of taxation structure in the periods t and t -1 has been analysed by means of structural change degree measure $\varepsilon_{t,\,t-1}$ (Kukuła, 1986):

$$\varepsilon_{t,t-1} = \frac{\sum_{i=1}^{k} \left| \alpha_{it} - \alpha_{i(t-1)} \right|}{2}, \tag{1}$$

where:
α_i – share of structure component i.

The more diversified structures, the higher the value of structural change degree measure.

The direction of these changes has been examined using structural changes monotonicity measure, η_m (Kukuła, 1986):

$$\eta_m = \frac{\varepsilon_{m,1}}{\sum_{t=2}^{m} \varepsilon_{t,t-1}} \; . \tag{2}$$

If η_m equals zero, the structure in the period m is identical with the structure in the starting (first) period. If the ηm equals one, the shares of all structure components form monotonic sequences and the structure evolves in the steady direction.

Results of the research

The share of environmental taxes in total taxation in the EU member states in 2003-2015 is diversified and varies from 4.5% to 10.1% on average (figure 1). France, Belgium and Spain belong to the states with the lowest share and Croatia, Bulgaria and Malta have the highest share in the EU. The share of environmental taxes in total taxation in "new" EU countries is slightly higher than in the "old" ones (8.1% and 7.2% on average respectively).

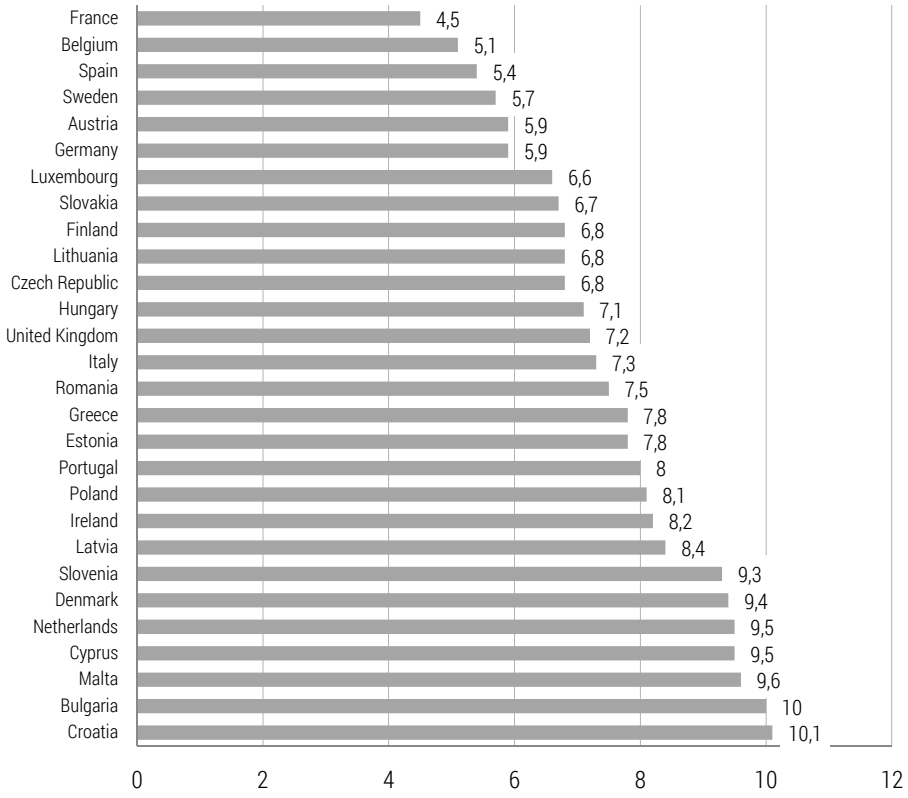

Figure 1. The average share of environmental taxes in total taxation in the EU member states in 2003-2015 [%]

Source: authors' own work based on European Commission (2017).

The detailed data on taxation structure (broken down by personal income, corporate income, environmental and other taxes) in ten selected EU member states are presented in table 1. The revenues from personal income taxes are higher than those from the corporate income ones except for Cyprus. Denmark distinguishes itself from other analysed countries by the high PIT share in taxation structure exceeding 50%.

The share of environmental taxes in total taxation in the particular member states was changing during the years 2003-2015 (table 1). Taking into account the first and the last year of the analysed period, we can distinguish six countries with a growth in the share of environmental taxes (Greece, Estonia, Slovenia, Bulgaria, Poland and Italy, by 3.6, 2.0, 1.9, 0.5, 0.5 and 0.4 percentage points, respectively) and four countries with a decrease in this share (Cyprus, Denmark, Netherlands and Croatia, by 3.0, 1.9, 0.5 and 0.2 percentage points, respectively).

In order to determine if the shift from income taxes to the environmental ones took place in the analysed EU member states, a two-element taxation structure was analysed using the $\varepsilon_{t,\,t-1}$ and ηm measures. The results are presented in table 2.

Significant changes of income and environmental taxation structure were observed in:

- Bulgaria in the period 2006/2007 ($\varepsilon_{t,\,t-1}$=0.075, structure change in favour of income taxes) and in the next period 2007/2008 ($\varepsilon_{t,t-1}$=0.054, in favour of environmental taxes),
- Croatia in the period 2009/2010 ($\varepsilon_{t,t-1}$=0.059, in favour of environmental taxes) and in the next period 2010/2011 ($\varepsilon_{t,\,t-1}$=0.040, in favour of income taxes),
- Cyprus in the period 2003/2004 ($\varepsilon_{t,t-1}$=0.055, in favour of environmental taxes) and in the next three periods ($\varepsilon_{t,t-1}$=0.055, $\varepsilon_{t,t-1}$=0.051, $\varepsilon_{t,t-1}$=0.045 respectively in favour of income taxes),
- Estonia in the period 2008/2009 ($\varepsilon_{t,t-1}$=0.054, in favour of environmental taxes),
- Greece in the period 2009/2010($\varepsilon_{t,t-1}$=0.063, in favour of environmental taxes),
- Slovenia in the period 2008/2009 ($\varepsilon_{t,t-1}$=0.053, in favour of environmental taxes).

Table 1. Taxation structure in selected EU member states

Taxes	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bulgaria													
PIT	10.2	9.5	8.7	8.4	9.5	9.0	10.2	10.9	10.7	10.7	10.2	11.3	10.6
CIT	8.9	7.8	5.9	6.8	13.1	9.8	8.8	7.4	6.9	6.3	7.3	7.1	7.3
Environmental	9.5	9.8	9.6	9.5	10.1	10.7	10.5	10.6	10.6	10.0	9.9	9.6	10.0
Other	71.4	72.9	75.9	75.4	67.3	70.6	70.5	71.1	71.8	73.0	72.6	71.9	72.1
Croatia													
PIT	9.8	10.1	9.6	9.8	10.5	10.4	10.6	9.6	9.8	10.3	10.6	10.6	9.6
CIT	5.2	5.0	6.3	7.7	8.3	7.9	7.0	5.4	6.6	5.6	5.6	4.8	5.0
Environmental	11.1	11.0	10.6	10.2	9.9	9.3	9.3	10.1	9.4	8.9	9.6	10.5	10.9
Other	73.9	73.9	73.5	72.3	71.3	72.3	73.1	74.9	74.2	75.3	74.2	74.0	74.5
Cyprus													
PIT	12.8	9.7	9.9	11.9	14.8	12.3	10.4	10.8	11.0	11.2	8.8	8.0	8.3
CIT	13.7	11.5	13.4	15.4	17.0	18.4	18.5	17.4	19.5	18.1	20.5	19.1	17.9
Environmental	12.0	12.3	10.6	9.6	8.7	8.7	8.8	8.7	8.7	8.2	8.7	9.2	9.0
Other	61.5	66.5	66.1	63.0	59.5	60.6	62.4	63.1	60.8	62.5	62.0	63.7	64.8
Denmark													
PIT	53.5	53.7	53.6	51.7	52.0	53.7	55.7	55.3	55.3	55.1	56.0	58.9	56.8
CIT	6.2	6.3	7.2	8.0	6.8	5.7	4.2	5.0	4.8	5.7	6.0	5.7	5.6
Environmental	10.5	10.8	10.3	10.1	10.2	9.3	8.9	8.9	8.9	8.7	8.9	8.1	8.6
Other	29.8	29.3	29.0	30.3	31.0	31.3	31.2	30.7	31.0	30.5	29.1	27.3	29.0
Estonia													
PIT	20.9	20.1	18.4	18.1	18.4	19.5	16.0	15.9	16.1	16.4	17.2	17.6	17.2
CIT	5.1	5.3	4.7	4.8	5.1	5.1	5.2	4.0	3.8	4.4	5.5	5.4	6.2
Environmental	6.1	6.7	7.6	7.2	7.0	7.4	8.4	8.8	8.6	8.6	8.1	8.3	8.1
Other	67.8	67.9	69.3	69.9	69.5	68.0	70.4	71.4	71.4	70.5	69.2	68.7	68.4
Greece													
PIT	12.9	13.4	13.7	14.0	14.2	14.3	14.5	12.4	14.1	19.5	16.7	16.4	14.9
CIT	8.7	8.9	10.2	8.2	7.2	6.7	8.2	7.9	6.1	3.1	3.2	5.2	5.9
Environmental	6.7	6.9	6.5	6.3	6.3	6.0	6.3	7.9	8.2	9.0	10.0	10.2	10.3
Other	71.6	70.8	69.6	71.5	72.3	73.0	71.1	71.8	71.5	68.4	70.0	68.1	68.9
Italy													
PIT	25.5	25.7	26.0	26.2	26.3	27.5	27.0	27.4	26.9	27.4	27.5	27.8	28.3
CIT	5.6	5.8	5.8	7.1	7.6	7.1	5.7	5.5	5.3	5.4	5.8	5.0	4.7
Environmental	7.5	7.2	7.4	7.1	6.6	6.2	6.7	6.7	7.4	8.0	7.9	8.3	7.9
Other	61.4	61.2	60.8	59.6	59.5	59.2	60.6	60.4	60.5	59.2	58.8	58.9	59.1
Netherlands													
PIT	17.5	16.0	17.5	17.7	18.7	18.1	22.0	21.4	20.7	19.3	18.7	18.6	20.4

Taxes	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CIT	8.1	8.8	9.7	9.5	9.5	9.1	6.1	6.4	6.1	5.9	6.0	6.9	7.2
Environmental	9.5	9.8	10.1	10.0	9.4	9.6	9.9	9.8	9.6	9.1	9.0	8.9	9.0
Other	64.9	65.3	62.7	62.9	62.3	63.3	62.0	62.4	63.6	65.6	66.3	65.6	63.4
Poland													
PIT	12.8	12.4	13.0	13.7	14.9	15.5	14.5	13.8	13.6	13.9	14.0	14.3	14.4
CIT	5.4	6.1	6.5	7.1	7.9	7.9	7.2	6.2	6.3	6.5	5.5	5.5	5.7
Environmental	7.7	8.5	8.1	7.9	7.9	7.7	8.0	8.7	8.3	8.1	7.6	8.1	8.2
Other	74.1	72.9	72.5	71.3	69.3	68.9	70.3	71.3	71.8	71.6	72.9	72.2	71.7
Slovenia													
PIT	15.0	15.0	14.3	15.0	14.7	15.7	15.6	15.0	15.2	15.3	13.9	13.8	13.9
CIT	4.6	5.0	7.2	7.7	8.6	6.7	4.9	5.0	4.5	3.3	3.3	3.9	4.0
Environmental	8.7	8.7	8.3	7.9	8.0	8.1	9.6	9.7	9.4	10.3	10.7	10.6	10.6
Other	71.8	71.3	70.3	69.4	68.8	69.5	69.8	70.3	70.9	71.1	72.1	71.7	71.4

Source: authors' own work based on European Commission (2017).

Table 2. Changes in income and environmental taxation structure in selected EU member states

Taxes	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bulgaria													
PIT&CIT [%]	66.7	64.0	60.3	61.6	69.1	63.7	64.5	63.3	62.4	63.0	63.9	65.7	64.2
Environ. [%]	33.3	36.0	39.7	38.4	30.9	36.3	35.5	36.7	37.6	37.0	36.1	34.3	35.8
$\varepsilon_{t,t-1}$	-	0.027	0.037	0.013	0.075	0.054	0.008	0.012	0.008	0.005	0.009	0.018	0.015
η_m	-	1.000	1.000	0.656	0.155	0.148	0.104	0.151	0.182	0.155	0.113	0.037	0.088
Croatia													
PIT&CIT [%]	57.4	58.1	59.9	63.0	65.3	66.2	65.6	59.6	63.6	64.1	62.8	59.5	57.2
Environ. [%]	42.6	41.9	40.1	37.0	34.7	33.8	34.4	40.4	36.4	35.9	37.2	40.5	42.8
$\varepsilon_{t,t-1}$	-	0.006	0.019	0.031	0.023	0.009	0.006	0.059	0.040	0.005	0.013	0.033	0.023
η_m	-	1.000	1.000	1.000	1.000	1.000	0.865	0.144	0.320	0.336	0.255	0.086	0.007
Cyprus													
PIT&CIT [%]	68.8	63.3	68.8	73.9	78.5	77.9	76.7	76.5	77.9	78.2	77.2	74.6	74.4
Environ. [%]	31.2	36.7	31.2	26.1	21.5	22.1	23.3	23.5	22.1	21.8	22.8	25.4	25.6
$\varepsilon_{t,t-1}$	-	0.055	0.055	0.051	0.045	0.006	0.012	0.002	0.014	0.004	0.010	0.026	0.002
η_m	-	1.000	0.000	0.317	0.466	0.428	0.351	0.338	0.375	0.384	0.330	0.208	0.199
Denmark													
PIT&CIT [%]	85.0	84.8	85.6	85.6	85.2	86.4	87.1	87.1	87.1	87.5	87.4	88.8	87.9
Environ. [%]	15.0	15.2	14.4	14.4	14.8	13.6	12.9	12.9	12.9	12.5	12.6	11.2	12.1
$\varepsilon_{t,t-1}$	-	0.002	0.008	0.000	0.004	0.012	0.007	0.000	0.000	0.004	0.001	0.014	0.009
η_m	-	1.000	0.603	0.608	0.167	0.572	0.659	0.662	0.642	0.685	0.651	0.745	0.487

Taxes	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Estonia													
PIT&CIT [%]	81.0	79.1	75.4	76.2	77.1	77.0	71.5	69.2	69.7	70.8	73.7	73.5	74.2
Environ. [%]	19.0	20.9	24.6	23.8	22.9	23.0	28.5	30.8	30.3	29.2	26.3	26.5	25.8
$\varepsilon_{t,t-1}$	-	0.019	0.037	0.008	0.009	0.001	0.054	0.023	0.005	0.010	0.029	0.002	0.007
η_m	-	1.000	1.000	0.746	0.530	0.538	0.732	0.773	0.713	0.609	0.371	0.376	0.328
Greece													
PIT&CIT [%]	76.2	76.4	78.5	77.8	77.1	77.8	78.2	71.9	71.1	71.5	66.6	67.9	67.0
Environ. [%]	23.8	23.6	21.5	22.2	22.9	22.2	21.8	28.1	28.9	28.5	33.4	32.1	33.0
$\varepsilon_{t,t-1}$	-	0.002	0.021	0.008	0.007	0.007	0.004	0.063	0.008	0.004	0.049	0.014	0.010
η_m	-	1.000	1.000	0.509	0.235	0.352	0.404	0.387	0.428	0.381	0.557	0.442	0.469
Italy													
PIT&CIT [%]	80.5	81.3	81.0	82.3	83.8	84.7	83.0	83.0	81.4	80.3	80.8	79.8	80.8
Environ. [%]	19.5	18.7	19.0	17.7	16.2	15.3	17.0	17.0	18.6	19.7	19.2	20.2	19.2
$\varepsilon_{t,t-1}$	-	0.008	0.003	0.013	0.015	0.010	0.017	0.000	0.016	0.011	0.005	0.010	0.010
η_m	-	1.000	0.491	0.770	0.859	0.888	0.383	0.380	0.105	0.025	0.023	0.071	0.022
Netherlands													
PIT&CIT [%]	72.9	71.6	73.0	73.2	74.9	74.0	73.9	74.0	73.5	73.5	73.2	74.0	75.5
Environ. [%]	27.1	28.4	27.0	26.8	25.1	26.0	26.1	26.0	26.5	26.5	26.8	26.0	24.5
$\varepsilon_{t,t-1}$	-	0.013	0.014	0.002	0.017	0.009	0.001	0.001	0.004	0.001	0.003	0.008	0.014
η_m	-	1.000	0.041	0.097	0.437	0.196	0.169	0.182	0.097	0.087	0.042	0.152	0.291
Poland													
PIT&CIT [%]	70.1	68.5	70.5	72.5	74.3	75.1	72.9	69.8	70.6	71.5	72.0	71.0	70.9
Environ. [%]	29.9	31.5	29.5	27.5	25.7	24.9	27.1	30.2	29.4	28.5	28.0	29.0	29.1
$\varepsilon_{t,t-1}$	-	0.017	0.021	0.019	0.018	0.008	0.022	0.032	0.008	0.009	0.005	0.011	0.001
η_m	-	1.000	0.106	0.408	0.550	0.595	0.265	0.029	0.031	0.091	0.119	0.049	0.046
Slovenia													
PIT&CIT [%]	69.3	69.8	72.1	74.3	74.5	73.5	68.3	67.2	67.6	64.3	61.5	62.5	62.8
Environ. [%]	30.7	30.2	27.9	25.7	25.5	26.5	31.7	32.8	32.4	35.7	38.5	37.5	37.2
$\varepsilon_{t,t-1}$	-	0.005	0.023	0.022	0.002	0.010	0.053	0.011	0.004	0.033	0.028	0.010	0.003
η_m	-	1.000	1.000	1.000	1.000	0.687	0.092	0.172	0.133	0.309	0.411	0.338	0.321

Source: authors' own work based on European Commission (2017).

According to the value of η_m measure, the changes of income and environmental taxation structure in favour of environmental taxes show a weak (in case of Greece) or a very weak (in case of Estonia and Slovenia) tendency to keep a steady direction. On the contrary, the evolution of the observed structure in Denmark evinces a weak trend to decrease in the share of environ-

mental taxes. In other six analysed member states incidental fluctuations of tax shares in the long period do not lead to consequent changes against the structure of the first period.

Conclusions

In recent years, countries have implemented some forms of ETR unilaterally according to their own needs, capabilities and political benefits of governments. Only in some cases it existed coordinated action in the European Union, positive inspiration or reaction on negative behaviour of other states.

The environmental tax reform can be defined as the action of state authorities to enhance the role of environmental taxes in the tax system of the country. It consists in increasing environmental taxes and reducing concurrently other taxes. In this study the significance of changes in taxation structure in selected EU member states has been analysed by means of structural change degree measure. The direction of these changes has been examined using structural changes monotonicity measure. A weak trend to shift slightly from income taxes to the environmental ones has been observed only in three out of ten analysed member states. It can therefore be concluded that ETR has not been implemented so far in sufficiently satisfactory terms to fully assess its effects. In general, reductions in rates for payroll taxes and the introduction of new tax credits or extension of the existing ones have only been partially offset by a transfer to other forms of taxation. The average level of environmental taxation in the EU remains at a similar level in relation to GDP or to total taxes as compared to 2003.

It should be emphasized that this study focuses on examining the relationship between specific types of taxes. Due to the limited scope of the study, the broadly understood fiscal instruments related to environmental protection have not been included, i.e. subsidies and tax expenditures such as tax credits and allowances in income taxes. It focuses closely on specific types of taxes.

The implementation of ETR requires the emphasis on both fiscal and environmental purposes to focus public discussions on key themes, such as the advantages and disadvantages of environmental taxation, as compared to other types of taxation and the relationship between general taxation and expense demands. ETR and, more broadly, the EFR must be implemented prudently, without succumbing to pressure from the business or industrial lobby and not in order to derive political benefits. Otherwise, the effects of the reform will be destroyed by arbitrary rebates and tax exemptions, as well as subsidies granted to energy-pressure industries at the expense of low-income households.

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The contribution of the authors

Justyna Dyduch – 50% (conception, literature review, acquisition of data, analysis and interpretation of data).

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Literature

Bosquet, B. (2000), *Environmental tax reform: Does it work? A survey of the empirical evidence,* "Ecological Economics" No. 34(1), p. 19-32

ten Brink P., Mazza L. (2013), *Reforming Environmental Taxes and Harmful Subsidies: challenges and opportunities*, Institute for European Environmental Policy, Brussels

Clinch J.P., Dunne L., Dresner S. (2006), *Environmental and wider implications of political impediments to environmental tax reform*, "Energy Policy" No. 34, p. 960-970

Cottrell J. et al. (2016), *Environmental Tax Reform in Developing, Emerging and Transition Economies*, Deutsches Institut für Entwicklungspolitik, Bonn

Deroubaix J-F., Lévèque F. (2006),*The rise and fall of French Ecological Tax Reform: social acceptability versus political feasibility in the energy tax implementation process*, "Energy Policy" No. 34, p. 940-949

Dresner S. et al. (2006), *Social and political responses to ecological tax reform in Europe: an introduction to the special issue*, "Energy Policy" No. 34, p. 895-904

Folmer H., Gabel L., Opschoor H. (eds) (1996), *Ekonomia środowiska i zasobów naturalnych*, Warszawa

European Commission (2017), *Taxation Trends in the European Union,* Data for the EU Member States, Iceland and Norway, Luxembourg, Publications Office of the European Union

European Commission (2018), *Taxation Trends in the European Union,* Data for the EU Member States, Iceland and Norway, Luxembourg, Publications Office of the European Union

Garnier G. et al. (2014), *A Wind of Change? Reforms of Tax Systems since the launch of Europe 2020*, Taxation Paper, Working Paper No. 49, Office for Official Publications of the European Communities, Luxembourg

Kosonen K., Nicodème G. (2009), *The role of fiscal instruments in environmental policy, European Commission*, Working Paper No. 19/2009, Taxation Papers, Luxembourg: Office for Official Publications of the European Communities

Kukuła K. (1986), *Dynamika oraz kierunki zmian struktury usług produkcyjnych w rolnictwie*, „Ruch Prawniczy, Ekonomiczny i Socjologiczny" Vol. 3

Patuelli R., Pels E., Nijkamp P. (2002), *Environmental tax reform and the double dividend*, Tinbergen Institute Discussion Paper

Withana S. et al. (2014), *Environmental Tax Reform in Europe: Opportunities for the future,* Final report, Institute for European Environmental Policy, Brussels

STUDIES AND MATERIALS

STUDIA I MATERIAŁY

Magdalena **ZABOCHNICKA-ŚWIĄTEK** • Roksana **KOCELA**

ORGANIC AND MINERAL SOIL IMPROVERS INTENDED FOR THE CULTIVATION OF BUTTERHEAD LETTUCE

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ABSTRACT: The aim of the research was to select soil improver which will enhance the soil fertility and to assess the effect on the growth and yielding of lettuce. Algal biomass from the species *Scenedesmus acutus, Chlorella vulgaris* and soil supplement – zeolite was used in the laboratory experiment. Four fertilizing combinations were used for each plant three times. Doses of fertilizers were established according to the content of nitrogen. Physicochemical analysis of the soil, tested substrates and plant growth parameters were examined. Algal biomass had the greatest impact on the improvement of soil fertility and plant productivity. Fertilization with *Scenedesmus acutus* caused the increase of almost all soil parameters, e.g. an increase in total organic carbon by 3694 mg kg-1, Kjeldahl's nitrogen by 1287 mg kg-1. It was found that algal can be used in organic farming, in which the use of soluble mineral fertilizers is impermissible.

KEY WORDS: algal biomass, fertilization, productivity, zeolite, sustainable agriculture

Introduction

By the year 2050 the world population will reach 9.6 billion and generations are expected to be much wealthier and urbanized than nowadays (PRB, 2017). These changes result in rapid increase in food and feed demand and as a consequence may lead to environmental risks such as soil depletion. Approximately 52% of the land used for agricultural purposes worldwide is moderately or severely affected by soil degradation (FAO, 2015). Economic data indicates that since 2008 land degradation affects as much as 1.5 billion people on the world.

The value of the agricultural market is strongly dependent on the quality of soil which is assessed in Poland as one of the lowest in EU countries. Organic matter content in Polish soils oscillated between 0.5-10% (RDP, 2017). Soil acidity is another problem to face it because approximately 50% of soils are highly acidic (Stańczyk-Mazanek et al., 2012). Over 50% of arable land belongs to unfavorable farming conditions (OPR, 2017). Diminishment of soil fertility is caused by overusing of chemical fertilizers and its improper use. In Poland the consumption of mineral fertilizers is constantly increasing as in 2015/2016 amounted to 1895.4 thousand tons and it is projected to achieve in year 2025 approximately 2300 thousand tons (Sroka, Musial, 2015). Additionally, there is maintained unfavorable ratio of nitrogen, phosphorus and potassium in mineral fertilizers (NPK–1.00:0.30:0.48) with too high share of nitrogen content. Therefore, surplus nitrogen leakage from agriculture is the main reason of surface and groundwater pollution (CSO, 2017).

Considering the above facts it should be stated that sustainable agricultural approach is highly desirable to eliminate the adverse effect of chemical fertilizers for human health and the environment while ensuring increase the yield and quality of crops. Global programs such as those involved in Sustainable Development Goals and the Post-2015 Agenda confirm that sustainable management of natural resources provide opportunities to combat with land degradation (US, 2015). Also, the 7th Environment Action Programme adopted by the European Parliament, assumes that by 2020 soil will be managed in a sustainable way and soil remediation will be carried out at an advanced stage (GIOS, 2014).

Sustainable manner of agricultural practices consists in transition from conventional to organic farming which reduces negative impacts on the environment and as a key point prevents loss of organic matter content. There is increased financial support within Rural Development Program 2014-2020 which allocates near EUR 700 million for ecological farming. Sobczyk (2014)

confirm that number of organic farms keeps constantly increasing, therefore sustainable development of rural areas in Poland may attain high level in future years. The sustainable fertility management may be achieved not only by popular organic fertilizers but by means of algal biomass which has great potential to provide nutritional requirements in ways similar or better than traditional green manures such as lupine, phacelia, wheat or barley (Waldenstedt, 2003). It is well documented by scientific research that algal biomass may be applied as biostimulant, biofertilizer, seed primer and stimulate growth and yield of different plants (Boghdady et al., 2016; Badry, Salim, 2016; Garcia-Gonzalez, Sommerfeld, 2016), improve nutrients availability and nutrients uptake from the soil (Turan, Köse, 2004), enhance tolerance to environmental stresses (Lichner et al., 2013; Abdel Aziz et al., 2011). The wide range of benefits of algal biomass used as organic fertilizer has been evidenced by high content of micronutrients (e.g. Fe, Cu, Zn) and macronutrients (N, P, K, Ca, Mg), plant growth promoting substances, amino acids and vitamins (Blunden et al., 2010; Challen, Hemingway, 1965; Khan et al., 2009; Stirk et al., 2004; Zabochnicka-Świątek, 2017). Unlike chemical fertilizers, algal biomass and their extracts are natural, fully biodegradable, non-polluting the environment, possible to use in sustainable and organic farming. Moreover, removal of heavy metals can also be achieved by algal biomass (Zabochnicka-Świątek, 2013).

The objectives of the present study were to take into investigation the following: (i) the influence of adding algal biomass in dry (dry biomass) and liquid (living biomass) phase on growth and yielding of butterhead lettuce, (ii) assessment of physicochemical characteristics of fertilized soil.

Research methods

Study site and soil characterization

The study area is located within the city of Czestochowa in the province of Silesia in Poland on Polish Jurassic Highland. The Czestochowa region is characterized by average vegetation period – 212 days, 60-80 days of snow cover in the wintertime and annual precipitation around 650-700 mm. Soils typical to this area are podzolic soils, brown soils, moor soils and carbonate soils. Most agricultural soils are characterized by periodic or permanent water scarcity (66.4%). The quality of soils within this region is relatively low. Most of arable land belongs to IV and V valuation class (EKO-LOG, 2017). Predominant soils are light or very light that occupy about 64% of arable land. Approximately 63% of soils are acidic or highly acidic. Statistical data of

the Czestochowa region indicates on very low usefulness of agricultural production.

The soil used for the experiment is classified as podzolic soil and is assessed as low-productive and inhomogeneous. Alkaline character of the soil is probably caused by the human activity in this regions e.g. liming. According to grain size analysis dominant fraction occurring in the tested soil is sand. Sources as FAO/WRB (2006) and USDA (2006) allow classifying soil as sand; in turn other sources PTG (2008) and PSSS (2008) classify the soil as loose sand. Based on granulometric analysis the agronomic class was established as very light soil. Due to The Act from 12th September 2012 on soil classification the soil is classified as VI valuation class.

Materials and experimental procedure

The pot experiment was conducted in April 2017 under laboratory conditions at Institute of Environmental Engineering, Technical University of Czestochowa. The experimental soil samples were taken from the area of Steelworks and prepared for physicochemical analysis The experiment were performed under sandy soil conditions to study the effect of organic and inorganic improvers on growth of lettuce and mineral changes of soil. Butterhead lettuce, variety 'Attractie' was used as the object of the research due to short growing period of this plant ant its high popularity as green vegetable in Poland. The strains of unicellular green microalgae *Chlorella vulgaris* were obtained from the Culture Collection of Baltic Algae (CCBA) in Poland and had been cultivated in laboratory till the exponential phase and then harvested. Dry biomass of *Scenedesmus acutus* were obtained from University of Kentucky, USA.

Prior the main experiment, physical and chemical properties of soil and materials were subjected to analysis. Parameters of soil and materials were determined by following methods: pH was determined by means of norm PN-ISO 10390:1997 using ph-meter CyberScan 11, the analysis of dry matter content in compliance with PN-ISO 11465:1999. Total carbon (TC) was determined by using Multi N/C 2100 Analytik Jena, the results of Total Organic Carbon (TOC) was achieved on Spectrophotometer HACH DR/4000 V with wavelength of 600 nm. Kjeldahl's nitrogen was determined based on PN-ISO 11261:2002, using Büchi apparatus for mineralization K-435 and Büchi Labortechnik A6, Model K-355 for distillation with water vapour. Macro and microelements: P – phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Fe – iron, Zn – Zinc, Cu – copper were determined in accordance to PN-ISO 11047:2001 by using plasma spectrometer, Spectro Arcos ICP-OES. For the soil, determination of available forms of phosphorus and potassium was applied, in compliance with Egner-Riehm method. The avail-

able content of magnesium was also determined, using Schachtschabel method. Soil improvers used in the experiments are varied in terms of physicochemical properties and nutrients (table 1). Due to different state of materials of dry and liquid algal biomass, parameter of TOC was determined for *Scenedesmus acutus,* while DOC was tested for *Chlorella vulgaris*. The values of pH measured in H_2O of all soil improvers are placed within the range of slightly acidic and neutral values (pH from 6.0 to 7.0). Among organic based soil improvers the Scenedesmus acutus has relatively high organic matter content 254 390 mg kg^{-1}. Dry biomass – Scenedesmus acutus is characterized by relatively high Kjeldahl's nitrogen content – 70 387 mg kg^{-1}. *Chlorella vulgaris* contained significantly increased nitrogen content in the amount of 222 564 mg kg^{-1}. Zeolite as representative of mineral additive is especially rich in potassium and calcium content – 15 444 and 14 064 mg kg^{-1}.

Table 1. Physicochemical properties of soil improvers

Parameter	Unit	Results		
		Scenedesmus acutus	*Chlorella vulgaris*	*Zeolite*
pH H_2O	–	6.0	7.0	6.7
Kjeldahl's nitrogen	mg kg^{-1}	70387	222564	106
TOC	mg kg^{-1}	254390	nd*	nd*
DOC	mg kg^{-1}	nd*	179074	nd*
P	mg kg^{-1}	30529	7901	49
K	mg kg^{-1}	3116	16926	15444
Mg	mg kg^{-1}	4644	10103	3558
Ca	mg kg^{-1}	44484	19553	14064

* not detected

Source: author's own work.

The experiment was arranged in block consist of 4 combinations of fertilization with three replicates. There were planted 12 plants in 0.5 L plastic pots filled with previously mixed soil with appropriate fertilizer dose. The pots contained holes at the bottom to provide drainage and were lined with agrofabric avoiding the undesirable soil run-off. The doses of soil improvers were determined on nitrogen content which on mineral soils should be at the

level of 3500 mg kg^{-1}. As the result of different physicochemical composition of each improver, the doses are varied.

Treatments were as follows:

- dry algal biomass *Scenedesmus acutus* in the dose of 35.5 g kg^{-1},
- living algal biomass *Chlorella vulgaris* in the dose of 11.6 g kg^{-1},
- zeolite in the dose of 35.5 g kg^{-1},
- control – tap water without fertilization.

The soil improvers were applied in time of plants transplantation. The whole fertilization procedure was conducted in accordance with good agricultural practice in order to avoid over-fertilization and its side effects.

Plants were cultivated thought the entire experiment in greenhouse conditions by means of phytotron chamber. They have grown in the period of one month with conditions such as 12 h daytime with temperature around 18°C and nighttime 12°C. The irrigation of plants was done regularly by hand. The plants were harvested at the end of experiment and growth parameters were measured. Also, physicochemical analysis of the soil subjected to fertilization was performed.

Results of the research

Determined pH analysis indicated that soil is alkaline. The Kjeldahl's nitrogen in the examined soil amounted to 806 mg kg^{-1} which ranks the soil below the average value of nitrogen for Polish mineral soils – 1200 mg kg^{-1}. Similarly, total organic carbon in the soil is as low as – 7493 mg kg^{-1} in comparison to the average value occurring in the soils – 11 200 mg kg^{-1}. Carbon to nitrogen ratio of tested soil (C/N = 9.64) is similar to the other soils of Poland. The nutrients levels of phosphorus, potassium, calcium and magnesium in the soil are lower than the average level of nutrients of Polish soils. The values of available phosphorus and potassium ranks the soil in the average fertility class for which range of limit numbers are 10.1-15.0 mg P_2O_5 100 g^{-1} and 7.6-12.5 mg K_2O 100 g^{-1}, respectively. The available magnesium content of the soil with the amount of 5.88 mg Mg 100 g^{-1} is reported as high due to limit numbers for high fertility class which are: 4.1-6.0 mg Mg 100 g^{-1}. Humic acids content extracted from the tested soil on the level of 4.75 g kg^{-1} is indicated as low. Most of above mentioned results point out that examined soil is characterized by low quality and low agriculture suitability. Therefore, fertilization is required to recover soil productivity and provide nutrients necessary for plants growth. The effects of fertilization on the soil are varied, depending on applied soil improvers (table 2).

Table 2. Effect of organic and mineral additives on the soil (Mean ± SD)

Parameter	Unit	Control	*Scenedesmus acutus*	*Chlorella vulgaris*	Zeolite
pHKCl	mg kg^{-1}	7.6±0.02	7.7±0.01	7.6±0.01	7.4±0.02
pHH_2O	mg kg^{-1}	7.8±0.02	7.9±0.02	7.7±0.01	7.6±0.01
Kjeldahl's nitrogen	mg kg^{-1}	939±61	2226±135	996±35	828±47
TC	mg kg^{-1}	17806±859	25984±1244	19010±788	nd*
TOC	mg kg^{-1}	8527±836	12221±317	12411 ±451	9393±1384
C/N ratio	–	9.08	5.49	13.12	11.34
P	mg kg^{-1}	140±1.1	561±70	176±5.6	143±13
K	mg kg^{-1}	574±17	611±79	716±10	1651±160
Mg	mg kg^{-1}	895±8	973±64	1079±32	1242± 99
Ca	mg kg^{-1}	4278 ±38	4675±231	4967 ±144	5389±25
Cu	mg kg^{-1}	20.5±0.4	17.4±0.2	24.4±1.0	20.8±1.4
Zn	mg kg^{-1}	403 ±5	305±48	494 ±15	409±36
Fe	mg kg^{-1}	13841±111	11359±624	15690±1034	13432±680
Available P	mg P_2O_5 100 g^{-1}	12.0 ±1	160.3±5	15.1 ±1	12.3±0.5
Available K	mg K_2O 100 g^{-1}	9.0±0.8	16.8 ±1	8.3 ±0.3	21.5±0.8
Available Mg	mg Mg 100 g^{-1}	6.4 ±0.3	12.6±0.9	6.1±0.1	6.7±0.5

* not detected

Source: author's own work.

The use of zeolite caused decrease of pH from 7.60 to 7.40, while algal based soil improvers maintained pH on similar range. However, the soil after treatment with different soil improvers maintained alkaline character. There was observed increase of Kjeldahl's nitrogen content among soil improvers excluding zeolite. The greatest increase was noticed after addition of dry algal biomass *Scenedesmus acutus* – 2.4 fold increase compared to control. The analysis of the soil pointed out that algal based soil improvers are rich in organic carbon content to similar degree. Among them, *Chlorella vulgaris* caused the greatest increase of organic carbon content, namely 1.4 increase compared to control soil. Carbon to nitrogen ratio decreased in case of using *Scenedesmus acutus* while addition of *Chlorella vulgaris*, and zeolite caused increase of C/N ratio at similar degree. As a result of fertilization, the content of macronutrients: phosphorus potassium, calcium and magnesium were changed in comparison to control soils. After application of *Scenedesmus acutus* the total phosphorus content increased up to 561 mg/kg which constitute 4 fold increase compared to control soil. The zeolite is considered to be the

best additive in terms of enrichment the soil in potassium content – 1651 mg kg^{-1}, while control soil include only 574 mg kg^{-1}. The greatest increase of magnesium and calcium content was recorded after zeolite treatment. Relatively high content of magnesium was observed in the soil when *Chlorella vulgaris* was added – 1079 mg kg^{-1}. Given data of microelements showed that *Chlorella vulgaris* applied to the soil caused the considerable increase of copper, zinc and iron content compared to control and other soil improvers. For each type of applied treatment the content of available phosphorus increased. The range of limit numbers for available phosphorus content for average, high and very high fertility class are respectively: 0.1-15; 15.1-20.0 and from 20.1 mg P_2O_5 100 g^{-1}. The significant increase was observed in the soil treated with *Scenedesmus acutus* for which the value amounted to 160.3 mg P_2O_5 100 g^{-1} and soil fertility class changed from average to very high. In case of fertilization with *Chlorella vulgaris* the soil fertility class changed from average to high. The zeolite fertilization resulted in the highest increase of available potassium content (21.5 mg K_2O 100 g^{-1}) which caused change fertility class from average to very high. Limit numbers for average, high and very high fertility class for available potassium content are following: 7.6-12.5 mg K_2O 100 g^{-1}; 12.6-17.5 mg K_2O 100 g^{-1} and greater than 17.6 mg K_2O 100 g^{-1}, respectively. The application of *Scenedesmus acutus* caused change of the soil fertility class from average to high, while the use of *Chlorella vulgaris* caused slight decrease of available potassium, maintaining the fertility class at average level. The highest increase of available magnesium was found in case of application of *Scenedesmus acutus* for which the value was 12.6 mg Mg 100 g^{-1}, respectively. The soil is regarded as highly rich in available magnesium content when the values are greater than 6.1 mg Mg 100 g^{-1}.

The soil improvers differently influenced on growth parameters of lettuce (table 3). The pot experiment showed that generally all treatments influenced positively on growth of lettuce. Among all of soil improvers the greatest amount of leaves was recorded for *Chlorella vulgaris* treatment – 1.4 fold increase compared to control. Leaves length after treatment with zeolite and *Chlorella vulgaris* was the same (8.93 cm). It was observed that roots length in fertilized plants were better developed and branched compared to control. The longest roots and the best developed was characterized for plants fertilized with *Chlorella vulgaris*. The effects of applied *Scenedesmus acutus* are not presented in the table because plants did not survive the experiment. The probable factors could be physiological stress of plants in reaction for transplantation and overwatering which caused damage to plants, however over-fertilization is excluded.

Table 3. Effect of natural and organic soil improvers on growth parameters of lettuce (Mean ± SD)

Treatments	Number of leaves [-]	Leaves length [cm]	Leaves width [cm]	Roots length [cm]
Control	5.00±0	7.40±0.4	2.30±0.1	8.97±0.7
Chlorella vulgaris	7.00±0	8.93±0.1	2.80±0.2	9.27±0.6
Zeolite	6.33±0.9	8.93±0.2	2.23±0.1	7.67±1.3

Source: author's own work.

Discussion of the results

The experiment revealed that natural and organic amendments efficiently improved properties of low-productive and sandy soil. The literature sources confirm that optimum range of pH suitable for proper plants growth and development is: 5.5-7.2 (Dyśko et al., 2014) hence the studied soil is beyond this range. Soil improvers applied to the soil did not exhibit considerable changes of pH compared to control. Addition of zeolite caused decreased of pH while in other literature sources was found that zeolite usually is responsible for increase of pH levels (Ming, Boettinger, 2001). Algal based materials used for fertilization due to organic matter content and buffering properties allow for counteracting pH changes (Tiessen et al., 1994). The study results found out that algal biomass constitute big reservoir of nitrogen content–as much as 2.4 fold increase of Kjeldahl's nitrogen in the soil treated with *Scenedesmus acutus* compared to control soil. Addition of zeolite is favourable due to falling trend of nitrogen loss which was reported by Wang et al. (2017).

Algal based soil improvers incorporated similar and also significant amounts of total organic carbon to the soil. Addition of organic matter content is strongly associated with cation exchange capacity which was observed within study of Habashy and Abdel-Razek (2011) where cation exchange capacity increased the most in the soil treated with seaweed extract and zeolite. C/N ratio was subjected to changes in all of treatments. The narrowing of C/N was recorded when *Scenedemsus sp.* was applied. The increase of C/N occurred after treatment with *Chlorella vulgaris* and zeolite. The all soil improvers enhanced mineralization processes in the soil because it is reported that C/N ratio smaller than 15.0 favours mineralization while C/N>20.0 s cause immobilization processes (Fertilizers Europe, 2016). The applied natural and organic amendments resulted in increase of macro- and micronutrients to varying degrees. The highest increase of total P content

was recorded for soil treated with microalgae *Scenedesmus acutus* which is 4 times more than result obtained for control. Similarly the available Mg and P content was the highest for *Scenedesmus acutus* which caused change of soil fertility class from average to very high. It was observed that high P content influenced on decrease of content of micronutrients – Cu and Zn compared to control soil. Such obtained data are in agreement with literature which reported that surplus of PO^{4-} ions cause immobilization of Zn and Cu and additionally may be the reason of formation sparingly soluble calcium-phosphate salt when pH>7 (Fang et al., 2012; Wandruszka, 2006).

Compared to other soil improvers, the application of zeolite resulted in the considerable increase of total K, Mg and Ca content. Also, the value of available potassium content for zeolite was the highest (21.52 mg K_2O 100 g^{-1}) which placed the soil in the very high fertility class. The calcium content was at similar level at fertilized soils. Taking into account the results of micronutrients: Zn, Cu and Fe, it can be concluded that the use of C*hlorella vulgaris* had the greatest impact on the increase of given nutrients in the soil followed by zeolite and *Scenedesmus acutus.* The stimulatory effects of dry and living algal biomass was tested in the experiment conducted *on Lectuca sativa* by Faheed and Abd-El Fattah (2008) and revealed that application of 2 and 3 g kg^{-1} of dry microalgae – *Chlorella vulgaris* significantly increased growth parameters of lettuce and content of chlorophyll. The other experiments used urea, poultry compost, dry and living blue green algae – *Anabaena sp.* as organic fertilizers and then recorded the highest increase of P, Zn and Fe content and all lettuce growth parameters for dry biomass of algae (Abuye, Achamo, 2016). The above results are in line with this experiment where dry algal biomass – *Scenedemsus acutus* achieved the highest nutritional values. The vast majority of literature sources focused of using algal extracts or algal compost as organic fertilizers and achieved favorable results concerning high plants growth and considerable improvement of physicochemical properties of soil (Michalak et al., 2016; Garcia-Gonzalez, Sommerfeld, 2016). The inorganic but of natural origin soil amendment – zeolite is proved to be good quality mineral fertilizer. For instance, the application of zeolite in the research of Eprikashvili et al. (2016) and Wang et al. (2017) resulted in increase of germination index and the nutrients content.

So far, the combination of mixed organic and chemical fertilizers were examined in different literature sources and resulted in the high yield of agricultural crops (Islam et al., 2017; Priyadarshani, 2013). Based on those results, the range of this experiment may be broaden by combining zeolite with algal based materials to sustain soil fertility and obtain high yields in a sustainable way without using chemical fertilizers. What is more, study of Habashy and Abdel-Razek (2011) revealed that application of algal extract is beneficial

from the economic point of view because of the highest net income 4554 LE fed-1 compared to other fertilizers.

It is recommended to conduct further experiment under field and laboratory conditions to fully exploit high potential of algal based additives as organic fertilizers. Encouraging farmers to transition from conventional to organic farming is a key point in diminishment of environmental pollution and reduction of chemical fertilizers and hence practices sustainable agricultural approach (Mieszajkina, 2016). Data collected by Bryła (2015) indicates that Poland has a high place – 4th in terms of organic food producer and 5th place regarding the area of organic crops in Europe. Implementation of new methods of organic fertilization is crucial due to intense and dynamic growth in the market value of organic food in developed countries.

Conclusions

According to the obtained results the following conclusions can be drawn:

1. Algal based soil improvers are valuable source of organic matter content and may replace chemical fertilizers.
2. Organic and mineral soil improvers of natural origin significantly increased growth parameters of examined plants.
3. The application of *Scenedesmus acutus* considerably improved physicochemical parameters of soil, increasing its fertility.
4. In soil, increase of total organic carbon by 3694 mg kg^{-1}, Kjeldahl's nitrogen by 1287 mg kg^{-1}, total phosphorous by 421 mg kg^{-1}, available phosphorus by 148.3 mg P_2O_5 100 g^{-1} was found after application of *Scenedesmus acutus.*
5. Application of *Chlorella vulgaris* resulted in the greatest increase in the soil parameters: total organic carbon up to 12 411 mg kg^{-1}, Kjeldahl's nitrogen up to 996 mg kg^{-1} and C/N ratio up to 13.12.
6. Zeolite as mineral additive caused great contribution of macro nutrients in the soil: potassium – 1651 mg kg^{-1}, magnesium 1242 mg kg^{-1}, calcium – 5389 mg kg^{-1} and available potassium content – 21.5 mg kg^{-1}. Simultaneously, after the application of zeolite, no improvement in lettuce growth was observed.
7. The most beneficial effect on lettuce was observed after fertilization with *Chlorella vulgaris* due to the observed increase number of leaves up to 7, leaves length up to 8.93 cm, leaves width up to 2.80 cm and increase of roots length up to 9.27 cm.

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The contribution of the authors

Magdalena Zabochnicka-Świątek – 70% (concept and objectives, correction).
Roksana Kocela – 30% (literature review, research).

Literature

Abdel Aziz N.G., Mahgoub M.H, Siam H.S. (2011), *Growth, flowering and chemical constituents performance of amaranthus tricolor plants as influenced by seaweed (ascophyllum nodosum) extract application under salt stress conditions*, "Journal of applied sciences research" Vol. 7 No. 11, p. 1472-1484

Abuye F., Achamo B. (2016), *Potential use of cyanobacterial bio-fertilizer on growth of tomato yield components and nutritional quality on grown soils contrasting pH*, "Journal of Biology" Vol. 6 No. 17, p. 54-62

Badry B., Salim M. (2016), *Influence of biochar and seaweed extract applications on growth, yield and mineral composition of wheat (Triticum aestivum L.) under sandy soil conditions*, "Annals of Agricultural Sciences" Vol. 61 No. 2, p. 257-265

Blunden G. et al. (2010), *Betaine yields from marine algal species utilized in the preparation of seaweed extracts used in agriculture*, "Natural Product Communications" Vol. 5 No. 4, p. 581-585

Boghdady M. et al. (2016), *Influence of foliar spray with seaweed extract on growth, yield and its quality, profile of protein pattern and anatomical structure of chickpea plant (Cicer arietinum L.)*, "Middle East Journal of Applied Sciences" Vol. 6 No. 1, p. 207-221

Bryła P. (2015), *The Development of Organic Food Market as an Element of Sustainable Development Concept Implementation*, "Problemy Ekorozwoju" Vol. 10 No. 1, p. 79-88

Challen S.B., Hemingway J.C. (1965), *Growth of higher plants in response to feeding with seaweed extracts*, "Proceedings of the Fifth International Seaweed Symposium" Vol. 5, p. 359-367

CSO (2017), *Means of production in agriculture in the 2015/2016 Farming Year*

Dyśko J. et al. (2014), *Zrównoważone nawożenie roślin ogrodniczych*, Skierniewice

EKO-LOG (2017), *Aktualizacja programu ochrony środowiska dla miasta Częstochowy z uwzględnieniem lat 2010 – 2014 z perspektywą do roku 2017*, Poznań, http://www.czestochowa.pl/data/other/aktualizacja_programu_ochrony_srodowiska.pdf [02-01-2018]

Eprikashvili L. et al. (2016), *Intensification of bioproductivity of agricultural cultures by adding natural zeolites and brown coals into soil*, "Annals of Agrarian Science" Vol. 14 No. 2, p. 67-71

Faheed F.A., Abd-El Fattah Z. (2008), *Effect of Chlorella vulgaris as biofertilizer on growth parameters and metabolic aspects of lettuce plant*, "Journal of Agriculture and Social Sciences" Vol. 4, p. 165-169

Fang Y., Cao X., Zhao L. (2012), *Effects of phosphorus amendments and plant growth on the mobility of Pb, Cu, and Zn in a multi-metal-contaminated soil*, "Environmental Science and Pollution Research" Vol. 19 No. 5, p. 1659-1667

FAO (2015), *Food and Agriculture*, http://www.fao.org/land-water/land/land-assessment/en/ [01-01-2018]

FERTILIZERS EUROPE (2016), *Infinite nutrient stewardship*, http://www.fertilizer-seurope.com/index.php?id=114 [08-01-2018]

Garcia-Gonzalez J., Sommerfeld M. (2016), *Biofertilizer and biostimulant properties of micro alga Acutodesmus dimorphus*, "Journal of Applied Phycology" Vol. 28 No. 2, p. 1051-1061

GIOS (2014), *Stan środowiska w Polsce, Raport 2014*, Biblioteka Monitoringu Środowiska, Warszawa

Habashy N.R., Abdel-Razek M.K.M. (2011), *Effect of some natural and organic soil amendments on improving some clayey soil properties and its productivity*, "Journal of Applied Sciences Research" Vol. 7 No. 11, p. 1721-1731

Islam M.A. et al. (2017), *Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh*, "Agriculture" Vol. 7 No. 18, p. 1-7

Khan W. et al. (2009), *Seaweed extracts as biostimulants of plant growth and development*, "Plant Growth Regulation" Vol. 28 No. 4, p. 386-399

Lichner L. et al. (2013), *Algae influence the hydrophysical parameters of a sandy soil*, "Catena" Vol. 108, p. 58-68

Michalak I., Tuhy Ł., Chojnacka K. (2016), *Co-Composting of algae and effect of the compost on germination and growth of Lepidium sativum*, "Polish Journal of Environmental Studies" Vol. 25 No. 3, p. 1107-1115

Mieszajkina E. (2016), *Ecological Entrepreneurship and Sustainable Development*, "Problemy Ekorozwoju", Vol. 12 No. 1, p. 163-171

Ming D.W., Boettinger J.L. (2001), *Zeolites in Soil Environments*, "Reviews in Mineralogy and Geochemistry" Vol. 45 No. 1, p. 323-345

OPR in Poland (2017), *Multifunctional development*, http://opr.iung.pulawy.pl/index.html?st=char [20-05-2017]

PRB (2017), *World Population Data Sheet*, http://www.prb.org/pdf17/2017_World_Population.pdf [15-12-2017]

Priyadarshani N. et al. (2013), *Effect of organic and inorganic fertilizers on biomass production, oil yield and quality of vetiver (Vetiveria zizanioides L.)*, "The Journal of Agricultural Sciences" Vol. 8 No. 1, p. 28-35

Rozporządzenie Rady Ministrów z dnia 12 września 2012 r. w sprawie gleboznawczej klasyfikacji gruntów, http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20120001246/O/D20121246.pdf

RDP Program 2014-2020 (2017), Ministry of Agriculture and Rural Development

Sobczyk W. (2014), *Sustainable development of rural areas*, "Problemy Ekorozwoju" Vol. 9 No. 1, p. 119-126

Sroka W., Musiał W. (2015), *Multifarious forecasts concerning the use of mineral fertilizers in Poland in 2014-2025*, "Journal of Agribusiness and Rural Development" Vol. 2 No. 36, p. 291-302

Stańczyk-Mazanek E., Nalewajek T., Zabochnicka M. (2012), *Drug-resistant microorganisms in soils fertilized with sewage sludge*, "Archives of Environmental Protection" Vol. 38 No. 1, p. 97-102

Stirk W.A. et al. (2004), *Changes in cytokinin and auxin concentrations in seaweed concentrates when stored at an elevated temperature*, "Journal of Applied Phycology" Vol.16 No. 1, p. 31-39

Tiessen H., Cuevas E., Chacon P. (1994), *The role of soil organic matter in sustaining soil fertility*, "Nature", Vol. 371, p. 783-785

Turan M., Köse C. (2004), *Seaweed extracts improve copper uptake of grapevine*, "Acta Agriculturae Scandinavica", Section B – Soil & Plant Science, Vol. 54 No. 4, p. 213-220

US, A/RES/70/1 (2015), *Transforming our world: the 2030 Agenda for Sustainable Development*, http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E [20-12-2017]

Waldenstedt L. et al. (2003), *Effect of astaxanthin–rich algal meal (Haematococcus pluvalis) on growth performance, caecal campylobacter and clostridial counts and tissue astaxanthin concentration of broiler chickens*, "Animal Feed Science and Technology" Vol. 108, p. 119-132

Wandruszka R. (2006), *Phosphorus retention in calcareous soils and the effect of organic matter on its mobility*, "Geochemical Transactions" Vol. 7 No. 6, p. 1-8

Wang Q. et al, (2017), *Comparison of biochar, zeolite and their mixture amendment for aiding organic matter transformation and nitrogen conservation during pig manure composting*, "Bioresource Technology" Vol. 245, p. 300-308

Zabochnicka-Świątek M. (2013), *Utilization of Chlorella vulgaris and sediments after N-NH4 removal containing clinoptilolite for sorption of heavy metals from wastewater*, "Rocznik Ochrona Środowiska" Vol. 15 No. 1, p. 324-347

Zabochnicka-Świątek M. (2017), *Usuwanie azotu amonowego ze ścieków w procesie sorpcji i biosorpcji*, Częstochowa

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TRENDS IN DAILY CHANGES OF PRECIPITATION ON THE EXAMPLE OF WROCŁAW

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ABSTRACT: The study analyzed 8295 daily rainfalls recorded in Wrocław from 1960 to 2017. The frequency of daily precipitation in a year was determined in nine categories: from very weak (less than 1.0 mm) to disastrous (over 100 mm). In addition, the precipitation trends were determined by linear regression and the Mann-Kendall test. Analysis of the variability of the number of days with precipitation of particular categories showed a statistically significant downward trend for moderately strong precipitation (10.1-20.0 mm). In case of other categories of precipitation, the tests did not show statistically significant changes.

KEY WORDS: rainfalls, urban flooding, urban hydrology

Introduction

One of the most important infrastructures in the urbanized area is the rainwater drainage system, which drains excess rainfall from the catchment area to a natural watercourse like a river or a lake – away from urban areas. The construction of rainwater drainage systems is one of the most expensive investments in infrastructure. Such systems are usually designed to last at least 50 years or even 100 years.

Rainwater drainage should protect against the effects of extreme rainfall causing significant economic and social losses. However, it is not possible to achieve its fully reliability, neither now nor in the future, due to the stochastic nature of precipitation. Safe design of sewerage systems is aimed at ensuring an adequate standard of drainage of the area, which is defined as adapting the system to accept forecasted maximum rainwater streams with a frequency equal to the allowed (socially acceptable) frequency of their flooding on the area (Kotowski, 2015). The standard EN 752 (2017) limits the permissible frequency of sewer overflow to once every year for areas of very low importance (e.g. roads and open spaces located away from buildings), to, among others, once every 5 years for areas of medium importance (e.g. roads and open spaces located near buildings), up to once every 50 years for areas of very high importance (e.g. critical infrastructure). Examples of project criteria for outflows according to EN 752:2017 are presented in table 1.

Table 1. Examples of design sewer flooding criteria for standing floodwater

Impact	Example locations	Examples of design sewer flooding frequency, years
Very low	Roads or open spaces away from buildings	1
Low	Agricultural land	2
Low to medium	Open spaces used for public amenity	3
Medium	Roads or open spaces adjacent to buildings	5
Medium to high	Flooding in occupied buildings excluding basements	10
High	Deep flooding in occupied asements or road underpasses	30
Very high	Critical infrastructure	50

Source: EN 752, 2017.

The issue of drainage of rainwater from urbanized areas has gained special significance in recent years. On the one hand, the continuing sealing of the surface area results in increased rainwater runoff coefficients, which in turn leads to hydraulic overloading of rainwater drainage systems or com-

bined sewer systems (Kotowski, 2015). On the other hand, more and more attention is given to climate change, especially in the context of global warming and the increased occurence of extreme weather events (Schiermeier, 2011; Walsh et al., 2016; Dai, 2011; Kundzewicz et al., 2012), although there is no consensus as to their causes (Dąbrowski, Dąbrowska, 2012). The increase in the average annual temperature on the globe causes increased water circulation in the hydrological cycle and influences, among others, the frequency of extreme precipitation. Due to global warming and anthropogenic activities, extreme precipitation will become more common and will have a negative impact on the functioning of rainwater drainage systems (Kaźmierczak, Kotowski, 2014; Fleig et al., 2015). Potential problems with the functioning of sewage systems related to climate change include flooding of surfaces and basements, increased number and volume of stormwater, as well as increased volume of sewage flowing into the sewage treatment plants (Saboia et al., 2017; Ahmed et al., 2016; Kotowski, 2013).

Urban infrastructure planners and designers should use the forecasted changes in the occurrence of intense precipitation to adapt urban drainage systems as part of the reconstruction of aging infrastructure. To meet the combined challenges of climate change and urbanization, carefully selected adaptation measures that would require technical, economic and political commitment are needed (Semadeni-Davies et al., 2008; Yazdanfar, Sharma, 2015; Arnbjerg-Nielsen et al., 2013). The technical adaptive solutions include increasing diameters of sewers, constructing retention reservoirs and separating sewage into domestic wastewater and rainwater (Fratini et al., 2012; Kirshen et al., 2015). However, it should be noted that the current practice of drainage of land involving the discharge of rainwater away from urban areas is increasingly being put into question (Wong, Brown, 2009; Spatari et al., 2011). Green infrastructure is mentioned increasingly as one of the adaptation solutions aimed at utilizing rainwater at the place of intake (Fratini et al., 2012; Hostetler et al., 2011). The adaptation of urban infrastructure determined by the changing climate will become increasingly important to enable safe living in the cities in the future.

The aim of this work is to analyze the variability of daily precipitation recorded in Wrocław between 1960 and 2017. The frequency of daily precipitation in a year was classified from very weak (less than 1.0 mm) to disastrous (over 100 mm). In addition, the precipitation trends were determined using linear regression and the Mann–Kendall test for predicting their future frequency.

Materials and methods

Daily precipitation records from the Institute of Meteorology and Water Management (IMWM) meteorological station from the time span 1960-2017 were used as a research material. The meteorological station of IMWM in Wroclaw is a part of national measurement and observation network at hydrological and meteorological service. The station coordinates: 51–06 N, 16–54 E; terrain altitude: about 120 m above sea level. The classification of daily rainfall was made using the Olechnowicz-Bobrowska criterion (Olechnowicz-Bobrowska, 1970), extended by the criteria presented in the paper (Lorenc et al., 2012). As a result, daily precipitation was divided into 9 categories, depending on their sum (table 2).

Table 2. Criteria of daily rainfall

Rainfall criteria	Daily sum, mm
Very weak	0.1-1.0
Weak	1.1-5.0
Moderate	5.1-10.0
Moderately strong	10.1-20.0
Strong	20.1-30.0
Dangerous	30.1-50.0
Constituting flood hazard	50.1-70.0
Flood	70.1-100.0
Disastrous	≥ 100.1

Source: Lorenc et al., 2012.

The classic linear regression and the non-parametric Mann–Kendall test were used to detect trends in the changes in precipitation time series. This test answers the question as to whether the values measured in the time series $\{x_1, x_2, ..., x_n\}$ have a tendency to gradually increase or decrease (Schiermeier, 2011). The Mann–Kendall test analyzes the sign of the difference between successively measured measurement values. The newly measured value is compared to all previously measured values, which gives a total of n(n-1)/2 of possible data pairs, where n is the number of observations. Statistic S of the test is calculated using the following formula:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right). \tag{1}$$

By substituting $(x_j - x_i) = \theta$ we get:

$$\operatorname{sgn}(\theta) = \begin{cases} 1 \text{ for } \theta > 0 \\ 0 \text{ for } \theta = 0 \\ -1 \text{ for } \theta < 0 \end{cases}. \tag{2}$$

If the statistic S is positive, the newly measured values are greater than those measured earlier, which indicates an upward trend in the measured values x. Otherwise, there is a downward trend. The rate of the change of the analyzed trend in time can be described by the directional coefficient of the straight line expressed by Sen's slope estimator:

$$\beta = \text{mediana}\left(\frac{x_j - x_i}{j - i}\right), \tag{3}$$

calculated for every $i<j$, where $i = 1,2, \ldots, n-1$ and $j = 2,3, \ldots, n$.

Changes (increases or decreases) at a materiality level above 95% are considered statistically significant. A change with the significance level from 90 to 95% is assumed to be close to statistical significance, while changes with the significance level from 75 to 90% are considered as a tendency to change. Changes at the level of significance below 75% are considered as irrelevant and without a specific direction of change (Pińskwar, 2010).

Results

In Wrocław in the years 1960-2017 a total of 8295 days with precipitation were registered, of which 7491 were classified (according to the classification presented in table 2) as very weak, weak or moderate. The number of instances of daily precipitation with a volume exceeding 10 mm was much lower (804 in total). The summary of the number of days with precipitation in individual categories registered in Wrocław in the years 1960-2017 is presented in table 3.

Table 3. Number of days with precipitation according to criteria

Rainfall criteria	Number of days with precipitation	Average number of days with precipitation
Very weak	2892	49.86
Weak	3497	60.29
Moderate	1102	19.00
Moderately strong	581	10.02
Strong	139	2.40
Dangerous	71	1.22
Constituting flood hazard	11	0.19
Flood	2	0.03
Disastrous	0	0.00

Source: author's own work.

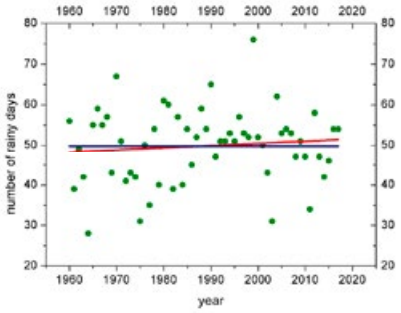
The linear regression ($y = ax + b$) and the Mann–Kendall test were used to determine the trends of the change in the number of days with precipitation representing individual categories in the years 1960-2017. Due to the very small number of days with daily precipitation exceeding 70 mm, the precipitation representing the last three categories was grouped for further analysis. The calculation results are presented in table 4 and in figure 1. The trend line is marked red for linear regression and blue for the Mann–Kendall test.

Table 4. Trends in the number of days with precipitation according to criteria

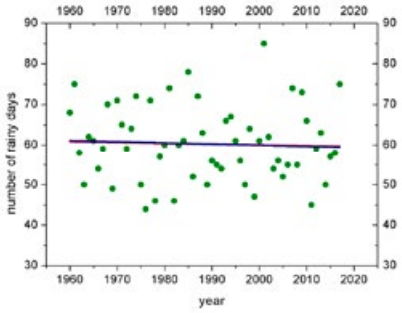
Rainfall criteria	Linear regression			Mann–Kendall test		
	R^2	*a*	Significance level	*S*	*β*	Significance level
Very weak	0.010	0.054	54.8%	54	0.000	27.8%
Weak	0.001	-0.021	22.5%	-52	-0.028	26.8%
Moderate	0.017	-0.036	66.4%	-147	-0.034	67.4%
Moderately strong	0.092	-0.056	98.0%	-297	-0.044	95.5%
Strong	0.020	-0.013	71.2%	-194	0.000	81.4%
Dangerous	0.000	-0.000	1.7%	63	0.000	34.0%
Constituting flood hazard, flood and disastrous	0.000	0.000	7.4%	-19	0.000	13.7%

Source: author's own work.

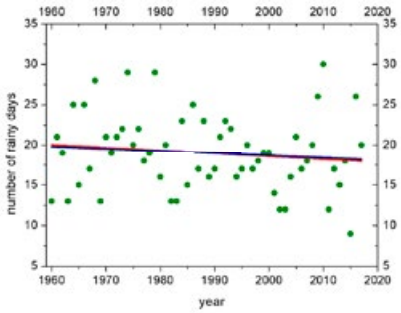
a) very weak



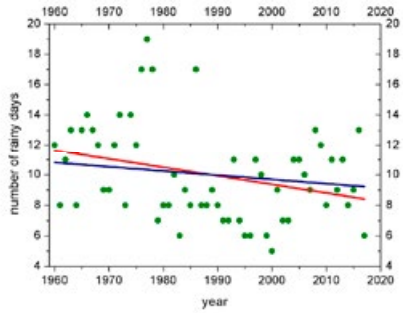
b) weak



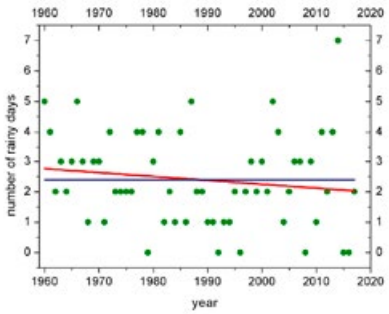
c) moderate



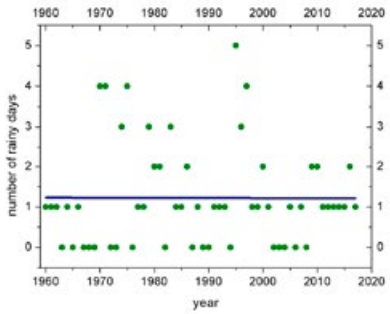
d) moderately strong



e) strong



f) dangerous



g) constituting flood hazard, flood and disastrous

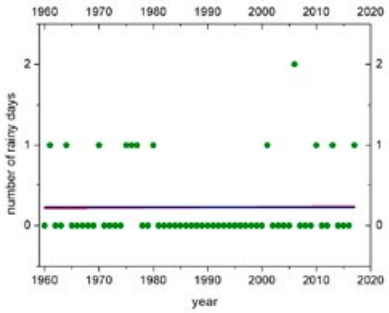


Figure 1.
The number of days with precipitation according to criteria

Source: author's own work.

Analysis of the changes in the number of days with precipitation of particular categories (table 4) showed a statistically significant downward trend for moderately strong precipitation (10.1-20.0 mm). In case of other categories of precipitation, the tests did not show statistically significant changes in precipitation in Wrocław in the years 1960-2017.

Summary and conclusions

The study analyzed daily precipitation recorded in Wrocław in the years 1960-2017. In total, 8295 days with precipitation were recorded during this period, of which 90.3% were days with very weak (0.1-1.0 mm), weak (1.1-5.0 mm) and moderate precipitation (5.1-10.0 mm) that occurred 2892, 3497 and 1102 times, respectively. Consequently, such precipitation occurs, on average, 50, 60 and 19 times a year.

Moderately strong precipitation (10.1-20.0 mm), strong precipitation (20.1-30.0 mm) and dangerous precipitation (30.1-50.0 mm) occurred 581, 139 and 71 times respectively, i.e. 10, 2.4 and 1.2 times a year on average. Precipitation constituting flood hazard (50.1-70.0 mm) and flood precipitation (70.1-100.0 mm) occurred only 11 and 2 times, while disastrous precipitation (above 100.0 mm) was not recorded during the analyzed period.

Analysis of the variability of the number of days with precipitation of particular categories showed a statistically significant downward trend for moderately strong precipitation (significance level of 98.0% and 95.5% – for linear regression and Mann–Kendall test respectively). A drop in the number of days with moderately strong precipitation was approx. 0.5 per decade. In case of other categories of precipitation, the tests did not show statistically significant changes.

It should be noted that for urban hydrology the most important is the short-term precipitation, with duration spanning from several minutes to several hours. These are the most intense rainfalls that can cause hydraulic overloading of drainage systems. Analysis of the changes in the duration of short-term rainfalls shall be the goal of further research that will complement this work.

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The contribution of the authors

Bartosz Kaźmierczak – 40% (concept and objectives, literature review, research).
Marcin Wdowikowski – 30% (concept and objectives, literature review, research).
Joanna Gwoździej-Mazur – 30% (objectives, literature review, research).

Literature

Ahmed S., Tsanis I. (2016), *Climate Change Impact on Design Storm and Performance of Urban Storm-Water Management System – A Case Study on West Central Mountain Drainage Area in Canada*, "Hydrology Current Research" No. 1(7), p. 1-11

Arnbjerg-Nielsen K. et al. (2013), *Impacts of climate change on rainfall extremes and urban drainage systems: a review*, "Water Science & Technology" No. 1(68), p. 16-28

Dai A. (2011), *Drought under global warming: a review*, "WIREs Climate Chang" No. 1(2), p. 45-65

Dąbrowski W., Dąbrowska B. (2012), *Przewidywany wpływ zmian klimatu na dysfunkcję systemów odprowadzania ścieków*, „Gaz, Woda i Technika Sanitarna" No. 1, p. 17-20

EN 752 (2017), *Drain And Sewer Systems Outside Buildings – Sewer System Management*, Comite Europeen de Normalisation

Fleig A.K. et al. (2015), *Attribution of European precipitation and temperature trends to changes in synoptic circulation*, "Hydrology and Earth System Sciences" Vol. 19, p. 3093-3107

Fratini C.F. et al. (2012), *Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality*, "Urban Water Journal" No. 5(9), p. 317-331

Hostetler M., Allen W., Meurk C. (2011), *Conserving urban biodiversity? Creating green infrastructure is only the first step*, "Landscape and Urban Planning" No. 4(100), p. 369-371

Kirshen P. et al. (2015), *Adapting Urban Infrastructure to Climate Change: A Drainage Case Study*, "Journal of Water Resources Planning and Management" No. 4(141), p. 1-11

Kaźmierczak B., Kotowski A. (2014), *The influence of precipitation intensity growth on the urban drainage systems designing*, "Theoretical and Applied Climatology" No. 1(118), p. 285-296

Kotowski A. (2015), *Podstawy bezpiecznego wymiarowania odwodnień terenów. Tom I – Sieci kanalizacyjne*, Warsaw

Kotowski A. (2013), *Prognozowane skutki ocieplenia klimatu w modelowaniu przeciążeń systemów kanalizacyjnych w Polsce*, „Gaz, Woda i Technika Sanitarna" No. 5, p. 201-205

Kundzewicz Z.W. et al. (2012), *Flood risk and climate change: global and regional perspectives*, "Hydro-logical Sciences Journal" No. 1(59)

Lorenc H. et al. (2012), *Struktura występowania intensywnych opadów deszczu powodujących zagrożenie dla społeczeństwa, środowiska i gospodarki Polski*, in:

Lorenc H. (ed.), *Klęski żywiołowe a bezpieczeństwo wewnętrzne kraju*, Warsaw, p. 7-32

Olechnowicz-Bobrowska B. (1970), *Częstość dni z opadem w Polsce*, Warsaw

Pińskwar I. (2010), *Projekcje zmian w ekstremach opadowych w Polsce*, Komitet Gospodarki Wodnej Polskiej Akademii Nauk

Saboia M.A.M. et al.(2017), *Climate changes impact estimation on urban drainage system located in low latitudes districts: a study case in Fortaleza-CE*, "Brazilian Journal of Water Resources" No. 21(22), p. 1-15

Schiermeier Q. (2011), *Increased flood risk linked to global warming: likelihood of extreme rainfall may have been doubled by rising greenhouse-gas levels*, "Nature" No. 7334(470), p. 316

Semadeni-Davies A. et al. (2008), *The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Combined sewer system*, "Journal of Hydrology" Vol. 350, p. 100-113

Spatari S., Yu Z., Montalto F.A. (2011), *Life cycle implications of urban green infrastructure*, "Environmental Pollution" Vol. 159, p. 2174-2179

Walsh K.J.E. (2016), *Tropical cyclones and climate change*, "WIREs Clim Change" No. 1(7), p. 65-89

Wong T.H.F., Brown R.R. (2009), *The water sensitive city: principles for practice*, "Water Science & Technology" No. 3(60), p. 673-682

Yazdanfar Z., Sharma A. (2015), *Urban drainage system planning and design – challenges with climate change and urbanization: a review*, "Water Science & Technology" No. 2(72), p. 165-179

Andrzej STUDZIŃSKI • Katarzyna PIETRUCHA-URBANIK

FAILURE RISK ANALYSIS OF WATER DISTRIBUTIONS SYSTEMS USING HYDRAULIC MODELS ON REAL FIELD DATA

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ABSTRACT: At this paper the analysis of failure risk in the two water supply systems in the south-eastern Poland is presented. For this purpose the hydraulic models of the water networks created in the EPANET 2 on the basis of data obtained from the water networks operation were used. The consequences of failure of individual pipelines were determined. The areas that are most vulnerable to pressure fluctuations in the water supply system resulting from the failure of these pipelines, were located.

KEY WORDS: water supply, failure, hydraulic models, risk indicators, reliability analysis

Introduction

The hydraulic and quality water supply network models are a huge source of information about the system being operated. The dynamic models of water distribution systems are particularly useful in diagnosing the state of the operating system, developing the concept of expansion or modernization of water supply systems (Haimes, 1998; Hallmann, Suhl, 2016; Mielcarzewicz, 2000; Zimoch, 2012; Zimoch, Lobos, 2012).

The failure in water supply network can disturb the operation of water supply network (Blokker, 2006; Boryczko et al., 2014; Tchórzewska-Cieślak et al. 2018; Tchorzewska-Cieslak, Pietrucha-Urbanik, 2014; Tchorzewska-Cieslak, Rak, 2010). The failure occurrence of water pipes can influence waterworks company and the water consumers. The emerging consequences can cover the following spectrum of losses, from financial losses to losses which are difficult to estimate, such as losses related to the decrease of life quality or health loss due to lack of water or poor quality water (Iwanejko, Wieczysty, 2001; Rak, 2004; 2008; Zimoch et al., 2007). In this case calculating the real value of losses in the monetary units can be the best solution for the further implementation in risk management. However, obtaining such values can constitute the extremely difficult issue, also related to criterial reliability values of communal water supply systems (Roman, 1986).

A number of water supply systems and obtained results for almost whole range of pipe diameters, distinguishing pipe age and material, operating conditions and seasonality, were analysed (BS EN 15975-2:2013; Hotloś, 2007; Karamouz et al. 2010; Kowalski et al. 2015; Kozłowski, 2018; Królikowska, 2011; Kutylowska, 2015), but the issue of losses resulting from failure of water pipes still remains to be developed.

By conducting computer simulations it is possible to test various possible solutions and to compare the effects between them (Bene, Selek, 2012; Knapik, 2001; Wierzbicki, 2015). The effect of the study is that universal indicators of losses resulting from the failure of waterworks pipes seem necessary to be obtained.

Research methodology

Research object

In the work two water supply systems were distinguished.

Water supply system (A) is supplied from three independent water intakes. The distribution of water to consumers takes place through water

supply network, which has a ring-radial system, which positively affects the assessment of the reliability of the water supply system. The total length of the water supply network is approximately 400 km. The material structure of the water supply network is as follows: grey cast iron 30%, steel 1%, PVC 34% and PE 35%. In terms of the age structure of the water supply network pipes is as follows 5 years – 5%, from 6 to 10 years – 11%, from 11 to 20 years – 28%, over 20 years – 56%, where: from 21 to 30 years – 22%, from 31 to 50 years – 32%, over 50 years – 2%. Almost 50 thousand of inhabitants are being supplied from distinguished water supply network with the average daily water demand through the year equal to 13,3 thousand m^3/d. The failure rate for distributional pipes in last year of observation equals to 0,38 $km^{-1} \cdot year^{-1}$. The failure rates in the concerned system are below the 0,5 $km^{-1} \cdot year^{-1}$, which can be considered as an average failure rate according to the criteria presented in (Kwietniewski, Rak, 2010; Kwietniewski, et al., 1993).

Network of water supply system (B) is made almost entirely of PVC, pipelines that have been damaged are converted into PE. The total length of the network is 250 km. The intake of water is a set of four wells with a total operating capacity of 110 m^3/h. Distribution of water to users is conducted through the water supply network system, which is ring-radial, which positively affects the water supply reliability. The average daily water consumption is 500 m^3/d. Comparing the determined failure rate of the tested network (0,11 $km^{-1} \cdot year^{-1}$) to the rigorous criteria related to the main network and amounting to 0,3 $km^{-1} \cdot year^{-1}$ (Rak, 2005). This is probably due to the young age of the water supply network, the oldest sections of which are only 25 years old.

The Hydraulic Model of Water Supply Network

The hydraulic model of the water supply network was created in the Epanet 2 program on the basis of real operational data received from the water supply company.

The research methodology consists in determining the consequences of failure of selected sections, including the water supply risk indicators presented in point 3.2. For each pipe in which the failure was simulated, the duration and consequences of the failure were determined. In the work, the hydraulic model of the water supply network was created using the EPANET 2.0 program. It is a program that performs extended hydraulic simulations and simulations of water quality behaviour in pressure networks. The network is made of pipes, nodes, pumps, valves and storage tanks or reservoirs. During the simulation, the EPANET program enabled tracking water flow in

pipes, pressure changes in individual nodes, changes in water level in all tanks.

The purpose of the water supply failure analysis is to present the hydraulic effects of failure of individual water supply network pipes of the considered water supply systems. The following factors such as range, duration of failure and the number of inhabitants without water, were examined. The hydraulic models created on the basis of the program Epanet 2 were used for the analysis of failures of each distributional pipe by determining the difference in pressure in the network nodes in failure-free conditions and during failures. State of emergency was simulated by closing the individual sections of the network.

Implementation of Water Pipe Failure Risk Indicators

The following water pipe failure risk indicators were implemented according to the methodology presented in (Pietrucha-Urbanik, Studziński, 2018) and adapted from (Kwietniewski et al., 1993; Wieczysty, Iwanejko, 1996).

The probability of pipes exclusion was calculated on the basis of operational data. It can be determined using the formula describing the empirical probability (Kwietniewski et al. 1993; Wieczysty, Iwanejko, 1996):

$$P_i = \frac{T_{wi}}{T_{wi} + T_{ci}}, \tag{1}$$

where:
T_{wi} (h) is the average working time without failures,
$T_{wi} = 1/\lambda_i$,
T_{ci} (h) is the average segment closing time during its repair.

$$T_{wi} = \frac{1}{\lambda_i l_i}, \tag{2}$$

where:
λ_i is the failure rate ($d^{-1} \cdot km^{-1}$),
l is pipe length (km).

The risk indicator is based on the expected value of water shortage R_t – the indicator which binds the probability of failure and resulting water shortage.

It is determined according to the dependence (Wieczysty, Iwanejko, 1996):

$$R_t = 1 - \frac{E(S)}{V_n}, \tag{3}$$

where:

$E_{(S)}$ is an expected value of water shortage during the relevant period [m^3],

V_n is total volume of water needed in the given balancing period, usually calculations are carried out for 1 day, hence Vn is assumed as a nominal daily demand Q_n [m^3].

Index of Average Time of Water Not Supplied (ATWNS) distinguish the time in which the water supply does not meet the requirements of the consumer, below the acceptable standards, both in quantitative and qualitative way and is expressed by time (hours) of exposure of the statistical water consumer per year, determined as (Pietrucha-Urbanik, Studziński, 2019) the multiplication the duration of the *i*-th failure (h) – T_{ti} and the number of inhabitants affected by the *i*-th failure – INH_i per a number of residents supplied by the water supply system – INH_i.

The range of the failure consequences can be calculated as the expected number of customers without water due to failure of the pipe. In this case the risk indicator is the expected number of residents affected by water deficit *E*(*INH*) (Pietrucha-Urbanik, Studziński, 2019).

Failure consequences can also be expressed by the losses of the expected number of water connections without water supply, as a result of the consequences of water pipes failure.

The other risk indicators can distinguish interruption frequency and length, as well as not supplied average water volume (Hotloś, 2007; Królikowski, Królikowska, 2010; Marques, Monteiro, 2001, Mays, 1998).

Results

Hydraulic simulation of consequences of water pipes failures – a case study concerning the most serious failures

Due to the large number of obtained results of the failure analysis, it was decided to present only those that have the largest operating range and cause the highest pressure drops in the distribution network.

Water network (A)

Simulation of pipe failure No. 347 with a diameter of 160 mm and a length of 716 meters. The failure caused the close of section 347 for 7 hours: 7:00 – 14:00. The pipe is located in the Polanka district on Skłodowska-Curie Street (figures 1 and 2). During the renewal of the section without water will be 152 inhabitants.

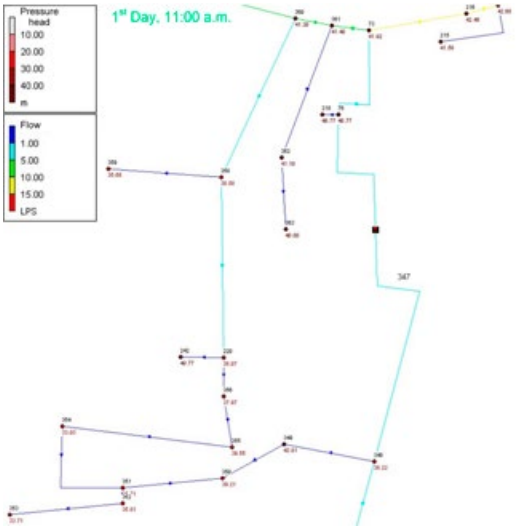

Figure 1. Model of water supply system during failure-free operation – no 347

Source: author's own work.

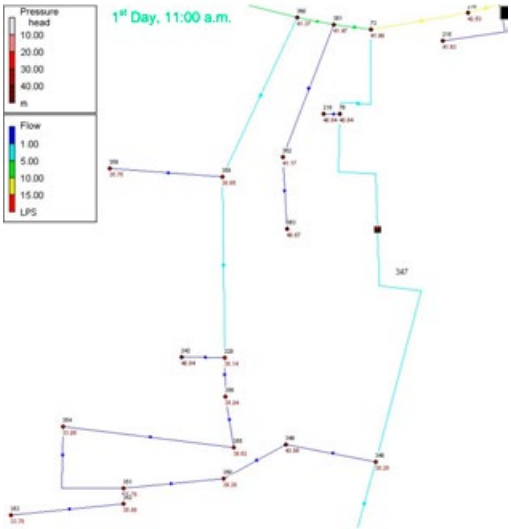

Figure 2. Model of water supply network during failure operation – no 347

Source: author's own work.

The results of calculations of failure of section 347 regarding only selected network nodes are shown to cause the following pressure changes in the nodes:

- node 348 – pressure drop by 2,17 m H_2O to the level of 36,05 m H_2O at 11:00 a.m. (4th hours of failure) in relation to the work of a failure-free model,
- node 353 – pressure drop by 1,96 m H_2O to the level of 31,75 m H_2O at 11 a.m. (4th hours of failure) in relation to failure-free operation,
- node 349 – pressure drop by 2,09 m H_2O to the level of 41,72 m H_2O at 11 a.m. (4th hours of failure) in relation to failure-free operation.

Water network (B)

The failure was simulated on section 226, it is the main power supply for the commune, from water treatment plant towards city. The diameter of the pipe is 225 mm and length of 100 m. Failure caused the section to be closed for 7 hours from 7 a.m. to 2 p.m. During the renewal of the section, the majority of the commune residents will struggle with large water problems. This is the most serious failure, which covers a very large area of the commune, the worse situation from the above is the damage of the main from the water treatment plant, when the whole commune will remain without water for the period of repair (figures 3 and 4).

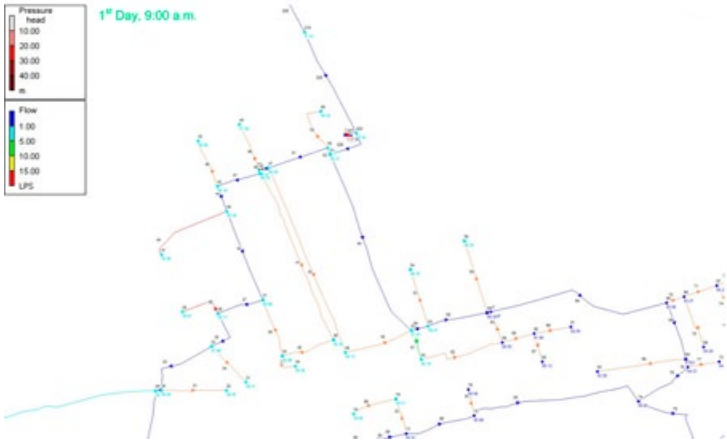

Figure 3. Model of water supply system during failure-free operation – no 226

Source: author's own work.

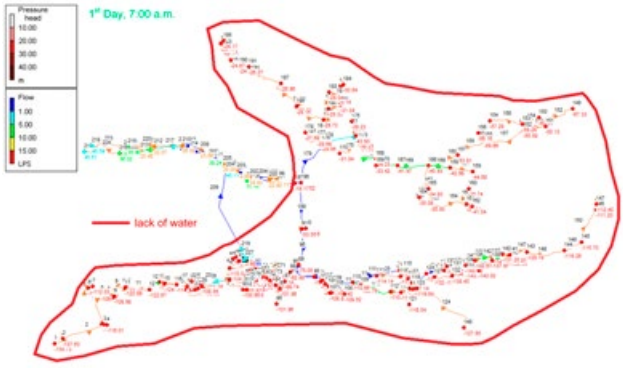

Figure 4. Simulated failure of water pipe section no 226 – the first to the third hour of failure-free operation – no 226

During the first three hours, only one commune had access to the water, the remaining part of the commune was without water. A significant drop in pressure was noted compared to work without failure in places where water was available, without water was in total 5274 inhabitants.

Comparison of Risk Indicators of Water Networks Operation

On the basis of formulas presented in point 2.3 the risk indicators of the consequences of failure in water pipeline in two concerned water supply systems were calculated.

The results are summarized in figures 5-10.

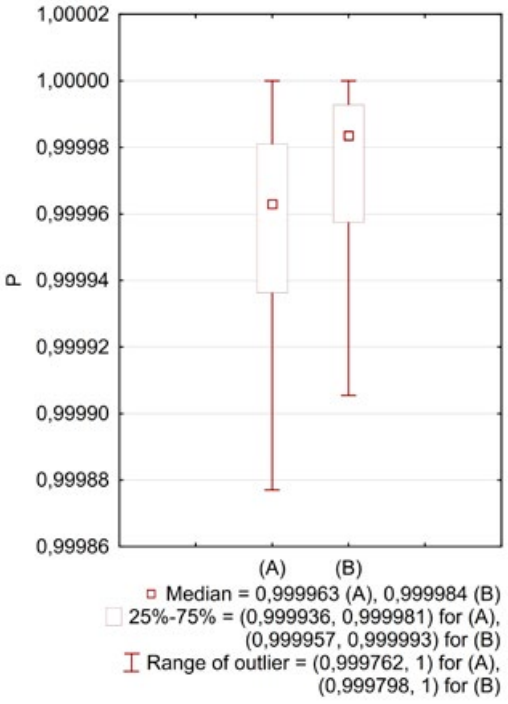

Figure 5. Summary of risk calculations for the water networks (A) and (B): the probability of pipes exclusion – P

Source: author's own work.

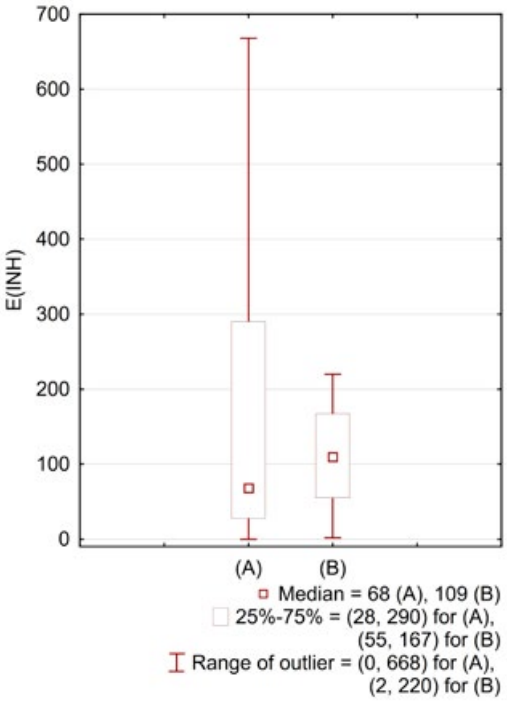

Figure 6. Summary of risk calculations for the water networks (A) and (B): the expected number of residents affected by water deficit – E(INH)

Source: author's own work.

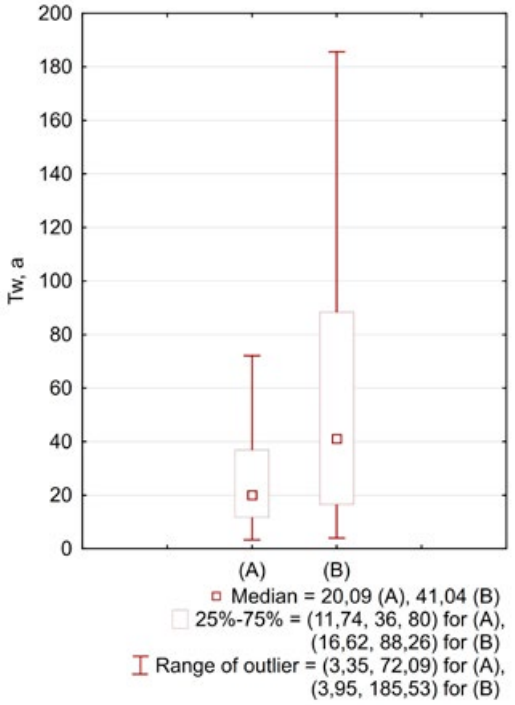

Figure 7. Summary of risk calculations for the water networks (A) and (B): the average working time without failures – Tw

Source: author's own work.

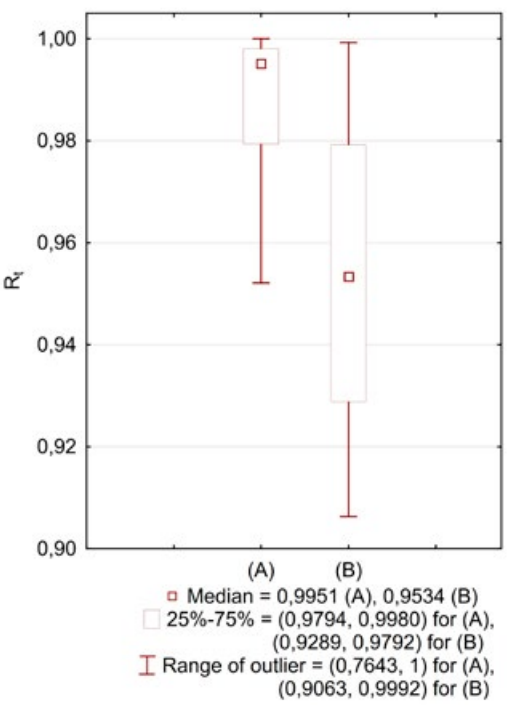

Figure 8. Summary of risk calculations for the water networks (A) and (B): the risk indicator – Rt

Source: author's own work.

The results confirm the specificity of the considered systems. Water network (A) is characterized by lower values of average time of water not supplied (ATWNS), with median value in this system 0,0099. In comparison to water network (B) with median value of ATWNS 0,99, such difference is a result of water-ring network in (A) case, and cause smaller consequences of failures. The branch structure of water network (B) influence dependent indicators, such as risk indicator and the expected number of residents affected by water deficit.

The obtained values indicate the necessity of providing the calculations as to propose the criteria values of risk indicators.

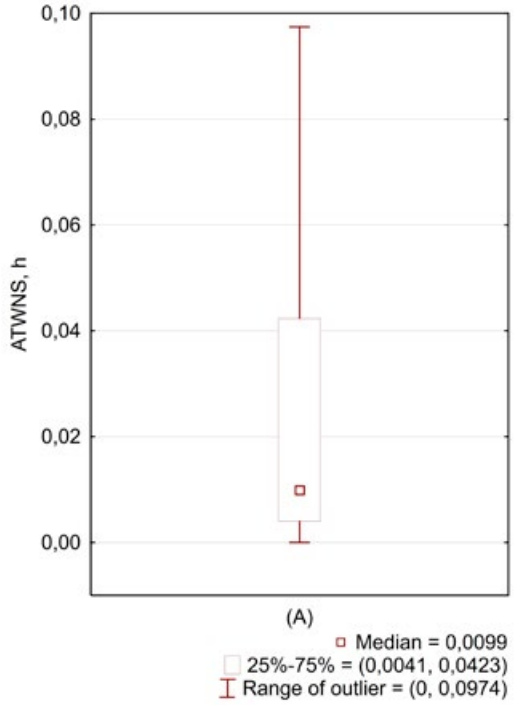

Figure 9. Summary of risk calculations for the water network (A): average time of water not supplied – ATWNS, hour

Source: author's own work.

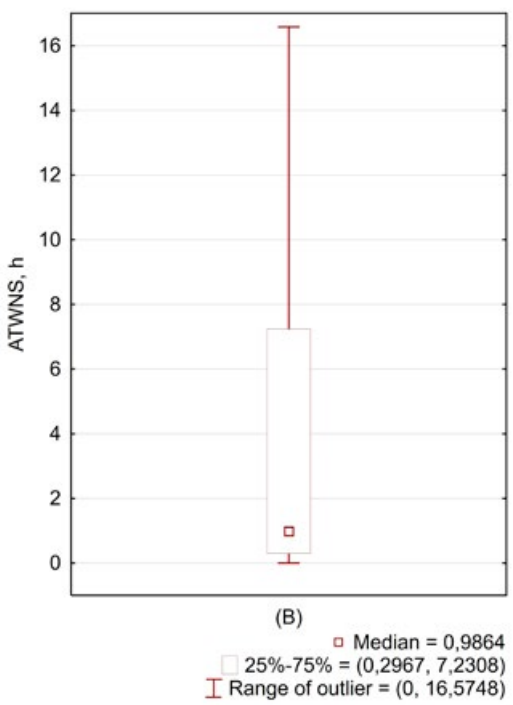

Figure 10. Summary of risk calculations for the water network (B): average time of water not supplied – ATWNS, hour

Source: author's own work.

Discussion of results

Water network (A)

The largest decreases in pressure were recorded on the other seven sections: 281, 265, 617, 149, 368, 475 and 45. The range of effects of failure of individual pipes is local. It results from the fact that the analyzed water supply network has in the majority of cases ring structure, which significantly affects the minimization of the failure consequences of a single section. The following results were obtained: pressure drop to 0 meters H_2O: 95 sections, pressure drop above 5 m H_2O: 3 sections, pressure drop 2-5 m H_2O: 8 sections, pressure drop 1-2 m H_2O: 14 sections, pressure drop below 1 m H_2O:

100 sections. After analyzing the pressure drops in the distribution network and the minimum value of the economic pressure (depending on the number of buildings floor), it was stated that the limit values were not exceeded. All the more so considering the required pressure will be maintained during fire on the outside hydrant of 0,1 MPa (Journal of Laws No. 121 item 1139). It can therefore be concluded that failures on individual sections will not have a significant impact on the supply of water to residents of other streets.

Water network (B)

During the failure-free operation, it was noticed that the water supply network is considerably oversized, the flow velocities are almost lower than 0,2 m/s in almost entire water supply network. This is due to the need to adapt the water supply network to the fire regulations, the water network is extensive and during fire distribution oversized diameters allow to reduce pressure losses and keep the required pressure on the head of the hydrant in accordance with applicable regulations. The negative effect is the significant time of water remaining in water network and the possibility of its secondary contamination. Counteract this phenomenon requires frequent flushing of pipes, which at the extent of the water supply network generates significant water loss. Oversizing the water pipes forming the ring: 58, 64, 69, 76, 84, 86, 89, 90 helps to maintain high pressure in the event of failure of one of them. The consequences of the failure only affect the recipients supplied from this section. The sections whose failure influences the largest number of water consumers are aforementioned section 226, the remaining sections deprive the water to a smaller number of residents 2937 and 2391, respectively, during the most unfavorable conditions on the network (the largest hourly distribution during a failure). In most cases, the radial geometric structure of the water supply network causes that failure of the sections results in lack of water of all subsequently supplied sections. Therefore, it seems necessary to connect another ring between nodes 162 and 137 or at the end of the western network between nodes 147 and 149.

Conclusions

The obtained values of the indicator $E(INH)$ specified by the formula (5) result from two components: the probability of failure and its consequences understood as the number of recipients experiencing water deficit. The probability of failure is mainly related to the age and material of the pipe, it also results from the assembly technology or the diameter of the pipe and has been thoroughly characterized in (Kwietniewski, Rak, 2010). The number of

recipients experiencing water deficit is mainly the result of the structure of the water supply network. Comparing the results obtained for the city A and for the city B, it can be noted that in the municipal water supply A the median is much smaller than in B, which results from the fact that during the repair of pipes being part of a closed ring it is possible to detach customers directly connected to the excluded section, the other water consumers use it without any quantitative restrictions. At the same time the average value of the median of water network (A) and the obtained maximum value significantly exceed those values for water network (B). This is due to the areas of high population density (the residential areas with a high population density) supplied by the individual pipes. Such a situation is not observed in the municipal water supply system.

An interesting reference is made to compare the obtained values to water network (C) in the city concerned in (Pietrucha-Urbanik, Studziński, 2019), where the water supply system is entirely constructed contemporarily (the beginning of the water network reaches the seventies of the last century, refers to both the structure of the material and geometric of water supply system, in particular of similar distribution of diameters). The city (C) has the size and population density close to A (1073 inhabitants/km^2 in A and 982 inhabitants/km^2 in C, respectively), but the median of indicator $E(INH)$ is only 19, and the average value is 35. The observed difference in relation to A should be explained primarily by the geometric diversity of the water supply network. The waterworks (C) has the smallest network terminals in the open structure, which determine the largest number of residents affected by water deficit. In turn, the highest values of $E(INH)$ concern the water supply (B) with dominant open structure, which proves that the geometric structure of the water supply network is one of the key risk factors for the lack of water supply for residents. The results obtained for waterworks confirm the conclusion presented in (Pietrucha-Urbanik, Studziński, 2019), that values of water network (C) can be treated as desirable reference values for other waterworks.

The contribution of the authors

All authors contributed equally to the manuscript.

Literature

Bene J.G., Selek I. (2012), *Water network operational optimization: Utilizing symmetries in combinatorial problems by dynamic programming*, "Periodica Polytechnica Civil Engineering" No. 1, p. 51-61

Blokker E.J.M. (2006), *Substandard Supply Minutes in the Netherlands*, ASCE Conference Proceedings of Water Distribution Systems Analysis Symposium, Ohio 247, p. 128-133

Boryczko K., Piegdon I., Eid M. (2014), *Collective water supply systems risk analysis model by means of RENO software*, in: Steenbergen R.D.J.M. et al. (eds) *Safety, Reliability and Risk Analysis*, London, p. 1987-1992

BS EN 15975-2:2013, *Security of drinking water supply. Guidelines for risk and crisis management. Risk management*

Haimes Y.Y. (1998), *Risk Modeling, Assessment and Management*, New Jersey

Hallmann C., Suhl L. (2016), O*ptimizing Water Tanks in Water Distribution Systems by Combining Network Reduction*, "Mathematical Optimization and Hydraulic Simulation. OR Spectrum" No. 38, p. 577-595

Hotloś H. (2007), *Quantitative assessment of the effect of some factors on the parameters and operating costs of water-pipe networks*, Wroclaw

Iwanejko R., Wieczysty A. (2001), *O konieczności i sposobach określania ryzyka producenta i odbiorcy wody w systemie wodociągowym*, materiały konferencyjne „Bezpieczeństwo, niezawodność, diagnostyka urządzeń i systemów gazowych, wodociągowych, kanalizacyjnych, grzewczych", Zakopane – Kościelisko, p. 163-172

Karamouz M., Moridi A., Nazif S. (2010), *Urban Water Engineering and Management*, New York

Knapik K. (2001). *Dynamiczne modele w badaniach sieci wodociągowej*, Kraków

Kowalski D., Kowalska B., Kwietniewski M. (2015), *Monitoring of water distribution system effectiveness using fractal geometry*, "*Bulletin of the Polish Academy of Sciences*" No. 63, p. 155-161

Kozlowski E. et al. (2018), *Water demand forecasting by trend and harmonic analysis*, "Archives of Civil and Mechanical Engineering" No. 18(1), p. 140-148

Królikowska J. (2011), *Zastosowanie metody PHA do oceny ryzyka uszkodzeń sieci kanalizacyjnej na przykładzie systemu kanalizacyjnego miasta Krakowa (Application of PHA method for assessing risk of failure on the example of sewage system in the city of Cracow)*, "Annual Set the Environment Protection" No. 13, p. 693-710

Królikowski A., Królikowska J. (2010), *Analiza porównawcza wskaźników niezawodności wiejskich i komunalnych systemów zaopatrzenia w wodę*, in: Sozański M.M., *Zaopatrzenie w wodę, jakość i ochrona wód – zagadnienia współczesne*, t. 2, Poznań, p. 383-392

Kutylowska M. (2015), *Modelling of Failure Rate of Water-pipe Networks*, "Periodica Polytechnica Civil Engineering" No. 1, pp. 37-43

Kwietniewski M., Rak J. (2010). *Reliability of Water and Wastewater Infrastructure in Poland*, Warsaw

Kwietniewski M., Roman M., Kłoss-Trębaczkiewicz H. (1993), *Reliability of water system and sewerage*, Warsaw

Marques R., Monteiro A. (2001), *Application of performance indicators in water utilities management – a case-study in Portugal*, "Water Science Technology" Vol. 44, pp. 95-102

Mays W.L. (1998), *Reliability Analysis of Water Distribution Systems*, New York

Mielcarzewicz E.W. (2000), *Obliczanie systemów zaopatrzenia w wodę*, Warszawa

Pietrucha-Urbanik K., Studziński A. (2017), *Case study of failure simulation of pipelines conducted in chosen water supply system*, "Eksploatacja i Niezawodnosc -Maintenance and Reliability" No. 19(3), p. 317-323

Pietrucha-Urbanik K., Studziński A. (2019), *Qualitative analysis of the failure risk of water pipes*, "Engineering Failure Analysis" No. 95, pp. 371-378

Rak J. (2004), *Istota ryzyka w funkcjonowaniu systemu zaopatrzenia w wodę*, Rzeszów

Rak J. (2005), *Podstawy bezpieczeństwa systemów zaopatrzenia w wodę*, Lublin

Rak J. (2008), *Wybrane zagadnienia niezawodności i bezpieczeństwa w zaopatrzeniu w wodę*, Rzeszów

Roman M. (1986), *Problemy kryteriów niezawodności komunalnych systemów wodociągowych i kanalizacyjnych*, materiały konferencyjne „Niezawodność systemów wodociągowych i kanalizacyjnych", p. 13-26

Regulation of the Minister of Internal Affairs and Administration dated 16 June 2003, on the fire water supply and fire roads (Journal of Laws No. 121 item 1139)

Tchórzewska-Cieślak B., Pietrucha-Urbanik, K. (2014), *Water Supply System operation regarding consumer safety using Kohonen neural network*, in: Steenbergen et al. (eds), *Safety, Reliability And Risk Analysis: Beyond The Horizon*, p. 1115-1120

Tchórzewska-Cieślak B., Rak J. (2010), *Method of identification of operational states of water supply system*, in: Pawłowski L. et al. (eds) "Environmental Engineering III", London, p. 521-526

Tchórzewska-Cieślak B. et al. (2018), *Approaches for safety analysis of gas-pipeline functionality in terms of failure occurrence: A case study*, "Energies" No. 11

Wieczysty A., Iwanejko R. (1996), *Wyznaczanie wymaganego poziomu niezawodności obiektów systemu zaopatrzenia w wodę (Calculating Required Reliability Level of Water Supply System)*, „Gaz, Woda i Technika Sanitarna" No. 2, p. 54-58

Wierzbicki R. (2015), *Zastosowanie modelowania matematycznego w projektowaniu modernizacji systemów zaopatrzenia w wodę na przykładzie systemu wodociągowego gminy Zator,* „Czasopismo Inżynierii Lądowej, Środowiska i Architektury" No. 3/I, p. 511-522

Zimoch I. (2012), *Pressure control as part of risk management for a water-pipe network in service*, "Ochrona Środowiska" No. 34, p. 57-62

Zimoch I., Lobos E. (2012), *Comprehensive Interpretation of Safety of Wide Water Supply Systems*, "Environment Protection Engineering" No. 38, p. 107-117

Zimoch I., Kotlarczyk B., Soltysik A. (2007), *Use of prehydrolyzed coagulants for the enhancement of water treatment efficiency in the Czaniec Water Treatment Plant*, "Ochrona Środowiska" No. 29, p. 45-49

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THE CHOICE OF LOCATION FOR A COMMUNITY WATER TREATMENT PLANT USING THE AHP METHOD

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ABSTRACT: The aim of the research was to identify the location of the local sewage treatment plant with use of hierarchical multi-criteria analytical analysis: AHP (Analytical Hierarchy Process) taking into account the technical, economic, and social criteria. The analysis was carried out for the rural commune of Szumowo (Zambrów district) which since 2016 forms an agglomeration. According to the Functional and Utility Programme a sewage treatment plant with a capacity of 350 m^3/d was proposed, taking into account 4 location variants with an area of approx. 1.3 ha.

KEY WORDS: sewage treatment plants, AHP, multicriteria decision, rural areas

Introduction

Regulation of wastewater management, in addition to providing people access to clean water, is one of the most important activities. Developing water and wastewater management can improve health and lead to economic expansion.

In rural areas, similar to the urban areas in range of produced sewage amount, we can observe large disproportion between water and wastewater systems length. Sustainable environmental development should lead to reduce this disproportion. The dispersed development and low settlement concentration in rural areas are the key issue when designing wastewater management.

Selection of location is a commonly experienced strategic problem, not only in wastewater management. Selecting sites for small wastewater-treatment plants depend on many technical, environmental, social and economic aspects. It may be achieved by using the multi-criteria decision making, evaluating different alternatives and variants to compare different sides of analysed problem (Janssen, 2001).

In rural areas a key issue is to decide installation of central wastewater system or local small household treatment plants. Rural areas produce almost half of the sewage in Poland, but predominant septic tanks are often old and in poor technical condition (LPO-4010-003/2011). Planning of wastewater systems should be based on the principles of sustainable development, and therefore consider political, economic and social aspects in accordance with environment balance and sustainability of fundamental natural processes (Journal of Laws 2001 no. 62 pos. 627, Consolidation). In the rural areas there are some difficulties we need to manage while preparing the wastewater management plans (ATV A 200, 1997):

- low settlement concentration,
- unfavourable population trends – countryside depopulation,
- settlements with scattered buildings,
- small villages and districts distant from each other,
- low ratios of covered surface (up to 20% of the settlement areas),
- low implementation of sewage and treatment systems,
- high ratio of areas under environmental protection,
- frequent seasonal variation of the wastewater amounts due to tourism.

This paper focuses on small wastewater treatment plant location within rural commune's area. The AHP method and Expert Choice 11 software was used to compare and rank alternative sites in relation to offered weights.

Analytical Hierarchy Process

The multi-criteria decision making methods are techniques supporting the decision maker facing a problem that has several alternatives.

The AHP is based on the experience gained by its developer, T.L. Saaty, while providing research projects in the US Arms Control and Disarmament Agency. It was developed as a reaction to the finding that there is a miserable lack of common, easily understood and easy-to-implement methodology to enable making of complex decisions (Saaty, 1980).

Since then the AHP has gained popularity across multiple domains in every part of the world. The AHP has found use in business, government, social studies, defence, and many others, involving decisions in which choice, prioritization, or forecasting is needed (Bhushan, Rai, 2004).

Making decision according to AHP method includes the following steps (Saaty, 2008):

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which the subsequent elements depend) to the lowest level (which usually is a set of alternatives).
- Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
- Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for each element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

Comparisons are made using the importance scale of numbers (table 1).

Verifying the results' reliability is made by calculating the consistency index (CI) and the consistency ratio (CR). In order to eliminate the noncompliance, the CR ratio is calculated according to (Saaty, 2001):

$$CR = \frac{CI}{RI} \cdot 100\%, \tag{1}$$

where RI (Random Consistency Index – Golden and Wang, 1990) is related to the dimension of the matrix. Consistency Index is determined according to:

$$CR = \frac{(\lambda_{max}) - n}{(n-1)}, \quad (2)$$

where λ_max is maximum eigen value of matrix (eigen values calculations are explained e.g. in: Ostręga, 2004). CI less than 0.1 means, that pairwise comparison and evaluation results are acceptable.

Table 1. Scale of numbers in AHP

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

Source: Saaty, 1996.

Research area and method

Szumowo Commune, of area of 141.15 km^2, is located in Podlaskie Voivodeship, in the south-west part of the Zambrowski District. Over 70% of land is under agricultural use (Uchwała Nr XXI/103/04). The analysed area is not currently supplied with sewage systems, although until 2019 the commune will build pressure sewer and plug in at least 410 households (http://www.szumowo.pl). On the other hand about 95.6% of commune population have access to the waterworks. Szumowo forms an agglomeration according to the Polish Water Law, with an equivalent of 2527 inhabitants – Szumowo city and Nowe Szumowo, Srebrna villages (Resolution No. XXIX/263/2016).

The study aims to provide an evaluation of four small wastewater treatment plant locations in rural commune, based on seven criteria using the AHP method. For Szumowo Commune the modular wastewater treatment plant with sewage flow of 360 m^3/d, composed of mechanical (bar screens, mesh screens), biological (sewage reactors, primary and final sedimentation) and sludge section (dewatering press) has been proposed (RRG.271.5.2018).

The following criteria were considered:

- Economic:
  - Cr4: parcel cost,
  - Cr5: parcel adaptation cost.
  - Social:
  - Cr6: distance from the residential buildings,
  - Cr7: natural barriers between the residential buildings and WTP (wastewater treatment plant),
- technical:
  - Cr1: distance from the road,
  - Cr2: distance from the sewage receiver,
  - Cr3: network length needed to connect WTP with sewage system,
- economic:
  - Cr4: parcel cost,
  - Cr5: parcel adaptation cost,
- social:
  - Cr6: distance from the residential buildings,
  - Cr7: natural barriers between the residential buildings and WTP.

The analysed commune do not possess any suitable property, which is why all analysed variants require purchase. Parcel adaptation costs were based on the average cost of trees and bushes removal, terrain denivelation, and media connections.

Potential locations of small wastewater treatment plant were selected determining its area for about 1.3 ha (figure 1). The first variant (W1), proposed in the functional and utility programme prepared for the commune (GLOBAL TECHNICS, 2017), is located in IV and V class meadow area, without road infrastructure and other media. This option was selected because of its location in relation to sewage receiver – Szumowo Łętownica Channel as Bug tributary. The second site (W2) also provides discharge to Łętownica Channel for the sewage. In contrast to the situation in W1 this variant is located closest to the road. The third variant (W3) is located near the road leading to Srebrna village, which is a part of agglomeration and will be developed with sewage system. This location, along with W4, involve sewage disposal into Jasionka River (Bug tributary). The last selected variant (W4) is located southwest from Szumowo and includes the highest distance from the sewage receiver – about 450 m.

After agglomeration and sewage system plan studies it was found that variant 4 area is located nearest to the sewerage (130 m) while other variants are located 260 m (W1), 300 m (W3), and 400 m (W2) from the sewerage.

Figure 1.
Small wastewater treatment plant location variants within Szumowo Commune

Source: Google Maps, 2018.

Regarding to the economic criteria, the most advantageous alternative seems to be W3, which together with W4 are the least expensive. Moreover, parcel number 3 requires the lowest adaptation cost.

Likewise the technical and economic criteria, social requirements were analysed. The largest distance from the residential buildings – 400 m – was presented by variants W2 and W3, which have natural barriers in form of forestation stripes and large wooded area. Area 4 is located 300 m from the nearest building, and the first variant 230 m. Alternatives W1 and W4 are separated by only minor wooded and bushy areas from the buildings.

All selected WTP's locations are presented in the figure 2.

Figure 2. Small wastewater treatment plant sites

Source: Geoportal, 2018.

Results of the research

According to Saaty's methodology (Saaty, 1980, 1996, 2001, 2008), using 9-point scale presented in table 1, criteria were pairwise compared, as well as variants for each criterion. Table 2 shows analysed alternatives priorities.

Table 2. The value of priorities for variants

Criterion (weight)	Variants			
	W1	W2	W3	W4
Cr1 (0.04)	0.002	0.009	0.017	0.017
Cr2 (0.08)	0.024	0.006	0.034	0.003
Cr3 (0.078)	0.011	0.003	0.008	0.034
Cr4 (0.358)	0.035	0.086	0.154	0.154
Cr5 (0.175)	0.011	0.030	0.075	0.017
Cr6 (0.112)	0.012	0.048	0.048	0.024
Cr7 (0.157)	0.068	0.034	0.017	0.017

Source: author's own work.

Based on the alternatives pairwise comparison, priority for economic criteria was the highest (over 50%). The second most important criteria were social (Cr6 and Cr7), of almost 30% of participation.

Alternatives analysed with respect to each criteria were pairwise compared and the variants hierarchy was obtained as a result. The sequence was as follows: W3>W4>W2>W1. The optimal variant was W3, with large advantage over the second best variant – W4 (figure 3).

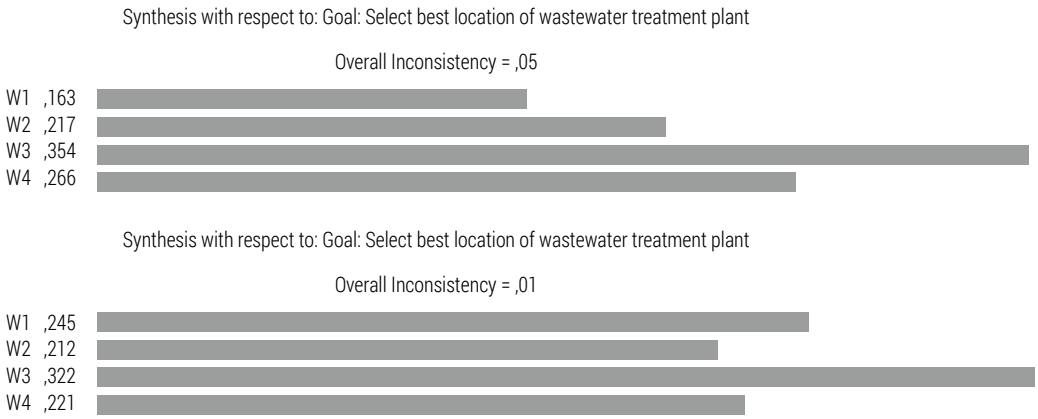

Figure 3. AHP final results with regard to different (above) and equal (below) criteria weights Source: author's own work.

Analysis for equivalent alternatives importance were also prepared, however the final result was the same. Criteria weights alignment affect W1 priority increase (figure 3).

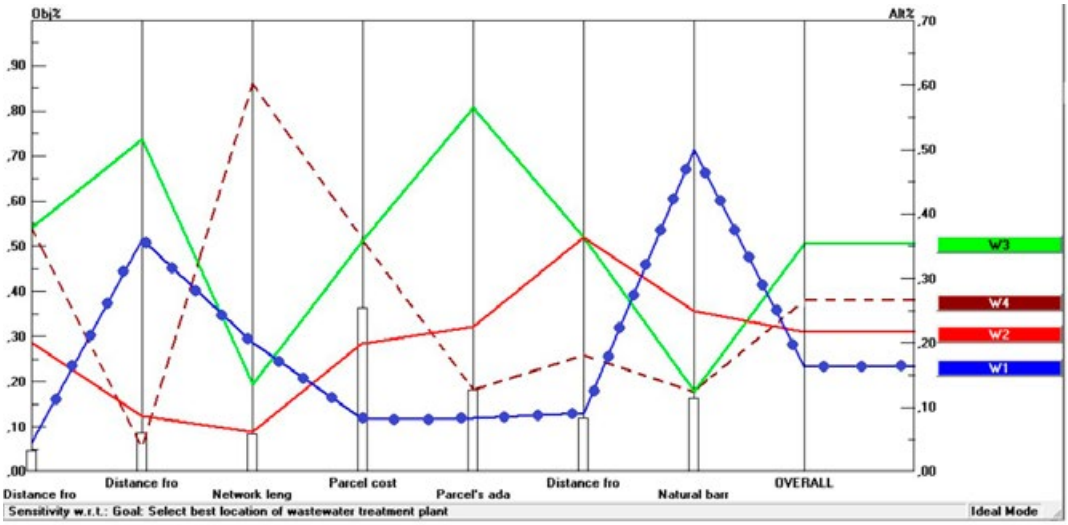

Figure 4. AHP final results with regard to each criterium importance

Source: author's own work.

As it can be seen in the figure 4, high variant 3 advantage over other alternatives was due to criterion 2 (distance from the sewage receiver) and 5 (parcel adaptation cost). The second best result was characterized by very high criterion 3 impact – network length needed to connect WTP to the sewage system.

All presented results were prepared in Expert Choice 11 software.

Conclusions

Due to the flexibility, simplicity, and possibility to compare the qualitative and quantitative factors the method invented by Saaty has been applied in many different fields. In this work, the AHP method was used to compare the alterative locations of a small wastewater treatment plant in a rural commune. The study included analysis of seven criteria and four variants.

- Due to many factors affecting the sewage treatment plants location selection, it is necessary to carefully analyse the possible solutions.
- AHP analysis allowed to easily compare many alternative solutions to the problem for many criteria.
- The best sewage treatment plant's location in accordance with the results of the analysis was variant 3, mainly due to the low costs of plot adaptation for the investment needs and distance from the sewage receiver.
- Equalization of the criteria weights did not affect the final variant choice.

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The contribution of the authors

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Literature

Ostręga A. (2004), *Sposoby zagospodarowania wyrobisk i terenów po eksploatacji złóż surowców węglanowych na przykładzie Krzemionek Podgórskich w Krakowie*, doctoral thesis, Kraków

ATV A 200 (1997), *Grundsätze für die Abwasserreinigung in ländlich strukturierten Gebieten*, Arbeitsblatt ATV A 200, GFA, Hennef, 5

Golden B.L., Wang Q. (1990), *An Alternative Measure of Consistency*, in: Golden B.L., Wasil A., Harker P.T, *Analytic Hierarchy Process: Applications and Studies*, New York, p. 68-81

Geoportal 2, www.geoportal.gov.pl

Google Maps 2018

http://www.szumowo.pl/972-gmina-szumowo-przymierza-sie-waznej-inwestycji [10-09-2018]

Bobkowski K. (2018), *Specyfikacja istotnych warunków zamówienia w postępowaniu o udzielenie zamówienia publicznego prowadzonym w trybie przetargu nieograniczonego w formule „Zaprojektuj i wybuduj"*, Szumowo (RRG.271.5.2018)

Bhushan N., Rai K. (2004), *Strategic Decision Making. Applying the Analytic Hierarchy Process*, IX, p. 11-21

Najwyższa Izba Kontroli, Delegatura w Poznaniu (2012), *Informacja o wynikach kontroli realizacji przez gminy województwa wielkopolskiego zadań z zakresu gospodarki ściekami bytowymi*, Poznań (LPO-4010-003/2011)

Przedsiębiorstwo Naukowo-Techniczne GLOBAL TECHNICS (2017), *Program Funkcjonalno-Użytkowy – Uporządkowanie Gospodarki Wodno-Ściekowej w Aglomeracji Szumowo*

Janssen R. (2001), *On the use of multi-criteria analysis in environmental impact assessment in the Netherlands*, "Journal of Multi-Criteria Decision Analysis" No. 10(2), p. 101-109

Rozporządzenie Ministra Rozwoju Regionalnego i Budownictwa z dnia 29 marca 2001 r. w sprawie ewidencji gruntów i budynków, Dz.U. 2001 nr 38 poz. 454

Saaty T.L. (2008), *Decision making with the analytic hierarchy process*, "Int. J. Services Sciences" Vol. 1, No. 1, p. 83-98

Saaty T.L. (2001), *Decision-Making for Leaders. The Analytic Hierarchy Process for Decision in a Complex world*, Vol. II, Pittsburgh

Saaty T.L. (2000), *The Analytic Hierarchy Process, New York: McGraw Hill. International, 1980, Translated to Russian, Portuguese, and Chinese, Revised editions*, Pittsburgh

Saaty T.L. (1996), *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, Pittsburgh

Uchwała Nr XXI/103/04 Rady Gminy Szumowo z dnia 26.08.2004 r.

Uchwała Nr XXIX/263/2016 Sejmiku Województwa Podlaskiego z dnia 24 października 2016 r. w sprawie wyznaczenia aglomeracji Szumowo

Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska, Dz. U. 2001 nr 62 poz. 627

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GREEN MANAGEMENT IMPLEMENTATION IN ACCOMMODATION FACILITIES IN BULGARIA

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ABSTRACT: Sustainability is currently one of the major priorities of tourism all over the world. This paper deals with applying elements of green management in accommodation facilities in the city of Sofia, Bulgaria. It analyses the implementation of green management elements and the principles of sustainable development in accommodation services. It focuses on accommodation facilities and their use, and environmental measures. The primary survey was conducted from May until June 2018 and we used a questionnaire survey to obtain primary data. We used the methods of scientific work; and, i.e., the analysis method, a generalization method, mathematical, and statistical methods. A total of 96 accommodation facilities participated in this research and they reached the best results with sorting containers, dual flush toilets, compact fluorescent lamps, and LED lamps. We state that the surveyed accommodation facilities should invest more funds in green initiatives and acquaint employees and guests with this philosophy.

KEY WORDS: eco-friendly accommodation facility, environmental measures, green management, hotel industry, services

Introduction

Tourism is a sector of considerable economic importance and its new ways of development are still emerging (Linderová, Janeček, 2017). Butler (2008) reports that trends in tourism, especially in the hospitality and accommodation market are continually evolving. Managers are finding new ways to harmonize the proposed higher standard with a focus on environmental measures. Environmental practices and innovations of hotel business are a widely discussed topic in scientific literature nowadays due to the benefits they bring to organizations, notably increasing revenues and reducing costs (Petkova, 2017). Green or organic products/services have achieved enormous relevant results in response to the escalated consumer sensitivity to concerns over the ever-worsening environment (Gupta et al., 2019).

Generally, tourism and especially accommodation facilities are responsible for waste pollution, increased water and energy consumption in destination areas, creating many (low paid) jobs for residents, consumption of products and materials produced by the local community (Ivanov, 2005; Ivanov et al., 2014). The literature repetitively argues that to facilitate sustainability, accommodation facilities need to adopt a new environment and socially friendly principles, attitudes and behaviors (Sarkis, 2018).

Therefore we can state that sustainability is one of the major priorities of tourism all over the world nowadays. One part of sustainable tourism is green management. Stakeholders in tourism are increasingly aware of their impact on the environment. Therefore they get involved in various voluntary programs, where they seek appropriate measures by which to contribute to improving the environment at both the local and national levels. A lot of accommodation facilities are turning green at an increasing rate due to a single reason, which is not directly based on profitability, longevity, or sustainability (Scholz, Linderová, 2016).

An overview of literature

A lot of accommodation facilities comprise the largest sector of the travel and tourism industry and have been shown to have the highest negative influence on the environment. Nowadays we can hear or read that green is in. Green is in vogue. A lot of consumers are asking for it. Organizations are requesting it. The future of business is being built by green and socially responsible organizations (Tran, 2009). If hotel guests are not interested in this philosophy, it is necessary to motivate them to go green. Hotels should pay more attention to guests' perceptions of green practices. Social media

can be a useful tool for stimulating guests to go green (Lee et al., 2016). To deal with these environmental, societal, and primarily economic issues, hotel managers or owners are required to be capable of identifying and understanding new sustainable challenges in their accommodation facilities and business environments (Shan, Wang, 2018). Despite the opportunity, some hotel managers remain hesitant to invest in green initiatives because they are not convinced whether or not such investments are financially beneficial. That is, while implementation of some new green practices and elements requires significant initial investments, quantifying returns is often tricky for investments which produce less tangible results such as the improvement to a firm's reputation for being conservation oriented (Bird et al., 2007). Robinot and Giannelloni (2010) argue that 75% of all environmental impacts are created by the hotel industry. This value can be attributed to excessive consumption of local and imported perishable goods, and the waste of energy and water.

On the other hand, the laws or regulations of most countries do not have a legal or a universally accepted definition of what is a "green accommodation facility or eco-friendly hotel." It means that the practice of using "green or eco-friendly" as a marketing ploy is still widespread in many cities and towns around the world. A lot of hotel managers are claiming that they are "green or environmentally friendly" by just hanging a sign and declaring themselves to be green (Pizam, 2009). However, European hoteliers have not perceived their environmental commitment as a significant marketing factor, as they believe that guests have a limited interest in environmental issues and that eco-friendly behavior in hotels involves considerable investment costs (Bohdanowicz, 2005).

A number of measures to protect the environment are focused on reducing energy (Chan, Lam, 2003; Khemiri, Hassairi, 2005; Ali et al., 2008; Pan et al., 2018), water (Deng, Burnett, 2002; Gössling et al., 2015; Reddy, Wilkes, 2015), chemicals, office supplies, reduction of waste (Wie, Shanklin, 2001; Chan, Lam, 2001), transport and mobility, smart technologies (Pan et al., 2018), increasing the proportion of natural materials, aesthetic environment, reducing noise and emissions (mainly carbon emissions), etc. (Patúš, Gúčik, 2004; Hillary, 2004; Bohdanowicz, 2005; Mensah, 2006; Chen, Hsieh, 2011; Petkova, 2017). The best innovative practices are, e.g., linen napkins and terry washing towels, recovery of cutlery, converting old guestrooms bed linens into pot holders and aprons for the kitchen, using TVs for guests information about recycling (Enz, Siguaw, 1999). The international chain Marriott teamed up with their vendors to introduce greener solutions at no extra cost, e.g., eco-friendly pillows filled with materials made from recycled bottles, earth-friendly towels which do not need to be pre-washed, pens made of

75% recycled materials, low volatile organic compounds paint, which are safer and less polluting, Biodegradable laundry bags, laundry detergent that cuts the amount of phosphates released into wastewater (Hu, 2012).

Beyond the traditional return on investment calculation, a framework is needed to evaluate the costs, benefits and return on all activities under the three pillars of sustainability. Sloan et al. (2013) state, some activities are still difficult to quantify in terms of financial or monetary gains (e.g. reduction of carbon dioxide emission or greater biodiversity conservation) although progress in that field has been made over the past decade, by measuring the effect of their actions, owners and managers of accommodation facilities require a more holistic approach to their operations. Greater awareness of the impacts of hotel decisions on the broader eco-system, environmental or social, can ensure a shift from the tradition "make the most money in the shortest time" paradigm towards a long-term approach, which is the very basis of sustainability thinking (table 1).

We can see economics advantages in eco-friendly accommodation facilities, too. We state that reduced consumption of limited resources can signify reduced costs. It should be noted that if the accommodation facilities decide on environmental management, it can increase profits and investment in areas that will be directly beneficial to their guests (Scholz, Voráček, 2016).

Worldwide, accommodation facilities in First Class or Luxury Class begin or have already started to implement green management which results from the moral, social and political reasons. An individual hotel or guest house affects only a small part of the global environment but with suitable environmental measures can contribute to improving the environment at the local level.

Environmentally sustainable purchasing decisions in everyday buyer behavior, therefore, offer a chance to reduce this environmental impact by substituting higher-impact products with products which are environmentally friendlier. This not only produces benefits for the environment but also creates opportunities for businesses (Moser, 2015). The research found that hotels with a green orientation achieve higher profitability and market shares (Menguc, Ozanne, 2005), better levels of employee commitment (Maignan, Ferrell, 2001) and increased guest satisfaction (Luo, Bhattacharya, 2006). Green product and distribution programs furthermore positively affect a hotels' overall product – market performance, while green pricing and promotion practices are directly and positively related to a hotels' return on assets (Leonidou et al., 2013).

Accommodation facilities tend to apply differently in the selection of saving measure. Some hotels and guest houses make decisions according to what is currently the most urgent; others focus on measures that will bring

Table 1. Hotel sustainability performance indicators

ECONOMIC PERFORMANCE	ENVIRONMENTAL PERFORMANCE	SOCIAL PERFORMANCE
– hotel revenues – operating costs (implementation of ISO 14001, Eco-Management and Audit Scheme) – hotel profits (purchasing larger volumes and minimizing packaging and products that the hotel really needs, purchasing products from suppliers in the region, purchasing quality and truly useful products, purchasing of environmentally friendly products, and measuring guests´ satisfaction) – employee compensation – donations and other community investments – retained earnings – payments to capital providers and governments – proportion of spending on locally-based suppliers (purchase of raw materials and products in the region, support local infrastructure) – corporate philanthropy	– total direct and indirect greenhouse gas emissions – energy consumption by primary source (regulating heating and air conditioning, thermal insulation of buildings) – energy saved through conservation and efficiency improvements (low energy technologies, appliances min. class A (A +, A ++, A+++), compact fluorescent lamps) – initiatives to reduce energy consumption (utilization of geothermal energy and waste heat) – total water consumption (installation of single-lever mixers and faucet aerators, energy-saving shower heads, and two-stage flush toilets) – total water recycled and reused (grey-water reuse, rainwater harvesting) – waste output (waste separation in the background of hotels, sorting bins for plastic, paper, etc. in each room, reuse recycled materials, composting organic waste)	– incidents of discrimination – workforce by employment type – workflows and their control – promotion of environmental program to the public, – compliance with environmental principles by guests and employees (use of public transport and bicycles) – employee turnover rates (employment of local population) – workplace representation in health and safety committees – injury rates – employee training – programs for skills management and lifelong learning – percentage of employees receiving performance and career development reviews
INDICATORS BENEFITS	**INDICATORS COSTS**	
– Monetary ↓ energy costs ↓ waste and water costs ↑ revenues ↑ profits ↑ other operational savings – Non-monetary ↓ greenhouse gas and pollutant emissions ↑ biodiversity conservation ↑ employee health and productivity	– Investments in environmental management initiatives – Investments in economic performance initiatives – Investments in social engagement initiatives – Investments in stakeholder reporting	

Source: processed by the International Tourism Partnership, 2017 [06-10-2018].

the most significant savings at the lowest cost. A lot of accommodation facilities invest financial resources into the lighting, where they can attain significant savings. Incandescent bulbs are most often replaced with the compact fluorescent lamps. They reach about 80% less energy consumption compared to the incandescent lamp for the same light flux and also significantly lower power dissipation.

Pollution, waste, greenhouse gases and environmental hazards do not necessarily spring to mind when considering the hospitality and tourism

industries. According to estimates, an average hotel releases between 160-200 kilograms (kg) of carbon dioxide (CO_2) per square meter of room floor area per year and water consumption per guest per night is between 170-440 liters in the hotel in Luxury Class (Sloan et al., 2013). In comparison to the World Health Organization (WHO, 2011) there is a big difference. WHO suggests that a minimum of 7.5-15.0 liters per person per day are necessary for survival, with 2.5-3.0 liters for drinking and food, 2.0-6.0 liters for basic hygiene practices and 3.0-6.0 liters for basic cooking needs. We can state that this estimate of required water is for basic needs, and not a reflection of water "wants" for a much more full range of other purposes (Lundqvist, Gleick, 1997). On average, hotels produce 1 kilogram of waste per guest per night. The US Environmental Protection Agency calculates during a one-night stay in a hotel room 29.53 kg of CO_2 are generated on average in an average hotel. For an upscale hotel, emissions are higher at 33.38 kg CO_2 per room day.

Mainly chain hotels are also increasingly subscribing to eco-labeling and certification schemes (Hamele, 2004 in Mensah, 2013). In Europe, there are over 600 accredited facilities. We state that France is the country with the highest number of accommodation facilities (352) with an environmental certificate in 2015. Especially, The Region of Brittany, Provence-Alps-Côte d'Azur, Aquitaine, and Poitou-Charentes, there is the highest number of accommodation facilities with the environmental certificate of the European Union – The Flower. There are also known other environmental labels: Audubon Green Leaf, Building Research Establishment Environmental Assessment Method (BREEAM), Certified Green Restaurants, Eco Hotels Certified (EHC), Green Globe Certification, Green Key, Green Key Eco-rating Program, Green Seal, Green Tourism Business Scheme, Leadership in Energy and Environmental Design (LEED), etc.

The eco-label certification plays an important role in visitors' decision-making processes. A vast majority of visitors staying in spas and wellness hotels consider eco-labels to be a reliable criterion for choosing environmentally friendly service quality. An eco-label attracts tourists with higher environmental expectations as well as higher incomes. Environmentally conscious visitors are willing to pay a premium to obtain hotel service quality with eco-components. The managers can use eco-label certification or environmentally oriented behavior and practices as marketing tools to reach environmentally conscious visitors (Bastič, Gojčič, 2012).

On the other hand, for accommodation facilities, it is not easy to implement green management. Managers even though start to be creative of the utilization of existing materials and convert to efficient and environmentally friendly (Scholz, Voráček, 2016).

Research methods

This paper aims to analyze the application of environmental measures in selected accommodation facilities in Bulgaria focusing on the city of Sofia. We also set a research question: Which environmental measures are most used in the surveyed hotels?

There were used primary data collected by questionnaire survey and secondary data. The questionnaire survey consisted of twelve questions. They were mostly closed and some were half open questions. The questionnaires were in English and Bulgarian. At the end of the questionnaire, there were three segmentation questions and respondents had space for their views and comments. The primary survey was conducted in Sofia, Bulgaria. We used PAPI and CAWI methods. Paper and pencil interviewing (PAPI), data obtained from the interview is filled in on a paper form using a pencil (Baker, 1992). Computer-assisted web interviewing (CAWI) is an Internet surveying technique in which the interviewee follows a script provided in a website. The questionnaires are made online for creating web interviews. The website can customize the flow of the questionnaire based on the answers provided, as well as information that is already known about the respondent. It is considered to be a cheaper way of surveying since one does not need to use respondents to hold surveys unlike computer-assisted telephone interviewing (Reips, 2000). The survey was conducted from May until June 2018. In the city of Sofia, there are located 108 hotels. We contacted all of them, especially their managers or owners; 89% of them answered willingly. We used the methods of scientific work; and, i.e., the analysis method (also Correspondence analysis – CA), a method of generalization, mathematical, and statistical methods. Using graphic tools of this CA, it is possible to describe an association of nominal or ordinal variables and to obtain a graphic representation of relationship in multidimensional space – for the readers; it is easier to understand. The analysis provides further evidence that dependencies exist between variables.

Correspondence analysis (CA) is a multivariate statistical technique. It is conceptually similar to principal component analysis but applies to categorical rather than continuous data. In a similar manner to principal component analysis, it provides a means of displaying or summarizing a set of data in a two-dimensional graphical form (Zámková, Prokop, 2014).

All data should be non-negative and on the same scale for CA to be applicable, and the method treats rows and columns equivalently. It is traditionally applied to contingency tables – CA decomposes the chi-squared statistic associated with this table into orthogonal factors. The distance among single

points is defined as a chi-squared distance. The distance between i-th and i'-th row is given by the formula 1.

$$D(i,i') = \sqrt{\sum_{j=1}^{c} \frac{\left(r_{ij} - r_{i'j}\right)^2}{c_j}}, \quad (1)$$

where:

r_{ij} are the elements of row profiles matrix R and weights,

c_j are corresponding to the elements of column loadings vector cT, which is equal to mean column profile (centroid) of column profiles in multidimensional space.

The distance between columns j and j' is defined similarly, weights are corresponding to the elements of the row loadings vector r and sum over all rows. In correspondence analysis we observe the relation among single categories of two categorical variables. Result of this analysis is the correspondence map introducing the axes of the reduced coordinates system, where single categories of both variables are displayed in graphic form. The aim of this analysis is to reduce the multidimensional space of row and column profiles and to save maximally original data information. Each row and column of correspondence table can be displayed in c-dimensional (r-dimensional respectively) space with coordinates equal to values of corresponding profiles. The row and column coordinates on each axis are scaled to have inertias equal to the principal inertia along that axis: these are the principal row and column coordinates (Hebák, 2007).

Results of the research

Sofia is the capital and largest city of Bulgaria. The city of Sofia is also the most visited tourist destination in Bulgaria besides coastal and mountain alternatives. Its area is 492 sq. km and is divided into 24 administrative districts, the most populous of which are Lyulin and Mladost. The population of the capital city numbers 1.33 million inhabitants, and it is almost one fifth (18.6%) of the population of Bulgaria. There were located 485 accommodation facilities; 114 of them were in the class A and the rest (371) were in the class B. Based on their location, there is apparent concentration of accommodation facilities in the central part of the city as well in the southern peripheral districts.

The distribution of the different types of accommodation facilities is traditionally characterized by a significant predominance of guest rooms, hotels, guest suites, and family run hotels. Guest rooms represent one-third of all accommodation facilities but they have less than 5% of the bed places, while hotels represent 22% of all accommodation facilities but have almost three quarters (72%) of the total of beds in accommodation facilities (table 2).

Table 2. Categorized accommodation facilities on the territory of Sofia

TYPE OF AF	Number of facilities	Number of rooms	Number of beds
AF – class A	114	7,797	13,763
Hotel	108	7,681	13,535
Motel	3	72	143
Holiday village	1	20	40
Tourist village	0	0	0
Villa	2	24	45
AF – class B	371	2,277	4,965
Boarding house	18	350	711
Holiday house	3	58	116
Family-run hotel	61	767	1,493
Guest room	161	416	899
Guest house	25	151	359
Bungalow	2	12	35
Campsite	0	0	0
Hut	9	106	361
Guest suite	82	259	638
Hostel	10	158	353
Total	485	10,074	18,728

Note: AF–accommodation facilities.
Source: processed by Sofia Tourism Administration [06-10-2018].

In our research, we focused on hotels only. In Sofia, there are located 108 hotels, and we contacted all of them, especially their managers or owners; 89% of them answered willingly. The sample of surveyed hotels by class looked follows; Tourist class 3%, Economy class 7%, Standard class 41%, First Class 41%, and Luxury class 8%. It is important to highlight that the accommodation facilities in First Class and Luxury class represent scarcely

10% of all accommodation facilities on the territory of Sofia. On the other hand, they also have almost one half (46%) of the total number of beds in the capital.

The surveyed hotels in the Tourist class had mostly 5-20 rooms, in the Economy class 41-60 rooms, in the Standard class 21-40 rooms, in Class First Class 61-90 rooms, and in the Luxury class, it was mostly about hotels with more than 100 rooms (figure 1).

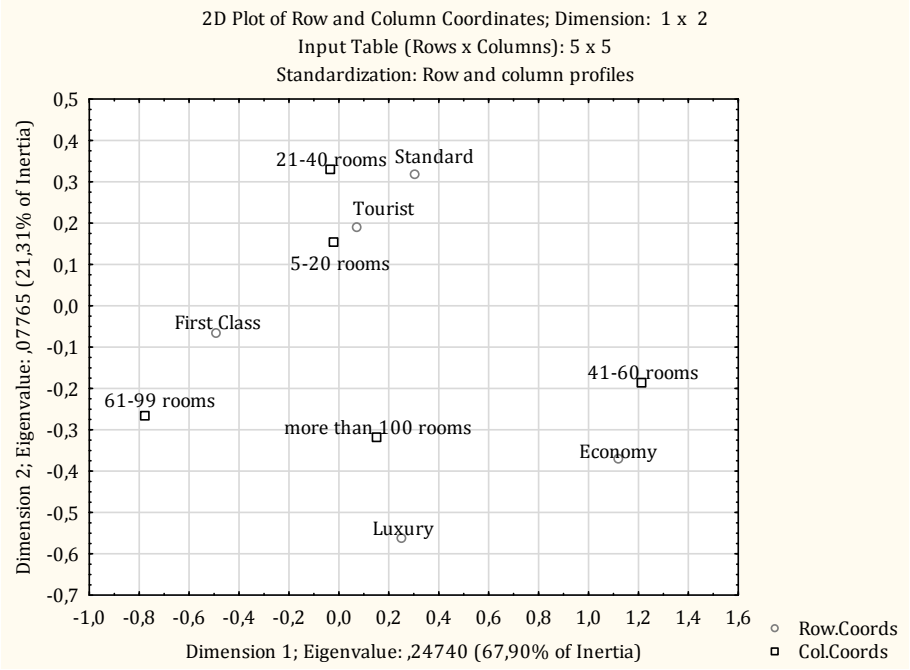

Figure 1. Surveyed hotels and the most frequent number of rooms

Source: author's own work processed by Statistica program [06-10-2018].

Environmental measures were discussed with experts in ecology area and environmental sciences. These measures were selected on the basis of a pilot survey among 45 hotel managers or owners in Czechia. We had to keep only basic environmental measures because managers and owners were not interested in these hospitality trends and had only heard about some of the measures for the first time. We also carried out a pilot survey in Bulgaria, but we encountered a significant language barrier. The questionnaire was therefore translated by a native speaker from Czech into Bulgarian. The English version of the questionnaire was not filled in by managers or owners.

Generally, the surveyed hotels had the best results with compact fluorescent lamps and LED lamps. Hotels in the Tourist class carried two environ-

mental measures only (sorting containers and dual flush toilets). On the other hand, hotels reached better results with sorting containers (66%) than other class besides Luxury class (table 3).

Good results were reached by hotels in the Economy class with compact fluorescent lamps and LED lamps (71%) and saving appliances (57%). The surveyed hotels did not apply almost one half (44%) of environmental measures. Unsatisfactory results were noticed with measures such as heating regulation in each room individually, changing linen and towels on request, cleaning products and laundry detergents friendly to the environment, or informing guests about environmental efforts (each 14% only).

Hotels in the Standard class achieved very good results with compact fluorescent lamps and LED lamps (93%), most measures had the average values, e.g., changing linen and towels on request (66%), central lighting switches in rooms (62%), minimizing the use of disposable products (62%), and windows thermal insulation (59%). Insufficient results were found by more one half (57%) of measures.

Very good results were noticed by hotels in the First Class with compact fluorescent lamps and LED lamps (100%), saving appliances (79%), and windows thermal insulation (74%). It was surprising that no hotel was interested in the individual heating control installed in the rooms. If the room is not occupied by the hotel guests, it is not environmentally friendly to use the air conditioning or to heat in the room. It is completely sufficient if the heating or air conditioning is turned on a few hours before the expected arrival of the guests. The worst results were shown in the providing of information to the guests about sorting bio-waste (0%), preference for products with the "eco" label (18%), and reducing the flow of faucet aerators or shower heads (28%).

Hotels in the Luxury reached outstanding results with compact fluorescent lamps and LED lamps, central lighting switches in rooms, using recycled paper, and informing guests about environmental efforts (each 100%). Other measures were primarily on the average or high level.

The managers or owners of the surveyed hotels stated that green management implementation in accommodation facilities providing a competitive advantage over other accommodation facilities, cost reduction, increased sales, guest benefits, and environmental improvements. On the other hand, more than one quarter (26%) of the hotels were interested in the environmental certificate. They were mainly hotels in the First Class and Luxury class.

Table 3. Environmental measures used in accommodation facilities in the city of Sofia [%]

Environmental measures/ Hotels by class	Tourist	Economy	Standard	First Class	Luxury
sorting containers	67	43	55	56	88
sorting bio-waste	-	-	7	-	38
windows thermal insulation	-	-	59	74	88
heating regulation in each room individually	-	14	55	54	75
saving appliances	-	57	34	79	63
compact fluorescent lamps and LED lamps	-	71	93	100	100
central lighting switches in rooms	-	29	62	72	100
using recycled paper	-	-	31	56	100
reducing the flow of faucet aerators or shower heads	-	-	7	28	63
dual flush toilet	33	29	28	56	63
changing linen and towels on request	-	14	66	69	88
cleaning products and laundry detergents friendly to the environment	-	14	14	53	75
minimizing the use of disposable products	-	-	62	38	25
giving priority to products with the „eco" label	-	-	10	18	38
green management employees education	-	-	3	54	63
informing guests about environmental efforts	-	14	3	100	100

Source: author's own work processed by Statistica program [06-10-2018].

Discussion

The findings provide us with answers to the research question: Which environmental measures are most used in the surveyed hotels? Generally, the surveyed hotels had the best results with compact fluorescent lamps and LED lamps. Hotels in the Tourist class carried two environmental measures only (sorting containers and dual flush toilet). On the other hand, hotels reached better results with sorting containers (66%) than any other class besides Luxury class.

Following the world trends in tourism, Sofia city invests in the development of its accommodation facilities, taking into consideration the sustainable development of the hotels. In general, our recommendation is to invest more funds towards faucet aerators and water saving shower heads and sorting containers. It is utterly inadequate that each class reach very low values.

The faucet aerator achieves great results and costs no more than 10 euro, and water savings are in the range of 48% to 84%. This is in line with results from previous studies in the field of green management in accommodation facilities in Czechia and Slovakia (Patúš, Gúčik, 2004; Scholz, Linderová, 2016). We have to state, that not so many surveyed hotels were not interested in sorting containers and sorting bio-waste. Pham Phu et al. (2018) say that 72% hoteliers in Hoi An, a tourism city in the center of Vietnam, disliked storing waste in their hotels, while 58% of the hotels thought that they lacked information and skills in recycling. Some hotel managers explained that recycling took more time and labors (42% and 22%) and was unsanitary (18%). It was a surprising fact because there is a law about sorting waste and many hotels do not recycle at all. We agree that mentioned accommodation facilities should definitely invest in the green initiatives (Chan, Lam, 2003; Bohdanowicz, 2005; Ready, Wilkes, 2015).

Limitations

This paper contributes to the research of hotels' environmental measures in some aspects, but there are several limits, too. On the other hand, mentioned limits provide directions for further research.

Firstly, our research cannot be generalized. We were merely interested in hotels, and the research was conducted in the city of Sofia only. We would like to investigate other important towns in Bulgaria (e.g., Bourgas, Varna, Plovdiv, etc.) and compare it with the results of Sofia city. Subsequently, we would like to focus on other towns and regions and map the adoption of environmental measures in accommodation facilities in Bulgaria. We also mapped accommodation facilities and their environmental measures in Czechia. We think that a comparison of these two states would be desirable.

Secondly, an in-depth analysis was not realized with the environmental measures. It was not stated there whether the hotels were focused on the particular environmental measures or not.

Finally, in our future research, we would like to focus on environmental measures individually (e.g., analyzing solid waste practices in a hotel – categories such as paper, cardboard, garden waste, kitchen and food waste, tissues, PET, nylon, plastic, glass, etc.). In our opinions, the results would have a more meaningful value.

Conclusions

This paper contributes to research by furthering understanding of the particular relevance of factors determining green management implementation. Selected hotels in the city of Sofia attained average results. With the rise of environmental consumption, guests are also increasingly critical of hotel practices, especially in cases where it is difficult to verify that environmental themes take precedence over that cost. The First Class and Luxury class hotels had better care of the environment in comparison with other classes.

The main reasons for the adoption of environmental measures are also guests. Some of them generally recognize the practices of eco-friendly hotels by showing their willingness to pay more, sacrificing part of their comfort and luxury during the implementation of environmental measures. Although their demand for eco-friendly accommodation is still relatively low, some guests are looking for hotels that demonstrate the use of just environmental practices. Therefore, it is essential to have a better understanding of the behavior of the guests regarding the use of eco-friendly accommodation so that the marketing and operational strategies that influence the behavior of the participants in tourism can be successfully implemented.

Green management extends the portfolio of services in the accommodation facilities. We can state that a greener workplace can mean a lighter ecological footprint, a healthier and more productive place to work, and finally better conditions for employers, employees, and guests.

Literature

Ali Y. et al. (2008), *Potential of energy savings in the hotel sector in Jordan,* "Energy Conversion and Management" No. 11(49), p. 3391-3397

Baker R.P. (1992), *New technology in survey research: Computer-assisted personal interviewing (CAPI),* "Social Science Computer Review" No. 2(10), p. 145-157

Bastič M., Gojčič S. (2012), *Measurement scale for eco-component of hotel service quality,* "International Journal of Hospitality Management" No. (31), p. 1012-1020

Bird R. et al. (2007), *What corporate social responsibility activities are valued by the market?,* "Journal of Business Ethics" No. 2(76), p. 189-206

Bohdanowicz, P. (2005), *European Hoteliers' Environmental Attitudes: Greening the Business,* "Cornell Hotel and Restaurant Administration Quarterly" No. 2(46), p. 188-204

Butler J. (2008), *The Compelling „Hard Case" for „Green" Hotel Development,* "Cornell Hospitality Quarterly" No. 3(49), p. 234-244

Chan W.W., Lam, J.C. (2001), *Environmental accounting of municipal solid waste originating from rooms and restaurants in the Hong Kong hotel industry*, "Journal of Hospitality and Tourism Research" No. 4(25), p. 371-385

Chan W.W., Lam, J.C. (2003), *Energy-saving supporting tourism sustainability: A case study of hotel swimming pool heat pump,* "Journal of Sustainable Tourism" No. 1(11), p. 74-83

Chen H., Hsieh T. (2011), *An environmental performance assessment of the hotel industry using an ecological footprint,* "Journal of Hospitality Management and Tourism" No. 1(2), p. 1-11

Deng S., Burnett J. (2002), *Water use in hotels in Hong Kong,* "Hospitality Management" No. 1(21), p. 57-66

Enz C.A., Siguaw J.A. (1999), *Best hotel environmental practices*, "Cornell Hotel and Restaurant Administration Quarterly" No. 5(40), p. 72-77

Gössling S., Hall C.M., Scott D. (2015), *Tourism and Water,* Bristol

Gupta A., Dash S., Mishra A. (2019). *All that glitters is not green: Creating trustworthy ecofriendly services at green hotels,* "Tourism Management" No. (70), p. 155-169

Hebák P. (2007), *Vícerozměrné statistické metody 3,* Praha

Hillary R. (2004), *Environmental management systems and the smaller enterprise,* "Journal of Cleaner Production" No. 6(12), p. 561-569

Hu H. (2012), *The Effectiveness of Environmental Advertising in the Hotel Industry,* "Cornell Hospitality Quarterly" No. 2(53), p. 142-164

International Tourism Partnership (2017), *Sustainable Supply Chains*, www.tourismpartnership.org [05-10-2018]

Ivanov S., Ivanova M., Iankova K. (2014), *Sustainable tourism practices of accommodation establishments in Bulgaria: an exploratory study,* "Tourismos: an international multidisciplinary journal of tourism" No. 2(9), p. 175-205

Khemiri A., Hassairi M. (2005), *Development of energy efficiency improvement in the Tunisian hotel sector: a case study,* "Renewable Energy" No. 6(30), p. 903-911

Lee H.R. Jai T.M., Li X. (2016). *Guests' perceptions of green hotel practices and management responses on TripAdvisor,* "Journal of Hospitality and Tourism Technology" No. 2(7), p. 182-199

Leonidou C.N., Katsikeas C.S., Morgan N.A. (2013), *Greening' the marketing mix: do firms do it and does it pay off?,* "Journal of the Academy of Marketing Science" No. 2(41), p. 151-170

Linderová I., Janeček P. (2017), *Accessible Tourism for All – Current State in the Czech Business and Non-Business Environment,* "E&M Economics and Management" No. 4(20), p. 168-186

Luo X., Bhattacharya C.B. (2006), *Corporate social responsibility, customer satisfaction, and market value,* "Journal of Marketing" No. 4(70), p. 1-18

Lundqvist J., Gleick P. (1997), *Sustaining Our Waters into 21st Century,* Stockholm

Maignan I., Ferrell O.C. (2001), *Antecedents and benefits of corporate citizenship: an investigation of French businesses,* "Journal of Business Research" No. 1(51), p. 37-51

Menguc B., Ozanne L.K. (2005), *Challenges of the 'green imperative': a natural resource-based approach to the environmental orientation – business performance relationship,* "Journal of Business Research" No. 4(58), p. 430-438

Mensah I. (2006), *Environmental management practices among hotels in the greater Accra region,* "International Journal of Hospitality Management" No. 3(25), p. 414-431

Mensah I. (2013), *Different Shades of Green: Environmental Management in Hotels in Accra,* "International Journal of Tourism Research" No. 5(169), p. 450-461

Moser K.A. (2015), *Thinking green, buying green? Drivers of pro-environmental purchasing behavior,* "Journal of Consumer Marketing" No. 3(32), p. 167-175

Pan S.Y. et al. (2018), *Advances and challenges in sustainable tourism toward a green economy,* "Science of the Total Environment" No. 635, p. 452-469

Patúš P., Gúčik M. (2004), *Manažment ubytovacej prevádzky hotela,* Banská Bystrica

Petkova E. (2017), *Environmental practices of hotels businesses,* in: Asenova M. (ed.), *Contemporary tourism – traditions and innovations: proceedings of the international scientific conference,* Sofia, p. 94-108

Pham Phu S.T., Hoang M.G., Fujiwara T. (2018), *Analyzing solid waste management practices for the hotel industry,* "Global Journal of Environmental Science and Management" No. 1(4), p. 19-30

Pizam A. (2009), *Green hotels: A fad, ploy or fact of life?,* "International Journal of Hospitality Management" No. 1(28), p. 1

Reddy M.V., Wilkes K. (2015), *Tourism in the Green Economy,* New York

Robinot E., Giannelloni J.L. (2010), *Do hotels' "green" attributes contribute to customer satisfaction?,* "Journal of Services Marketing" No. 2(24), p. 157-169

Reips U.D. (2000), *The Web Experiment Method: Advantages, disadvantages, and solutions,* in: Birnbaum M.H. (ed.), *Psychological experiments on the Internet,* San Diego, p. 89-118

Sarkis J. (2018), *Sustainable and green supply chains: advancement through Resources,* "Conservation and Recycling" No. 134, p. A1-A3

Scholz P., Linderová I. (2016), *Green management v ubytovacích zařízeních jako faktor regionálního rozvoje v Kraji Vysočina,* in: Klímová V., Žítek V. (eds), *Sborník příspěvků z XIX. mezinárodního kolokvia o regionálních vědách,* Brno, p. 1095-1101

Scholz P., Voráček J. (2016), *Organizational culture and green management: innovative way ahead in hotel industry,* "Measuring Business Excellence" No. 1(20), p. 41-52

Shan W., Wang J. (2018), *Mapping the landscape and evolutions of green supply chain management,* "Sustainability" No. 3(10), p. 1-23

Sloan P., Legrand W., Chen, J.S. (2013), *Sustainability in the Hospitality Industry: Principles of Sustainable Operations*, New York

Tran B. (2009), *Green Management: The Reality of Being Green in Business,* "Journal of Economics, Finance and Administrative Science" No. 27(14), p. 21-45

World Health Organization (2011), *Water,* www.who.int [05-10-2018]

Wie S.H., Shanklin C.W. (2001), *Cost effective disposal methods and assessment of waste generated in foodservice operations,* "Foodservice Research International" No. 1(13), p. 17-39

Zámková M., Prokop M. (2014), *Comparison of consumer behavior of Slovaks and Czechs in the market of organic products by using correspondence analysis*, "Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis" No. 4(62), p. 783-795

Michał **BOŁTRYK** • Krzysztof **GRANATYR** • Natalia **STANKIEWICZ**

ECOLOGICAL ASPECTS IN THE APPLICATION OF GEOPOLYMER COMPOSITES ON ROAD SURFACES

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ABSTRACT: The article presents, based on preliminary research, the possibility of using a geopolymer composite as a protective layer of engineering structures, which protects it against the impact of harmful factors of the surrounding environment as well as the effects of mechanical interactions. The most common solutions of such layers are insulations based on synthetic feeds, bitumens – products obtained in the process of processing crude oil. The ecological aspect of the implementation of geopolymer materials and the process of their production are presented. Technological problems in the application of geopolymer protective layers on an industrial scale were considered. The paper presents the results of own research on the influence of the geopolymer composite layer thickness on adhesion to concrete based on Portland cement, in which the compaction method of the composite was considered.

KEY WORDS: geopolymers, CO_2 emission, cement, binder

Introduction

The cement industry is responsible for 5% of global CO_2 emissions, which accounts for almost 20% of industrial emissions. Every ton of cement produced emits about 0.81 tons of CO_2 to the atmosphere (Benhelal et al., 2012; Siemieniuk, Szatyłowicz, 2018). In a short time, cement plants will be noticed as one of the main culprits of global warming, which will result in the imposition of new emission fees, as a result of which the price of Portland clinker can increase by up to several dozen percent. An excellent alternative to Portland cements seems to be geopolymer binders. They are characterized by better properties compared to concrete obtained from cements based on Portland clinker. These properties include: high compressive and bending strength, including high early strength, good chemical and thermal resistance, high degree of adhesion with steel, minimal shrinkage, no corrosion of reinforcement. In addition, the production of geopolymer, including all raw materials needed to obtain it, causes 4-8 times less CO_2 emissions (Mikuła et al., 2014; Zhang, 2015). One of the materials used to obtain it is fly ash which is a byproduct of combustion of coal dust in power units, and also created in fluidized bed boilers. This makes the technology of geopolymer concrete "green" with a large development potential.

The process of obtaining and the structure of geopolymers

The synthesis of geopolymers consists in the alkaline activation of pozzolanic material. The material may be primarily fly ash from the combustion of coal dust, the activator is a solution of a strong base (NaOH or KOH) with sodium or potassium silicate. Obtained paste hardens after activation at elevated temperature giving an amorphous material, reminiscent of concrete based on Portland cement, but with other properties, i.e. high early strength, good chemical corrosion resistance, high strength at high temperatures, frost resistance (Hynowski et al., 2017).

The process of binding a geopolymeric paste is based on the polycondensation reaction, during which tetrahedrons $[SiO_4]^{4-}$, $[AlO_4]^5$ form amorphous structures, and the presence of Na^+ or K^+ ions in the chambers balances the structure charge. The stages of the formation of a composite based on geopolymers run differently than in cement concrete. The polymerization process consists of successive reactions, not permeating as in the case of classical cement bonding. In addition, the polymerization and hardening reaction of the geopolymer composite is not a spontaneous reaction and requires the heat to be supplied from the outside, usually heated in the 30-100°C range.

The synthesis process is usually presented in the literature via two reaction equations (Zhang, 2015; Davidovits, 1994):

$$n(Si_2O_5, Al_2O_2) + 2nSiO_2 + 4nH_2O \xrightarrow{NaOH,KOH} n(OH)_3 - Si - O - Al(OH)_2^{(-)} - O - Si - (OH)_3 \quad (1)$$

$$n(OH)_3 - Si - O - Al(OH)_2^{(-)} - O - Si - (OH)_3 \xrightarrow{NaOH,KOH} (Na,K)^{(+)} - \left(\begin{array}{c} | \\ Si - O - \\ | \\ O \\ | \end{array} \begin{array}{c} | \\ Al^{(-)} - O - \\ | \\ O \\ | \end{array} \begin{array}{c} | \\ Si - O - \\ | \\ O \\ | \end{array} \right) + 4nH_2O \quad (2)$$

Substrates Si_2O_5, Al_2O_2, SiO_2 are firstly dissolved by alkali hydroxide solutions, such as NaOH and KOH, to release reactive aluminate and silicate oligomers, represented by $(OH)_3$-Si-O-Al$(OH)_2$ and $(OH)_3$-Si-O-Al$(OH)_2^{(-)}$-O-Si-$(OH)^3$ (1). In the alkaline environment, the polymerization reaction occurs along with the cross-linking of the structure (2).

Ecological aspect of the implementation of engineering products and constructions from geopolymers

The production of Portland clinker is a highly energy intensive process, the temperatures prevailing in the rotary kiln reach 1500°C (Kurdowski, 1981), however in this process it is not the fuel emission that has the largest share in CO_2 emissions, but the raw material emission (Duda, Tamasiak, 2015). This is because raw materials for the production of Portland clinker are dominated by carbonates – above all calcium carbonate, which is decarbonising at a temperature of approx. 850°C. The demand for cements based on Portland clinker is still growing. Therefore, the cement industry is becoming one of the main emitters of anthropogenic CO_2. The geopolymer composite has a great chance of reducing greenhouse gases in this industry sector, the synthesis of which consumes twice less energy with 4-8 lower CO_2 emissions than in the case of Portland clinker (figure 1).

An important aspect of geopolymer concrete technology is the use of incidental combustion products (ICP) in the process of obtaining geopolymer. ICP can include fly ash from conventional coal boilers with well-known properties as well as fly ash from fluidized bed boilers. The latter due to the unstable chemical composition of the fuel used for firing the boiler are characterized by variable parameters, which is why they are currently classified as arduous waste.

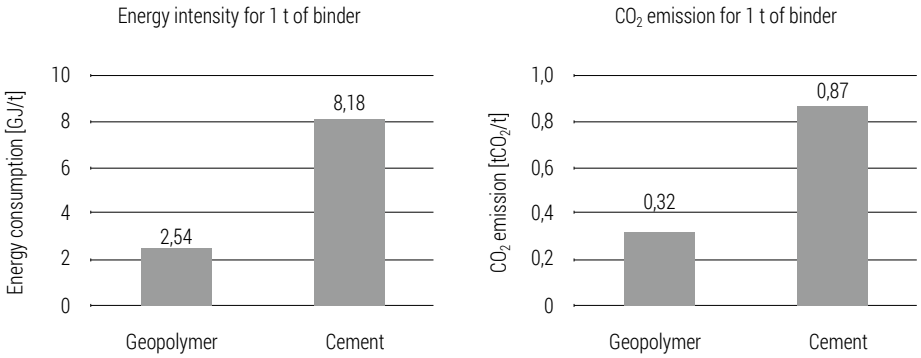

Figure 1. Comparison of CO_2 emissions and energy consumption in the production of cement and geopolymer binders

Source: Provis, Van Deventer, 2009, p. 195.

At Bialystok University of Technology, research on thin protective layers of concrete structures was carried out, resulting in patent protection of the number PL 230045 B1 "Method of ensuring durability of concrete structures and concrete mix in the protective layer" (Bołtryk et al., 2016). Further research is carried out to replace concrete based on Portland cement with geopolymer concrete and to use it as protective layers of road surfaces, both asphalt and concrete. This layer, protecting the road surface against harmful environmental factors and mechanical impacts, will prolong its service life, which in turn will reduce the consumption of bitumen in the form of asphalt or in the case of concrete Portland cement.

Own research in the field of thin protective layers from geopolymers

The aim of the conducted preliminary research was to assess the possibility of using geopolymer mortars as thin protective layers of cement composites. The research consisted in examining the dependence of the adhesion of the geopolymer layer to the cement concrete on its thickness. Standard sand was used as the aggregate. The activator used was a mixture of sodium water glass with a molar modulus of $1.6 < MR \leq 2.6$ with a substance content of approx. 35-43% ($Na_2O + SiO_2$) and a 14 molar NaOH solution. The mass ratio of the sodium silicate solution to the sodium hydroxide solution Na_2SiO_2/NaOH was constant at 2.5. However, the ratio of activator to fly ash was 0.5. The fly ash used came from the combustion of coal dust in the

Ostrołęka Heat and Power Plant. The chemical composition and physical properties of the ash are presented in the table (table 1). The plain concrete used in the composite was designed for class C30/37 based on Portland cement CEM I 42.5 R (table 2) with a w/c ratio of 0.5. The thickness of the tested layers was 1.5 cm, 3.0 cm and 4.5 cm, respectively.

Table 1. Chemical composition and physical properties of fly ash

Component	% by weight
SiO_2	54,6
Reactive SiO_2	42,36
Al_2O_3	25,3
Fe_2O_3	4,97
Na_2O	0,84
CaO	2,14
Reactive CaO	1,84
Free CaO	<0,03
K_2O	2,8
MgO	1,8
TiO_2	1,07
P_2O_5	0,55
SO_3	0,37
BaO	0,15
SrO	0,07
Mn_3O_4	0,06
Ignition losses	4,37
Humidity	0,12

Source: external laboratory [31-12-2018].

The samples were formed by two methods in steel cubic molds with a side of 100 mm. The first method (I) was done by compacting the geopolymer concrete layer on the bottom of the mold by 30 second vibration. Then the mold was supplemented with ordinary concrete, then vibrated with a steel piston for 30 seconds. In the second method (II), both the geopolymer layer and the ordinary concrete were successively vibropressed for 30 seconds (figure 2).

Table 2. Technical parameters of Portland cement CEM I 42.5R used in the tests

Properties	Requirements according to the standard PN-EN 197-1	Test results	The basis of tests
Specific surface (Blaine method) [cm^2/g]	-	4124	PN-EN 196-6
The beginning of binding [min]	≥ 60	184	PN-EN 196-3
End of binding [min]	-	242	PN-EN 196-3
Change in volume [mm]	≤ 10	1,0	PN-EN 196-3
Compressive strength [MPa] - after 2 days: - after 28 days:	 ≥ 20,0 ≥ 42,5 ≤ 62,5	 30,1 60,2	PN-EN 196-1
SO_3 content [%]	≤ 4,0	2,95	PN-EN 196-2
Cl content [%]	≤ 0,1	0,089	PN-EN 196-21
Cr(VI) soluble content [ppm]	≤ 2,0	0,18	PN-EN 196-10
Insoluble residue [%]	≤ 5,0	0,57	PN-EN 196-2
Ignition losses [%]	≤ 5,0	3,33	PN-EN 196-2

Source: https://www.cemex.pl/cement-czerwony.aspx [03-01-2019].

The composite molds were seasoned for 24 h on the grate above the water surface, then placed for another 24 h in a laboratory dryer at 65°C to accelerate the activation of the geopolymer and accelerate the hydration of concrete based on Portland cement. The seasoning method was aimed at assessing the possibility of shortening the time that should be allowed to allow the surface to be used in the summer season.

After a 48 h curring period, the samples were subjected to testing, which consisted in applying a shear force at the interface between the two layers carried with a steel bar. Previously, the samples (rotated by 90° in relation to the forming direction) were placed on the pressure plate of the testing machine (figure 3).

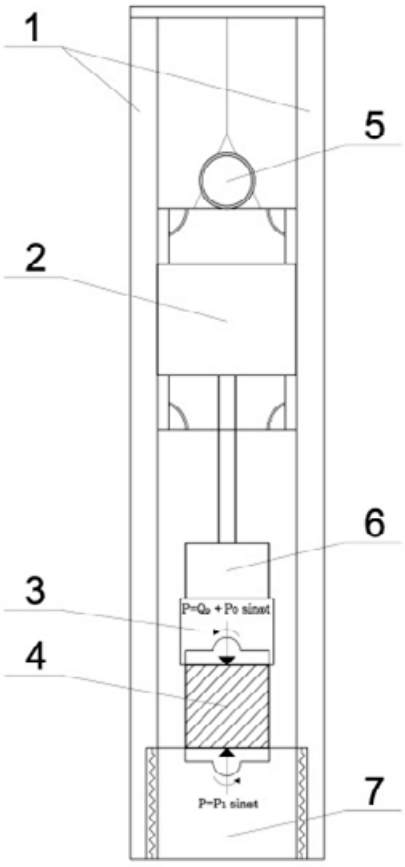

Figure 2. Schematic diagram of the vibrating station with vibropressing: Qp – pressure force, Po – force forcing the upper vibrator to vibrate, P1 – force forcing the vibrator to vibrate; 1 – guides, 2 – inertial load, 3 – extension, 4 – form, 5 – upper vibrator with adjustable force, 6 – pressure piston, 7 – bottom vibrator

Source: Falkowski, 2012, p. 27.

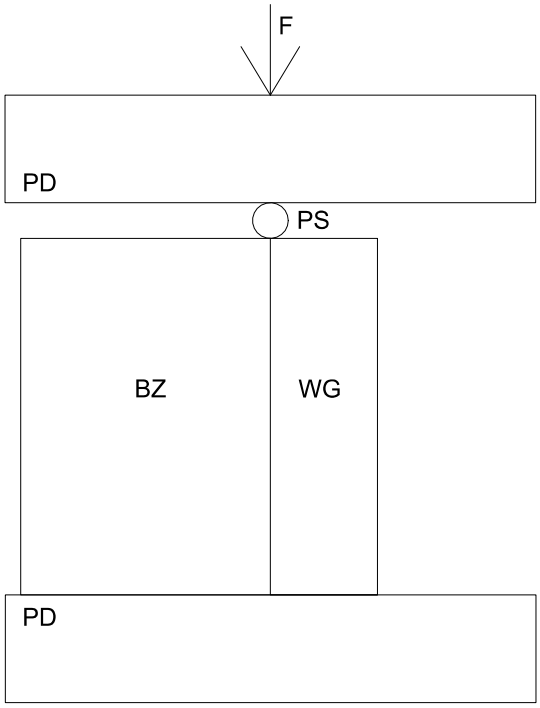

Figure 3. Scheme of the station for testing the adhesion between layers by splitting (PD – the press platens, BZ – ordinary concrete layer, WG – geopolymer layer, PD – steel bar carrying the load, F – the direction of load application)

Source: author's own work.

Results of the research

The results obtained are shown in the graph (figure 4). The dependence of the splitting force of the composite layer on both the compaction method and the thickness of the geopolymer layer is visible. Three samples were made and tested for each of the compaction methods. The average values of the destructive force of the combination of layers were: for a layer with a thickness of 1.5 cm: I method – 6.67 kN, II method – 14.0 kN; for the 3.5 cm layer: I method – 6.17 kN, II method – 19.17 kN; and for the 4.5 cm layer in the case of I method, 8.33 kN, and II, 35.83 kN.

In the case of the second compaction method, the mean values of shear force grow linearly with the increase of the geopolymer layer thickness, while with the application of the compaction method I the values differ slightly. It can be assumed, which requires further research, that better adhesion will be obtained by subjecting both layers to vibropressing.

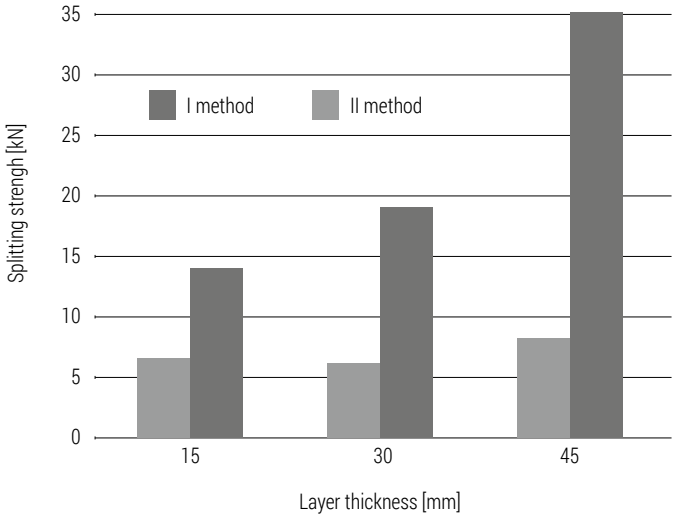

Figure 4. Graph of dependence of splitting force and compaction methods on geopolymer layer thickness

Source: author's own work.

Conclusions

Obtained results of preliminary tests on the application of geopolymers in the form of protective layers encourage further research on the use of geopolymer material as protective layers of concrete structures and road surfaces. At the further stage of testing, it is necessary to carry out tests such as: abrasion, roughness, thermal expansion, water absorption, frost resistance, compressive and tensile strength as well as stiffness of the obtained composite. An extremely important aspect is the development of the optimal technology of works, because the presented data unambiguously indicate that the value of the shear force needed to break the geopolymer protective layer is affected by both thickness and compaction method. When using this solution on an industrial scale, attention should be paid to the stability of the geopolymer embedment parameters to the structure being protected, because it will affect the quality of the obtained composite. The implementation of geopolymeric materials for general use will indirectly result in a decrease in anthropogenic CO_2 emissions and a reduction in the use of petroleum materials in construction.

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The contribution of the authors

All authors contributed equally to the manuscript.

Literature

Benhelal E., Zahedi G., Hashim H. (2012), *A novel design for green and economical cement 14 manufacturing,* "Journal of Cleaner Production" No. 22, p. 60-66

Bołtryk M., Stankiewicz N., Pawluczuk E. (2016), *Patent, Sposób zapewnienia trwałości konstrukcjom betonowym oraz mieszanka betonowa w warstwie ochronnej,* Polska PL 230045 B1

Davidovits J. (1994), *Properties of geopolymer cements*, First International Conference on Alkaline Cements and Concretes, Kiev

Duda J., Tamasiak J. (2015), *Redukcja emisji CO_2 w procesie produkcji cementu,* Konferencja Innowacje w Zarządzaniu i Inżynierii Produkcji p. 384-395

Falkowski K. (2012), *Technologia ochrony materiałowo-strukturalnej betonów cementowych w środowisku agresywnym, "*Civil and Environmental Engineering" No. 3, p. 25-31

Hynowski M. et al. (2017), *Wpływ granulowanego żużla wielkopiecowego na kształtowanie właściwości mechanicznych zaczynów geopolimerowych z popiołu krzemionkowego, "*Scientific Works of Institute of Ceramics and Building Materials" No. 34, p. 70-80

Kurdowski W. (1981), *Poradnik technologa przemysłu cementowego,* Warszawa

Mikuła J. et al. (2014), *Rozwiązania proekologiczne w zakresie produkcji.* Nowoczesne materiały kompozytowe przyjazne środowisku, part. 1, Politechnika Krakowska, Kraków

Provis L., Van Deventer J.S.J. (2009), *Geopolymers: structure, processing, properties and industrial applications,* New York

Siemieniuk J., Szatyłowicz E. (2018), *Zmniejszenie emisji CO_2 w procesie produkcji cementu*, "Civil and Environmental Engineering" No. 9, p. 81-87

Zhang M. (2015), *Geopolymer, Next Generation Sustainable Cementitious Material – Synthesis, Characterization and Modeling*, PhD thesis, Worcester Polytechnic Institute

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

PROBLEMATYKA OGÓLNOEKOLOGICZNA I SPOŁECZNA

Dariusz **PIEŃKOWSKI** • Wojciech **ZBARASZEWSKI**

THE CONCEPT OF CLIMATE RESILIENT ECONOMY FROM THE PERSPECTIVE OF LOCAL COMMUNITIES

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ABSTRACT: The concept of a climate-resilient economy appeared prominently in the 2015 economic considerations in the context of the Paris Agreement. However, the very concept of resiliency emerged in the 1970s in ecological research and was also widely considered from the perspective of socio-economic development. This paper presents the objectives of the European Union policy related to the creation of climate-resilient economies and the rationale behind the concept of resiliency. This analysis seeks to reveal differences between the resilient-oriented strategies of local rural communities in developed countries, based on the example of bioenergy villages, and in less-developed countries, using the example of reintroduced traditional farming. This research reveals the key strategies and benefits generated by the particular local communities.

KEY WORDS: resilience, European Union policy, climatic shocks, chinampa, waru-warus, bioenergy villages

Introduction

Significant signs of long-term climate change have been observed in recent years. The World Meteorological Organization recognized the last three years, i.e. 2015-2017, as the warmest in history, and its data confirms the long-term upward trend in global temperature. The average global temperature in 2017 was higher by 1.1°C than the average temperature in the pre-industrial period (WMO, 2018). The climate changes resulting from this increased temperature affect both human environments and the conditions of socio-economic development. The Paris Agreement, which came out of the 2015 conference of the United Nations Framework Convention on Climate Change, is considered to be crucial for disseminating the concept of a climate-resilient economy (Bahadur et al., 2016; Ninan, Inoue, 2017). However, a widely understood concept of resilient economy was developed in economics much earlier. In the broader meaning, resilience means "*the capacity for a complex system to survive, adapt, evolve and growth in the face of turbulent change"* (van Opstal, 2007, p. 8). With regard to economic systems, it can be defined as the *"ability of the system to withstand either market or environmental shocks without losing the capacity to allocate resources efficiently (the functionality of the market and supporting institutions), or to deliver essential services (the functionality of the production system)"* (Perrings, 2006, p. 418).

The concept of a climate-resilient economy challenges local communities, which are an important link in the process of adaptation to environmental changes, and at the same time constitute far-open requirements based on very specific local conditions for development determined by very specific external (natural) and internal (socio-economic) environments. This is a creative process and, as in the case of most adaptation processes, it *"contains an element of freedom but also a risk of failure"* (Dobzhansky, 1959, p. 76). The key element is therefore to understand the specificity of the goals set in the creation of climate-resilient socio-economic systems. These general postulates should be directly implemented into practice due to specific conditions of particular communities.

This paper aims to present the concept of resiliency for rural areas from the perspective of the best practices identified in the world. It analyses the basic political postulates, the concept of climate-resilient economies and the key principles identified in research. There are two hypotheses stated in this paper: 1) some resilient economic activities were originally successfully developed in ancient times or rural areas and can be reintroduced, particularly in developing countries and 2) industrialized societies will need to develop new socio-economic structures to work out new strategies based on their technological advancements. The latter is mostly due to the different

stages of their economic development and the structural transition of the rural areas that has resulted in their having a high share of non-economic activities. The case studies identified in the literature will be analysed to show the key successful strategies of resilient economies. It will help to understand the determinants of resiliency and their relationship to sustainable development. Two types of economic strategies for rural areas have been pointed out in the context of climate-resilient economies. This research helps to identify the differences and complexity of the strategies, as well as the key features that have determined the success of these economies.

Stability, resiliency and economy

The origin of the concept of resiliency is strongly related to the natural sciences and the evolutionary view of economic processes. Holling (1973) pointed out that resilience differs from stability in that stability refers to the ability of a system to remain within equilibrium, while resilience has a broader meaning, which is the *"persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist"* (Holling, 1973, p. 17). The key is, in particular from the perspective of modern anthropogenic systems whose ecological balance is difficult to maintain, that the system can be highly resilient, but have low stability. This concept seems important to accept in real situations, where there are highly changed and often unbalanced ecological and socio-economic systems. Both from the perspective of increasingly rapid climate change and economic shocks caused in various parts of the world that lead to crises on a global scale, the resiliency concept becomes more important equilibrium-based approaches typical of the debate of neoclassical economists (Pike, Dawley, Tomaney, 2010).

Perrings (2006) points to four areas of understanding resiliency:

- *latitude* – the ability to tolerate different shocks that do not cause the loss of functionality of an economy,
- *resistance* to changes,
- *precariousness* – understood as not exceeding of the economic stability limits,
- *panarchy* related to adaptive cycles of individual subsystems – the highest risk exists when various economic subsystems are in the same, least shock-resistant point of the adaptive cycle (hypercoherency).

The mechanisms of adaptation to these exogenous shocks are characteristic for individual economic systems. Moreover, at the same time there are many different resilient states for a single system (Perrings, 2006; Pisano, 2012).

A climate-resilient economy is understood as having appropriate political regulations in terms of the place, structure and functioning of the infrastructure, enabling reduction of vulnerability to the physical consequences of climate change. Lowering the sensitivity to threats associated with these changes is related to the use of both "soft" (socio-economic) and "hard" (technological) tools (Vallejo, Mullan, 2017). These postulates are related to the sustainable development policy and, in the context of these assumptions, indicate that it is necessary to reduce the emission of harmful substances through economic growth and reduction of poverty; seek adaptation strategies related to temperature rise and ocean levels; adjust to price changes on international markets (e.g. due to increased transport costs); apply new energy technologies; or create new international financial institutions and regulations for climate change (Mitchell, Maxwell, 2010). However, it is also pointed out that this is a very difficult process, due to the scale and long-term perspective of changes, as well as the potential beneficiaries and losers of these changes (Mitchell, Maxwell, 2010).

The European Union's policy in the light of the concept of climate change resiliency

The European Union (EU) monitoring report of 2015 states that "*the normal functioning and prosperity of Europe's economy and society in general depend on the use of natural resources [...] In this respect, the efficient management and use of materials is essential for resource security and increased ecosystems resilience"* (Eurostat, 2015, p. 86). These issues are primarily related to the size of the resources consumed (including energy resources), waste management (including hazardous waste) and the volume of emissions (Eurostat, 2015). The issue of adaptation to climate change was particularly strongly addressed in the recommendations of the EU White Paper of 2009, which followed the Green Paper of 2007 (Commission of the European Communities, 2007). The White Paper stressed that climate changes will particularly influence certain social groups, such as the elderly or low-income households. Two main areas of action are the reduction of greenhouse gas emissions and adaptation aimed at dealing with unexpected shocks (Commission of the European Communities, 2009).

A roadmap for moving to a competitive low carbon economy, published in 2011, ended with the statement of the necessity of cooperation and global actions for "*a resilient low carbon economy*" (European Commission, 2011, p. 16). That is why the EU was a signatory to the above-mentioned Paris Agreement, pursuing a policy aimed at achieving climate resilience of socio-eco-

nomic systems. Article 2 of the Agreement indicated three main objectives (Paris Agreement, 2016):

- limiting the temperature rise (up to a maximum of 1.5°C above the pre-industrial temperature),
- increasing adaptability in the field of negative climate change and development of climate resilience and policy to reduce greenhouse gases emissions without threatening food production,
- adjusting the financial flows policy to the above activities.

The EU project of the LIFE program for 2021-2027 indicates as the main objective *"to contribute to the shift towards a clean, circular, energy-efficient, low-carbon and climate-resilient economy, including through the transition to clean energy, to the protection and improvement of the quality of the environment and to halting and reversing biodiversity loss, thereby contributing to sustainable development"* (European Commission, 2018, p. 16). In light of the main objective, it is necessary to develop and promote legislative mechanisms and policies, including the involvement of public and private actors and citizens (European Commission, 2018). Recommendations of the European Committee of the Regions from 2017 point directly to the role of regions, noting that they should be catalysts that support the efforts of local self-governments *"in strengthening their resilience to climate and disaster risks, building capacities and deploying available financing"* (The European Committee of the Regions, 2017, p. 52). The idea of resistance to climate change has become an inherent element of considerations in the field of socio-economic transformation and is an inseparable element of the sustainable development strategy, in particular in the area of approaches to climate change. However, the strategies usually differ between the different parts of the world.

Bioenergy villages, chinampas and waru-warus as an example of resilient economic activities

The studies carried out in Nicaragua, Guatemala and Honduras after Hurricane Mitch have shown that farmers who used diversification, such as cover plants, intercrop and agroforestry, suffered less damage than farmers who had monocultures (Holt-Giménez, 2002). Moreover, surveys carried out in Cuba in 2008 after Hurricane Ike showed that farms with diversified crop structure show losses in the amount of 50% compared to 90-100% losses in the case of monocultures (Rosset, 2011). The Tscharntke study (2005) similarly suggested that agriculture can contribute to the preservation of large diversity systems that can guarantee resilience, i.e. the ability to reorganize after a disruption. All of these studies have confirmed the great importance

of diversity in farming systems in terms of resilience to extreme climatic shocks.

Examples of climate-resilient economies can be shown in the distant past. For example, economies exposed to temporary flooding included *chinampas* (artificial fertile islets on the shores of lakes that secured themselves from flooding with, among other things, water-absorbing wicker) in the Valley of Mexico, as well as *waru-warus* near Lake Titicaca in Peru and Bolivia (Wilken, 1987; Altieri, 2018). Waru-warus were originally developed in the year 300 BC. The farming system used a network of canals separated by dykes for water storage and plant watering. The dykes were used for crop cultivation. They consisted of a mixture of clay soils and sand to enable the holding of water in the beds, while the soil within such created beds enhanced infiltration and the recycling of nutrients. The canals supplied water during droughts, and during floods they removed the excess. Moreover, the system created specific thermal conditions, as the water in canals absorbs solar energy during the day and radiates it back during nights; it also prevents against frost. The network of canals accumulated nutrients and served as a reservoir of natural fertilizers for the crops. The specific microclimate and organic conditions resulted in very high productivity and resiliency against environmental shocks (floods, drought or frost) (Altieri, 2018; UNEP, 1997).

A similarly successful farming system, called chinampas (the floating gardens), was developed in Mexico. The farming system was registered by UN FAO in 2018 in Globally Important Agricultural Heritage Systems (GIAHS) (UN FAO 2018). Chinampas were developed in 1100 AD from the muck excavated from swamps and the bottoms of shallow water reservoirs. The different layers of the nutrient-rich soil were piled into plots surrounded by water canals or lake water. A group of such gardens was integrated into a complex agricultural system. Willow trees were planted along their edges to control erosion (Sutton, Anderson 2010; Wilken, 1987). This system characterizes high productivity, biodiversity and climate resilience, and therefore, it is an example of sustainable and resilient farming. In 1984, a project was created to reconstruct the farming systems in Peru and Bolivia. It was particularly recommended for regions with extreme climate conditions. The cost of the infrastructure was relatively low and it increased the productivity of crops (usually potatoes) (UNEP, 1997). Moreover, this farming system has also been introduced in other countries such as China, Korea, Japan, Egypt and Spain (UN FAO, 2018).

Finally, in some communities, renewable resources were widely disseminated that were focused on energy self-sufficiency. The concept of bioenergy villages was originally related to the use of biomass as a new source of energy for rural areas. The process of building biomass plants assumed a social com-

mitment and community ownership (at least 50%). Therefore, communities were created around these common investments and new forms of economic activities, which included cooperatives. Zbaraszewski and Pieńkowski (2017) presented the evolution of renewable energy communities and the development of new activities, such as educational centres, or more complex forms of energy usage, including solar or wind energy. The key benefits include climate change mitigation, energy security and energy independence, stable and affordable energy prices, new job creation and social cohesion.

However, the selected cases show different strategies and forms of climate-resilient economies, although all the cases represent climate change strategies. The renewable energy communities mostly focus on climate change mitigation and resistance to economic shocks, while the farming examples represent a strategy of environmentally friendly farming and resistance to climate shocks (table 1).

Table 1. Benefits of economic activities on the example of bioenergy villages, waru-warus and chinampas

Dimensions of development	Bioenergy villages	Waru-warus and chinampas
Environmental	– lower pollution – climate change mitigation – waste management (biomass energy sources)	– lower pollution – biodiversity – resistance to climate shocks – natural flows of matter and energy
Economic	– new job creation – resistance to energy market shocks – lower prices – energy surplus sales – development of new non-farm activities (i.e. agritourism)	– higher productivity – healthy, organic food – food security
Social	– social cohesion – energy security (self-sufficiency) – young people's attraction to rural areas	– social cohesion (farming provided by communities as a whole) – traditional cultivation

Source: author's own work.

Conclusion and recommendations

The effects of climate change, which have intensified in recent decades, have become a main focus of the international community. Events related to climate change, in particular, temperature increase, as well as the intensity and frequency of extreme weather events, affect the functioning of society and the environment and have effects on the economy. Climate change has

caused an increase in activities that can be classified into two groups. One group is mitigation activities, which are aimed at stopping climate change and counteracting the negative effects of these changes. This group of activities consists of contracts and agreements on the reduction of the use of fossil fuels, increase in the share of renewable energy sources in energy production, reduction of greenhouse gas emissions into the atmosphere and improvements in energy efficiency. The second group consists of adaptation activities, in which efforts are undertaken to reorganize and optimally adapt to the ongoing climate change. These strategies are mostly determined by the specific socio-economic conditions of particular local communities. The development of waru-warus or chinampas is an example of adaptation to climate changes – climate-resilient farming – while renewable energy communities are focused on climate change mitigation. The strategies are determined by particular socio-economic and ecological conditions. Local communities have to design and develop strategies based on their own resources and capabilities. The most developed countries, which have a relatively high share of non-farming activities, try to limit their greenhouse gas emissions and create new socio-economic structures that will not compromise the well-being of rural areas, while the highly populated developing countries need to secure food production and develop climate-resilient farming activities, as climate change challenges the relatively higher agricultural sector in those countries. Based on the analysis of the case studies provided, it should be stated that the accepted research hypotheses should not be rejected. It is necessary to comprehensively support the local economy so that it can prepare for the threats and opportunities that climate change can bring in the different parts of the world.

The contribution of the authors

Dariusz Pieńkowski – 50% (concept and objectives, literature review, analysis and interpretation of data, revising critically the article).

Wojciech Zbaraszewski – 50% (concept and objectives, literature review, data acquisition, drafting the article).

Literature

Altieri M.A. (2018), *Agroecology: The Science of Sustainable Agriculture*, Boca Raton

Bahadur A. et al. (2016), *Resilience Scan: October-December 2015. A Review of Literature, Debates and Social Media Activity on Resilience*, London

Commission of the European Communities (2009), White Paper, *Adapting to Climate Change: Towards a European Framework for Action*, Commission of the European Communities (COM(2009) 147 final)

Commission of the European Communities (2007), Green Paper, *Adapting to Climate Change*, Commission of the European Communities (COM(2007) 354 final)

Dobzhansky T. (1959), *Human Nature as a Product of Evolution*, in: Maslow A.H. (ed.), *New Knowledge in Human Values*, New York

European Commission (2011, December 15), *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Energy 2020*. *Energy Roadmap 2050*

European Commission (2018, January 6), *Commission Staff Working Document Impact Assessment Accompanying the Document Proposal for a Regulation of the European Parliament and of the Council on the Establishment of a Programme for the Environment and Climate Action (LIFE) and Repealing Regulation (EU) No 1293/2013*

Eurostat (2015), *Sustainable Development in the European Union. 2015 Monitoring Report of the EU Sustainable Development Strategy*, Luxembourg

Holling C.S. (1973), *Resilience and Stability of Ecological Systems*, "Annual Review of Ecology and Systematics" No. 4, p. 1-23

Holt-Giménez E. (2002), *Measuring Farmers' Agroecological Resistance after Hurricane Mitch in Nicaragua: A Case Study in Participatory, Sustainable Land Management Impact Monitoring*, "Agriculture, Ecosystems & Environment" No. 93, p. 87-105

Mitchell T., Maxwell S. (2010, November), *Defining Climate Compatible Development*, London

Ninan K.N., Inoue M. (eds) (2017), *Building a Climate Resilient Economy and Society: Challenges and Opportunities*, UK – Northampton

Opstal van D. (2007), *The Resilient Economy: Integrating Competitiveness and Security*, Washington, DC: Council on Competitiveness Defining Climate Compatible Development

Paris Agreement (2016, October 19), Official Journal of the European Union

Perrings C. (2006), *Resilience and Sustainable Development*, "Environment and Development Economics" No. 11(4), p. 417-427

Pike A., Dawle S., Tomaney J. (2010), *Resilience, Adaptation and Adaptability*, "Cambridge Journal of Regions, Economy and Society" No. 3(1), p. 59-70

Pisano U. (2012), *Resilience and Sustainable Development: Theory of Resilience, Systems Thinking and Adaptive Governance*, ESDN Quarterly Report No. 26, Wien

Rosset P.M. et al. (2011), *The Campesino-to-Campesino Agroecology Movement of ANAP in Cuba*, "Journal of Peasant Studies" No. 38(1), p. 161-191

Stigter C. et al. (2005), *Using Traditional Methods and Indigenous Technologies for Coping with Climate Variability*, "Climate Change" No. 70, p. 255-271

Sutton M.Q., Anderson E.N. (2010), *Introduction to Cultural Ecology*, Lanham-New York-Toronto-Plymouth

The European Committee of the Regions (2017, June 30), *Opinion of the European Committee of the Regions. Towards a New EU Climate Change Adaptation Strategy – Taking an Integrated Approach*, Official Journal of the European Union

Tscharntke T. et al. (2005), *Landscape Perspectives on Agricultural Intensification and Biodiversity: Ecosystem Service Management*, "Ecology Letters" No. 8, p. 857-874

UNEP (1997), *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean,* Washington

UN FAO, *Chinampas of Mexico City were recognized as an Agricultural Heritage System of Global Importance*, http://www.fao.org/americas/noticias/ver/en/c/1118851 [02-09-2018]

Vallejo L., Mullan M. (2017), *Climate-Resilient Infrastructure: Getting the Policies Right*, Environment Working Paper No. 121, Paris

Wilken G.C. (1987), *Good Farmers: Traditional Agricultural Resource Management in Mexico and Central America*, Berkeley

WMO (2018), *WMO Confirms 2017 Among the Three Warmest Years on Record*, https://public.wmo.int/en/media/press-release/wmo-confirms-2017-among-three-warmest-years-record [18-01-2018]

Zbaraszewski W., Pieńkowski D. (2017), *Biowioska. Niemiecka koncepcja wsi bioenergetycznej*, "Optimum" No. 4(88), p. 71-85

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INITIATIVES FOR PEOPLE AGED 50+ IMPLEMENTED BY MUNICIPALITIES AND ENTERPRISES IN THE OPOLE SPECIAL DEMOGRAPHIC ZONE

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ABSTRACT: The article addresses an innovative instrument of regional development management, namely the Special Demographic Zone (SDZ). The zone has been established in Opolskie Voivodeship, a region marked by the most unfavourable demographic trends among other Polish regions. The article aims to highlight activities intended for people aged 50+ pursued by municipalities and enterprises operating within the SDZ as well as discussing the assessment the Opolskie for the Family programme by surveyed stakeholders. Based on the theoretical framework of the SDZ, a questionnaire has been designed, and a survey has been carried out with a view to achieving the aforesaid aim. Based on the analysis of survey results, the authors have identified the need for and scope of further action that will allow local self-governments and enterprises to implement the concept of the SDZ in a more effective manner.

KEY WORDS: Opolskie Voivodeship, people aged 50+, special demographic zone, enterprises, municipalities

Introduction

Social phenomena, including a demographic shift (attributed to the ageing of the population and depopulation of some areas of the European Union), are ranked among the barriers that will shape the visions of the future and EU development strategies (EU, 2014). The territorial distribution of demography-related barriers to development is uneven – some areas or regions, depending on their characteristics, are likely to face these barriers to a lesser extent or at a later time; however, there is no doubt that their results will affect the entire EU. Demographic forecasts until 2060 reveal profound changes in the age structure of the EU population (they will mirror the fertility, life expectancy, and migration figures). The European society of 2060 will be not only older but also unevenly distributed (the differences will be visible between and across states and regions) (EU, 2017).

As regards Poland, the region with the most challenging demographic situation is Opolskie Voivodeship. According to a forecast of the Central Statistical Office, by 2035 the population of the region will have dropped by over 15%, with a faster decline in urban areas (Dybowska, 2016, p. 240). What affects this highly unfavourable demographic condition of the region is: the birth rate in Opolskie Voivodeship at -3.4 (-1.3 for Poland), the region's net migration rate of -4.4 (-0.4 for Poland) (Szczygielski, 2015, p. 65). An extra challenge for the region's development strategy is the age structure of the population. In 2015 the number of people aged 50 and over was 38.4% (Poland's average 36.5%), which is up by 5.4 pp compared with 2007 (Urząd Marszałkowski Województwa Opolskiego, 2016, p. 9).

Given the above indicators, as well as general global and European socio-demographic trends, the development strategy of Opolskie Voivodeship focuses on demographic issues, especially accommodating the needs of 50+ people. With this end in view, the Opolskie for the Family: a Special Demographic Zone Programme for Opolskie Voivodeship until 2020 was adopted by the Resolution of the Executive Board of Opolskie Voivodeship on 16 September 2014. The programme is one of the tools adopted to further the implementation of the Opolskie Voivodeship Development Strategy until 2020, which prioritises the prevention and counteracting of depopulation as a horizontal development challenge (Urząd Marszałkowski Województwa Opolskiego, 2012, pp. 81-82, 130, 132). The programme contains four thematic packages corresponding to priority impact areas. One of them, Golden Autumn, is intended for people aged 50+ and promotes the development of favourable living conditions for elderly people and helps tap their potential for region's development.

This article aims to identify and analyse (based on completed questionnaires) initiatives for people aged 50+ launched by municipalities and enterprises as well as assessing the awareness and implementation of the programme by the stakeholders. The article is based on the analysis of source materials (literature, strategic documents, reports) and the results of an original online survey.

An overview of literature

The Special Demographic Zone programme is a pilot initiative both Poland – and EU-wide. It embraces holistic and innovative tools implemented at the regional (voivodship) level and serving, on the one hand, the counteraction and, on the other, adaptation to unfavourable demographic changes (Urząd Marszałkowski Województwa Opolskiego, 2014, p. 11).

Searching scientific databases for the key word of "special demographic zone" only returns several hits. Foreign literature on the subject lacks references to similar solutions implemented in other countries. However, an initiative by the German government is worth mentioning as discussed by Klimczuk (2015, pp. 32-36). In 2005 the state of North Rhine-Westphalia proposed the establishment of a network organization, SEN@ER – Silver Economy Network of European Regions, rested on similar assumptions and pursuing similar goals as the Golden Autumn package. The literature on the subject also reveals some attempts to incorporate demographic challenges and activation initiatives for people 50+ (and, more broadly, the promotion of the silver economy) in the local strategies of Łódzkie, Małopolskie and Pomorskie Voivodeships (Martinez-Fernandez et al., 2013, pp. 95-116).

The authors of several articles covering the SDZ focus primarily on highlighting the demographic situation (including demographic issues as development barriers) of Opolskie Voivodeship and the framework of the Opolskie for the Family programme (Rauziński, Szczygielski, 2014; Goleński, 2015), also exposing the EU (Gerejczyk, Pilewicz, 2017) and global demographic trends (Szczygielski, 2015) or assessing activities intended to seniors as one of the programme packages (Wawrzyniak, 2015). When assessing the Opolskie for the Family programme, Gerejczyk and Pilewicz (2017) highlight the SDZ as a special case of regional strategy well-aligned with their theoretical model of local and regional strategies addressing demographic challenges. None of the above studies covers the assessment of awareness and implementation of the SDZ programme.

Research methods

A study of initiatives undertaken by local self-governments (municipalities) and enterprises operating in the SDZ for people aged 50+ was carried out in liaison with the Marshal's Office of Opolskie Voivodeship in the period from December 2017 to January 2018. An anonymous online survey was submitted to all local self-governments of the voivodeship (71 municipalities and one city with district (Pol. powiat) rights) and 25 business support institutions, 45 beneficiaries of the Managing Authority of the Regional Operational Programme Opolskie Voivodeship 2014-2020 (Measures 7.4, 8.1 and 8.2) and 17 beneficiaries of the Intermediate Body (the Opole Centre for Economic Development or OCED).

The survey was completed by 40 municipalities and 12 enterprises. Among the municipalities, there were two urban municipalities (out of three in the Opole region), 18 urban-rural municipalities (out of 33) and 20 rural municipalities (out of 35). The research conducted among the municipalities confirms that demographic issues (especially a decline in population) are among the most urgent development problems. Over the last 5 years, out of 40 surveyed municipalities, only two reported an increase in the number of inhabitants, while as many as 18 reported a significant decrease. This condition makes the municipalities aware and galvanise them to design policies of competitiveness, such as: rehabilitation and creation of attractive public spaces as meeting points (18 municipalities), infrastructure and senior-friendly services (14 municipalities) and the development of social (and intergenerational) integration facilities (10 municipalities).

Among the 12 surveyed enterprises, there were 8 micro (0-9 employees) and 4 small businesses (10-49 employees). Ten of them were private businesses with the Polish capital (100%) headquartered in Opolskie Voivodeship (five outside the city of Opole). The surveyed businesses represented commercial, service and care industry (three indications each), as well as the health care and rehabilitation and medical segment (two indications each). The surveyed enterprises were mainly operating in Opolskie Voivodeship (11), and most had been on the market for less than 15 years (eight).

Results of the research

Moving on to the discussion of the results of original research, it should be noted that they will address the following matters: 1) who (what entities) should take action for the inclusion of seniors, 2) what initiatives are implemented for people aged 50+, 3) the level of awareness of the implementation

of the Opolskie for the Family programme, 4) assessment of the programme and identification of the leaders.

The surveyed municipalities all pointed to the state as an entity that should take action for the inclusion of seniors (40 responded "definitely yes" and "rather yes", including 30 with "definitely yes"). As many as 38 of the surveyed municipalities indicated that they should be responsible for such initiatives themselves (15 responded "definitely yes"), and their main partner should be non-governmental organisations (38 indications, including 13 for "definitely yes") and 50+ people (35 responses, including 14 for "definitely yes"). The Church and religious associations seem to play a minor role in such action (28 indications, including 9 for "definitely yes"). In the opinion of the surveyed municipalities, entities that should get involved in initiatives for the inclusion of the elderly to the smallest extent are enterprises (15 municipalities were positive: "definitely yes" and "rather yes", among them only three for "definitely yes"; however, most returned answers – as many as nine – were "no").

All of the surveyed businesses agreed that action for the inclusion of seniors should be taken first of all by local self-government units (12 positive answers for "definitely yes" and "rather yes") and the state (11 positive answers, including as many as seven for "definitely yes"). Other (but of secondary importance) entities that should assume responsibility for such activities and named by enterprises were non-governmental organisations, private companies, and 50+ people themselves (nine positive answers each). The Church and religious associations were, in the enterprises' opinion, the least expected to get engaged in such initiatives (six answers for "yes" and as many as five for "no").

For the sake of the research analysis, initiatives for people aged 50+ are divided into the following categories: 1) improvement in the quality of products and services for seniors, 2) improved availability of products and services for seniors, 3) activation of seniors, 4) improvement in digital competence of seniors, 5) age management (age management underlines employee age diversity as an important factor in the development of an organisation).

The surveyed municipalities were primarily active in the following areas:

- activation of seniors – 31 municipalities (this category covers the following activities: organisation of social events for/with the participation of seniors, practical classes aligned with interests/hobbies of 50+ people, supporting Senior Clubs, general and specialised courses and training for seniors, supporting the development of Third Age Universities, promotion of a healthy lifestyle, tailor-made educational projects and activities related to disease prevention and health education; one response pointed to the idea of time bank as a method of activation of the elderly),

- development of digital competences among seniors – 26 indications (mainly through: computer, software and application training and the set-up of Internet cafés),
- improvement in the accessibility of products and services for seniors (above all, the initiatives of: cooperation with various entities for solving seniors' problems, price reductions for seniors, adaptation of the municipal website to seniors' needs) and improvement in the quality of products and services for seniors (understood as the enhancement of existing services to accommodate the needs of the elderly) – 20 and 19 responses, respectively.

The least popular initiatives reported by the surveyed municipalities were related to age management – only five indications – primarily consisting in maintaining employment of seniors who wish to keep working.

The 12 surveyed businesses mainly take action aimed at activating seniors (seven indications), improving the quality and availability of products and services for seniors (six indications each); less frequently, they are involved in initiatives developing seniors' digital competence (three) or age management programmes within their organisation (two) – figure 1. In this question, three enterprises declared that they were not taking any action for seniors, so they failed to continue the survey.

As regards the initiatives for the activation of seniors, the surveyed businesses most often reported the following: promotion of a healthy lifestyle among 50+ people, support for the establishment and operation of social integration facilities for seniors, general and specialised courses and training for seniors, promotion of disease prevention and health education among 50+ people and organisation of social events for/with the participation of seniors. With regard to the improvement of quality of products and services for seniors, the surveyed enterprises, and municipalities alike, admitted to improving mainly existing services with a view to satisfying seniors' needs. However, when improving the availability of products and services for seniors, the businesses mainly decided to introduce new technologies/products/services intended for seniors and (again like municipalities) cooperation with various entities working towards solving older people's problems. Less often did they point to the improvement of the quality of services for the elderly. Speaking of initiatives aimed to raise seniors' digital competence, the surveyed enterprises mostly pointed to courses and training in the use of computer, software and applications (just like municipalities). As part of age management, the surveyed businesses most often pointed to continued employment of seniors who want to keep working, on top of company events integrating all generations of employees.

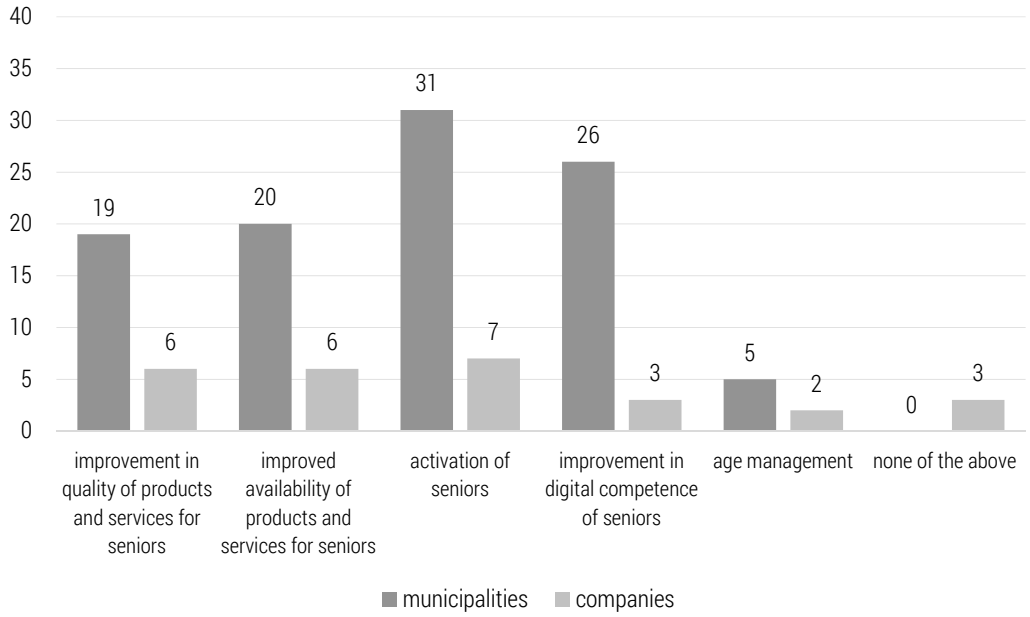

Figure 1. Initiatives implemented by municipalities and enterprises operating in the SDZ for people aged 50+
Source: author's own work based on completed surveys.

As regards the awareness of the implementation of the Opolskie for the Family programme, the research done among the municipalities returns interesting results. Among 40 of the surveyed municipalities, 11 declared that their action resulted directly from the programme; at the same time, as many as 15 indicated that their initiatives for seniors were not related to the Opolskie for the Family programme; 14 did not have an opinion on the matter and responded, "don't know."

Among the nine businesses questioned in the successive section of the survey (excluding three that did not take any action for seniors), four declared that their initiatives came from the Opolskie for the Family programme; the same number of enterprises gave the opposite answer, and one did not have an opinion on the matter – figure 2.

The assessment of the Opolskie for the Family programme by the questioned municipalities was positive – 21 rated it "very good" (2) or "good" (19); obviously, the assessment of the programme was very strongly linked to the awareness of the initiative. 15 municipalities did not know how to measure the programme, and four admitted that they did not know it. It is positive that no municipality responded "bad" or "very bad."

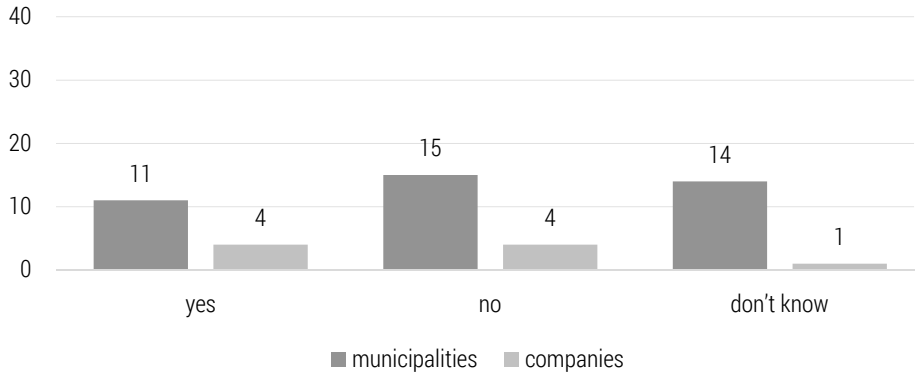

Figure 2. Awareness of the implementation of the Opolskie for the Family programme by municipalities and enterprises operating in the SDZ

Source: author's own work based on completed surveys.

The surveyed enterprises were mostly positive about the Opolskie for the Family programme (four answers "good" and two "very good;" no negative answers were given). Only two enterprises were unable to assess the programme, and one did not know it – figure 3.

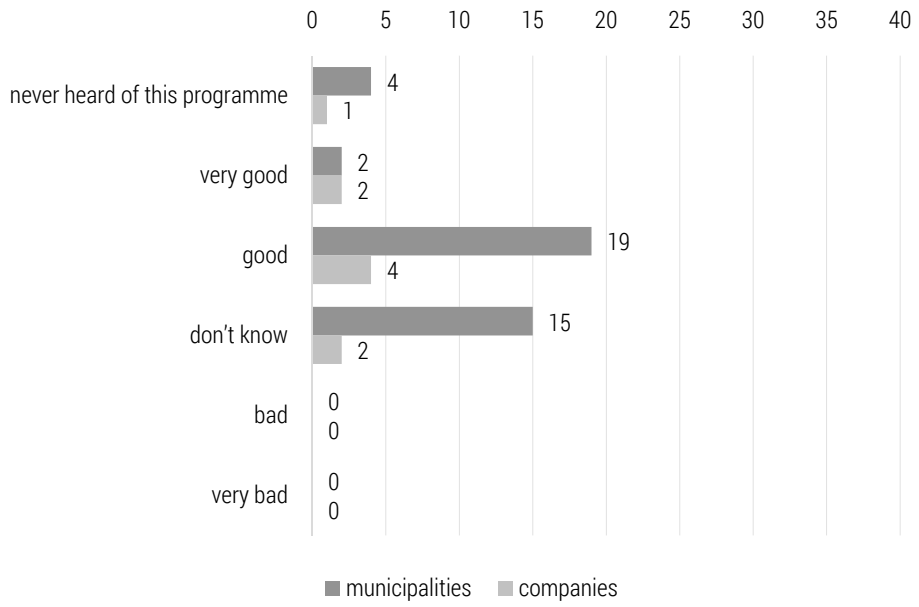

Figure 3. Assessment of the Opolskie for the Family programme by municipalities and enterprises operating in the SDZ

Source: author's own work based on completed surveys.

With regard to the effectiveness of action intended for the elderly in the region, the surveyed municipalities pointed to the initiatives by the Marshal's Office of Opolskie Voivodeship (the average ranking position for four possible positions in the question was two in this case), followed by NGOs and local self-governments (position 2.18). Businesses received the poorest assessment (position 3.65).

In the opinion of nine of the surveyed enterprises, the most effective action for seniors in the region is taken by local self-governments (the average ranking position was 2.11), followed by the Marshal's Office and NGOs (the same position 2.44) and businesses (position 3.0).

As for the leaders of activities for seniors, eight of the surveyed municipalities pointed to individual local self-governments, among them: Opole, Kluczbork, Gogolin (two indications) and Kędzierzyn Koźle and Prudnik (one indication each).

However, none of the nine surveyed enterprises were able to point to a company from the Opole region which could be considered a leader in activities for people aged 50+.

Conclusions

Through the initiative of the Special Demographic Zone, Opolskie Voivodeship attempts to respond to the demographic challenges of the region. The pilot programme, Opolskie for the Family, encompasses a number of integrated activities addressing: the labour market, improvement of the standard of living in the region, and broadly understood activation. A large part of these activities (mainly regarding the promotion of professional, physical, cultural, and educational activity) is intended for people aged 50+.

Already at the stage of programme development (based on the expert-social method), it was emphasized that its implementation would require cooperation and commitment of various stakeholders, including businesses and local self-governments (Urząd Marszałkowski Województwa Opolskiego, 2014, pp. 35, 38). As demonstrated in the completed research, both the surveyed municipalities and enterprises undertake many activities for people aged 50+, however, it is not possible to assess unambiguously whether it is the result of conscious implementation of the programme. This situation is the outcome of insufficient familiarity with the programme, both of municipalities and enterprises. As demonstrated by the research, the programme-related services are better known than the programme itself: Opole Family and Senior Card, Opole Senior Card or Regional Opole Senior Service Cluster.

The research also revealed that the surveyed municipalities and businesses do not see each other as natural partners implementing/undertaking activities benefiting people aged 50+ (in the opinion of municipalities, enterprises are the least likely to implement initiatives for the benefit of seniors). Meanwhile, according to the research, both municipalities and enterprises take the same types of action for the benefit of seniors.

Given the results of the conducted survey, we recommend further research of the effectiveness of the programme, including, in particular, activities carried out through intersectoral cooperation. It is necessary to identify best practice in this respect that may be employed not only by local self-governments and enterprises from the Opole region. This is also relevant in the light of the Opinion of the European Committee of the Regions (EU, 2017) which reads that the current EU's response to demographic challenges is limited and poorly developed, while regions and cities should perceive the demographic change not only as a barrier but as a development opportunity related to the silver economy.

Further research should be carried out and more effort should also be taken to promote the awareness of the programme and the knowledge of its framework, especially among local self-governments, and the need for conscious participation of both local self-governments and enterprises in the implementation of programme's objectives.

The contribution of the authors

Ewa Jastrzębska – 50%.
Paulina Legutko-Kobus – 50%.

Literature

Dybowska J. (2016), *Ludność na obszarach wiejskich województwa opolskiego – przeszłość i perspektywy demograficzne*, „Studia Obszarów Wiejskich" Vol. 41, pp. 229-244, DOI: http://dx.doi.org/10.7163/SOW.41.15

EU (2014), *Making Europe Open and Polycentric. Vision and Scenarios for the European Territory towards 2050*, ESPON Report, Luxembourg

EU (2017), *Opinia Europejskiego Komitetu Regionów – Reakcja UE na wyzwania demograficzne*, Dziennik Urzędowy Unii Europejskiej, 2017/C 017/08

Gerejczyk K., Pilewicz T. (2017), *Special Demographic Zone in Poland – in search for the gist of the phenomenon*, "Journal of Economics and Management" Vol. 29(3), pp. 37-57, DOI: 10.22367/jem.2017.29.03

Goleński W. (2015), *Project of a special demographic zone as a response to a threat of depopulation in the Opole province*, "Zeszyty Naukowe Wyższej Szkoły Oficerskiej

Wojsk Lądowych im. gen. T. Kościuszki" No. 4, pp. 48-63, DOI: 10.5604/17318157.1200167

Klimczuk A. (2015), *Regional Development in an Ageing Society: Overview of Selected Foreign and Polish Recommendations and Practices*, in: Chudý Š., Tomczyk Ł. (eds), *Aktywna starość w perspektywie społeczno-kulturowo-edukacyjnej*, Kraków, pp. 21-50, DOI: 10.13140/RG.2.1.2353.8402

Martinez-Fernandez C. et al. (2013), *Demographic Transition and an Ageing Society: Implications for Local Labour Markets in Poland*, Local Economic and Employment Development (LEED) Working Papers, No. 8, Paris, DOI: http://dx.doi.org/10.1787/5k47xj1js027-en

Rauziński R., Szczygielski K. (2014), *Związki polityki ludnościowej z polityką społeczną na przykładzie koncepcji Specjalnej Strefy Demograficznej w województwie opolskim*, „Problemy Polityki Społecznej. Studia i Dyskusje" No. 27(4), pp. 161-173

Szczygielski K. (2015), *Opolska Specjalna Strefa Demograficzna – kaprys czy konieczność?*, „Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach" No. 223, pp. 57-72

Urząd Marszałkowski Województwa Opolskiego (2012), *Strategia Rozwoju Województwa Opolskiego do 2020 r.*, Opole

Urząd Marszałkowski Województwa Opolskiego (2014), *Program Specjalnej Strefy Demograficznej w województwie opolskim do 2020 roku „Opolskie dla Rodziny"*, Opole

Urząd Marszałkowski Województwa Opolskiego (2016), *Analiza sytuacji społeczno-ekonomicznej województwa opolskiego w obszarach oddziaływania Europejskiego Funduszu Społecznego*, Opole

Wawrzyniak J.K. (2015), *Specjalna Strefa Demograficzna obszarem dobrych praktyk na rzecz seniorów. Założenia i realizacja programu*, „Rocznik Andragogiczny" Vol. 22, pp. 341-353, DOI: http://dx.doi.org/10.12775/RA.2015.021

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PROTECTION OF VALUABLE AREAS OF LOCAL CULTURAL HERITAGE IN SUSTAINABLE DEVELOPMENT. CULTURAL PARKS IN THE LODZ REGION

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ABSTRACT: Cultural park is one of the forms, in which valuable areas and historical establishments are protected under the Polish law. Protection covers "space" in its entirety with elements of wild nature and man-made structures. Such spaces have been shaped by the history of human interventions into a unique and original cultural landscape, a complex spatial structure consisting of: passages (rivers, channels, roads, and borders), plains (meadows, fields, water reservoirs, and forests), and objects (natural objects and monuments). They ensure sustainability of development processes. In circumstances created by globalisation, investment pressure, and seeking short-term benefits, comprehensive protection of valuable cultural areas acquires special importance from the point of view of sustainable growth. The paper aims to identify valuable areas of local cultural heritage in the context of sustainable development on the example of cultural parks established in the Lodz voivodeship.

KEY WORDS: cultural heritage, cultural park, comprehensive protection, cultural landscape, sustainable development

Introduction

The term *cultural heritage* covers a wide spectrum of meanings, which are not obvious and unambiguous. Yet, currently it gains in importance and popularity. Cultural heritage is no more seen as part of a non-productive "superstructure" that should be done away with but it has become an appreciated market asset (Murzyn-Kupisz, 2012, p. 11). Cultural heritage is expressed in tangible and intangible elements typical of a given area which reveal its culture and history making it a vital component of any territorial unit. These components are not just the housing stock, monumental architectural structures, sculptures, paintings, collections of public and private institutions, such as museums, libraries or archives. They also include products of craftsmanship, works of applied arts, wooden architecture and technological structures. Cultural heritage is not just about cultural (aesthetic, artistic, historical) but also economic and social (applied and ornamental) values. Through its components that carry the features of a public good, cultural heritage generates external benefits (economic and non-economic) (Murzyn-Kupisz, 2011). The main thesis adopted for our research argues that cultural heritage represents the characteristics of a public good that we need to protect since in the long-term perspective it is critical for sustainable development and social justice.

Nowadays, cultural heritage attracts increasingly more attention of representatives of different areas of science. It has also become the theme of multidisciplinary research conducted not only by art historians, conservation officers or researchers into cultural studies but also by planners, economists, and management experts. Moreover, cultural heritage typical of a particular territory increasingly more features in strategic documents drafted by local authorities and in discussions over regeneration plans or local development efforts (Boryczka, Zasina, 2016). Thus, we need to stress that the inclusion of new groups of professionals (e.g., representatives of economics, natural sciences, law, management, social sciences, marketing, and IT) into the protection and the observed increased appreciation of the social role played by the cultural heritage are positive occurrences. All of them bring in research methodologies and tools specific of their individual fields of expertise by which they improve the collection and processing of data and knowledge about heritage and its components. That has enriched forecasting capabilities and ways of shaping the future fate of components of cultural heritage as well as improved protection efficiency (Rouba, 2008).

The primary goal of the paper is to identify valuable areas of local cultural heritage in the context of sustainable development on the example of cultural parks established in the Lodz voivodeship. Attempt has been made

to specify the role and importance of cultural parks in sustainable development of municipalities and in the building of their potential and attractiveness.

Local Cultural Heritage as a Factor of Sustainable Development and Its Protection

How we understand the meaning and role played by cultural heritage closely links with the idea of sustainable development. Cultural heritage is one of factors of sustainable development, which "meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is a development aimed at efficient use of limited resources having alternative use now and in the future" (Rzeńca, 2016, p. 52). Sustainable development is not just about using constantly shrinking resources in accordance with certain principles, it is also a requirement to secure more prosperity to the mankind in which local communities have a special place on condition that the development may not restrict future generations' ability to meet their needs (Kobyliński, 2000). Hence, sustainable development consists in acting in a way not destructive for natural resources. Moreover, it covers long-term use of renewable resources, efficient exploitation of fossil fuels, maintaining the stability of environmental processes and eco-systems, protection of genetic diversity and overall protection of nature as well as the maintenance and improvement of prosperity, safety at work, and human health. Sustainable development is also economic development which does not exert significant negative or irreversible impact on human environment and reconciles the laws of economics and nature (Kozłowski, 2002). Cultural heritage has also got a valid and direct share in sustainable development through its economic, social, and environmental dimension. It also contributes to the building of economic base by boosting local employment in areas such as tourism, environmental protection, monument conservation or in activities linked with regeneration (O'Brien et al., 2015; Boryczka, 2016). Hence, cultural heritage described as an asset owned by territorial authorities (at different levels. e.g., natural and economic) representing, to a different extent, characteristics of a public good, must be protected and exploited to a different often limited degree. Cultural heritage is increasingly more often seen as an economic asset (Nijkamp, 2012; Boryczka, Zasina, 2016). Cultural heritage must also be rationally managed and secured to be maintained for future generations (Barthel-Bouchier, 2016).

Being an endogenous factor of sustainable development and in order to produce benefits (influence economic and social development), cultural

heritage must be properly managed (Guzmán, Pereira Roders, Colenbrander, 2017). Proper use of the heritage may also produce indirect positive multiplier effects (Murzyn-Kupisz, 2011). However, to be able to properly manage cultural heritage we must protect it not only to preserve its components in a good shape, build the identity of local communities, images or brands of places but also to facilitate control over establishments and areas. Similarly to natural resources, cultural heritage may be used in different ways (properly or improperly) in production or human consumption. Cultural heritage treated as a resource must be managed in a manner specific of natural or economic resources. Economically speaking, cultural heritage does not directly generate tangible goods. It is connected with the production of intangible goods, such as knowledge about the past, building individual and collective identity, production and consumption of services that highlight the heritage (Kobyliński, 2000).

The mere presence of a certain resource within a given territory, including cultural heritage, does not automatically ensure the development of a territorial unit. The resource impacts territorial development when it becomes a real asset which can be used in diverse, e.g., economic and social, activities. To become an asset important for development, cultural heritage, which is "just" a potential, needs to be used in a sustainable and responsible way (Jewtuchowicz, 2013, Boryczka; Zasina, 2016). Efficient and effective management of cultural heritage calls for a number of instruments, mainly "soft" ones, which help produce incentives for other stakeholders to make them behave in a desired way (Thorsby, 2012, p. 85) and engage various operators into the "game" of taking care of the public good such as cultural heritage.

Using a non-renewable resource, such as cultural heritage in a too intensive and not well-thought-out manner may produce irreversible consequences, including its total annihilation. Thus, we need to intensify its protection and minimise its use. Cultural heritage must be managed in a manner that is conscious, rational and well thought out (O'Brien et al., 2015). We need to stress that cultural heritage is not owned by historians, archaeologists, conservation experts, art historians or any other group composed of representatives of a given local community. It is owned publically as a public good whose components are used and enjoyed by the local community or users of a given area. If we consider cultural heritage a non-renewable and unique resource, our duty is to manage it properly and preserve for future generations (Kobyliński, 2000). This is how it becomes an internal factor of sustainable development (Chabiera, 2016).

Protection is one of the major duties of modern management of cultural heritage. Yet, increasingly more attention is paid to sustainable and responsible exploitation. Thus, it is worth stressing that effective protection of herit-

age includes the ability to include it into development processes as cultural heritage will survive only if used (Boryczka, Zasina, 2016).

In Poland the Act of 23 July 2003 on Monuments Protection and Guardianship contains the main body of regulations and specifies the scope and forms of protection of monuments and historical buildings. It lays down principles to be followed when drafting the national programme of monuments protection, caring for them as well as funding all restoration, preservation and construction works in such buildings or objects. The Act introduces a number of tools that one may use to protect cultural heritage in Polish municipalities. It also lists responsibilities and duties of public administration bodies entrusted with the protection of historic monuments and sites (Dz. U. 2003 No. 162 item 1568). These responsibilities are organised around securing organisational, legal and financial framework that would ensure lasting and sustainable maintenance, preservation and management of these monuments, help prevent threats that could reduce their value and, ultimately, counteract their misuse, destruction, loss, theft or illegal exports, enhance control over their use and shape, in which they are preserved, and specify protection responsibilities in local development plans, as well as shape cultural environment (Gosztyła, Pasztor, 2013). The Act provides for four basic levels of status of monuments protection: inclusion in monuments register, listing on the National Heritage List, denominating as a historic monument, identification of protection requirements in the local development plan, and, finally, a cultural park (Dz. U. 2003 No. 162 item 1568).

Cultural park is a specific form of cultural landscape protection. It deals with the protection of a certain area, in which such landscape can be found. The role of a cultural park focuses on the preservation of unique areas of outstanding beauty and monuments based in them, which make a given area distinctive (Dz. U. 2003 No. 162 item 1568). A cultural park extends over a delineated area, not just over individual elements of cultural heritage. It highlights cultural merits that give some specific features to the area in question. Cultural park contains natural elements and man-made objects. Over the years, human activities have shaped the area into a unique and original cultural landscape. When a cultural park is established, its operating rules are also adopted, including bans and limitations on how it can be used by local residents, visitors, and economic operators based in it intended primarily to protect and maintain the heritage (Lipińska, 2011).

By setting up a cultural park we can generate diverse benefits to the area of cultural heritage covered by such a protection format and to the specific municipality and its local authorities. Such benefits include, inter alia, increased tourist and education attractiveness of a given municipality (development of the area), protection of all of its territory, enhanced spatial man-

agement efficiency (e.g., possibility to use diverse tools to protect the park from haphazard investment projects and avoid disorganised outdoor advertising), and acting towards the fostering of local community ties and identification with the place. The decision to establish a cultural park is taken by the municipal Council but fully fledged cultural parks are created as a result of multi-stage efforts (Chabiera, 2016).

Having cultural parks within the borders of a given territorial unit can contribute to:

- comprehensive protection of nature and monuments within the area,
- increased attractiveness of a city/town to its residents and potential tourists,
- spatial order (e.g., preventing disorganised outdoor advertising) and sustainable development,
- higher management efficiency within the protected area,
- more intensive feeling of social identity,
- putting individual bans and restrictions in place.

The establishment of a cultural park may also effectively contribute to sustainable development and spatial order within the area where monuments and the environment are protected on equal grounds (Chabiera, 2016).

On top of that, to many territorial local authorities a cultural park is a valid additional argument when applying for EU subsidies and financial resources allocated by the Ministry of Culture and National Heritage, which provide a vital impulse for local authorities in Poland suffering from budget deficits to act and use new instruments of cultural heritage protection (www.dladziedzictwa.org/programy-fundacji/parki-kulturowe-i-pomniki-historii).

Obviously, discussions about cultural parks also address negative aspects involved in the format. The most frequently stressed are costs of additional outlays made by municipalities to pay for the drafting of mandatory documents, such as, inter alia, local spatial development plan, park protection plan and the draft resolution on the establishment of a cultural park. These costs, however, are borne as part of regular operations of local authorities and practically remain little relevant in the context of a multiplicity of benefits resulting from choosing this form of protection and shaping the cultural landscape. In these discussions we can also hear unfavourable opinions about putting in place restrictions on space management and types of solid structures that are allowable in cultural parks. These voices and arguments criticise restrictions imposed on the "Polish sacred right of real property ownership" and result from many years of negligence and absence of a genuine spatial planning system in Poland. Interestingly, in the light of surveys that are discussed further in the paper, local communities see these restric-

tions mainly as benefits of having a cultural park (more than ¼ of respondent group), which allows us to conclude that negative opinions may originate from those whose vital interest lies in preserving the *status quo*.

Research Methodology

The survey was conducted in four stages (figure 1). Research methods used in the first stage were based on heuristic techniques that deploy expert knowledge and desk research. The second stage focused on the stock taking of cultural parks in the Lodz voivodeship or, more precisely, in four municipalities (Lodz, Sieradz, Zgierz, and Leszczynek). These municipalities were selected for the survey because they have been hosting cultural parks for some years already. Besides, at this stage we also conducted a study based on questionnaire interviews with representatives of local authorities and local administration (offices, departments) and organisational units directly taking care of cultural parks in the above mentioned municipalities. Respondents for the interviews were selected in a target sampling.

In the third stage we conducted a comparative analysis of cultural parks in Poland paying special attention to cultural parks in the Lodz region (Lodz, Sieradz, Zgierz, Leszczynek).

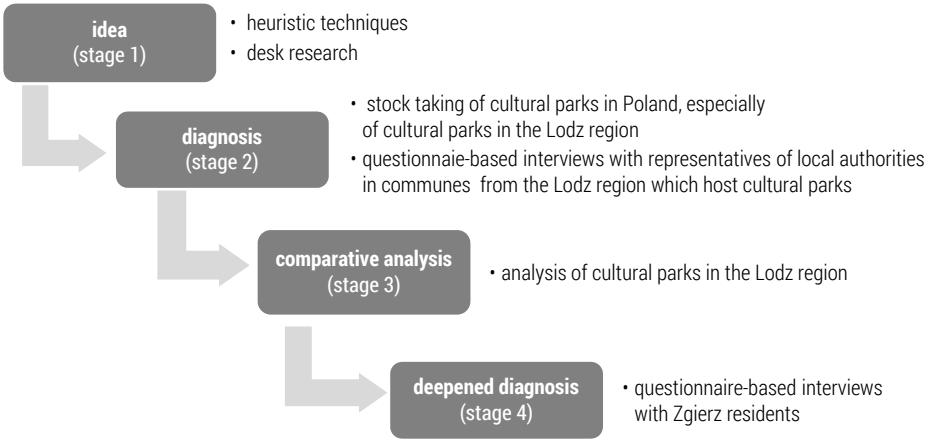

Figure 1. Stages of research

Source: authors' own work.

In the fourth stage we carried out a questionnaire-based social survey among residents of one of the examined towns (Zgierz). It was a pilot study and the sample was selected on a random basis. The survey was conducted between May and July 2018.

Our research was undertaken to find out about the role and importance of cultural parks in sustainable development of towns and municipalities and in the building of potential and attractiveness of these territorial units.

Cultural Parks: Typology and Distribution over the Territory of Poland

Until the early 2018 thirty five cultural parks have been established throughout the territory of Poland. We can divide them into 7 groups based on categories of heritage they are supposed to protect: (www.dworniczak.com/parki-kulturowe-w-polsce-rozmieszczenie-i-typologia/)

1. Protection of cultural townscape of ancient city centres.
2. Protection of cultural heritage encapsulated in complexes of historic buildings situated nowadays outside of strict city centres.
3. Protection of (mainly) cultural landscape in non-urbanised areas.
4. Protection of landscapes connected with religious warship.
5. Protection of fortresses and military complexes.
6. Protection of relicts in cultural landscape.
7. Protection of sites and objects linked with historic personalities and events.

In the Lodz voivodeship there are four cultural parks representing three theme categories of protection: protection of relicts in cultural landscape (Sieradz), protection of sites and objects linked with historic personalities and events (Leszczynek), protection of cultural landscape in complexes of historic buildings currently situated outside of strict city centres (Zgierz, Lodz). The above-mentioned cultural parks in the Lodz voivodeship differ a lot from one another on many grounds, such as, e.g., history, characteristics of cultural heritage, functions or date of establishment.

Table 1. Typology of cultural parks in Poland

Cultural parks established to:	Locations in Poland
1. Protect cultural townscape of ancient city centres	– Stare Miasto [Old Town] Cultural Park in Wroclaw, – Stare Miasto [Old Town] Cultural Park in Krakow, – Old Town and Dominican Monastery Cultural Park in Jaroslaw, – Konskie City Cultural Park, – Krupowki Cultural Park in Zakopane, – Old Town Cultural Park, – Princely Town of Brzeg Cultural Park.
2. Protect cultural heritage encapsulated in complexes of historic buildings situated outside of strict city centres	– Weavers' Town Cultural Park in Zgierz, – Stary Radom [Old Radom] Cultural Park, – Wilanow Cultural Park in Warsaw, – Piotrkowska Cultural Park in Lodz.
3. Protect (mainly) cultural landscape in non-urbanised areas	– Jeleniogorska Valley Cultural Park, – Zakopianska Valley Cultural Park, – "Hałda Popłuczkowa" [The Friedrich Mine Washing Tip] Cultural Park, – Warmia Landscape Route Gietrzwałd-Woryty Cultural Park, – Mickiewicz Cultural Park, – Causeway Area Cultural Park in Bierun, – Cultural Park of the Castle Hill and Budzowka and Nysa Klodzka Rivers Valley in Kamieniec Zabkowicki.
4. Protect landscapes connected with religious warship	– Kalwaria Pakoska Cultural Park, – Eight Blessings Cultural Park in Sierakowice village, – Jewish Cemetery Cultural Park in Żory, – Cardinal Stefan Wyszynski Cultural Park.
5. Protect fortresses and military complexes	– Fortress Cultural Park in Srebrna Gora, – Twierdza Klodzka Fortress Cultural Park.
6. Protect relicts in cultural landscape	– Wietrzychowice Cultural Park, – St. Oswald Church Cultural Park in Plonkow, – Sarnowo Cultural Park, – Dolina Trzech Mlynow [Three Mills Valley] Cultural Park in Bogdaniec, – Grodzisko (Settlement) Cultural Park in Wicina, – Castle Hill Cultural Park in Sieradz, – Osada Lowcow Fok [Seal Hunters Village] in Rzucewo, – Klasztorne Stawy [Monastery Ponds] Cultural Park.
7. Protect sites and objects linked with historic personalities and events	– Cultural Park of ethnographic sub-region of Kutno associated with the Romantic poet Jozef Bohdan Zaleski, – "Ossow the Gate to the Battle of Warsaw 1920" Cultural Park.

Source: authors' own work based on: www.dworniczak.com/parki-kulturowe-w-polsce-rozmieszczenie-i-typologia/, [10-06-2018].

Table 2. Characteristics of cultural parks in the Lodz region

Cultural park	Established on	Heritage characteristics
Miasto Tkaczy [Weavers' Town] Cultural Park in Zgierz	30.12.2003	A 19th century settlement of drapers – historic wooden architecture mixed with traditional urban layout in one place.
Castle Hill Cultural Park in Sieradz	09.2009	The area of ancient town within which the castle was later erected on an oval grass island in the valley of the rivers Warta and Żeglina (more than 600 m from the Old Town market). (Plan Ochrony Parku Kulturowego[Protection Plan for Cultural Park], 2009, p. 30)
Cultural Park of ethnographic sub-region of Kutno associated with the Romantic poet Jozef Bohdan Zaleski in Leszczynek	28.04.2015	A palace and garden complex with monuments and natural assets. Protection efforts are motivated by the wish to cultivate the memory of the Romantic poet Józef Bohdan Zaleski who lived and worked there and to preserve features typical of the culture of the region. (Resolution No. VI/35/2015)
Piotrkowska Cultural Park in Lodz	09.12.2015	The layout of Piotrkowska, together with Wolnosci Square and Moniuszki Street (former Meyer's Precinct) preserved in their authentic and integral shape. The sites were awarded with the prestigious title of a Historic Monument (the most protected category of monuments in Poland) "Lodz – multicultural landscape of an industrial city". The area includes buildings in different architectural styles: Classicism, Art Nouveau, Historicism, and Modernism.

Source: authors' own work.

Because of the diversity and theme-related differences each cultural park in the Lodz voivodeship fulfils a different function. The oldest one amongst them, the Weavers' Town Cultural Park, is focused on historical education and social integration, which it promotes by organising events for the residents of Zgierz and for visitors. It has got a well developed cultural, catering and hotel service infrastructure.

Castle Hill Cultural Park in Sieradz covers the area of the ancient historic city and the nearby town market with shops and restaurants. In summer, the old city hosts cyclical cultural and entertainment events. Cultural events organised in the park in Sieradz make it a perfect recreational, integration, and historic destination.

Events organised in the cultural park established in the ethnographic sub-region of Kutno associated with the Romantic poet J. B. Zaleski in Leszczynek turn it into a recreational and historic area that performs educational and integration function. Local residents and visitors may take part in a number of cultural and recreational events.

Piotrkowska Cultural Park in Lodz extends protection over the historic area, one of the most recognisable places associated with Lodz. From the very beginning, Piotrkowska has been a shopping street. Nowadays, besides being a shopping area, Piotrkowska fulfils recreational, integration, historic, and cultural functions. It is filled with restaurants, cafes, pubs, clubs, shops, business headquarters, commercial offices and institutions. Piotrkowska also becomes a stage for concerts, fairs, sports and cultural events organised on different occasions and attracting big numbers of residents and visitors from Poland and from abroad.

Moreover, as shown by results of the social surveys carried out with the involvement of representatives of local authorities and civil servants from local administration dealing directly with cultural parks, the main function of park areas is to protect cultural heritage (table 3).

Table 3. Area and functions of cultural parks in Lodz voivodeship as seen by representatives of local authorities and administrative units responsible for these parks

Cultural park	Main functions
Piotrkowska Cultural Park in Lodz	• protection • tourist • social
Castle Hill Cultural Park in Sieradz	• protection • cultural • recreational
Weavers' Town Cultural Park in Zgierz	• protection • cultural • integration
Cultural Park of the ethnographic sub-region of Kutno associated with a Romantic poet Józef Bohdan Zaleski in Leszczynek	• protection • cultural • integration

Source: authors' own work based on research.

According to respondents, each of the above cultural parks protects, above all, elements of cultural heritage typical of given areas. Yet, due to their nature, parks play a number of other functions serving the needs of local communities. Interestingly, results of studies suggest that cultural parks also have a powerful impact on integration. As indicated by respondents, the setting up of cultural parks in Zgierz and in Leszczynek and activities undertaken to this end in collaboration with the local community and local business circles have strengthened the identification with the area and integrated local residents.

Cultural Heritage and Its Protection as a Factor Generating Sustainable Development –Case Study of Weavers Town Cultural Park in Zgierz

Cultural park is an arrangement used in monument protection, which awards protection to an entire area with all property and structures situated there together with the surrounding space. There are pros and cons to this format. Social surveys with the participation of residents were carried out in Zgierz where the first cultural park in Poland was established back in 2003.

Results of these pilot studies indicate that throughout its operations the park has managed to occupy a remarkable place in the minds of local people. As many as 80% respondents (out of 50 questionnaire studies) declared being aware of its existence in Zgierz and 20% said they did not know that the city owns such a valuable area protected as a cultural park. Besides, only 10% of those who claimed they knew about cultural park have never visited it. Thus, the majority of investigated population are not only aware that there is a cultural park in Zgierz, but they also visited it and enjoyed its attractions. The most often visited places in the Weavers' Town Cultural Park in Zgierz are the Museum of Zgierz (52% respondents) and Weavers Cafe & Bistro [Café&Bistro U Tkaczy] (32% respondents). Respondents also stressed that they like walking in this area (42% respondents).

Results show that the cultural park established in Zgierz 15 years ago contributes to the development of the town and impacts the identity of local residents. The majority of respondents (94%) could successfully name cultural heritage of Zgierz, its tangible and intangible elements (i.e., property, sculptures, culture, and language) of high value, which provide an excellent source of knowledge available for present and future generations and can be used in the future as foundations of social and economic potential. Only 6% of respondents see elements of cultural heritage as something material, which can be considered outside of immaterial context (culture, tradition or language).

A clear majority of respondents included in the study (84%) also stressed that cultural heritage of Zgierz is very important as evidence of common history that needs to be cherished and developed. According to respondents, cultural heritage, because of its uniqueness and specificity of its components, makes an important basis for historic education and for building the awareness of local community (66% respondents), as well as for preserving the identity of the place (68% respondents). In the minds of residents of Zgierz, this heritage brings in an important potential for the development of tourism (62% respondents).

In the course of the study, respondents identified functions fulfilled by the cultural park in Zgierz. Most of them (74%) claimed that the main function of the park is the cultural function because of the number of cultural events organised there. The park also hosts cultural organisations and institutions of culture (Museum of Zgierz, Wood Preservation Centre, etc.). The majority of respondents also pointed to the educational (62%) and social (34%) functions as primary functions of a cultural park. Cultural park offers workshops and educational walks. Besides, respondents mentioned recreational (20%), tourist (16%), protection (11%), and integration (8%) functions of the cultural park in Zgierz. It is worth noting that the main function of the cultural park, i.e. – protection – identified as such by representatives of local authorities and organisational units responsible for cultural parks was seen as marginal by residents compared to other most often mentioned cultural, educational or social functions.

Cultural heritage is seen by respondents from Zgierz as a key factor that impacts the development of the town (3.82 on a scale from 0 to 5). This factor was enumerated together with local social capital, which ranked the highest in the eyes of residents (3.86 – we used the scale from 0 (no impact) to 5 (very big impact) upon the development of the town/city), cultural heritage (3.82), and economic potential of the town (3.74), but also high quality education (3.68), creativity, and entrepreneurship of local community (3.66). We need to bear in mind that most respondents believe that the above factors exert big or very big impact on the development of the town.

Interestingly, when asked about benefits from having a cultural park in Zgierz, respondents (Zgierz residents) most often pointed to the deepening of historic education, building residents awareness and identity (62% respondents), and the protection of cultural heritage (62% respondents). Residents of Zgierz are also aware of other benefits of the presence of a cultural park in their town, such as promotion of the place among local community and external users as a site of high cultural value (54% respondents) and putting the space covered by cultural park in order (48% respondents). Other benefits listed by respondents include the enhanced investment attractiveness to new business operators interested in locating their businesses in the cultural park (40% respondents) and putting in place bans and limitations aimed at reducing destruction within the area (26% respondents). Local people are aware of many benefits resulting from the presence of the cultural park in Zgierz, which materially contributes to the protection and maintenance of the existing cultural heritage but also significantly determines the development of the area in accordance with sustainable development principle.

According to respondents, the biggest threats to elements of cultural heritage are posed by the ignorance of owners of buildings who tend to neglect necessary major repairs or do not carry out current repairs of immovable structures (82% respondents) and by society who through their conduct may inflict destruction on monuments (intentional devastation or acts of vandalism) (58% respondents). Another often mentioned threat includes repair, restoration, regeneration or adaptation works conducted in a non-professional way by people who do not perform their work properly. Speaking of the awareness of representatives of local authorities and organisational units who take care of cultural parks, there is a constant threat that care for technical shape and the condition of cultural heritage objects will be neglected and the intergeneration transmission of the nature and value of local cultural heritage will get disrupted. This last threat remains almost unnoticed by the residents, who are natural carriers of the specific character and outstanding value of local cultural heritage of Zgierz.

Conclusions

Social awareness about the value of local cultural heritage is on the rise, however, as a non-renewable resource cultural heritage must be covered with proper protection and care and it must be well managed. We need to rationally manage and protect elements of local cultural heritage to preserve it for future generations and to maintain the identity of these places. Excessive and thoughtless exploitation may lead to irreversible consequences.

Most respondents claimed a cultural park is a correct format to protect cultural heritage because restoration plans and principles of protection laid down in resolutions and provisions of local development plans considerably facilitate the management of the protected areas and offer an array of tools that help to more effectively enforce these rules.

By protecting cultural landscapes, a cultural park covers the entire area with natural and man-made objects. It not only contributes to spatial order but also guarantees sustainable development. Cultural parks in Poland offer a wide range of elements of local heritage typical of respective areas in which they have been established. Very often parks host institutions of culture and businesses, which expand their service offer, help learn about the history of places, shape the identity and awareness of local population, and make people aware of the need to protect valuable areas of local cultural heritage.

Results of studies conducted among the residents and representatives of units that supervise cultural parks in the Lodz region suggest that cultural heritage is an appreciated element of culture. Respondents are increasingly

more aware of the existence of local heritage and threats with which it is faced. They highlight the need to especially protect common identity and history and take care of these places, while observing the principles of spatial order and sustainable development. Respondents see cultural parks as educational, recreational and cultural (rather than protection) spaces, which may mean that units which manage cultural parks are increasingly more skilful at combining protection with the inclusion of cultural heritage into development processes and its use by the local community.

The contribution of the authors

Ewa M. Boryczka – 50% (concept and objectives, literature review, data analysis, writing).

Justyna Michalak – 40% (concept and objectives, literature review, research, data analysis, writing).

Piotr Rzeńca – 10% (concept and objectives, literature review).

Literature

Barthel-Bouchier D. (2016), *Cultural heritage and the challenge of sustainability*, London, New York

Boryczka E., Zasina J. (2016), *Dziedzictwo kulturowe i tożsamość miasta*, in: Nowakowska A., Przygodzki Z., Rzeńca A. (eds), *EkoMiasto#Społeczeństwo. Zrównoważony, inteligentny i partycypacyjny rozwój miasta*, Łódź, p. 65

Boryczka E.M. (2016), *Economic base in urban regeneration process in postindustrial cities*, „Gospodarka w Praktyce i Teorii" Vol. 45

Chabiera A. (ed.) (2016), *Dziedzictwo obok mnie – poradnik zarządzania dziedzictwem w gminach*, Warszawa

Gosztyła M., Pasztor P. (2013), *Konserwacja i ochrona zabytków architektury*, Rzeszów

Guzmán P.C., Pereira Roders A.R., Colenbrander B.J.F. (2017), *Measuring links between cultural heritage management and sustainable urban development: An overview of global monitoring tools*, "Cities" No. 60

Jewtuchowicz A. (2013), *Terytorium i współczesne dylematy jego rozwoju*, Łódź

Kobyliński Z. (2000), *Zarządzanie dziedzictwem kulturowym a koncepcja ekorozwoju*, in: Gutkowska K. (ed.), *Problemy zarządzania dziedzictwem kulturowym*, Warszawa

Kozłowski S. (2002), *Ekorozwój: wyzwanie XXI wieku*, Warszawa

Lipińska I. (2011), *Turystyka dziedzictwa kulturowego – wybrane aspekty ochrony prawnej parku kulturowego*, in: Wyszkowska I. (ed.), „Turystyka Kulturowa" No. 3, Poznań

Murzyn-Kupisz M. (2011), *Dziedzictwo kulturowe jako endogeniczny zasób rozwojowy jednostek terytorialnych (polskie doświadczenia w ramach dotychczasowych perspektyw planowania unijnego)* No. 140

Murzyn-Kupisz M. (2012), *Dziedzictwo kulturowe a rozwój lokalny*, Kraków, p. 11

Nijkamp P. (2012), *Economic Valuation of Cultural Heritage*, in: Licciardi G., Amirtahmasebi R. (eds), *The economics of Uniqueness*, Washington

O'Brien G. et al. (2015), *Developing a model for building resilience to climate risks for cultural heritage*, "Journal of Cultural Heritage Management and Sustainable Development" Vol. 5 No. 2

Protection Plan for the Castle Hill Cultural Park in Sieradz [in Polish] (2009), Krajowy Ośrodek Badań i Dokumentacji Zabytków w Warszawie

Rouba B.J. (2008), *Autentyczność i integralność zabytków*, „Ochrona zabytków" No. 4, Warszawa

Rzeńca A. (2016), *Zrównoważony rozwój miast*, in: Rzeńca A. (ed.) *EkoMiasto#Środowisko. Zrównoważony, inteligentny i partycypacyjny rozwój miasta*, Łódź, p. 52

Thorsby D. (2012), *Heritage economics: A Conceptual framework*, in: Licciardi G., Amirtahmasebi R. (eds), *The Economics of Uniqueness*, Washington

Resolution No. VI/35/2015 of the Council of Kutno Municipality of 28 April 2015 establishing cultural park in Leszczynek [in Polish]

Act on Monuments Protection and Guardianship (2003) Dz.U. 2003 No. 162 item 1568

www.archiwum.uml.lodz.pl/miasto/rewitalizacja_i_zabytki_/park_kulturowy_ulicy_piotrkowskiej/ [11-03-2018]

www.dladziedzictwa.org/programy-fundacji/parki-kulturowe-i-pomniki-historii/ [10-08-2018]

www.dworniczak.com/parki-kulturowe-w-polsce-rozmieszczenie-i-typologia/ [10-08-2018]

www.nid.pl/pl/Informacje_ogolne/Zabytki_w_Polsce/Parki_kulturowe/Zestawienie_parkow/miejsce.php?ID=3710 [10-08-2018]

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