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Czasopismo Polskiego Stowarzyszenia
Ekonomistów Środowiska i Zasobów Naturalnych

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PROBLEMY TEORETYCZNE I METODYCZNE

Barbara TCHÓRZEWSKA-CIEŚLAK • Katarzyna PIETRUCHA-URBANIK • Agnieszka ZYGMUNT

IMPLEMENTATION OF MATRIX METHODS IN FLOOD RISK ANALYSIS AND ASSESSMENT

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ABSTRACT: In the work the matrix methods of flood risk analysis and assessment were presented. Also the issue of flood risk in terms of its regulations was presented. The flood risk analysis and assessment were performed with the use of risk matrix for one of the Subcarpathian commune. For this purpose, flood risk maps were prepared and potential flood losses were calculated in accordance with existing legislation.

KEY WORDS: flood risk, risk matrix, flood losses

Introduction

Flood due to possible negative effects should be included in crisis situation understood in accordance with art. 3 of the Act of April 26, 2007 on Crisis Management (Journal of Laws 2007 No. 89 item 590) as "a situation affecting negatively the level of safety of people, property of considerable size or the environment, causing significant restrictions on the operation of relevant public administration bodies due to the inadequacy of the forces and possessed means" (Dz.U. 2002 nr 62 poz. 558;Dz.U. 2017 poz. 209).

The Floods Directive contains important issues related to the adopted flood risk strategies. In order to create the basis of these strategies, it is necessary to develop flood risk maps and, on their basis, to develop flood risk management plans (Ahmad et al., 2013; Blažkova, Beven, 2002; Brocca, 2013; Flores-Montoya et al., 2016; Röthlisberger et al., 2017). In the latter, Member States should refrain from taking measures and implementation of measures that could increase the risk of flooding in the other Member States. And even, in accordance with the principle of solidarity, the decision should be made jointly and act along the entire course of the river (Graniczny, Mizerski, 2007).

For each river basin district, Member States should prepare a preliminary flood risk assessment, containing at least: river basin maps, description of floods that occurred in the past if the likelihood of similar floods occurrence in future is big, description of floods from the past if similar events in the future can have negative consequences. On the basis of an initial flood risk assessment, Member States identify areas where there is a high risk of flooding or the occurrence of such a risk is likely. For each river basin district flood hazard maps and flood risk maps should be prepared. Flood hazard maps show geographic areas where the probability of flooding is low or extreme events are likely to occur. For each of the above scenarios, the following elements are depicted on the maps: flood range, water depth and, depending on the needs, the water flow rate. Flood risk maps present possible negative consequences of flooding and include: estimated number of inhabitants affected by floods, type of economic activity in the area affected by flooding and other useful information depending on the Member State. On the basis of flood risk maps Member States develop flood risk management plans and set objectives for flood risk management "with particular emphasis on reducing the potential negative consequences of flooding for human health, the environment, cultural heritage and economic activity" (Bartnik, Jokiel, 2012; Dyrektywa 2007/60/WE).

From the known methods of risk analysis and assessment to perform a flood risk analysis, the most appropriate is risk matrix that is based on

a basic risk definition (Cuellar, McKinney, 2017; Haimes, 2009; Lubowiecka, Wieczysty, 2000; Rak, 2004, 2008, 2009, 2010, 2014; Rincón et al., 2018; Sieg et al., 2017; Tchórzewska-Cieślak, 2008; Zhou et al., 2018). In order to create flood risk maps, the Geographic Information Systems (GIS) should be applied to the numerical terrain model (NMT) of water table elevations during floods obtained as a result of mathematical hydrological modelling (Tokarczyk et al., 2012). To set an example to show the issue, the exemplary matrices of flood risk for the commune X located in the Subcarpathian province, were presented. As a determinant of losses during floods, the number of inhabitants residing in the area at risk of flooding according to the flood hazard map was adopted. In this way, flood risk matrices were prepared for X commune, taking into account the number of people at risk of flooding in relation to the flooding probability.

The Water Law defines the flood risk as "the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event" (Dz.U. 2017 poz. 1566).

Flood protection is the task of government and self-government administration bodies assisted by water users. The protection against floods is performed taking into account flood hazard maps (Armenakis et al., 2017; Dawson et al., 2011; Haberlandt et al., 2008; Ouma, Tateishi, 2014; Simonovic, 2009; Zischg, 2018), flood risk maps and flood risk management plans, through e.g. multi-index evaluation for flood disaster (Dou et al., 2018), building ANN-Based Regional Multi-Step-Ahead Flood models (Chang et al., 2018), using a response curve approach (Murdock et al., 2018), sketch maps (Klonner et al., 2018), cloud-model-based method for risk assessment (Yang et al., 2018), application of a bayesian approach to dynamic assessment of flood (Wu et al., 2018), a parametric distance function approach (Zheng et al., 2018).

For their preparation, it is necessary to conduct preliminary flood risk assessment, taking into account the method of calculating the value of potential flood losses in individual classes of land use, for the purposes of developing flood risk maps (Dz.U. 2013 poz. 104). The paper proposes the use of matrix methods for the analysis and assessment of flood risk in accordance with the applicable legislation.

Research methods

Matrix methods for risk analysis

The risk matrix is a combination of a point scale probability of the undesirable event with a scale of consequences. The two-parameter risk estimation matrix is one of the simplest. Point values defining the risk categories were obtained using the dependence (Rak, 2004):

$$r = P \cdot C \tag{1}$$

where:
P – the probability of the undesirable event,
C – consequences of this event.

Considering the complexity of the systems, a three-parameter risk matrix was proposed. Additional parameters included in the matrix are: exposure to hazard – E or vulnerability – V. According to the above parameters, the numerical risk assessment is their product (Rak, 2004; Rak, Tchórzewska-Cieślak, 2005):

$$r = P \cdot C \cdot E \tag{2}$$

or

$$r = P \cdot C \cdot V \tag{3}$$

Along with the development of modern techniques, almost all the areas of life are equipped with various types of security and monitoring systems, in order to increase their safety and reliability. Therefore, it seems advisable to include in the matrix a fourth parameter defining the amount of protection.

A four-parameter matrix for risk estimation based on the formula is proposed (Rak, 2004; Rak, Tchórzewska-Cieślak, 2005):

$$r = \frac{P \cdot C \cdot V}{O} \tag{4}$$

where:
O – protection against threats.

In addition to protection in the risk matrix, the risk exposure (E) known from the three-parameter matrix can be taken into account, in that way we obtain a five-parameter risk estimation matrix along with the formula (Rak, 2004; Rak, Tchórzewska-Cieślak, 2005):

$$r = \frac{P \cdot C \cdot M \cdot E}{O} \tag{5}$$

where:
O – protection point weight.

Each time, for individual parameters, the size level is assigned according to the adopted point scale, e.g. low – N = 1, medium – S = 2, high – W = 3.

In this way, a punctual scale of risk measures is obtained in numerical form, which is the basis for risk assessment.

The acceptable level of risk is determined by introducing criterion values for each level of tolerable, controlled and unacceptable risk.

Implementation of risk matrices in the assessment of flood risk

Adaptation of a two-parameter matrix

On the basis of the number of endangered inhabitants, consequences categories (C) presented in table 1 were adopted. In table 2 the categories of probability (P) of flood occurrence are presented (Zygmunt, 2017).

Table 1. Categories of consequences – C

Number of endangered inhabitants	Point weight	Description
0	1	No danger
1–10	2	Negligible
11–100	3	Marginal
101–200	4	Significant
>200	5	Serious

Source: author's own work.

Table 2. Probability categories – P

Probability of flood occurrence	Point weight	Description
0,5%	1	Improbable
1%	2	Unlikely
5%	3	Occasional
10%	4	Possible
50%	5	Frequent

Source: author's own work.

After combining the probability and consequences categories, a risk matrix was obtained according to the dependence 1, which was presented in the form of table 3.

Table 3. Risk matrix

POINT WEIGHT			PROBABILITY – P				
			0,5%	1%	5%	10%	50%
			Improbable	Unlikely	Occasional	Possible	Frequent
			3	4	5		
CONSEQUENCES – C	No threat	1	1	2	3	4	5
	Negligible	2	2	4	6	8	10
	Marginal	3	3	6	9	12	15
	Significant	4	4	8	12	16	20
	Serious	5	5	10	15	20	25

Source: author's own work.

Depending on the obtained results in the risk matrix theflood risk was divided into:

- weight from 1 to 4 – tolerable risk,
- weight from 6 to 10 – controlled risk,
- weight from 12 to 25 – unacceptable risk.

Adaptation of a three-parameter matrix

Considering the vulnerability (V) related to flood risk zones, the risk assessment may be determined by multiplying the probability parameter (P), the consequences (C) and the vulnerability to the risk (V), according to the equation 3.

The following scale and weight for individual parameters were proposed:

- point weights for the probability parameter – P:
  - improbable event, the probability of flood occurrence 0,5%; with a weight 1,
  - unlikely event, the probability of flood occurrence 1%; with a weight 2,
  - occasional event, the probability of flood occurrence 5%; with a weight 3,
  - possible event, the probability of flood occurrence 10%; with a weight of 4,
  - frequent event, the probability of flood occurrence 50%; with a weight of 5.
- point weights for the consequences parameter – C:
  - no threat, number of endangered inhabitants 0; with a weight of 1,
  - negligible, number of endangered inhabitants 1-10; with a weight of 2,

  - marginal, number of endangered inhabitants 11-100; with a weight of 3,
  - significant, number of endangered inhabitants 101-200; with a weight of 4,
  - serious, number of endangered inhabitants > 200; with a weight of 5.
- point weights for the vulnerability parameter – V (Nachlik et al., 2000; Ozga-Zielińska et al., 2003; Radczuk et al., 2007):
  - flood threat zone (ZS) – this area is for the most part of the year constantly flooded with water up to the average of the highest flows in multi-year (SWQ); for a water depth range of ≤ 0,5 m, with a weight of 1,
  - high flood hazard zone (ZW) – this is the area above the ZS zone and with the upper limit at the level of water from the maximum flow with the probability of exceeding 1% of the so-called hundred-year water (Qmax 1%); for a water depth range of 0,5 < h ≤ 2 m, with a weight of 2,
  - significant flood zone (ZZ) – this is the area above the ZW zone with the upper limit at the level of water caused by the flow with half the maximum reliable flood (0,5xMWW); for a water depth range 2 < h ≤ 4 m, with a weight of 3,
  - small flood hazard zone (ZM) – this is the area above the ZZ zone up to the maximum reliable flood (MWW); for a water depth range > 4 m, with a weight of 4.

In this way, we get the quantitative risk matrix presented in table 4.

Table 4. Risk matrix

POINT WEIGH			PROBABILITY – P																			
			0,5%				1%				5%				10%				50%			
			Improbable				Unlikely				Occasional				Possible				Frequent			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
CONSEQUENCES – C	No threat	1	1	2	3	4	2	4	6	8	3	6	9	12	4	8	12	16	5	10	15	20
	Negligible	2	2	4	6	8	4	8	12	16	6	12	18	24	8	16	24	32	10	20	30	40
	Marginal	3	3	6	9	12	6	12	18	24	9	18	27	36	12	24	36	48	15	30	45	60
	Significant	4	4	8	12	16	8	16	24	32	12	24	36	48	16	32	48	64	20	40	60	80
	Serious	5	5	10	15	20	10	20	30	40	15	30	45	60	20	40	60	80	25	50	75	100

Source: author's own work.

In this way, point scale measures of risk in the numerical range from 1 to 100, for the following risk scale from 1 to 4 (tolerable risk), from 5 to 10 (controlled risk), from 12 to 100 (unacceptable risk) were obtained.

Adaptation of a four-parameter matrix

In order to assess the system of protection against threats, a four-parameter risk assessment matrix, according to formula 3, was implemented.

The description of the protection category is as follows (Ozga-Zielińska et al., 2003):

- low level of protection, basic zone – ZS and ZW hazard zones – it is a zone permanently protected against flooding, because the flow corresponding to the upper limit of the ZW threat zone is designed for technical flood protection solutions, e.g. flood banks, point weight 1,
- medium level of protection, extraordinary zone – ZZ threat zone – protection in this zone is introduced in the situation of a threat in the area where the population feels safe as it is protected by solutions applied at the border of the primary zone, point weight 2,
- high degree of protection, extreme zone – danger zone ZM – protection in this zone is usually activated after occurrence of events causing extreme high flow, point weight 3.

Other parameters are presented in point 3.2.The presented scale of point weights is a proposal for the initial risk assessment, in this way the following risk categories can be assumed:

- tolerable, point scale from 0,33 to 3,
- controlled, point scale from 3 to 20,
- unacceptable, point scale from 20 to 100.

Determination of potential flood losses

The estimated number of residents likely to be affected by the flood is assumed to be the number of people registered in the area. Residential buildings and objects of special social significance are distinguished between those "for which the water depth is less than or equal to 2 m, and objects for which the water depth is greater than 2 m" (Dz.U. 2013 poz. 104).

The values of potential flood losses for individual classes of land use are determined by the formula (Dz.U. 2013 poz. 104):

$$Sp_i = \sum_{j=1}^{4} Sp_{ij} \cdot A_i \qquad for\ i = 1...9 \tag{6}$$

where:

Sp_i – means the total values of potential unit losses for a given class of land use,

Sp_{ij} – means the value of potential unit losses for a given class of land use and the water depth range,
A_i – means the area occupied by a given land-use class.

However, the values of potential unit losses in classes are expressed as (Dz.U. 2013 poz. 104):

$$Sp_{ij} = W_i \cdot f(h_j) \tag{7}$$

where:
Sp_{ij} – means the value of potential unit losses for a given class of land use and the water depth range,
W_i – means the value of the property in a given class of land use,
$f(h_j)$ – means the value of the loss function relating to the depth of water with the loss of value of the property in a given class of land use.

The values of the loss function are selected for each class of land use according to the water depth at the limits of the intervals of these depths from the tables contained in the regulation (Dz.U. 2013 poz. 104). In turn, the value of assets in a given class of land use is selected from tables depending on the voivodship.

In table 5 the values of the loss function for residential areas which, according to the regulation, should be taken into account in order to link the water depth during floods with the loss of property value in a given class of land use, were presented.

Table 5. The value of the loss function for residential areas.

Water depth h [m]	Value of the loss function f(h) [%]
≤ 0,5	20
0,5 < h ≤ 2	35
2 < h ≤ 4	60
> 4	95

Source: author's own work based on (Dz.U. 2013 poz. 104).

Application example

The analysis was conducted on the basis of materials received from the office of the distinguished commune located in the Subcarpathian province and occupying an area of 200 km^2. For analysis, 12 villages of the considered commune were taken. The basic data were flood area coverage maps with a given probability of flooding. Using the ArcGIS Explorer version, a flood risk map was drawn up.

Table 6. Flood risk in the distinguished commune

Location	Number of residents	Flood threat			
		The probability of flood	The number of vulnerable households	Percentage ratio	Number of endangered people
A	3563	due to the lack of a large watercourse flowing through the distinguished location, there are no people at risk of being exposed to a flood			
B	1399	despite the flow of the stream through the settlement, there are no people at risk of flooding			
C	896	no watercourse threatening the inhabitants, so there are no people at risk of flooding			
D	1415	due to the location of the buildings directly on the banks of the river and near the estuary, the number of people at risk of flooding was determined depending on the flood probability			
		50%	1	0,3%	4
		10%	3	1%	13
		5%	10	3%	45
		1%	42	13%	188
		0,5%	57	18%	255
E	4191	the stream flowing through the village is a threat to the inhabitants only in the case of extremely high flood			
		0,5%	3	0%	14
F	788	due to the lack of a large watercourse flowing through the village, there are no people at risk of a flood			
G	318	no watercourse and endangered inhabitants			
H	1355	the location of the village on the banks of the river poses a great threat to the residents, therefore the number of people at risk was determined			
		50%	2	1%	10
		10%	20	7%	98
		5%	32	12%	157
		1%	61	22%	298
		0,5%	91	33%	445
		50%	2	1%	10
I	972	due to the lack of a watercourse in the village, there are no people exposed to the flood			
J	293	due to the proximity of the river, the number of endangered inhabitants is presented in the next lines			
		10%	5	8%	22
		5%	13	20%	58
		1%	30	45%	133
		0,5%	32	48%	142
K	1749	there is a threat due to the proximity of the river			
		10%	5	1,3%	23
		5%	6	2%	27
		1%	60	16%	273
		0,5%	70	18%	318
L	3483	as in the case of the village of E, despite the flow of the stream, the flood risk is not too high and the number of endangered inhabitants is presented in the following lines			
		5%	1	0,1%	5
		1%	4	1%	19
		0,5%	8	1%	39

Source: author's own work.

On the basis of the flood hazard maps, the flood hazard number obtained in each location and the number of households, the percentage of all households in a given location in danger of flooding, was calculated (table 6) (Zygmunt, 2017).

For particular location of the commune scales of the probability (P) and the consequences (C) were assumed and the value of flood risk (r) was calculated, according to the formula 1, using the guidelines of the two-parameter matrix. Summary of the results together with the division of flood risk is presented in table 7.

Table 7. Flood risk in the concerned commune

Location	P	C	r	Description
A	1	1	1	Tolerable risk
B	1	1	1	Tolerable risk
C	1	1	1	Tolerable risk
D	2	4	8	Controlled risk
E	2	1	2	Tolerable risk
F	1	1	1	Tolerable risk
G	1	1	1	Tolerable risk
H	2	5	10	Controlled risk
I	1	1	1	Tolerable risk
J	2	4	8	Controlled risk
K	2	5	10	Controlled risk
L	2	3	6	Controlled risk

Source: author's own work.

On the basis of the obtained results for the flood risk in particular localities of the analysed commune, the estimated flood losses in the housing areas of the commune were calculated.

The formula presented in the Regulation of the Minister of Environment, Minister of Transport, Construction and Maritime Economy, Minister of Administration and Digitization and Minister of the Interior of 21 December 2012 on the development of flood hazard maps and flood risk maps was used for this purpose (Dz.U. 2017 poz. 1566).

According to formula 5, the values of potential flood losses for residential areas and water depth ranges were calculated using formula 6.

The value of assets for residential housing areas, which according to the regulation is adopted for the calculation of flood losses depending on the province, for the Subcarpathian province is 201,25 PLN/m^2 (Dz.U. 2017 poz. 1566). The obtained values of potential unit losses for residential areas and water depth ranges are presented in table 8.

Table 8. Values of potential flood losses

Water depth h [m]	The value of the loss function f(h) [%]	Sp_{ij}
≤ 0,5	20	40,25
0,5 < h ≤ 2	35	70,44
2 < h ≤ 4	60	120,75
> 4	95	191,19

Source: author's own work based on (Dz.U. 2017 poz. 1566).

In order to estimate the area occupied by residential buildings in individual location of the considered commune flooded with water during the flood, with the probability assumed in the flood risk matrix with the division into water depth ranges, according to table 7, flood hazard maps were used. Analogously to the earlier proceedings, the map was enlarged to a size that makes it possible to distinguish individual households and the number of flooded householdsin the given depth ranges was calculated. Places in which tolerable flood risk occurred have not been taken into account in further calculations. Therefore flood losses were calculated for five locations in the analysed commune, in which the controlled flood risk was found (table 9).

For individual towns where flood losses occurred, the weights were calculated for the flood risk value (r), according to the formula 4, using a four-parameter matrix. The summary of the results together with the division of flood risk is presented in table 10.

Table 9. Number of households in water depth ranges

Location		Ranges of water depth [m]			
≤ 0,5		0,5 < h ≤ 2	2 < h ≤ 4	> 4	
D	Number of households in water depth ranges	21	21	0	0
	Percentage of the water depth ranges [%]	6,65	6,65	0,00	0,00
	The value of flood losses in thousand [PLN]	1 540	2 695	0,00	0,00
H	Number of households in water depth ranges	35	22	4	0
	Percentage of the water depth ranges [%]	12,64	7,94	1,44	0,00
	The value of flood losses in thousand [PLN]	3 472	3 819	1 190	0,00
J	Number of households in water depth ranges	21	9	0	0
	Percentage of the water depth ranges [%]	31,82	13,64	0,00	0,00
	The value of flood losses in thousand [PLN]	194	2 494	1 871	0,00
K	Number of households in water depth ranges	25	32	3	0
	Percentage of the water depth ranges [%]	6,49	8,31	0,78	0,00
	The value of flood losses in thousand [PLN]	2 328	5 215	838	0,00
L	Number of households in water depth ranges	4	0	0	0
	Percentage of the water depth ranges [%]	0,56	0,00	0,00	0,00
	The value of flood losses in thousand [PLN]	274	0,00	0,00	0,00

Source: author's own work based on (Dz.U. 2017 poz. 1566)

Table 10. Flood risk in the concerned commune

Location	P	C	V	O	r	Description
D	2	4	1	1	8	Controlled risk
	2	4	2	1	16	Controlled risk
H	2	5	1	1	10	Controlled risk
	2	4	2	2	8	Controlled risk
	2	4	3	2	12	Controlled risk
J	2	4	1	1	8	Controlled risk
	2	3	2	1	12	Controlled risk
K	2	5	1	1	10	Controlled risk
	2	5	2	1	20	Controlled risk
	2	3	3	1	18	Controlled risk
L	2	3	1	1	6	Controlled risk

Source: author's own work.

The estimated potential flood losses for residential areas in the concerned municipality at the occurrence of a flood with a probability of 1%, i.e. the floods of the century, are over PLN 25 million. Places in the order of the highest losses are: H, K, J, D and L.

Conclusions

Flood risk analysis and assessment aims to protect people, property and the environment from the effects of flood, it is developed in the form of flood hazard maps, flood risk and flood risk management plans.

The following conclusions were proposed after performed flood risk analysis:

- on the basis of the analysis of table 9, it was found that the flood risk in the considered commune depends on the distance of individual towns from the largest river flowing through the commune,
- the unacceptable risk does not occur in any location in the concerned commune,
- the controlled risk occurs in five locations of the commune: D, H, J, K and L. All these towns are in the vicinity of the river,
- the tolerable risk occurs in the other seven locations of the commune: A, B, C, E, F, G and I. None of these locations are adjacent to the river,
- the concerned commune is a relatively safe place in terms of flood risk when taking into account inhabited areas. For areas used for agriculture, flooding is likely to be more severe, because in these areas water depth will be larger,
- the largest flood hazard in the concerned commune is found in the location near the only bridge in the commune. In case of "the flood of the century" nearly half of the households in the J location will be flooded and almost 1/3 of the households in the neighbouring location H will be flooded,
- a slightly smaller threat is found in the village of K, also located near the bridge and in the village of D in the vicinity of the estuary, because less than 1/5 of the farms will be flooded with hundred-year-old wate,
- flood losses occur adequately to the flood risk: the higher the risk, the greater the losses.

For the location, where the controlled flood risk was found, exemplary flood losses for residential areas were calculated in accordance with the guidelines included in the regulation on the preparation of flood risk maps and flood risk maps. The flood losses expressed in monetary values in the event of "the flood of the century" will amount to approx. 25 740 thousand PLN.

The contribution of the authors

All authors contributed equally to the manuscript.

Literature

Ahmad S. et al. (2013), *Spatial and temporal analysis of urban flood risk assessment*, "Journal of Urban Water" No. 10, pp. 26-49

Cuellar A.D., McKinney D.C. (2017), *Decision-Making Methodology for Risk Management Applied to Imja Lake in Nepal*, "Water" No. 9(8)

Armenakis C. et al. (2017), *Flood risk assessment in urban areas based on spatial analytics and social factors*, "Geosciences" No. 7(4)

Bartnik A., Jokiel P. (2012), *Geografia wezbrań i powodzi rzecznych*, Łódź

Blažkova S., Beven, K. (2002), *Flood frequency estimation by continuous simulation for a catchment treated as ungauged (with uncertainty)*, "Water Resources" No. 38, pp. 1-14

Brocca L. et al. (2013), *Application of a model-based rainfall-runoff database as efficient tool for flood risk management*, "Hydrology and Earth System Science" No. 17, pp. 3159-3169

Chang L.C. et al. (2018), *Building ANN-Based Regional Multi-Step-Ahead Flood Inundation Forecast Models*, "Water" No. 10(9)

Dawson R.J. et al. (2011), *An agent-based model for risk-based flood incident management*, "*NaturalHazards*"No. 59, pp. 167-189

Dou Y. et al. (2018), *Multi-index evaluation for flood disaster from sustainable perspective: A case study of Xinjiang in China*,"International Journal of Environmental Research and Public" No. 15(9)

Dyrektywa 2007/60/WE Parlamentu Europejskiego i Rady z dnia 23 października 2007 r. w sprawie oceny ryzyka powodziowego i zarządzania nim, Dz.U.UE L 288/27 z dnia 6.11.2007

Flores-Montoya I. et al. (2016), *Fully Stochastic Distributed Methodology for Multivariate Flood Frequency Analysis*, "Water" No. 8(6)

Graniczny M., Mizerski W. (2007), *Katastrofy Przyrodnicze*, Warszawa

Haimes Y.Y. (2009), *On the complex definition of risk: A systems-based approach*, "Risk Analysis" No. 29, pp. 1647-1654

Haberlandt U. et al. (2008), *A space-time hybrid hourly rainfall model for derived flood frequency analysis*, "Hydrology and Earth System Science" No. 12, pp. 1353-1367

Klonner C. et al. (2018), *Capturing Flood Risk Perception via Sketch Maps*, "ISPRS Int. J. Geo-Inf." No. 7

Lubowiecka T., Wieczysty A. (2000), *Ryzyko w systemach zaopatrzenia w wodę*, in: M. Maciejewski (ed.), *Ryzyko w gospodarce wodnej*, Monografia Komitetu Gospodarki Wodnej PAN, z. 17, Warszawa, pp. 113-143

Murdock H.J. et al. (2018), *Assessment of Critical Infrastructure Resilience to Flooding Using a Response Curve Approach, "*Sustainability" No. 10(10)

Nachlik E. et al. (2000), *Strefy zagrożenia powodziowego*, Wrocław

Ouma Y.O., Tateishi R. (2014), *Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric AHP and GIS: Methodological Overview and Case Study Assessment*, "Water" No. 6, pp. 1515-1545

Ozga-Zielińska M. et al. (2003), *Powodziogenność rzek pod kątem bezpieczeństwa budowli hydrotechnicznych i zagrożenia powodziowego*, materiały badawcze, Warszawa

Radczuk L. et al. (2001), *Wyznaczanie stref zagrożenia powodziowego*, Wrocław

Rak J.R. (2004), *Istota ryzyka w funkcjonowaniu systemu zaopatrzenia w wodę*, Rzeszów

Rak J.R. (2008), *Wybrane zagadnienia niezawodności i bezpieczeństwa w zaopatrzeniu w wodę*, Rzeszów

Rak J.R. (2009), *Bezpieczeństwo systemów zaopatrzenia w wodę*, Warszawa

Rak J.R. (2014), *Problematyka ryzyka w wodociągach*, Rzeszów

Rak J.R., Kwietniewski M. (2010), *Niezawodność infrastruktury wodociągowej i kanalizacyjnej w Polsce*, Warszawa

Rak J.R., Tchórzewska-Cieślak B. (2005), *Metody analiza i oceny ryzyka w systemie zaopatrzenia w wodę*, Rzeszów

Rincón D. et al. (2018), *Flood Risk Mapping Using GIS and Multi-Criteria Analysis: A Greater Toronto Area Case Study*, "Geosciences" No. 8(8)

Röthlisberger V. et al. (2017), *Identifying spatial clusters of flood exposure to support decision making in risk management*, "Science of the Total Environment" No. 598, pp. 593-603

Rozporządzenie Ministra Środowiska, Ministra Transportu, Budownictwa i Gospodarki Morskiej, Ministra Administracji i Cyfryzacji oraz Ministra Spraw Wewnętrznych z dnia 21 grudnia 2012 r. w sprawie opracowywania map zagrożenia powodziowego oraz map ryzyka powodziowego, Dz.U. 2013 poz. 104

Sieg T. et al. (2017), *Tree-based flood damage modeling of companies: Damage processes and model performance*, "Water Resources Research" No. 53, pp. 6050-6068

Simonovic S.P. (2009), *Managing flood risk, reliability and vulnerability* "Journal of Flood Risk Management" No. 2, pp. 230-231

Tchórzewska-Cieślak B. (2008), *Niezawodność i bezpieczeństwo systemów komunalnych na przykładzie systemu zaopatrzenia w wodę*, Rzeszów

Tokarczyk T. et al. (2012), *Wstępna Ocena Ryzyka Powodziowego jak element wdrażania Dyrektywy Powodziowej*, "Infrastruktura i Ekologia Terenów Wiejskich" No. 3, pp. 67-78

Ustawa z dnia 18 kwietnia 2002 r. o stanie klęski żywiołowej, Dz.U. 2002 nr 62 poz. 558 z późn. zm.

Ustawa z dnia 18 lipca 2001 r. Prawo wodne, Dz.U. 2017 poz. 1121 z późn. zm.

Ustawa z dnia 20 lipca 2017 r. Prawo wodne, Dz.U. 201poz. 1566

Ustawa z dnia 26 kwietnia 2007 r. o zarządzaniu kryzysowym, Dz.U. 2017 poz. 209 z późn. zm.

Wu J. et al. (2018), *Application of Bayesian Approach to Dynamic Assessment of Flood in Urban Underground Spaces*, "Water" No. 10(9)

Yang S. et al. (2018), *Cloud-Model-Based Method for Risk Assessment of Mountain Torrent Disasters*, "Water" No. 10(7)

Zheng J. et al. (2018), *Re-examining regional total-factor water efficiency and its determinants in China: A parametric distance function approach*,"Water" No. 10(10)

Zhou Q. et al. (2018), *Recent Changes in the Occurrences and Damages of Floods and Droughts in the United States*, "Water" No. 10

Zischg A.P. (2018), *Floodplains and Complex Adaptive Systems-Perspectives on Connecting the Dots in Flood Risk Assessment with Coupled Component Models*, "Systems" No. 6(2)

Zygmunt A. (2017), *Zasady analizy ryzyka powodziowego*, praca dyplomowa magisterska, Rzeszów

Żelaziński J. (2007), *Rola map terenów zalewowych w planowaniu ochrony przeciwpowodziowej, Bezpieczna gmina nad Odrą*, Kampania informacyjno-promocyjna na rzecz ochrony i zachowania nadodrzańskich terenów zalewowych dla ochrony przyrody i poprawy bezpieczeństwa powodziowego, materiały informacyjne, Wrocław

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SEDIMENT QUANTITY MANAGEMENT IN POLISH CATCHMENT-RIVER-SEA SYSTEMS – SHOULD WE CARE?

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ABSTRACT: The continuity of sediment transport in many catchment-river-sea systems worldwide has been disturbed by anthropogenic interferences. These interferences alter the sediment balance and result either in a surplus or lack of sediment, and with mostly negative, impacts to the economy, development and infrastructure, and environment. The main issues discussed related to surplus or lack of sediment belongs to: i) siltation of reservoirs with negative effects on hydropower production or water storage, and ii) erosion at downstream reaches where sediments are essential for channel formation and aquatic habitats. Both problems are recognized in Poland, however, only dealt with when they cause local economic problems. The paper focuses on examples of sustainable sediment managements in catchment-river-sea systems, and presents the idea of combining the Macromodel DNS with the SWAT module. The resulting modelling and analytical tool can be considered very valuable in sediment quantity management.

KEY WORDS: sediment, quantity, management, catchment

Introduction

Recent years have brought about a gradual change in the approach to sediments and a growing understanding of their role in aquatic environments. Not more than two decades ago, the sediment research and management efforts were mainly site-specific, undertaken when sediment quality or quantity posed a nuisance forbeneficial uses, or risk to health or the environment (Apitz, 2012). Coarse and fine sediments are natural and essential components of ecosystems, providing habitat and substrate for a variety of organisms. They are also considered as a dynamic component of the hydrologic cycle which links terrestrial, freshwater and marine ecosystems. Sediments also play a role in a wide range of human activities within aquatic systems, including flood protection, water resource management, as well as the maintenance of navigability, and the protection of coastlines.

Natural and anthropogenic disturbances in sediment balances can result either in a surplus or lack of sediment, with large-scale mostly negative impacts to the economy, development, infrastructure, and environment. Therefore, estimating and predicting suspended sediment load in catchment systems has long been a goal for sedimentologists, hydrologists, hydraulic and environmental engineers, and many other earth specialists. Both, in Poland and globally, there are currently no comprehensive systems for monitoring of the transported sediments quantity and quality. Since, knowledge about sediment in surface waters usually comes from single computational profiles, where single measurements of low frequency are made, modeling and estimation have become key elements in global water resources and environmental policy and management (Olyaie et al., 2015; Suedel et al., 2015).

A somewhat disregarding approach to the sediment problem in Poland, observed in various management documents, is somehow undermining research in this field of knowledge. As consequence of this situation we still have many river basins where strong erosional processes induced by human activity are observed, but their extent and impact on ecosystems is not estimated and discussed. The problem becomes even more exacerbated in systems where sediment continuity is altered by dam construction. In this case, we should be concerned not only about how much sediment is being delivered and trapped in the reservoir, but also how much of the sediment is being released to the downstream reaches of the river. Such data is almost completely nonexistent for Polish dam reservoirs, especially for the outflow parts of such systems. Since, the surplus or lack of sediment in its budget may have serious consequences to the ecosystems, the issue of sediment quantity management shall be recognized and discussed more extensively in Poland. Following this idea, the paper discusses its importance, and provides examples

of sustainable sediment management. Taking into consideration shortages in the existing monitoring data, the Authors propose also a modelling tool to overcome this problem. This tool combines possibilities offered by environmental models and field studies based on the sediment fingerprinting method. Such a combination provides optimal opportunities to estimate the quantity and quality of suspended sediment in the whole catchment, and also assess the impact of climate change and land use on sediments.

Importance of sediment quantity management

In natural and non-altered anthropogenic intervention environments, sediments are usually not considered a stressor, and do not need to be managed, neither in terms of quality nor quantity (Apitz, 2012). However, since natural and non-altered conditions in aquatic environments become more and more rare, we shall mostly deal with results of human activity, additionally amplified in recent years by climate change. In case of sediments, rate and magnitude of input changes, alterations of hydromorphological conditions of water courses, intensive use of catchments and water bodies are only a few reasons to be concerned about their management.

The role of sediments in ecosystems has been discussed in countless publications. They have often been referred as "sink and source" for or a wide variety of organic and inorganic pollutants (e.g. Perelo, 2010), a "vital link between terrestrial and aquatic environment" (e.g. Likens, Bormann, 1974), or a "global problem" (Chapman, Smith, 2010). Originating from various processes and sources in the catchment, sediments are transported in form of fine (suspended sediment) and coarse (bedload) particles. Both types of sediment particles are of a crucial importance for aquatic systems, equally in terms of quality and quantity. They serve, among the others, as: a habitat for aquatic organisms (fish, macroinvertebrates, diatoms, and macrophytes), a key component of pollutant fate and transport (sorption and release of substances), and as a major factor shaping riverbeds, floodplains and estuarine mudflats (e.g. Kondolf, 1997; Kondolf et al., 2014). The rate of the sediment transport and its continuity in catchment-river-sea systems have been severely altered in many places, through implementation of different arrangements and structures to intensify or protect beneficial uses of watercourses by humans. The most common discourse on sediment transport interruption has been focused on trapping of sediment in dam reservoirs. Reservoirs serve different purposes (i.e. flood control, water supply, and power production), and their trap efficiency is frequently reported as 50-80% of the sediment volume delivered from the watershed (Sundborg, 1992; Vorosmarty et al.,

2003). The obvious consequence of sediment deposition is depletion in reservoir capacity, and accumulation of contaminants associated with sediment particles. An equally important consequence, however, definitely less frequently discussed in Poland, is observed in downstream reaches of dammed rivers. There is an increasing evidence of ecosystem effects resulting from sediment starvation downstream of dams, often called "hungry water" (Kondolf, 1997), including channel incision, coastal erosion, and delta drowning (e.g. Schmitt et al., 2017).

It should also be noted, that these results of human interventions can be additionally amplified by the impacts of climate change. Most of the currently available climate models, clearly indicate a warming trend of the Earth's surface, resulting from increased greenhouse gas concentrations (Errico et al., 2013; IPCC, 2014). According to the Fifth IPCC Assessment Report (AR5) conclusions, and the National Oceanic and Atmospheric Administration (NOAA) findings, climate change has an impact (with a different probability) among others on: the global water cycle, changes in precipitation distribution, and its intensification over land areas, as well as frequency of extreme weather events (NOAA, 2017). On a catchment scale, climate change can lead to alterations in water quantity reaching the soil, and thus to disturbances of natural processes like: increased weathering, increase of erosion rate and denudation, and increased surface runoff. Since, these processes are responsible for sediment delivery from catchment areas to surface waters (Middelkoop et al., 2001; Li et al., 2009), therefore, global climate change has the potential to modify suspended sediment quantity, and quality. This clearly indicates the need for development of comprehensive catchment-river-sea sediment management strategies, and accurate sediment quantity monitoring.

Examples of sustainable sediment management

Since, the erosive power of rainfall is expected to grow due to increase of precipitation intensity (e.g. Burt et al., 2016; Panagos et al., 2017), the increased erosion rates can elevate the sediment delivery from catchments to water bodies. Indeed, such phenomena has been observed in many lakes and reservoirs, especially in upland and mountain areas (e.g. Marziali et al., 2017). The reduction of reservoir storage capacity due siltation causes necessity of undertaking various management actions, such as dredging, flushing, sluicing, or hydropeaking (Kondolf et al., 2014). Some of these actions are highly expensive and time consuming (i.e. dredging), and can additionally increase economic and ecological costs due to the requirement of disposal sites. However, some of them can be considered as a means to reestablish

sediment continuity (i.e. sluicing), as proposed by the EU Water Framework Directive (2000/60/EC) (Fremion et al., 2016).

Process of bed erosion occurring downstream of dams, resulting from sediment entrapment in reservoirs, is well recognized and described in multiple publications (e.g., Babiński, 2007; Kondolf et al., 2014). Although the majority of dam management planning and operational documents take into account solutions counteracting erosion impacts, there is growing awareness that such solutions are not always effective. Some of the downstream reaches of dammed rivers require sediment augmentation or sediment replenishment, and such actions of riverbed "feeding" with sand and gravel deposits are undertaken for various reasons (table 1).

Table 1. Selected examples of sediment augmentation projects

Localization	Year	Action	Reasons	Source
Isar River (Germany)	since 1995	artificial sediment (re-)insertion	channel incision, groundwater table lowering, subsequent ecological consequences to floodplain	Heckmann et al., 2017
Trinity River (California, USA)	since 2000	supplementation of coarse sediment (gravel/cobble bars), improvement of its transport	reduced gravel bar deposits, and reduced salmon spawning and rearing habitat	http://www.trrp.net/
Mokelumne River (California, USA)	2003-2004	placement of cleaned floodplain gravel	protection of salmonids and their spawning grounds and benthic organisms	Merz et al., 2005
Yodo River system (Japan)	2004-2009	sediment replenishment	restoration of bed load transport and the associated habitat	Kantoush, Sumi, 2010
Lower American River (California, USA)	2011-2012	gravel augmentation	improvement of salmon spawning sites	Zeug et al., 2014
Wisłoka River (Poland)	2011-2015	gravel augmentation, large-scale boulders placement	reconstruction of gravel habitats of fish	http://www.krakow.rzgw.gov.pl/

Source: author's own work.

Most projects are undertaken to restore aquatic habitat, especially for fish, with gravels artificially added to enhance available spawning supply below dams (e.g. Kondolf, 1997; Kondolf et al., 2014), beginning with the creation of riffles for salmon spawning on the Trinity River below the Lewiston Dam in California. However, in the last couple of decades the increased use of sediment augmentation has been observed to support restoration of geomorphological processes, such as channel migration, or formation of bar features (Gaeuman, 2014), and to restore sustainable sediment management (Heckman et al., 2017). Gravel augmentation is also implemented for non-ecosystem purposes, such as damage to downstream infrastructure

(bridges, pipeline crossings, and embankments), with the largest ongoing project on the Rhine River below the Barrage Iffezheim (Kuhl, 1992).

Also, in Poland such operations are discussed more and more frequently. The first gravel feeding concept in Poland was proposed by Parzonka (Parzonka et al., 2010) for the Odra river below the Malczyce barrage (300 km). Since then, such projects are undertaken occasionally when river bed erosion induces local economic or ecological problems. For example, in 2010-2015 two projects of patency restoration for the Wisłoka and Biała Tarnowska rivers and their tributaries have been executed, which also included gravel supplementation to restore structure of fish habitats and spawning sites (Bartnik et al., 2015). Also, sediment augmentation has been proposed for the Vistula river downstream from the Włocławek reservoir since, the river is not able to autonomously recreate the transport of its deposits in the eroded sections of the river (Habel et al., 2017). Despite the research efforts, the sediment quantity issue seems to be neglected in the official management documents. It should be noted, that in the water management plans for the Vistula and Odra catchments adopted in 2016, the term of "sediment" ("rumowisko") has been mentioned only once, precisely in the context of expected increase of sediment transport in the upland parts of these catchments (Dz.U.2016.1911; Dz.U.2016.1967). In light of construction plans of new weir on the Vistula river (Siarzew, 706 km) these issues should be discussed and deal with more repeatedly.

Tools in sediment quantity monitoring

Research on sediment quantity, transport and fate is of crucial importance, not only from academic reasons to understand better geomorphological forms and processes, but also to provide assistance in engineering and management operations in riverine environments. The choice of the most accurate measuring systems, both for bedload and suspended matter, is often difficult and depends on many parameters, and can be broadly divided into direct and indirect techniques. The direct ones commonly use a variety of samplers, traps or slots allowing data collection in selected locations and time intervals (e.g. Habersack et al., 2017). While indirect (surrogate) monitoring systems are based on instruments operating mainly on bulk optic (turbidity), laser optic, pressure difference, and acoustic backscatter for suspended sediments (Lin et al., 2016) and acoustic Doppler current profilers (ADCPs), sonar, radar, and smart sensors for bedload measurements (Grey et al., 2010). In any case, quantifications of sediment volumes are time consuming, some of which are very expensive, and usually pose difficulties due to significant spatio-temporal variability of the sediment transport.

When monitoring data is limited, which is a common situation for many catchments, it becomes essential to use supplemental tools such as mathematical models. They provide an opportunity for the complementing of spatial and temporal resolution data, and simulation of interactions with various elements of the environment, also under forecasted climate changes. The proper choice of a modelling tool is crucial to incorporate necessary information from the field of hydrology, geology, and environmental engineering, and to integrate existing research data. Almost from the moment of its first creation, the SWAT model (Soil and Water Assessment Tool) (Neitsch et al., 2011) was used to simulate the intensity of water erosion occurring in river catchment areas and suspended sediment movement in the water column. Generally, it is a continuous long-term yield model, where processes associated with water and nutrient cycles are directly modeled by internal algorithms to describe the relationship between input and output variables. Physical processes are simulated within hydrologic response units (HRU), which are designed as land areas within a sub-basin that are comprised of unique land cover, and soil and management combinations. Although the SWAT module is most often used to simulate the transport of biogenic compounds in the catchment, it can also be used to simulate water erosion and suspended sediment transport in rivers and reservoirs. This possibility is provided by the built-in USLE module (Universal Soil Loss Equation) and its modifications R-USLE and M-USLE (Bagarello et al., 2010), which is an empirical, probabilistic equation developed for calculating the amount of soil loss in areas used for agriculture. This tool allows one to very precisely estimate the amount of suspended sediment on any number of calculation profiles on the river according to the following formula:

$$Sed = 11.8 \cdot (Q_{surf} \cdot q_{peak} \cdot area_{hru})^{0,56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG$$

where:

Sed – is the sediment yield on a given day [metric tons],
Q_{surf} – is the surface runoff volume [mm/ha],
q_{peak} – is the peak runoff rate [m^3/s],
$area_{hru}$ – is the area of the HRU [ha],
K_{USLE} – is the soil erodibility factor,
C_{USLE} – is the cover and management factor,
P_{USLE} – is the support practice factor,
LS_{USLE} – is the topographic factor,
CFRG – is the coarse fragment factor.

The SWAT modelallows also for conducting analyses of the river load time variability with the sediment load and the annual sediment production in each selected catchment area limited by calculation profiles (Peraza-Castro et al., 2014; Duru et al., 2017), and helps to understand soil erosion mech-

anisms (Li et al., 2017; Melaku et al., 2017). Currently, many publications describe calibration methods and obtained results for suspended sediment for catchments of various sizes located in different climatic zones (Vigiak et al., 2015; Rodríguez-Blanco et al., 2016). However, it should be noted that SWAT simulations of runoff discharge often have problems with showing any good fitting in suspended sediment concentrations (Mizugaki et al., 2014; Haregeweyn et al., 2017; Shivhare et al., 2017). In any case, the SWAT module works well in simulating phenomena related to suspended sediment transport both on natural and strongly altered basins. The use of this module on rivers with water dams also produces good results, especially when combined with radionuclide dating of sediment cores and bathymetric survey methods (Alighalehbabakhani et al., 2017). The built-in meteorological module also allows understanding the impacts of projected climate change on the hydrological processes. Simulations of the impact of climate change on water erosion and the amount of suspended sediment in surface waters using the SWAT module are used to prepare action programs aimed at reducing their negative impact on the environment (Verma et al., 2015; Nerantzaki et al., 2015; Li et al., 2017).

The Polish modelling tool, Macromodel DNS (Discharge-Nutrient-Sea) (Wilk et al., 2017) created at the Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB) allows analyzing of the processes which take place in catchments related to water and matter cycles. This macromodel combines existing and verified mathematical models and equations of hydrological transport process units. It allows the simulation of long-term impact of land use on water quality and the impact of pollutant such as suspended sediment discharges to surface waters. It is a combining of data processing modules, data replenishment modules, water quantity models and water quality models. The Macromodel DNS contains also theSWAT model as an integral module, and the resulting DNS/SWAT Macromodel has been successfully used for analyzing nutrient and suspended sediment transport, and also preliminary analysis of climate change in six catchments (Wilk, 2015).

The SWAT model can estimate soil erosion from the landscape and in-stream depositional and degrading processes during sediment routing. Therefore, the Macromodel DNS/SWAT will be able to accurately determine both the amount of sediment flowing into the river, as well as the amount of sediment on all designated calculation profiles. The important feature of this model is the fact that the data only from two monitoring profiles localized in the catchment area (with a minimum of two years of monitoring activity) is required for its correct calibration, verification, and validation. Based on such data, the model will be able to simulate results for all other computa-

tional profiles determined at any place in the catchment. The model is able to simulate the movement of suspended particles from the moment of release, up to the closing profile of the catchment even when the dam reservoir is located along the way. Moreover, it makes possible simulations of phenomena occurring in water reservoirs while analyzing water level fluctuations, sedimentation, median particle diameter of the suspension, bank erosion and many others.

Due to the fact that the DNS/SWAT simulations requires validation, and also quantitative analyses of suspended sediment should be supported by the qualitative information, combining this model with meta-aids, such as radioisotopes, or sediment fingerprinting is necessary. Combination of hydrological observation and natural radionuclide investigations enables to estimate the suspended sediment yield for each lithological source area within the watershed(s), relating them with potential factors such as erosion represented by steep slopes, landslides, and bare surface of slope failures. The use of the fingerprinting technique allows also to discriminate between potential sources of suspended sediment and to provide reliable estimates of the relative contribution of these sources. Therefore, a conceptual model combining Macromodel DNS/SWAT with other research and monitoring tools has been proposed by the Section of Modeling Water Quality of the Institute of Meteorology and Water Management and the AGH University of Science and Technology. Figure 1 presents a schematic diagram showing the concept of the proposed tool. Enabling precise analysis of quantity and quality for suspended sediment in the selected river catchment. Using such a tool also provides other significant benefits, like the possibility of considering climate change andland use scenarios.

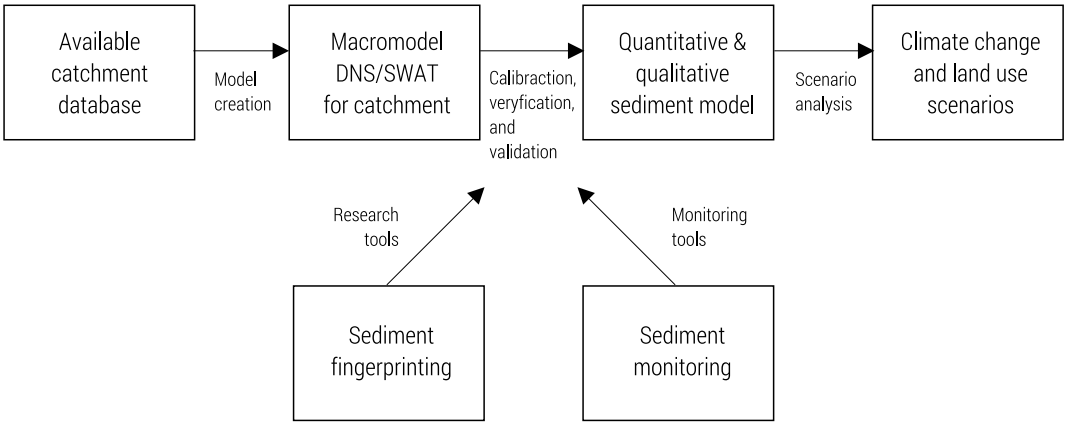

Figure 1. Conceptual model of suspended matter quantity and quality analytical tool

Source: author's own work.

Macromodel DNS/SWAT allows for the development of a baseline scenario reflecting the actual state of land use or meteorological conditions, and then comparing it with selected variant scenarios, which would take into account forecasted changes in the type of land use or climate change. The use of this tool is also possible for river catchments where the dam reservoir is situated. In such cases, monitoring data are particularly important because currently in Poland there are practically no measurements on suspended sediment quantity released from a dam. Lack of data results in possible errors in simulation results for individual calculation profiles downstream from the dam. The use of the proposed analytical tool allows to solve this problem to a large extent since, this model treats the river basin comprehensively, analyzing water erosion and suspended sediment in a watercourse as well as in a possible dam reservoir located in this watercourse.

Conclusions

Maintaining sediment transport continuity is crucial importance for important environmental and economic reasons. It has only recently begun that such a problem need be discussed for the whole catchment-river-sea system. Since monitoring data on sediment is far from being exhaustive there is an urgent need to employ different modelling tools. Despite invaluable advantages of these tools, there is still a requirement for the quantitative and qualitative data to validate and verify these model simulations. River basins where dam reservoirs are located, still pose the biggest challenge for researchers using modeling and analytical tools. Whilst the data on the quantity and quality of sediment from the source to the inflow to the reservoir can be relatively easily obtained and reproduced, the same data at the outflow from the reservoir remains thus, unattainable. The analytical tool proposed by the Authors, should help to overcome these obstacles, however, more attention to sediment monitoring is highly postulated.

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The contribution of the authors

Ewa Szalińska – 60%
Paweł Wilk – 40%

Literature

Apitz S.E. (2012), *Conceptualizing the role of sediment in sustaining ecosystem services: Sediment-ecosystem regional assessment (SEcoRA)*, "Science of the Total Environment" No. 415, p. 9-30

Alighalehbabakhani F. et al. (2017), *Forecasting the remaining reservoir capacity in the Laurentian Great Lakes watershed*, "Journal of Hydrology" No. 555, p. 926-937

Babiński Z. (2007), *Deep erosion downstream of reservoirs on the example of selected dams in the world*, "Nauka Przyroda Technologie" No. 1(2), p. 11 (in Polish)

Bagarello V. et al. (2010), *Testing alternative erosivity indices to predict event soil loss from bare plots in Southern Italy*, "Hydrological processes" No. 24(6), p. 789-797

Bartnik W. et al. (2015), *Warunki przywracania struktury siedlisk dla ryb na odcinku Wisłoki w km 73+200 – 42+600*, "Gospodarka Wodna" No. 5, p. 147-152 (in Polish)

Burt T. et al. (2016), *More rain, less soil: Long-term changes in rainfall intensity with climate change*, "Earth Surface Processes and Landforms" No. 41, p. 563-566

Chapman P.E., Smith M. (2010), *Assessing, managing and monitoring contaminated aquatic sediments*, "Marine Pollution Bulletine" No. 64(10), p. 2000-2004

Duru U. et al. (2017), *Modeling stream flow and sediment yield using the SWAT model: a case study of Ankara River basin, Turkey*, "Physical Geography", doi.org/10.1080/02723646.2017.1342199

Errico R.M. et al. (2013), *Development and validation of observing-system simulation experiments at NASA's Global Modeling and Assimilation Office*, "Quaterly Journal of Royal Meteorological Society" No. 139(674), p. 1162-1178

Fremion F. et al. (2016), *Impact of sediments resuspension on metal solubilization and water quality during recurrent reservoir sluicing management*, "Science of the Total Environment" No. 562, p. 201-215

Gaeuman D. (2014), *High-flow gravel injection for construction designed in-flow channel features*, "River Research and Applications" No. 30(6), p. 685-706

Gray J.R. et al. (2010), *Bedload-Surrogate Monitoring Technologies*, U.S. Geological Survey Scientific Investigations, Report 2010-5091

Habel M. et al. (2017), *Issues related to renewal of the bed load downstream of dams. Assessment of the possibility to artificially rebuild the load downstream the Włocławek dam*, "Gospodarka Wodna" No. 11, p. 361-363 (in Polish)

Habersack H. et al. (2017), *Integrated automatic and continuous bedload monitoring in gravel bed rivers*, "Geomorphology" No. 291, p. 80-93

Haregeweyn N. et al. (2017), *Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River*, "Science of the Total Environment" No. 574, p. 95-108

Heckmann T. et al. (2017), *Feeding the hungry river: Fluvial morphodynamics and the entrainment of artificially inserted sediment at the dammed river Isar, Eastern Alps, Germany*, "Geomorphology" No. 291, p. 128-142

IPCC (2014), *Climate Change 2014*, Synthesis Report, Core Writing Team, R.K. Pachauri, L.A. Meyer (eds), Geneva, p. 151

Kantoush S.A., Sumi T. (2010), *Geomorphic response of rivers below dams by sediment replenishment technique*, in: Dittrich et al. (eds), *River Flow*, Bundesanstalt für Wasserbau, p. 1155-1163

Kondolf G.M. (1997), *Hungry water: effects of dams and gravel mining on river channels*, "Environmental Management" No. 21(4), p. 533-551

Kondolf G.M. et al. (2014), *Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents*, "Earth's Future" No. 2, p. 256-280

Kuhl D. (1992), *14 years of artificial grain feeding in the Rhine downstream the barrage Iffezheim*, Proceedings of the 5th International Symposium on River Sedimentation, p. 1121-1129

Li P. et al. (2017), *Comparison of soil erosion models used to study the Chinese Loess Plateau*, "Earth-Science Reviews" No. 17, p. 17-30

Li Z. et al. (2009), *Impacts of land use change and climate variability on hydrology in an agricultural catchment on the Loess Plateau of China*, "Journal of Hydrology" No. 377(1), p. 35-42

Li Y. et al. (2017), *Assessing the impacts of climate and land use lane cover changes on hydrological droughts in the Yellow River Basin using SWAT model with time-varying parameters*, Proceedings of Agro-Geoinformatics 6th International Conference, p. 1-6

Likens G.E., Bormann F.H. (1974), *Linkages between terrestrial and aquatic ecosystems*, "BioScience" No. 24(8), p. 447-456

Lin CP. et al. (2016), *Extensive Monitoring System of Sediment Transport for Reservoir Sediment Management* in: L. Wang et al. (eds) *Natural Resources and Control Processes*. "Handbook of Environmental Engineering" Vol. 17

Melaku N.D. et al. (2017), *Prediction of soil and water conservation structure impacts on runoff and erosion processes using SWAT model in the northern Ethiopian highlands*, "Journal of Soils and Sediments" No. 1, p. 13

Merz J.E. et al. (2005), *Effects of gravel augmentation on macroinvertebrate assemblages in a regulated California river*, "River Research and Applications" No. 21(1), p. 61-74

Middelkoop, H. et al. (2001), *Impact of climate change on hydrological regimes and water resources management in the Rhine basin*, "Climatic change" No. 49(1), p. 105-128

Mizugaki S. et al. (2014), *Interpreting runoff process of suspended sediment at the watershed scale by observation and fingerprinting for improvement of model*, in: American Geophysical UnionFall Meeting Abstracts H23L-1047

Neitsch S.L. et al. (2011), *Soil and water assessment tool theoretical documentation version 2009*, Texas Water Resources Institute

Nerantzaki S.D. et al. (2015), *Modeling suspended sediment transport and assessing the impacts of climate change in a karstic Mediterranean watershed*, "Science of the Total Environment" No. 538, p. 288-297

NOAA (2017), *National Centers for Environmental Information, State of the Climate: Global Climate Report for Dec. 2016*,https://www.ncdc.noaa.gov/sotc/global/201612

Olyaie E. et al. (2015), *A comparison of various artificial intelligence approaches performance for estimating suspended sediment load of river systems: a case study in United States*, "Environmental Monitoring and Assessment" No. 187(4), p. 189

Panagos P. et al. (2017), *Global rainfall erosivity assessment based on high-temporal resolution rainfall record*, "Scientific Reports" No. 7, p. 4175

Parzonka W. et al. (2010), *Estimation of the degradation of the middle Odra river bed and programme of the restoration works*, "Infrastructure and Ecology of Rural Areas" No. 8(1), p. 59-68 (in Polish)

Peraza-Castro M. et al. (2015), *Modeling environmental services in rivers at catchment scale*, "Annales de Limnologie, International Journal of Limnology" No. 51(1), p. 59-70

Perelo L.W. (2010), *Review: In situ and bioremediation of organic pollutants in aquatic sediments*, "Journal of Hazardous Materials" No. 177(1-3), p. 81-89

Rodríguez-Blanco M.L. et al. (2016), *Sediment yield at catchment scale using the SWAT (Soil and Water Assessment Tool) model*, "Soil Science" No. 181(7), p. 326-334

Schmitt R.J.P. et al. (2017), *Losing ground – scenarios of land loss as consequence of shifting sediment budgets in the Mekong Delta*, "Geomorphology" No. 294, p. 58-69

Shivhare N. et al. (2017), *Identification of critical soil erosion prone areas and prioritization of micro-watersheds using geoinformatics techniques*, "Ecological Engineering", doi.org/10.1016/j.ecoleng.2017.09.004

Suedel B.C. et al. (2015), *The effects of a simulated suspended sediment plume on eastern oyster (Crassostrea virginica) survival, growth, and condition*, "Estuaries and coasts" No. 38(2), p. 578-589

Sundborg A. (1992), *Lake and reservoir sedimentation. Prediction and interpretation*, "Geografiska Annaler" No. 74A, p. 93-100

Vorosmarty C.J. et al. (2003), *Anthropogenic sediment retention: major global impact from registered river impoundments*, "Global Planet Change" No. 39, p. 169-190

Wilk P. (2015), *Method of calculating river absorption capacity (RAC) as a tool to assess the physicochemical state of surface flowing waters*, PhD thesis, IMGW-PIB (in Polish)

Wilk P. et al. (2017), *The flattening phenomenon in a seasonal variability analysis of the total nitrogen loads in river waters*, "Czasopismo Techniczne" No. 11, p. 137-159

Verma S. et al. (2015), *Climate change impacts on flow, sediment and nutrient export in a Great Lakes watershed using SWAT*, "CLEAN–Soil, Air, Water" No. 43(11), p. 1464-1474

Vigiak O. et al. (2015), *Adapting SWAT hillslope erosion model to predict sediment concentrations and yields in large Basins*, "Science of the Total Environment" No. 538, p. 855-875

Zeug S.C. et al. (2014), *Gravel augmentation increases spawning utilization by anadromous salmonids: a case study from California, USA*, "River Research and Applications" No. 30(6), p. 707-718

ENVIRONMENTAL POLICY AND MANAGEMENT

POLITYKA EKOLOGICZNA I ZARZĄDZANIE ŚRODOWISKIEM

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EXPENDITURE ON RESOURCE MANAGEMENT IN EU COUNTRIES

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ABSTRACT: The article presents an analysis of statistical data on expenditure on resource management in the European Union countries over the period of 2006-2017. In analysis, only the countries for which the full range of information was obtained were taken into account. The trend of changes in the amount of expenditure was analyzed and the amount of expenditure in individual countries was compared. Attention was also drawn to the structure of expenditure by areas of natural resources management.

KEY WORDS: resource management accounts, resource management expenditures

Introduction

The concept of resource management expenditure accounts in Eurostat's work first appeared in 1994 as part of the European System for the collection of economic information on the environment (SERIEE). The accounts were to cover the recording of activities related to the management of natural resources (SERIEE, 1994, p. 24), mainly the management of water and other resources (forests, soil, energy, etc.) and recycling and recovery which are not covered by the APEA environmental protection expenditure account. At that time, the accounting framework was very broadly defined and it was assumed that the methodological work would be carried out in the future. The result is the initial version of the methodology for compiling the resource management expenditure accounts developed in 2014 (ReMEA, 2014).

Work on the concept of ReMEA accounts has been temporarily suspended by Eurostat, which is why the member states have not carried out statistical surveys in this area. However, the results of a study of the Environmental Goods and Services Sector (EGSS) have been used to examine how this expenditure is developing in the era of a resource-efficient European economy.

The article presents an analysis of statistical data concerning the EGSS sector of the European Union Statistical Office Eurostat. The analysis covers the member states of the European Union and concerns the years 2007-2014.

The concept of ReMEA accounts

The ReMEA resource management expenditure accounts cover all activities related to natural resources management and are classified as (CEA, 2011):

- CReMA 10 – Management of waters
- CReMA 11 – Management of forest resources
- CReMA 12 – Management of wild flora and fauna
- CReMA 13 – Management of energy resources
- CReMA 13A – Production of energy from renewable sources
- CReMA 13B – Heat/energy saving and management
- CReMA 13C – Minimisation of the use of fossil energy as raw materials
- CReMA 14 – Management of minerals
- CReMA 15 – Research and development activities for resource management
- CReMA 16 – Other resource management activities

The activities included in the ReMEA accounts must fulfill a primary purpose criterion, i.e. the primary purpose is resource management. Any activity that has a beneficial effect on natural resources but is undertaken for other reasons is not eligible for ReMEA.

In ReMEA accounts are included:

1. Specific resource management activities:
- actions to reduce resource consumption such as recovery, re-use, recycling, rational use, and the replacement of natural resources,
- complementary actions: increasing renewable natural resources (water, forests, and wild flora and fauna),
- natural resources management and regulatory activities carried out by the government;
- monitoring, control, and surveillance,
- teaching, training, information and communication activities,
- research and development activities in the field of natural resources management.

2. Products related to the management of natural resources:
- specific products – used directly and exclusively for the protection of natural resources, for example, renewable energy and advice on water and energy saving,
- related products – non-characteristic products which only serve the protection of natural resources, but their production does not affect resource management, for example, wind turbines, rainwater storage tanks, and specific measuring instruments,
- resource-efficient products – non-characteristic products that may be present in a resource-efficient version, for example, energy and water saving washing machines, energy-saving candles, etc.; only additional costs are taken into account if resource-efficient products are more expensive than their alternative counterparts.

The sector of EGSS environmental products and services

Due to the fact that ReMEA accounts are still in the sphere of concept and theoretical considerations, no information on the amount of expenditure on resource management is available. For this reason, it was decided to use the results of research on the environmental products and services sector, which covers both environmental and resource management areas.

Environmental goods and services fall into the following categories:
- environmental services – typical of environmental protection and resource management, e.g. wastewater treatment, waste management,

organic farming, energy production from renewable resources, environmental monitoring and measurement, and environmental education,
- products with a purely environmental purpose (related products) – products that serve directly and exclusively for environmental protection and resource management or other services,
- adapted goods – alternatives to traditional ones, more environmentally friendly, less polluting and more resource-efficient,
- environmental technologies – broken down into "end-of-pipe" and integrated technologies.

The data on these elements is to be compiled according to the CEPA environmental classification and CReMA resource management (CEA, 2011). The breakdown by domains is analogous to that used in the APEA and ReMEA satellite accounts. As in these accounts, the main purpose criterion also applies here.

There are two approaches to compiling the accounts, both in the national accounts and in the EGSS accounts, i.e. a supply-side approach to production and a demand-side approach to use (Broniewicz, Domańska, 2016). The demand-side approach focuses on the use of statistics on environmental protection expenditure and resource management. As for the expenditure, the following categories are calculated: domestic demand, which is the sum of total consumption (individual and collective consumption) and gross accumulation (gross expenditure on fixed assets, the growth in tangible current assets, and the growth in valuables) and the external trade balance (export and import of goods and services).

A combination of both approaches, the production approach, and the used approach is used, depending on the variables presented. Therefore, with a certain error, it can be assumed that the production volume of the environmental goods and services sector is equal to the amount of expenditure on environmental protection and resource management.

The production of environmental goods and services sector in the European Union in the years 2007-2015 ranged from EUR 528,800 million in 2007 to EUR 735,700 million in 2015. As can be seen in figure 1, production in the sphere of environmental protection was higher than in the sphere of resource management. However, the growth rate of production volume was faster (figure 2). Eventually, in 2015 the production of the environmental protection sector increased by 16.7% compared to 2007, and the resource management sector by 75.7%.

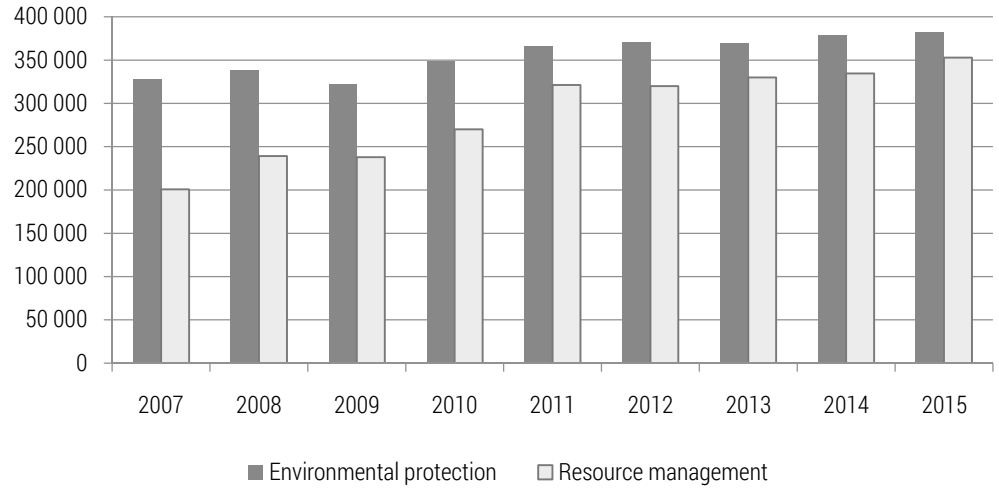

Figure 1. EGSS production volume in the European Union [million euro]
Source: author's own work based on Database-Eurostat.

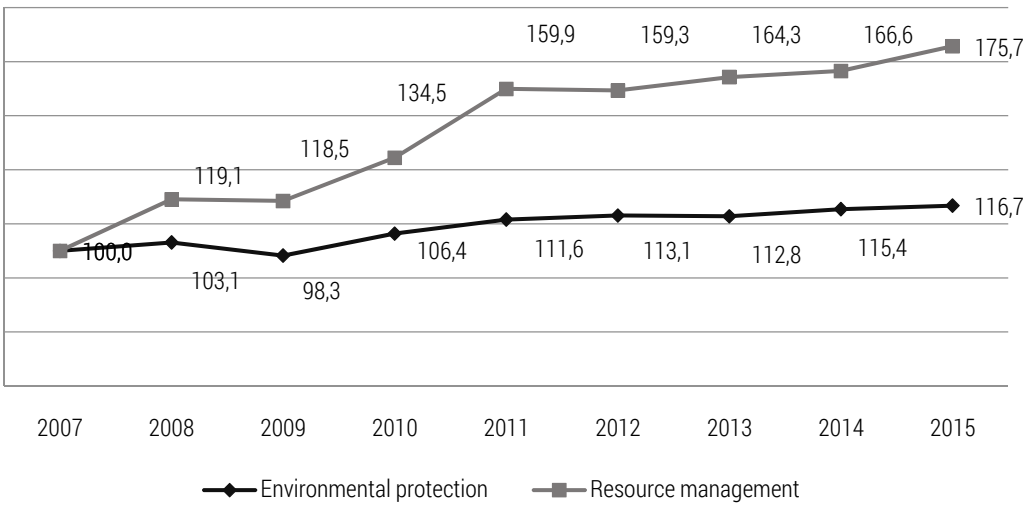

Figure 2. The growth rate of EGSS production in the EU [2007=100%]
Source: author's own work based on Database-Eurostat.

The analysis of expenditure on resource management in the European Union countries

In the European Union, the distribution of expenditure on resource management in 2016 was almost equal to that on environmental protection (52% to 48%). However, the situation in individual countries was different. The group of countries (e.g. in Western Europe), in which most of them are expenditures on resource management, cannot be clearly identified (figure 3).

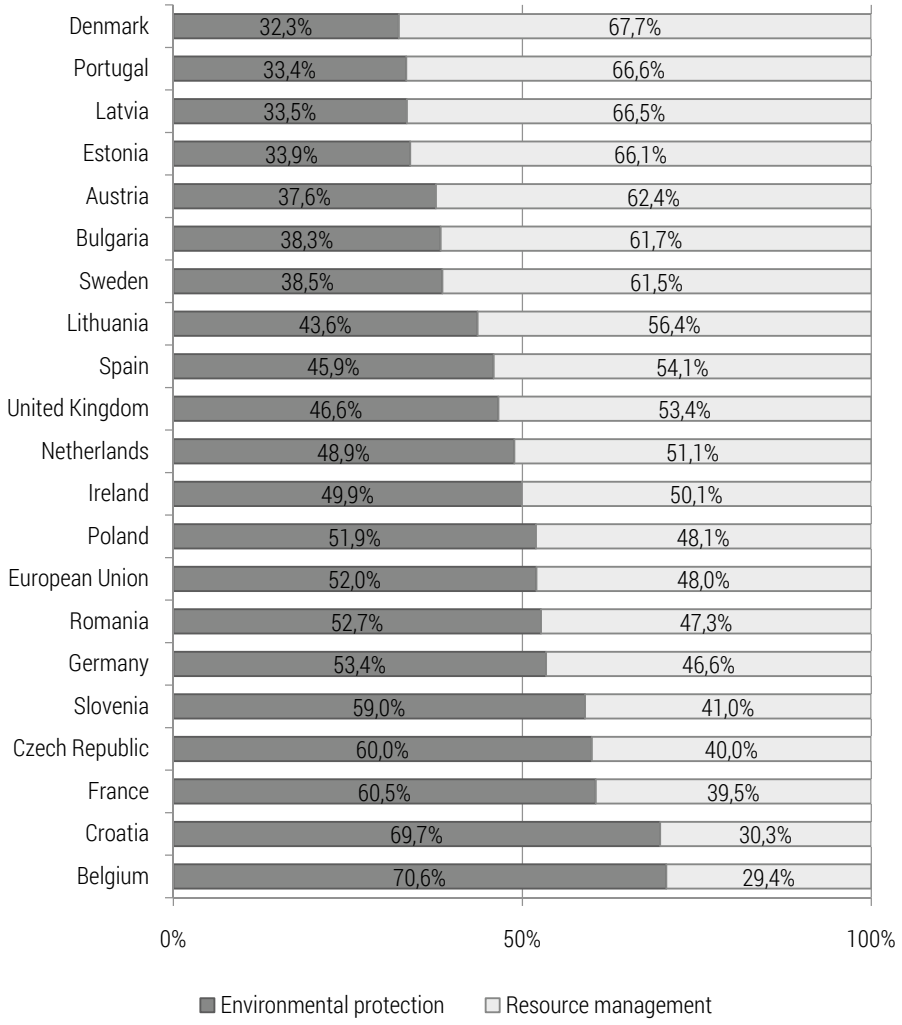

Figure 3. The structure of expenditure of the EGSS sector in EU countries in 2016

Note: only the countries for which the full range of information was obtained were taken into account.
Source: author's own work based on Database-Eurostat.

However, when comparing absolute values (in million EUR), it can be seen that it is mainly Western European countries that bear the burden of resource management in Europe (figure 4).

It is interesting to present the amount of spending on resource management in individual EU countries per capita. In 2016, Denmark (3311 euro/per capita) and Austria (2302 euro/per capita) were the leaders. Among the new EU member states, Estonia had the highest spending on resource management – EUR 1247 per capita. The lowest expenditure, 76 euro/per capita was in Croatia.

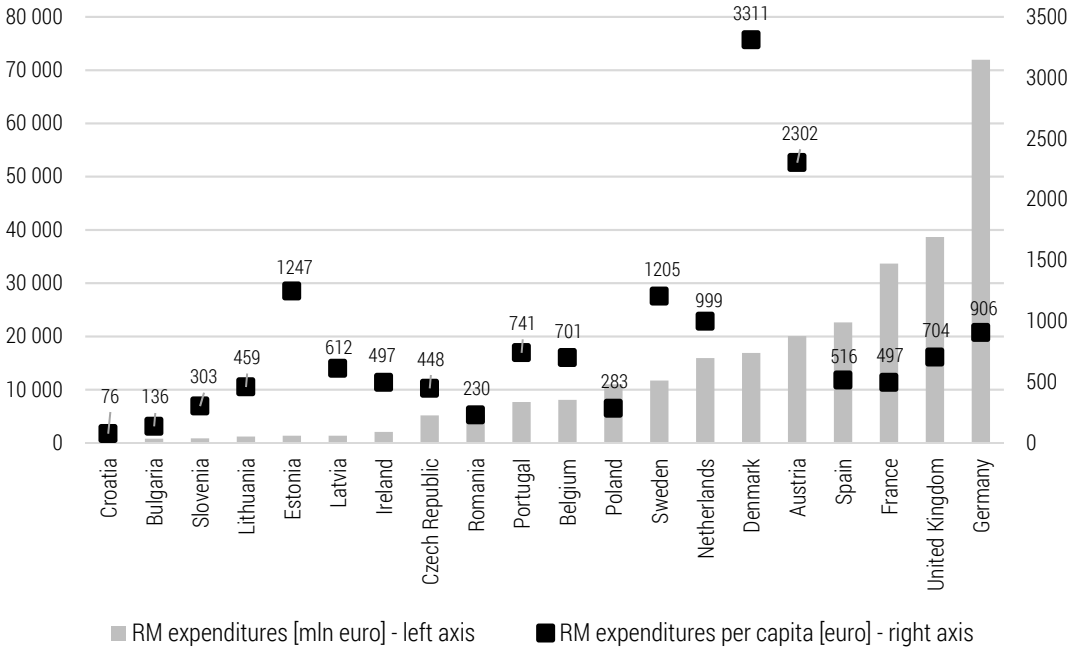

Figure 4. The expenditure on resource management in EU countries in 2016

Source: author's own work based on Database-Eurostat.

In establishing the reason for such a large difference between the level of expenditure on resource management in the European Union countries, a correlation was sought (for the years 2007-2015) between the expenditure on resource management and:

- the amount of GDP per capita,
- resource productivity understood as the level of GDP per a unit of consumption of natural resources in the national economy,
- environmental protection expenditure.

Only in the case of the relationship between resource management expenditure and environmental protection expenditure, the Pearson correlation coefficient was quite high at 0.74 (figure 5). In other cases, no correlation between variables was found. The above-presented expenditure on natural resources management is certainly influenced by non-economic variables, such as administrative and legal conditions, the level of environmental awareness of the society and the like.

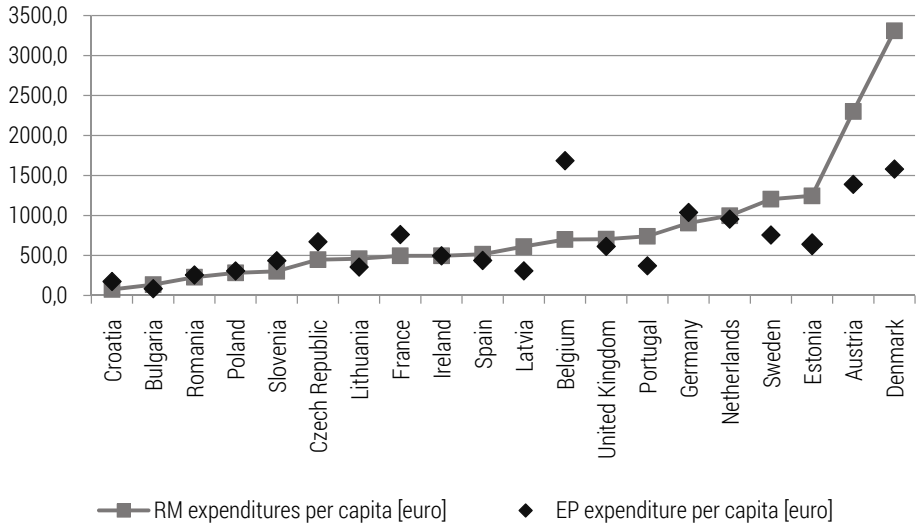

Figure 5. Expenditures on resource management vs. environmental protection expenditures in EU countries [euro/person] in 2016

Source: author's own work based on Database-Eurostat.

When analyzing the structure of spending on resource management by area, a similar correlation can be observed in all EU countries – the largest spending is on energy resources management. The lowest, but still a high share of this type of expenditure in 2016 constituted 50% of the total expenditure on resource management (Great Britain), while the highest – as much as 97% (Slovenia) – figure 6.

This phenomenon confirms the pan-European trend to reduce the consumption of non-renewable resources, to invest in renewable energy sources, and to save heat and energy. On the other hand, however, the Author, having experience in compiling data from the environmental goods and services sector in Poland, can state that the variables related to CReMA 13 – Management of energy resources are the easiest to identify and estimate. Therefore, it is possible to underestimate expenditure in other areas. For example, in Poland,

where CReMA 10 – Management of waters expenditure research is conducted in the form of direct research, the share of expenditure in this area of resource management is the highest among the countries analyzed (figure 6).

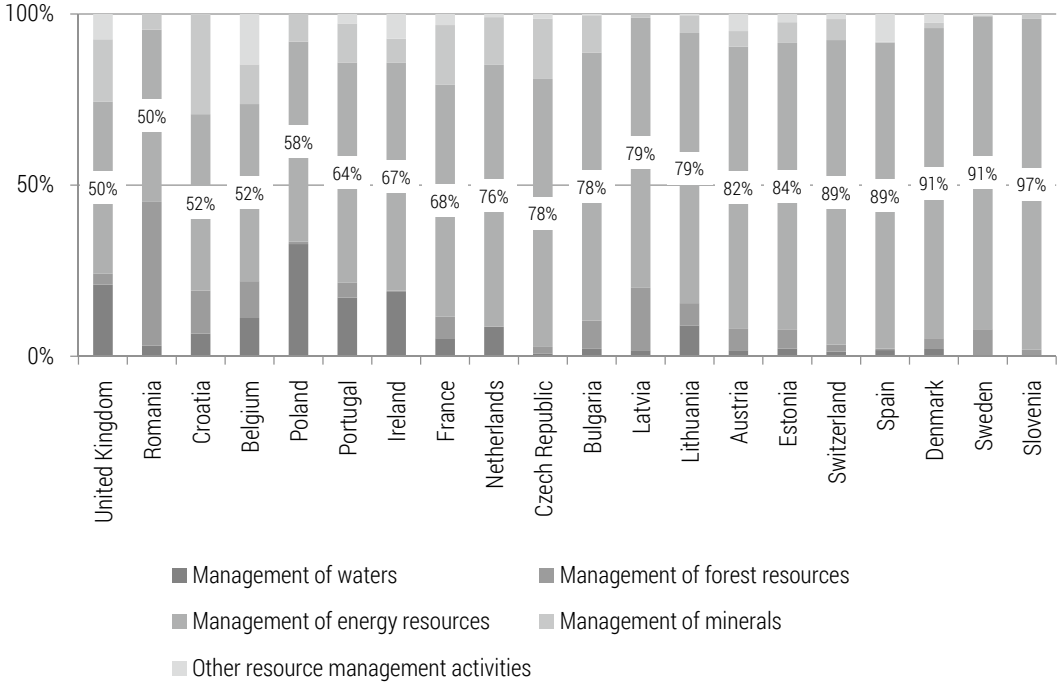

Figure 6. The structure of expenditure on resource management in EU countries in 2016 [%]

Source: author's own work based on Database-Eurostat.

Conclusions

When analyzing the volume of production (expenditure) on resource management, it can be stated that the desired trend towards the resource-efficient economy in Europe is being implemented. Not to the same extent in all countries as highly developed countries allocate more funds for natural resources management. The main direction of spending funds in all analyzed countries is energy resources management.

Due to the lack of data from the ReMeA account, the article uses the results of research on the sector of environmental goods and services, in which one of the two parts covers the management of natural resources. In both accounts, the division into areas of resource management is the same, but the approach to estimating economic quantities is slightly different. It is

therefore desirable to 'return' to the development of the concept and starts compiling the ReMeA satellite account, which is the twin 'half' of the EPEA environmental expenditure account.

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Literature

Broniewicz E., Domańska W. (2016), *Rachunki sektora towarów i usług związanych z ochroną środowiska (EGSS) jako moduł Europejskich Rachunków Ekonomicznych Środowiska*, "Wiadomości Statystyczne" No. 4

CEA (2011), *Classification of Environmental Activities (CEA), Classification of Environmental Activities (CEA),* https://unstats.un.org/unsd/class/intercop/expertgroup/2011/AC234-29.PDF [15-09-2018]

CSO (2015), *Report and the methodology description. Module for Environmental Goods and Services Sector (EEEA-EGSS), within the Grant Agreement No 05121.2013.003-2013.344*, CSO, Warsaw

Database-Eurostat, http://ec.europa.eu/eurostat/data/database

ReMEA (2014), *Resource management expenditure accounts – draft guidelines 2014*, European Commission. Eurostat, http://ec.europa.eu/eurostat/web/environment/methodology [10-09-2018]

SERIEE (1994), *EuropeanSystem for the collection of economic information on the environment – 1994 version*, European Community, http://ec.europa.eu/eurostat/web/environment/methodology [10-09-2018]

Anna **IWACEWICZ-ORŁOWSKA** • Dorota **SOKOŁOWSKA**

RANKING OF EU COUNTRIES IN TERMS OF THE VALUE OF ENVIRONMENTAL GOVERNANCE INDICATORS IN 2010 AND 2015, USING THE HELLWIG METHOD

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ABSTRACT: The purpose of this study is to analyze the indicators of environmental governance as one of the elements of sustainable development. The results of the study show the ranking of EU countries in terms of the value of selected indicators in the years 2010 and 2015, and the analysis of how these indicators influenced the position of individual countries in the ranking. The Hellwig method was used to analyze the data in this study. The main findings are that relatively low greenhouse gas emission in CO2 equivalent, a high share of renewable energy in transport fuel consumption and a high recycling rate of packaging waste are main determinants of sustainable development on the environmental field. This factors are affecting the position of individual states in the ranking.

KEY WORDS: indicators of environmental governance, sustainable development, the Hellwig method, EU countries

Introduction

The aim of this study is two-fold: to analyze the indicators of environmental sustainability that concern environmental governance, and to rank EU countries in terms of the value of these indicators in the years of 2010 and 2015. This knowledge will help in better understanding what determine the position of each country in the rank. The reader is able to state which from considered countries corrected one's position, and which not and what reasons for these changes were. It is also showing indicators which peculiarly contributed to get places in the ranking. The sphere of environmental governance is one of four principles of sustainable development (SD), along with the economic, social and institutional-political spheres. This encompasses such diverse areas as climate change, energy use, air protection, marine ecosystems, freshwater resources, land use, biodiversity, and waste management.

An overview of literature

A review of the literature showed that sustainable development (SD) is generally treated in a holistic manner. There are no studies that analyze only one element of sustainable development.

Elaborate descriptions of SD indicators can be found in older sources (Pearce, 1996; Kates, 2005; Opschoor, 1991; Bossel, 1999; Segnestam, 2003) as well as in more recent studies (Jeniček, 2013; Sachs, 2015). It is worth emphasizing that many of the authors drew attention to only selected areas of sustainable development in their analysis. These areas are as follows: industry (Azapagic, 2000), economic development (Callens, 1999) and the natural environment (Palme, 2005). SD is also analyzed based on different measurements from different countries (Rosenström, 2007; Nader, 2008; Rinne, 2013). The most recent contribution in Poland on the topic of SD indicators was published in 2015 (*Wskaźniki zrównoważonego rozwoju Polski*, 2015). However, this work complements a previous publication from 2011 (*Wskaźniki zrównoważonego rozwoju Polski*, 2011).

What the authors of this study did not find in the review of the literature was a ranking of countries in terms of their level of sustainable development. It seems that few authors have taken on the issue of ranking countries in terms of sustainable development. Research being focused exclusively on one of the sustainable development pillar are missing. This situation confirmed the legitimacy of the topic chosen and contributed to the cyclical study of the authoritative ranking of EU countries according to the four pillars of

sustainable development. The novelty of this study is the preparation of a ranking of EU countries based on the value of environmental governance indicators for two separate years: 2010 and 2015.

This analysis distinguishes the indicators that determine the positions of individual EU countries in the ranking. This information may be useful to potential stakeholders who have an impact on the natural environment and the economy of any given country. Recipients of this study may also be representatives of the political sphere who have an impact on the economical processes that influence the natural environment.

Research methods

The study only analyzed the indicators of sustainable development that concern environmental governance. The ranking of European Union countries was completed using Hellwig's synthetic measure of development. Hellwig's measure is one method of ranking multivariate objects (Roszkowska, Karwowska, 2014; Iwacewicz-Orłowska, Sokołowska, 2016).

A total of 29 indicators were identified in the context of environmental governance. The Statistical Office in Katowice developed a set of indicators for sustainable development in 2011 (*Wskaźniki zrównoważonego rozwoju Polski*, 2011). This list was updated in 2015 (*Wskaźniki zrównoważonego rozwoju Polski*, 2015). Eight new indicators were added to environmental governance. These indicators provide the basis for analysis within this study.

The selection of indicators used in the analysis (called "diagnostic variables") comprised the first stage of this study. Data published by the Statistical Office in Katowice included information on SD indicators up to the year 2015. For the study, 16 indicators were selected based on the fact that they had complete data for both periods analyzed. In using Hellwig's method (Hellwig, 1968) as the model for this study, indicators were divided into two groups: stimulants that caused a country to have a higher position in the ranking in terms of environmental governance, and inhibitors, which caused countries to have a lower position in the ranking (table 1).

Based on 16 standardized input variables, a reference object with coordinates is defined as:

$$z_{0k} = \begin{cases} \max\limits_{i}(z_k) \text{ for stimulant} \\ \min\limits_{i}(z_k) \text{ for inhibitor} \end{cases} \quad (1)$$

where:
$i = 1, \ldots m$, $k = 1, \ldots n$,
m – is the number of countries,
n – the number of indicators.

Table 1. List of 16 diagnostic variables*

No.	Indicators – Environmental Governance	
61	Greenhouse gas emissions, CO_2 equivalent, in % (year 1988=100)	Inhibitor
62	GHG emissions by sectors – TOTAL, in tons in CO_2 equivalent/km^2 *(industries: energy, manufacturing and construction, transportation, industrial processes, agriculture, waste, other)*	Inhibitor
63	Greenhouse gas emissions per unit of energy consumption, in % (year 2000=100)	Inhibitor
64	Share of renewable energy in gross final energy consumption, in %	Stimulant
65	Share of renewable energy in transport fuel consumption, in %	Stimulant
67	Energy intensity of the economy, Kgoe/1000 euro **	Inhibitor
69	Average CO_2 emissions per 1 km from new vehicles, g/km	Inhibitor
71	Emission of acid rain pollution, tons/km^2	Inhibitor
72	Size of Fishing fleet, kW ***	Inhibitor
74	Percentage of population using waste water treatment plants (at least II degree), in %	Stimulant
79	Forest cover, in %	Stimulant
82	Damage of forest stands by defoliation, in %	Inhibitor
85	Non-perishable waste per capita, in kg	Inhibitor
86	Municipal waste generated per capita, in kg	Inhibitor
87	Disposal of municipal waste per capita, in kg	Inhibitor
88	Recycling of packaging waste, in %	Stimulant

* Indexing is not an ordinal number.
** Ratio of gross energy consumption (coal, electricity, oil, natural gas and renewable energy sources available for use) to GDP, at fixed prices from the base year of 2010.
*** The size of the fishing fleet determines the total power of the fishing fleet engines.
Source: author's own work.

The next step was to calculate for each object (country) the distance from the reference object using the Euclidean metric (Malina, 2004, p. 37):

$$d_{i0} = \sqrt{\sum_{k=1}^{n} (z_{ik} - z_{0k})^2} \tag{2}$$

The final step in the Hellwig method was to establish a synthetic measure of development for the *i*-th country according to the formula:

$$q_i = 1 - \frac{d_{i0}}{\overline{d}_{i0} + 2S(d_{i0})} \tag{3}$$

where:
$\overline{d}_{i0}$ – arithmetic mean of distance d_{i0},
$S(d_{i0})$ – standard deviation of distance d_{i0}.

The measure q_i is usually a value in the interval [0,1]. The higher the value, the closer the object (country) is to the set pattern (Panek, 2009, p. 69).

Results of the research

In the first step basic statistical calculations were carried out for the variables accumulated.

Table 2. Descriptive statistics of selected environmental governance indicators of SD for EU countries in 2010 and 2015

Indicator	Average		Minimum		Maximum		standard deviation		coefficient of variation	
	2010	2015	2010	2015	2010	2015	2010	2015	2010	2015
61	82.6	73.5	42.1	40.7	123.1	115.8	23.4	20.9	28.4	28.5
62	1 776	1 544	149	125	11,085	8,596	2 311	1,875	130	121
63	95.1	88.2	83.8	74.2	124.0	112.0	9.1	8.6	9.5	9.8
64	15.9	19.8	1.0	5.0	47.2	53.9	11.0	11.9	69.1	60.1
65	4.1	6.6	0.0	0.4	10.9	24.0	2.5	5.2	62.9	79.4
67	192.2	165.8	82.4	62.0	464.9	448.5	95.8	87.2	49.8	52.6
69	144.1	124.7	126.2	107.3	162.0	140.9	10.0	9.9	6.9	8.0
71	7.0	5.3	0.6	0.0	56.3	40.3	10.4	7.5	149.1	142.4
72	233.220	228.199	0	0	1,106,214	999,040	331,688	304,971	142	134
74	70.9	77.1	6.6	36.9	99.5	100.0	22.9	17.3	32.3	22.4
79	33.4	33.7	1.1	1.1	73.1	73.1	17.3	17.2	51.7	51.0
82	23.4	23.4	8.1	4.4	54.2	52.0	10.6	12.1	45.5	51.5
85	2,044.2	1,975.1	627.0	674.0	8,612.0	9,514.0	1,602.4	1,691.6	78.4	85.6
86	490.5	457.4	305.0	56.0	770.0	789.0	126.8	143.9	25.9	31.5
87	237.6	171.9	3.0	1.0	591.0	558.0	158.6	145.1	66.7	84.4
88	59.9	62.4	28.5	41.1	84.0	81.3	12.0	8.3	20.0	13.3

Source: author's own work based on GUS, *Wskaźniki zrównoważonego rozwoju Polski*, 2015 and 2010.

As a result of the research, the ranking of EU countries were obtained for the years 2010 and 2015. The countries that took first, second and third place in 2010 were Sweden, Austria and Germany in the context of environ-

mental governance in sustainable development. Poland was ranked 13th. The countries with the lowest positions were Cyprus, Bulgaria and Malta.

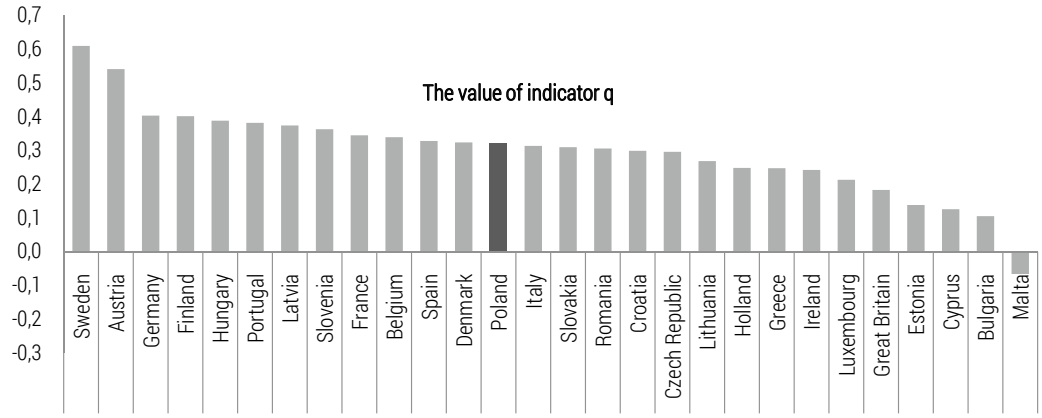

Figure 1. Ranking of EU countries in the context of environmental governance – 2010

Source: author's own work.

The following variables influenced Sweden being ranked the highest in terms of environmental governance:

- It had the lowest level of greenhouse gas emissions by sector in the EU. Greenhouse gas emissions are treated as an inhibitor to development in this study. This indicator presented the amount of greenhouse gas emissions (expressed in CO_2 equivalent) produced per capita, from different sources (economic sectors), per square kilometer. In Sweden, this amounted to 149.1 tons of CO_2 per km^2 in 2010. In comparison, the average for all countries analyzed was 1,776.3 tons of CO_2 per km^2.
- It had the highest share of renewable energy in the EU in gross final energy consumption. This indicator is considered a stimulant to development in this study and represents the gross final energy consumption from renewable sources divided by gross final energy consumption from all sources. In Sweden 27.2% of all energy was produced from renewable resources in 2010, whereas the EU average was 15.9%.
- It had the second highest share (after Austria) of renewable energy in fuel consumption in transport in the EU. This indicator is considered a stimulant and represents the % share of renewable energy used in all modes of transport in the final consumption of energy in transport. In 2010, this amounted to 9.2% in Sweden, whereas the EU average amounted to 4.1%.
- It was the second lowest emitter of acid rain pollution per 1 km^2 in the EU (after Croatia). This indicator, treated as an inhibitor of development,

takes into account the following acidifying pollutants (in 1 km^2): sulfur oxides, nitrogen oxides, and ammonia. In Sweden it amounted to 0.6 tons per 1 km^2 in 2010; the EU average amounted to 6.7 tons per 1 km^2.

- It had the second lowest indicator of municipal waste disposal per capita in the UE (after Denmark). This indicator is considered an inhibitor to development in this study. In the case of Sweden, it was 4 kg per capita in 2010, while the EU average was 236.8 kg per capita.
- It had one of the highest indicators for the recycling of packaging waste in the EU. This indicator is considered a stimulant of development and is calculated as the ratio of the mass or quantity of packaging waste recycled to the mass or quantity of recyclable packaging placed on the market. For Sweden it amounted to 69.2% in 2010 while the EU average was 58.7%.
- It had the second highest indicator of forest cover in the EU (after Finland); this means the ratio of the forest area to the total geodetic territorial area. This indicator is considered a stimulant for development. For Sweden it amounts to 68.4%, while the average is 33.4% for all EU countries.

Aside from the indicators mentioned above, attention should also be paid to the percentage of the population using wastewater treatment plants of at least second degree, such as biological wastewater treatment plants with enhanced biogenic compound removal,as a percentage of the total population. For Sweden the ratio amounts to 86%, which is very high compared to other EU countries (EU average is 55.1%).

Malta took last place in this ranking in 2010. What caused the country to be ranked the lowest among EU countries in the context of environmental governance? The position of this country in the ranking was influenced by the following factors:

- The high amount of greenhouse gas emissions by sector.This value amounted to 11,085.3 tons in CO_2 equivalent per km^2 in Malta in 2010. The average for all EU countries is more than six times lower and amounted to 1,776.3 tons in CO_2 equivalent per km^2. The Netherlands has the second highest greenhouse gas emissions after Malta (this indicator amounted to 5,183.5 tons in CO_2 equivalent per km^2, half of the value of Malta). This indicator is considered an inhibitor of development in this study. There are two main reasons for high greenhouse gas emissions in Malta. Firstly, the country did not comply with EU obligations concerning the reduction of carbon emissions for a long time. A drop in CO_2 emissions took place in 2015. Secondly, Malta is a very small country with an area of 316 km^2. It is the smallest country in the EU in terms of area and

186th in the world. In calculating the level of CO_2 emissions in terms of the size of the country, the coefficient is quite high.

- Malta has the lowest share of renewable energy in final gross energy consumption and fuel consumption in transport within the EU. These indicators are considered stimulants to development. In Malta they amount to 1% and 0% respectively for 2010 and 2015 (the EU average is 15.9% and 4.1%).
- Malta has the highest emission of acid rain pollution in the EU per 1 km^2, amounting to 56,3% (the EU average is 6.7%).
- The lowest indicator of forest cover in the EU (1.1%). The climate and the terrain have an impact on the island's flora, where forests are only found on a very small area of the island.
- It has the highest indicators in the EU (after Cyprus) of municipal waste generated per capita (601 kg) and municipal waste disposal per capita (545 kg) per year. There are two reasons for such high rates of waste production in Malta. First of all, tourism is the dominant economic sector in this country. Waste generated by tourists are statistically included in waste generated by residents. This greatly overstates the statistics on Maltese waste production. Secondly, a relatively small number of inhabitants (about 440,000 people) and a large number of tourists visiting Malta (nearly 2 million tourists a year), translates into a proportionally large amount of municipal waste being produced.

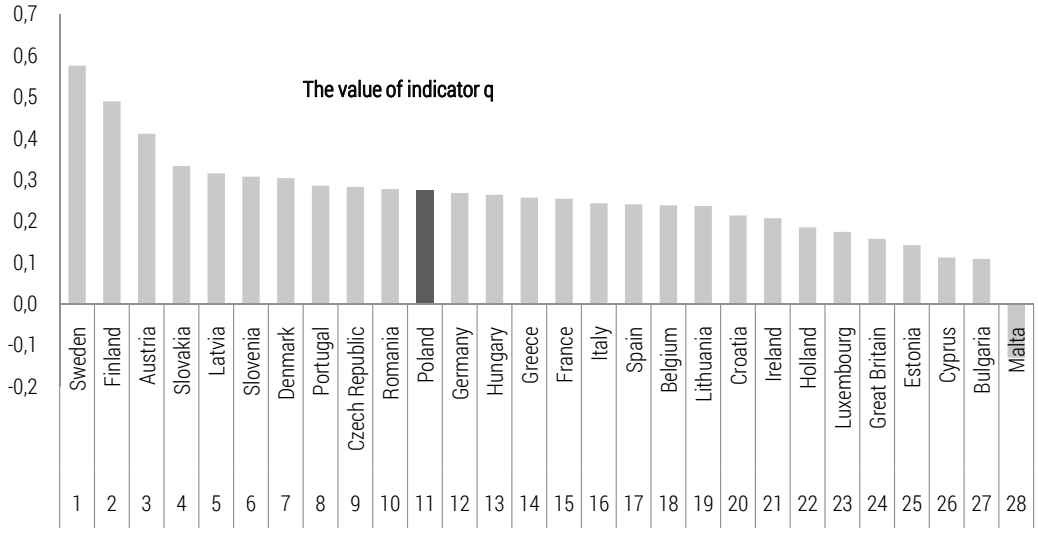

Figure 2. Ranking of EU countries in the context of Environmental governance – 2015

Source: author's own work.

Although the year 2015 brought changes in the ranking, these changes did not concern the countries that occupied the first and the last six places in the ranking (i.e. Sweden and Malta). Finland took second place. Austria took third place. The countries that reached the lowest positions in the ranking in 2015 are: Cyprus, Bulgaria and Malta. During the period studied, Poland took 11th place.

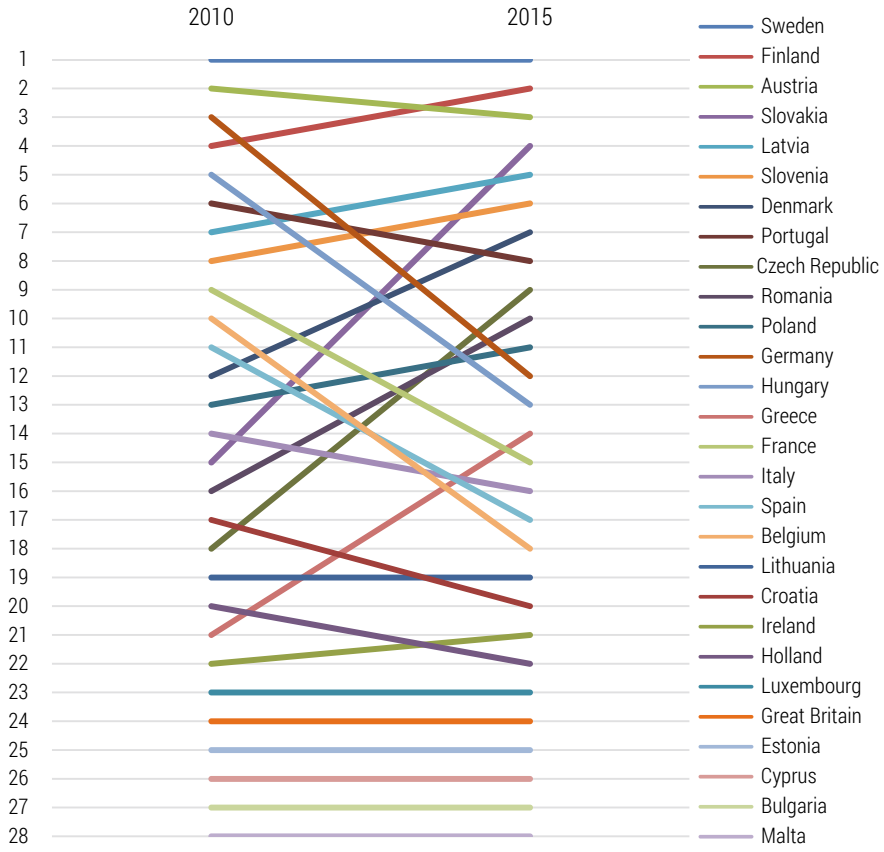

Figure 3. Changes in the ranking of countries from 2010 and 2015

Source: author's own work.

Figure 3 is demonstrating changes which occurred in the ranking of countries in years 2010 and 2015. Even though the period of analysis was short changes are significant. Ten of the countries analyzed experienced a rise in the ranking, ten experienced a drop, whereas the last eight did not change their position.

Slovakia experienced the highest increase in the ranking when comparing the two time periods (in 2010 the country was in 15th position, in 2015

it was in 11th). In terms of environmental governance, this country has made tremendous progress. All indicators taken into account have seen improvement. The main contributors to the change in ranking were:

- Relatively low greenhouse gas emission in CO_2 equivalent, amounted to 57.3% in 2015 (the EU average – 73.5%) and a related indicator of greenhouse gas emission (GHG) by total sectors amounted to 845.2 tons in CO_2 equivalent in 2015 (the EU average – 1,544.2 tons). These ratios were respectively 64.6% and 952.9 tons in CO_2 equivalent in 2010. A clear reduction of greenhouse gas emissions in Slovakia is therefore visible.
- A high share of renewable energy in transport fuel consumption in 2015 – 8.5% (in 2010 this share was 5.3%). The EU average is respectively 6.6% for 2015 and 4.1% for 2010.
- A high recycling rate of packaging waste, understood as the ratio of the mass or quantity of packaging waste recycled to the mass or quantity of recyclable packaging placed on the market. This ratio amounted to 45.7% in 2010 (the EU average for this period was 59.9%). This ratio has increased by 19.7 percentage points in Slovakia within five years and in 2015 it amounted to 65.4% (the EU average in this period was 62.4%). Recycling of packaging waste in Slovakia has therefore exceeded the average for all EU countries.

Other countries that recorded a favorable change in their ranking were the following: the Czech Republic (from 18th to 9th place – 9 positions); Greece (from 21st to 14th place – 7 positions); Romania (from 16th to 10th place – 6 positions); and Denmark (from 12th to 7th place – 5 positions).

Ten countries have noted a decrease in 2015 in relation to 2010. The largest decrease was recorded by Germany (this country was in 3rd position in 2010 and in 12th position five years later). The main reason for Germany's low position in 2015 was the lack of progress in most of the analyzed factors. The indicators from 2010 were very close to the ones from 2015. If the country does not improve its environmental situation, as evidenced by the lack of progress in the indicators compared to other countries, such a country may worsen its position in the ranking. This situation took place in Germany in 2015. Only one indicator had improved over the five year period – the share of renewable energy in gross final energy consumption (10.5% in 2010 and 14.6% in 2015).

Poland was in 13th position in 2010 and in 2015 the country was promoted to 11th place. There were three indicators that particularly distinguished Poland among the other analyzed countries:

- The size of the fishing fleet as the total power of fishing fleet engines. This value was 86,892 kW for Poland in 2010 and 81,545 kW in 2015 (the average for EU countries in 2010 amounted to 233,219 kW and in 2015

it was 228,198 kW). It should be noted that some EU countries do not have a fishing fleet due to lack of access to the sea (The Czech Republic, Slovakia, Austria, Hungary, etc.). The dominant countries, due to the size of the fishing fleet are as follows: France, Italy, Spain and the United Kingdom. This indicator was considered an inhibitor of development.

- One of the lowest indicators of municipal waste produced per capita per year in the EU. This indicator – also treated as an inhibitor of development – amounted to 316 kg per capita in 2010 and 286 kg per capita in 2015. Only Greece and Romania produced less municipal waste than Poland per inhabitant in 2015. The average amount of waste produced in the EU in 2010 and 2015 was respectively 490.5 kg and 457.4 kg per capita.
- Favorable indicator of municipal waste disposal per capita amounted to 195 kg in 2010 and 127 kg in 2015 (the EU average per capita is 237.6 kg in 2010 and 171.9 kg in 2015). The low rate of municipal waste disposal is related to the low total waste generation rate. However, it should be emphasized here that the low amount of generated waste in Poland causes less of it to be disposed, therefore this indicator is not proportionally low at all.

The main findings based on above research are that relatively low greenhouse gas emission in CO_2 equivalent, a high share of renewable energy in transport fuel consumption or a high recycling rate of packaging waste are main determinants of sustainable development on the environmental field. This factors are affecting the position of individual states in the ranking and the environmental responsibility of each of them.

Conclusions

In conclusion, it is important to state that the dominant areas in this analysis ofenvironmental sustainability were played by climate change, air protection and waste management. In particular, the high positions of certain countries in the ranking are due to their low greenhouse gas emissions, high share of renewable energy, including a high share of renewable energy in transport fuel consumption, low emission of pollutants, and a high rate of recycling of packaging waste. The top ranking countries were those that had the above mentioned ratios on a high and stable level (for stimulants) or on a low level (for inhibitors to development). The methodology used in research is an innovative approach of authors of the study. In the assumed form it wasn't used before for analysis of sustainable development pillars.

It is important to point out that is it possible for any particular country to improve its position in the ranking even if it has not made any progress in

terms of environmental governance, in cases where there is a regression in environmental governance in other countries. This factor needs to be taken into account during analysis of the data. Other indicators that were not considered carefully in the ranking were the state of coastal ecosystems, freshwater resources, land use, and biodiversity. These indicators played only a minor role in determining the position of the analyzed European Union countries in the ranking.

The contribution of the authors

Anna Iwacewicz-Orłowska – concept and objectives, literature review, research – 50%
Dorota Sokołowska – concept and objectives, literature review, research – 50%

Literature

Azapagic A., Perdan S. (2000), *Indicators of sustainable development for industry: a general framework*, "Process Safety and Environmental Protection" No. 78(4), p. 243-261

Bossel H. (1999), *Indicators for sustainable development: theory, method, applications,* a report to the Balaton Group

Callens I., Tyteca, D. (1999), *Towards indicators of sustainable development for firms: a productive efficiency perspective*, "Ecological Economics" No. 28(1), p. 41-53

Hellwig Z. (1968), *Zastosowanie metody taksonomicznej do typologicznego podziału krajów ze względu na poziom ich rozwoju i struktury wykwalifikowanych kadr*, "Przegląd Statystyczny" No. 4

Iwacewicz-Orłowska A., Sokołowska D. (2016), *Realizacja koncepcji zrównoważonego rozwoju w podregionach województw Polski Wschodniej metodą wzorca rozwoju Hellwiga*, "OPTIMUM. STUDIA EKONOMICZNE" No. 1, p. 182-197

Jeniček V. (2013), *Sustainable development-indicators*, "Agricultural Economics/ Zemedelska Ekonomika" No. 59(2)

Kates R.W., Parris T.M., Leiserowitz A.A. (2005), *What is sustainable development? Goals, indicators, values, and practice*, "Environment(Washington DC)" No. 47(3), p. 8-21

Malina A. (2004), *Wielowymiarowa analiza przestrzennego zróżnicowania struktury gospodarki Polski według województw,*"Zeszyty Naukowe, seria specjalna: Monografie Nr 162", Kraków

Nader M.R., Salloum B.A., Karam N. (2008), *Environment and sustainable development indicators in Lebanon: a practical municipal level approach*, "Ecological indicators" No. 8(5), p. 771-777

Opschoor H., Reijnders, L. (1991), *Towards sustainable development indicators*, in: *In search of indicators of sustainable development*, Netherlands, p. 7-27

Palme U. et al. (2005), *Sustainable development indicators for wastewater systems–researchers and indicator users in a co-operative case study*, "Resources, Conservation and Recycling" No. 43(3), p. 293-311

Panek T. (2009), *Statystyczne metody wielowymiarowej analizy porównawczej*, Warszawa

Pearce D., Hamilton K., Atkinson G. (1996), *Measuring sustainable development: progress on indicators*, "Environment and Development Economics" No. 1(1), p. 85-101

Rinne J., Lyytimäki J., Kautto P. (2013), *From sustainability to well-being: Lessons learned from the use of sustainable development indicators at national and EU level*, "Ecological indicators" No. 35, p. 35-42

Rosenström U., Kyllönen S. (2007), *Impacts of a participatory approach to developing national level sustainable development indicators in Finland*, "Journal of Environmental Management" No. 84(3), p. 282-298

Roszkowska E., Karwowska R. (2014), *Wielowymiarowa analiza poziomu zrównoważonego rozwoju województw Polski w 2010*, "Economics and Management" No. 1

Sachs J.D. (2015), *The age of sustainable development*, Columbia University Press

Segnestam L. et al. (2003), *Indicators of environment and sustainable development: theories and practical experience* (No. P01 234), World Bank, Washington, DC(EUA)

Wskaźniki zrównoważonego rozwoju Polski (2011), GUS, US Katowice

Wskaźniki zrównoważonego rozwoju Polski (2015), GUS, US Katowice

Janusz RAK • Krzysztof BORYCZKO

PROPOSAL FOR WATER SUPPLY SYSTEMS EVALUATION DUE TO DIVERSIFICATION OF WATER INTAKES AND WATER TANKS

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ABSTRCT: The aim of the study was to compare the various water supply systems – from rural to agglomerations, in terms of continuity of water supply to the inhabitants in a crisis situation. The work included the diversification of water intakes with their number and the maximum daily production capacity and the diversification of water in the water tanks, knowing their number and volume. RB1 and RB2 diversification indexes have been proposed. Assessment criteria were included with comment. The research component is a two-parameter assessment of diversification for selected water supply systems using the indicators proposed by the authors.The use of proprietary indicators to assess the diversification of water supply using preference functions gives the ability to perform calculations easily and accurately.

KEY WORDS: water supply, diversification, water intakes, water tanks, allocation

JEL: Q530, Q570

Introduction

The appurtenance of collective water supply systems (CWSS) to critical infrastructure implies that one of the basic conditions for cities is to provide water for consumption in adequate quality. It is obligatory to cover the current and prospective water demand in a technically and economically justified manner with respect tonatural water resources. Among the technical factors, the reliability of CWSS is the most important. Safety is defined as the system's ability to protect internal values against external threats (Kucharski, Rak 2009; Pietrucha-Urbanik, 2013; Szpak, Tchórzewska-Cieślak, 2015; Tchórzewska-Cieślak, Boryczko, Piegdoń, 2015; Tchórzewska-Cieślak, Rak, 2010). Analyses and assessments of both reliability and safety related to the CWSS functioning indicate the significant role of water supply diversification (Boryczko, 2016; Pietrucha-Urbanik, Studziński, 2017; Rak 2014a; Rak, 2014b; Rak, 2015; Rak, Boryczko, 2017; Rak, Włoch, 2015; Weitzmann, 1992).

The basic diversification indicators used by the authors to assess the diversification of water supply in earlier works are Shannon-Weaver (1962), Pielou (1979, 1984), Simpson (1949, 1951) and Hurlbert (1971).

The main objective of the work is to show the methodology of water supply diversification analysis and assessment taking into account the production capacity of water intakes and volume of water tanks. The use of proprietary diversification indicators has been proposed. The work also includes calculations for selected cities of Poland.

Methodology of water supply diversification analysis and assessment

The starting point in the structure of the diversification index is the selection of the preference function. It determines the volume of supplies most desirable for CWSS. The preference function is defined on the range <0,1>, it has positive values and additionally in 0 and 1 it takes the value 0.

So there are endless possibilities to choose preference functions. The work considers the diversification index based on the functions:

$$x^3 - 2x^2 + x \text{ for } x \in \langle 0,1 \rangle \tag{1}$$

The function promotes 0.5 shares.

Authors (Rak, Boryczko) diversification index built on function (1) is:

$$d_{RB1}(V) = \sum_{i=1}^{n} \left(u_i - 2u_i^2 + u_i^3 \right) \tag{2}$$

where:
n – number of water tanks,
u_i – the share of the i-th water tank in the total volume of network water tanks.

The contribution of the i-th tank is given by the formula:

$$\sum_{i=1}^{n} u_i = 1 \tag{3}$$

where $u_i \in \langle 0,1 \rangle$.

The water intakes diversification index is set in the same way:

$$d_{RB1}(Q) = \sum_{j=1}^{m} \left(u_j - 2u_j^2 + u_j^3 \right) \tag{4}$$

where:
m – number of water intakes,
u_j – share of the j-th water intake in the total water production of CWSS.

The contribution of the i-th tank is given by the formula:

$$\sum_{j=1}^{m} u_j = 1 \tag{5}$$

where $u_j \in \langle 0,1 \rangle$.

The work also considers the diversification index based on the following function:

$$y = x - x^2 \text{ for } x \in \langle 0,1 \rangle \tag{6}$$

The function promotes 0.5 shares.

The water tanks diversification indicator built on this function is as follows:

$$d_{RB2}(V) = \sum_{i=1}^{n} \left(u_i - u_i^2 \right) \tag{7}$$

The water intakes diversification index can be determined from the formula:

$$d_{RB2}(Q) = \sum_{j=1}^{m} \left(u_j - u_j^2 \right) \tag{8}$$

A two-parameter assessment of the water supply diversification was carried out according to additive models for RB1 and RB2, respectively:

$$d_{RB1} = \alpha \cdot d_{RB1}(V) + d_{RB1}(Q) \tag{9}$$

$$d_{RB2} = \alpha \cdot d_{RB2}(V) + d_{RB2}(Q) \tag{10}$$

where:
α – allocation factor – the ratio of the total amount of water accumulated in water tanks to the total capacity of all water intakes.

The α indicator is calculated as:

$$\alpha = \frac{\sum_{i=1}^{n} V_i}{\sum_{j=1}^{m} Q_i} \tag{11}$$

Tables 1 to 3 present the values of the dRB1 and dRB2 index calculated with formulas (2), (4), (7), (8).

Table 1. The numerical values of $d_{RB1}(V,Q)$ and $d_{RB2}(V,Q)$ for m, n=2

m=2	$u_1 = 0,5$ $u_2 = 0,5$	$u_1 = 0,6$ $u_2 = 0,4$	$u_1 = 0,7$ $u_2 = 0,3$	$u_1 = 0,8$ $u_2 = 0,2$	$u_1 = 0,9$ $u_2 = 0,1$	$u_1 = 0,95$ $u_2 = 0,05$	$u_1 = 0,99$ $u_2 = 0,01$
d_{RB1}	0,25	0,24	0,21	0,16	0,09	0,0475	0,0099
d_{RB2}	0,5	0,48	0,42	0,32	0,18	0,095	0,0198

Source: author's own work.

Table 2. The numerical values of $d_{RB1}(V,Q)$ and $d_{RB2}(V,Q)$ for m, n=3,

m=3	$u_1 = 0,33$ $u_2 = 0,33$ $u_3 = 0,33$	$u_1 = 0,4$ $u_2 = 0,3$ $u_3 = 0,3$	$u_1 = 0,5$ $u_2 = 0,3$ $u_3 = 0,2$	$u_1 = 0,6$ $u_2 = 0,3$ $u_3 = 0,1$	$u_1 = 0,6$ $u_2 = 0,2$ $u_3 = 0,2$	$u_1 = 0,7$ $u_2 = 0,2$ $u_3 = 0,1$	$u_1 = 0,8$ $u_2 = 0,1$ $u_3 = 0,1$
d_{RB1}	0,444	0,438	0,4	0,324	0,352	0,272	0,194
d_{RB2}	0,663	0,66	0,62	0,54	0,56	0,46	0,34

Source: author's own work.

Table 3. The numerical values of $d_{RB1}(V,Q)$ and $d_{RB2}(V,Q)$ for m, n=4,

m=4	$u_1 = 0,25$ $u_2 = 0,25$ $u_3 = 0,25$ $u_4 = 0,25$	$u_1 = 0,3$ $u_2 = 0,3$ $u_3 = 0,2$ $u_4 = 0,2$	$u_1 = 0,4$ $u_2 = 0,3$ $u_3 = 0,15$ $u_4 = 0,15$	$u_1 = 0,5$ $u_2 = 0,3$ $u_3 = 0,1$ $u_4 = 0,1$	$u_1 = 0,6$ $u_2 = 0,2$ $u_3 = 0,1$ $u_4 = 0,1$	$u_1 = 0,7$ $u_2 = 0,1$ $u_3 = 0,1$ $u_4 = 0,1$
d_{RB1}	0,5625	0,55	0,508	0,434	0,386	0,306
d_{RB2}	0,75	0,74	0,705	0,64	0,58	0,48

Source: author's own work.

The Analysis of d_{RB1} (V, Q) and d_{RB2} (V, Q) contained in tables 1÷3 indicates that:

- their maximum values are different for subsequent m or n,
- with the increase of m or n indexes values are growing,
- in cases of similar shares, the value of diversification indexes remains close to the maximum value for a given number m or n.

Proposal of categorization and standards determination of d_{RB1} diversification index taking into account the water intakes production and the volume of water tanks:

- lack of diversification $d_{RB1} = 0$
- small diversification $0 < d_{RB1} \leq 0,200$
- average diversification $0,200 < d_{RB1} \leq 0,400$
- sufficient diversification $0,400 < d_{RB1} \leq 0,600$
- very satisfactory diversification $d_{RB1} > 0,600$

Proposal of categorization and standards determination of d_{RB2} diversification according to (9):

- lack of diversification $d_{RB2} = 0$
- small diversification $0 < d_{RB2} \leq 0,300$
- average diversification $0,300 < d_{RB2} \leq 0,600$
- sufficient diversification $0,600 < d_{RB2} \leq 0,800$
- very satisfactory diversification $d_{RB2} > 0,800$

Calculations and discussion of results

The calculations for CWSS Rzeszów are presented below.

Two water intakes:

$Q_1 = 36120\ m^3/d$

$Q_2 = 47880\ m^3/d$

$Q = 84000\ m^3/d$

Twelve water tanks:

$V_1 = 600\ m^3$

$V_2 = V_3 = 1800\ m^3$

$V_4 = V_5 = V_6 = V_7 = 3000\ m^3$

$V_8 = 17700\ m^3$

$V_9 = V_{10} = V_{11} = V_{12} = 750\ m^3$

$V = 36900\ m^3$

$$\alpha = \frac{36900}{84000} = 0,44$$

$d_{RB1}(V) = 0,583$

$d_{RB2}(V) = 0,738$

$d_{RB1}(Q) = 0,245$

$d_{RB2}(Q) = 0,490$

$d_{RB1} = 0,44 \cdot 0,583 + 0,245 = 0,5$ – sufficient diversification

$d_{RB2} = 0,44 \cdot 0,738 + 0,490 = 0,81$ – very sufficient diversification

Table 4. Calculations of the two-parameter diversification index dRB1 including the allocation factor α

City	α	d_{RB1} (V)	d_{RB1} (Q)	d_{RB1}	diversification
Gorzów Wlkp.	0,23	0,296	0,403	0,47	sufficient
Jasło	0,39	0,192	0,019	0,09	small
Krosno	0,05	0,25	0,258	0,27	average
Poznań	0,39	0,222	0,227	0,31	average
Racibórz	0,31	0,444	0,188	0,33	average
Rzeszów	0,44	0,583	0,245	0,5	sufficient
Sanok	0,33	0,322	0,248	0,35	average
Szczecin	0,23	0,692	0,083	0,24	average
Tarnobrzeg	0,23	0,571	0,146	0,28	średnia
Tarnów	0,56	0,656	0,237	0,6	very sufficient

Source: author's own work.

Based on the analysis, it can be stated:

- inCWSS Tarnów very satisfactory diversification were found, due to the high α allocation factor,
- in SZZW Rzeszów a sufficient category of diversification was found, which results both from the high value of the allocation factor α (the second highest after CWSS Tarnów), and from the high (third of the analyzed CWSS) values of the d_{RB1} (V) index,
- low diversification was found in CWSS Jasła due to the low value of d_{RB1} (Q), which results from a large difference in the water produce of two basic water intakes.

The results of the d_{RB2} index calculation for all analyzed CWSS are presented in table 5.

Table 5. Calculations of the two-parameter diversification index dRB1 including the allocation factor α

City	α	dRB1 (V)	dRB1 (Q)	dRB1	diversification
Gorzów Wlkp.	0,23	0,494	0,55	0,66	sufficient
Jasło	0,39	0,384	0,04	0,19	small
Krosno	0,05	0,5	0,458	0,48	average
Poznań	0,39	0,444	0,454	0,63	sufficient
Racibórz	0,31	0,666	0,376	0,58	average

City	α	dRB1 (V)	dRB1 (Q)	dRB1	diversification
Rzeszów	0,44	0,738	0,49	0,81	very sufficient
Sanok	0,33	0,51	0,496	0,66	sufficient
Szczecin	0,23	0,828	0,166	0,36	average
Tarnobrzeg	0,23	0,752	0,292	0,46	average
Tarnów	0,56	0,799	0,41	0,86	very sufficient

Source: author's own work.

Based on the analysis, it can be stated:

- in the CWSS Tarnów and Rzeszów, categories of very satisfactory diversification were found, due to the high α allocation factor (the two highest among those analyzed) and the high value of both the $d_{RB2}(V)$ and $d_{RB2}(Q)$ indexes,
- in the CWSS Poznań, a sufficient diversification category was found, which results both from the high value of the α allocation factor (the third highest after the CWSS Tarnów and Rzeszów), as well as from the high values of $d_{RB2}(V)$ and $d_{RB2}(Q)$,
- despite the high value of the α allocation factor (the third highest), low diversification was found in CWSS Jasło – also due to the low value of $d_{RB2}(Q)$, which results from a large difference in the water produce of two basic water intakes.

Conclusions

The use of proprietary indicators to assess the diversification of water supply using preference functions gives the ability to perform calculations easily and accurately.

The proposed alpha allocation factor takes into account total amount of water accumulated in water tanks to the total capacity of all water intakes.

The high value of the alpha indicator should be interpreted as better diversification of water supply in a crisis situation.

The contribution of the authors

Janusz Rak – conception, literature review, acquisition of data, analysis and interpretation of data – 50%
Krzysztof Boryczko – conception, literature review, acquisition of data, analysis and interpretation of data – 50%

Literature

Boryczko K. (2016), *Water age in the water supply network as health risk factor associated with collective water supply*, "Ecological Chemistry And Engineering A" No. 23(1), p. 33-43

Hurlbert S.H. (1971), *The Non-concept of Spiecies Diversity: a critique and alternative parameters*, "Ecology" No. 4(52), p. 577-586

Kucharski B., Rak J. (2009), *Sludge management in water treatment plants*, "Environment Protection Engineering" No. 35(2), p. 15-21

Pielou E.C. (1979), *Biogeography*, New York

Pielou E.C. (1984), *The interpretation of ecological data: a primer on classification and ordination*, New York

Pietrucha-Urbanik K. (2013), *Multidimensional comparative analysis of water infrastructures differentiation*, "Proc. Conference on Environmental Engineering IV", p. 29-34

Pietrucha-Urbanik K., Studzinski A. (2017), *Case study of failure simulation of pipelines conducted in chosen water supply system*, "Maintenance And Reliability" No. 19(3), p. 317-323

Rak J., (2014), *Metoda oceny stopnia dywersyfikacji dostawy wody dla wybranych miast w Polsce*, "INSTAL" No. 5, p. 38-40

Rak J., (2014), *Problematyka dywersyfikacji dostaw wody*, "Technologia Wody" No. 1, p. 14-16

Rak J. (2015), *Propozycja oceny dywersyfikacji objętości wody w sieciowych zbiornikach wodociągowych*, "Journal of Civil Engineering, Environment and Architecture" No. 32(62), p. 339-349

Rak J., Boryczko K. (2017), *Assessment of water supply diversification using the Pielou index*, "Proc. 5th National Congress of Environmental Engineering", p. 53-58

Rak J., Włoch A. (2015), *Models of level diversification assessment of Water Supply Subsystems*, in: A. Kolonko et al. (eds), *Underground Infrastructure of Urban Areas 3*, London, p. 237-244

Shannon C. Weaver W. (1962), *The Matematical Theory of Communication*, Urbana

Simpson E.H. (1949), *Measurement of diversity*, "Nature" No. 163, p. 688-688

Simpson E.H. (1951), *The Interpretation of Interaction in Contingency Tables*, "Journal of the Royal Statistical Society" No. 13, p. 238-241

Szpak D., Tchórzewska-Cieślak B. (2015), *Water producers risk analysis connected with collective water supply system functioning*, "Proc. 11th International Conference on Dependability and Complex Systems (DepCoS-RELCOMEX)", p. 479-489

Tchórzewska-Cieślak B., Boryczko K., Piegdoń I. (2015), *Possibilistic risk analysis of failure in water supply network*, "Proc. European Safety And Reliability Conference (ESREL)", p. 1473-1480

Tchórzewska-Cieślak B., Rak J. (2010), *Method of identification of operational states of water supply system*, "Proc. 3rd Congress of Environmental Engineering", p. 521-526

Weitzmann M. (1992), *On diversity*, "Quartely Journal of Economics" No. 107, p. 363-405

Monika ZDEB • Justyna ZAMORSKA • Dorota PAPCIAK

THE EFFECT OF THE TYPE OF ROOFING AND THE SEASONS ON THE MICROBIOLOGICAL QUALITY OF RAINWATER

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ABSTRCT: This paper presents the results of research on the bacteriological quality of rainwater collected directly from precipitation and various roof surfaces – concrete and ceramic roof tiles, galvanised sheet and a terrace covered with epoxy resin. Samples for the research were collected in a suburban area in 2015-2016. The quality of rainwater was assessed based on the results of bacteriological analyses (the presence of indicator bacteria and the total mesophilic and psychrophilic bacteria count). The effect of the seasons and the type of roofing on the microorganism count was discussed. Significant differences in the quality of rainwater collected from various roof surfaces, related to the roughness and chemical composition of the materials covering the roofs were indicated. In the rainwater examined, significant numbers of potentially pathogenic microorganisms such as Escherichia coli, coliforms and faecal streptococci were detected. The results obtained were the basis for indicating the possibility of using rainwater for various household purposes. Rainwater is not suitable for uses requiring the quality of water intended for consumption due to a great number of psychrophilic, mesophilic and faecal bacteria.

KEY WORDS: rainwater, indicator microorganisms, pathogenic microorganisms

JEL: Q53, Q56

Introduction

The widespread household use of rainwater is the basis for strategies allowing the water sector to adapt to the ongoing climate changes. In many countries in the world, including Poland, systems using rainwater in households are becoming more and more popular. In such countries as Japan, Germany and Australia, rainwater is collected and used for the maintenance of public buildings, e.g. airports, sports halls and business premises (Zawilski, Sakson, 2010). Rainwater is the basic part of water resources that provide water renewal, therefore it should be protected against contamination and be managed and used in the place of precipitation (Królikowska, Królikowski, 2012). The collection of rainwater and its subsequent use brings many benefits, both ecological and economic (Słyś, Stec, 2012). As an alternative source of water, it satisfies the needs for water of a lower quality, which enables significant savings of tap water, and is a way to use it in the place of precipitation without having to be discharged outside the catchment area. The use of rainwater is most frequently associated with its use for household and sanitary purposes, but also in agriculture or industry. Rainwater used in households should be:

- free from pathogenic bacteria and solid contaminants,
- poor in nutrients,
- neutral to the materials with which it is in contact.

An analysis of the structure of water consumption for household and sanitary purposes in residential buildings shows that about 50% of drinking water can be replaced by rainwater, and in public buildings nearly 65% (Ludwińska, Paduchowska, 2017). Although it is commonly believed that rainwater is relatively clean, the results obtained demonstrate its physicochemical and microbial contamination (Koszelnik, 2009). The research carried out so far has shown that the consumption of rainwater without its prior treatment is dangerous for potential consumers. Rainwater may contain pathogenic microorganisms that are washed away from the atmosphere and roofing. Some microorganisms found in the air, once got into the water, have the ability to live in an aquatic environment. Examples of pathogenic bacteria that live both in the air and in the water include *Yersiniapestis*, *Corynebacteriumdiphtheriae*, *Mycobacteriumtuberculosis*, *Legionella pneumophila* (Błaszczyk, 2010). In the composition of rainwater, the presence of many pathogens, including *Salmonella, Campylobacter, Legionella sp., Clostridium perfringens, Giardia duodenalis and Cryptosporidium parvum* which cause serious disease symptoms in humans, were found. Disorders occurring after the ingestion of bacteriologically contaminated water mainly include gastrointestinal disor-

ders, as well as numerous infections, including mucosal, respiratory, urinary, nervous and systemic infections (Hadaś, Dera, 2014).

The quality of water determines the way it is used, generates costs, takes time and space to its treatment. Knowledge about the factors affecting the quality of rainwater can significantly impact the selection of the appropriate surface and method of collection.

The aim of the research was to determine the microbiological quality of rainwater collected from various roof surfaces, during different seasons and to indicate the possibility of its use for household purposes.

Research methods

The research was carried out in 2015-2016. Analyses were performed for the rainwater collected from the guttering of buildings with various roofing (concrete roof tiles, ceramic roof tiles, galvanised sheet and a terrace covered with epoxy resin). A control sample was the rainwater which had no contact with the roof surface and was collected directly from precipitation. Sampling was carried out in a suburban non-industrialised area, in accordance with PN-ISO 5667 – 8:2003, after rejection of the first runoff.

Microbiological tests were performed in compliance with the sterility rules under laminar flow cabinet conditions. All the analyses were carried out using the applicable and recommended methods (table 1).

Table 1. Scope and methodology for the number of microorganisms for the rainwater

Parameter	Method/standard
Escherichia coli	The method of membrane filters; PN-EN ISO 9308-1:2014-12
Fecal streptococcus	The method of membrane filters; PN-EN ISO 7889-2:2004
The total number of bacteria at 37°C after 24 hours	Platelet method on a standard nutrient agar; PN-EN ISO 6222:2004
The total number of bacteria at 22°C after 72 hours	
The number of *Clostridium perfringens*	The method of membrane filters; PN-EN ISO 14189:2016-10
ATP number	The luminometer marking
The number of particles of genetic material	Flow cytometry

Source: author's own work.

Results of the research

Table 2 summarises and describes two research cycles using the number of rain events, the sum of monthly rainfall, the length of breaks between rainfall and average air temperatures, 2015 was a year with fewer rain events, longer dry periods and higher air temperatures than 2016 (table 2).

Table 2. Characteristics of research cycles

Characteristic feature	2015	2016
Number of rain events	31	48
The number of rain events analyzed	11	23
Total precipitation from research months [mm]	254	413
Average air temperature in spring [°C]	12,3	12,2
Average air temperature in summer [°C]	24	19,5
Average air temperature in autumn [°C]	10,5	15,1
The longest break between precipitation [days]	40	27

Source: author's own work.

In all samples from both research cycles, great numbers of psychrophilic, mesophilic and faecal bacteria were found.

More psychrophilic bacteria were observed in the samples collected in 2015. In both research cycles, the highest psychrophilic bacteria count was recorded in the water collected from the terrace coated with epoxy resin – the median was 20,000 CFU/ml. Attention should be paid to the extreme values in 2015 (figure 1).

The reason for the poor sanitary condition of rainwater collected from flat surfaces can be the formation of mini hollows periodically filled with water in which the proliferation of bacteria and even the formation of a biofilm can take place. Such a biofilm is difficult to rinse due to the small pitch of flat roofs or terraces (Mendez et al., 2011).

The smallest number of potentially pathogenic (mesophilic) bacteria (figure 2) was in the samples of the water collected from the roof covered with concrete roof tiles, especially in 2015 (a smaller number of rain events compared to 2016).

The water collected from the roof covered with galvanised steel was also characterised by a small number of potentially pathogenic microorganisms. This is associated with the biocidal properties of zinc and the relatively smooth surface of the sheet, as well as fast heating in the period of high tem-

peratures. Mendez et al. (2011) indicate that appropriate roofing can be an effective measure protecting against the growth of microorganisms. The relationship between the roughness of the roof material and the number of microorganisms was confirmed in the works of Leong et al. (2017) and Dobrowsky et al. (2014).

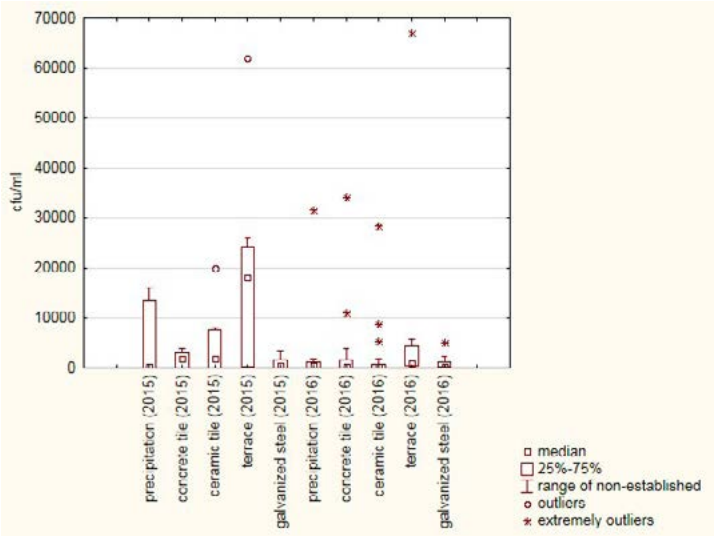

Figure 1. Statistical data for the number of psychrophilic bacteria present in rainwater

Source: author's own work.

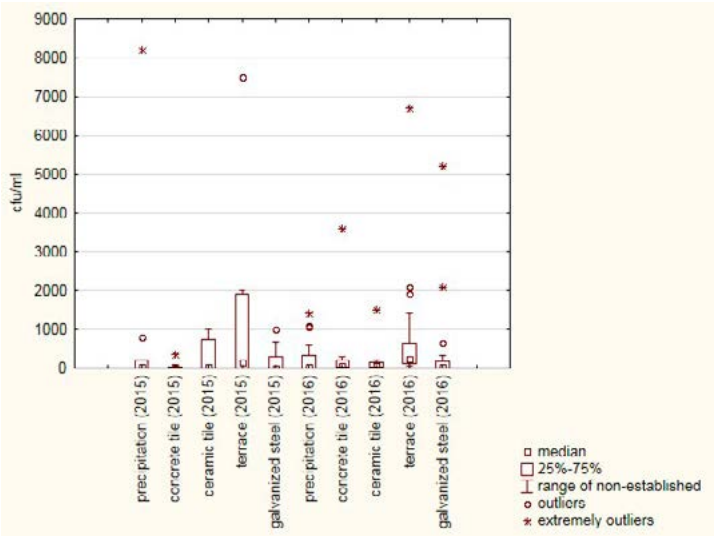

Figure 2. Statistical data for the number of mesophilic bacteria present in rainwater

Source: author's own work.

The highest count of mesophilic bacteria was found in the water collected during the summer and autumn seasons, while psychrophilic bacteria – in the spring and summer (figure 3 and figure 4).

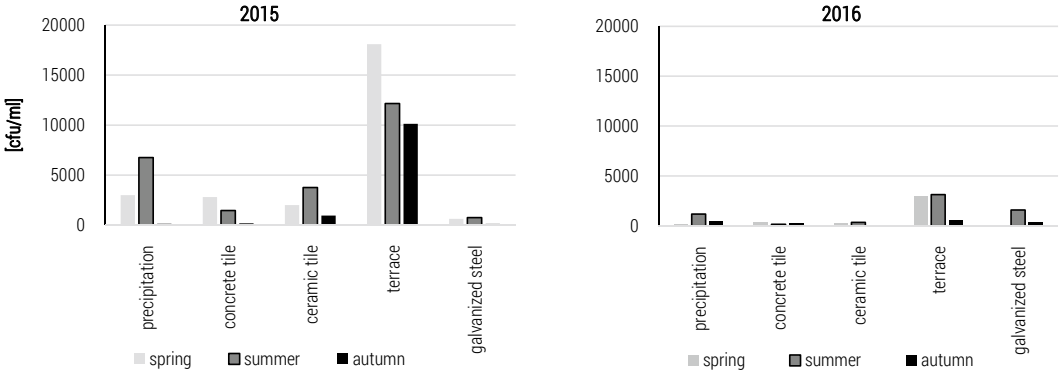

Figure 3. Medians of the number of psychrophilic bacteria in rainwater in various research seasons

Source: author's own work.

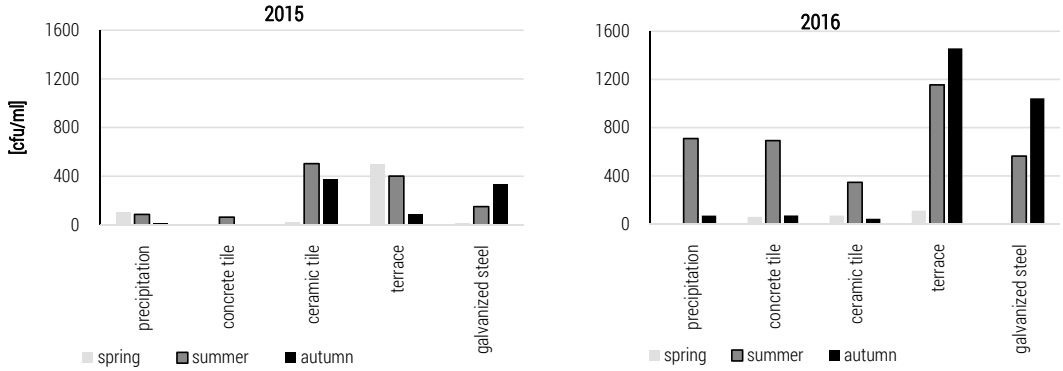

Figure 4. Medians of the number of mesophilic bacteria in rainwater in various research seasons

Source: author's own work.

This may mean that the main factor regulating their count is the air temperature and consequently the degree of heating of the roof surfaces. It was observed that the rainwater collected during warmer periods is more contaminated with bacteria.

The research carried out indicates the presence of significant numbers of potentially pathogenic bacteria in rainwater rinsing various types of roofs as well as that collected directly from the air in both research cycles. In the summer season, their number is much higher compared to colder seasons.

However, constant and clear relationships between the indicator microorganism count and the season cannot be indicated. Analysing figure 5 and figure 6 not only can differences between particular seasons but also between research cycles (2015 and 2016) be noticed, which reflects the dependence on the frequency and sum of rainfall (table 2).

The dependence on the air temperature and the surface from which rainfall is collected was observed by other researchers who recorded similar numbers of *E. coli* and faecal streptococci in the spring and summer seasons (Amin, Han, 2011).

In similar research, *E. coli* bacteria were detected in 50% of the examined samples in the summer season and only in 22% in the winter (Zhang et al., 2014).

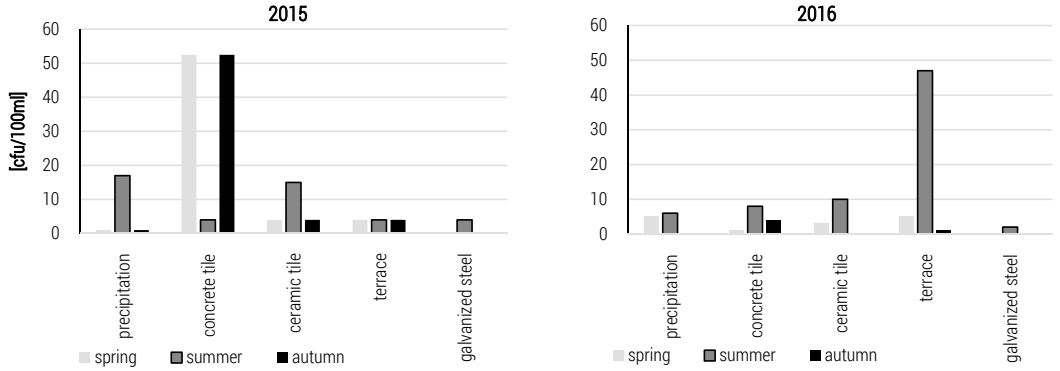

Figure 5. Medians of the number of *Escherichia coli* bacteria in rainwater at various research seasons

Source: author's own work.

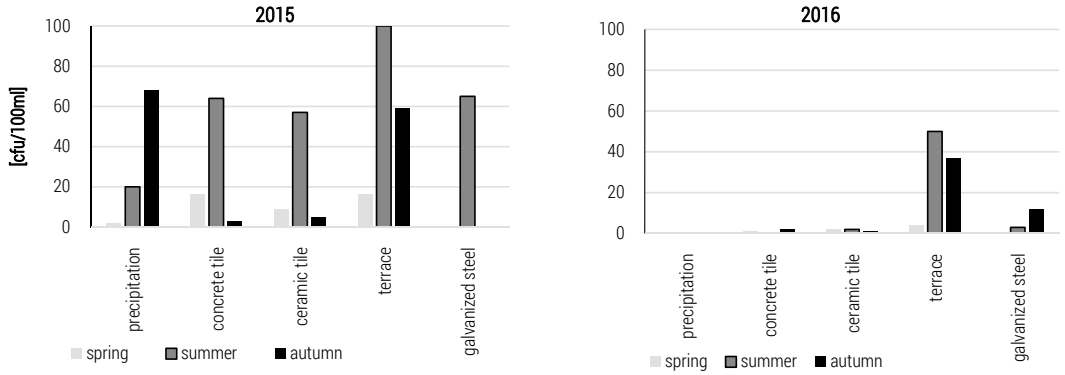

Figure 6. Medians of the number of *Enterococci* (fecal streptococci) in rain water in various research seasons

Source: author's own work.

In countries with moderate climate, the live bacteria count in the water, soil and air is variable and depends largely on temperature and humidity (Kaushik, Balasubramanian, 2012). The optimal temperature for the growth of pathogenic microorganisms (colonising warm-blooded organisms) is about 37°C, which explains the highest count of these bacteria during the summer season. Only in the rainwater collected from concrete roof tiles, the highest numbers of *E. coli* bacteria grew in the spring and autumn (figure 5). This may be due to the large thermal capacity of this roofing material, allowing the appropriate temperature for the growth of these bacteria to be maintained. The roof covered with galvanised sheet heats up very quickly, which may be a biocidal factor for bacteria, but it also cools down quickly, which may also inactivate cells and, despite viability, inhibit the ability to divide and grow on the medium (temperature shock) (Ding et al., 2017; Leong et al., 2017). The humidity of roofing is also important. It is on concrete roof tiles, with the greatest roughness, that humidity can be maintained much longer than on the other examined roofing. This enables microorganisms to survive in the periods between precipitation (Zhang et al., 2014). In the spring season, the number of these bacteria increases in the water taken from the roofs and directly from the air. In the summer season, a decrease in the number of microorganisms, despite the lack of a marked temperature fluctuation, may be caused by excessive heating of roofs and low humidity of the air.

The active cells of anaerobic bacteria *Clostridium perfringens* were most frequently detected just after the winter period (table 3). The presence of spores may be the evidence of former contamination, and due to their high resistance to environmental factors they may appear after longer periods without precipitation. A key role in the retention and accumulation of contamination may be played by the porosity of the roof surface and the roof pitch, making it difficult to effectively rinse with the first spouts of rain (Zdeb et al., 2016). The rainwater washing the terrace surface, collected in the spring, was found to be the most contaminated.

Due to the great number of psychrophilic and mesophilic bacteria, including faecal bacteria, rainwater is unsuitable for drinking, despite the fact that the latest Regulation of the Minister of Health does not specify the permissible number of psychrophilic microorganisms by introducing the provision "without abnormal changes" (Journal of Laws 2017 item 2294).

In countries deficient in groundwater and surface water resources, the use of rainwater for drinking is common (Gwenzi et al., 2015; Nalwanga et al., 2016). In the European reality, rainwater can be a valuable source of drinking water in crisis situations, caused by contamination of water taken to water supply systems: drought, large-scale floods or terrorist threats (biological weapon). This is allowed by Council Directive 98/83/EC of 3 November 1998,

Table 3. Number of *Clostridium perfringens* in the rainwater

Research cycle	Date of sampling rainwater	Clostridium perfringens [CFU/100 ml]				
		precipitation	concrete tile	ceramic tile	terrace	galvanized steel
2015	13.03	0	1	0	4	0
	30.03	0	0	0	2	0
	8.04	0	0	0	0	0
	7.05	0	0	0	0	0
	11.05	0	0	0	0	0
	21.05	0	0	0	0	0
	27.05	0	0	0	0	0
	13.07	0	0	0	0	0
	29.07	0	0	0	0	0
	10.11	0	0	0	0	0
	19.11	0	0	0	0	0
2016	8.03	0	0	0	6	0
	31.03	0	0	0	2	0
	8.04	0	0	0	0	0
	11.04	0	0	0	0	0
	15.04	0	0	0	0	0
	25.04	0	0	0	0	0
	28.04	0	0	0	0	0
	3.06	0	0	0	0	0
	15.06	0	0	0	0	0
	27.06	0	0	0	0	0
	6.07	0	0	0	0	0
	14.07	0	0	0	0	0
	18.07	0	0	0	0	0
	5.09	0	0	0	0	0
	19.09	0	0	0	0	0
	4.10	0	0	0	0	0
	27.10	0	0	0	0	0
	14.11	0	0	0	0	0

Source: author's own work.

stating that water intended for human consumption is "all water in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers".

Under conditions where it is impossible to obtain and maintain water of the highest quality, the presence of up to 10 CFU *E. coli* per 100 ml (Wisner, Adams, 2002 WHO) is allowed. The rainwater collected from the roof covered with galvanised sheet, as well as collected in the summer from the roof covered with concrete roof tiles, met the sanitary criteria for drinking water in crisis situations.

Due to the great number of *Escherichia coli* and mesophilic bacteria, rainwater cannot be fed directly into swimming pool basins used as bathing areas. Similar requirements can be applied to water used for hygienic purposes – bathing, brushing teeth, manual washing. During these activities water comes into contact with the digestive system, which, with significant microbiological contamination, causes gastric or intestinal disorders.

Rainwater collected from various roofing can be used only for purposes which do not require water of a good microbiological quality, e.g. for cleaning works in the curtilage and for flushing toilets. Rainwater could also be used for washing, provided that a temperature not lower than 60°C is used. The temperature, apart from detergents, guarantees the sanitary safety of clothing and materials after washing.

Due to the presence of *E. coli*, faecal streptococci and *C. perfringens*, there is a high risk of infection when using contaminated water for the irrigation of plantations where fruit cannot be washed.

Due to the great number of pathogenic microorganisms of *E. coli*, rainwater can be used for watering farm animals only after its disinfection.

In conclusion, rainwater without cleaning and disinfection processes cannot be used as an alternative to tap water, except for crisis situations.

Conclusions

Rainwater collected from roof surfaces is not suitable for uses requiring the quality of water intended for consumption, due to the great number of psychrophilic, mesophilic and faecal bacteria.

The worst microbiological quality was found in the rainwater collected in the summer (mesophilic and psychrophilic bacteria) and in the spring (*Clostridium perfringens*).

In crisis situations, when the requirements for the quality of water intended for consumption and hygienic purposes are less stringent, water

collected from the roof covered with galvanised steel can be used without prior treatment.

Rainwater collected from flat and porous surfaces (ceramic, concrete roof tiles), due to its poor sanitary condition, cannot be used without prior treatment for:

- water supply intended for human consumption,
- the filling and refilling of swimming pool basins used as bathing areas,
- the watering of animals and the preparation of feed,
- the irrigation of plantations of vegetables and fruit consumed without heat treatment and thorough cleaning.

Rainwater collected from various roofing can be used for purposes which do not require water of a good microbiological quality, e.g. for cleaning works and flushing toilets. Rainwater can also be used for washing, provided that a temperature not lower than 60°C is used. The temperature, apart from detergents, guarantees the sanitary safety of clothing and materials after washing.

The contribution of the authors

Monika Zdeb – literature review, conducting the experiment, research, writing a manuscript – 50%
Justyna Zamorska – research, analysis of the results – 20%
Dorota Papciak – concept and objectives, analysis and presentation of the results, writing a manuscript – 30%

Literature

Amin M.T., Han M.Y. (2011), *Improvement of solar based rainwater disinfection by using lemon and vinegar as catalyst,* "Desalination" No. 276, p. 416-424

Błaszczyk M. K. (2010), *Mikrobiologia środowisk*, Warszawa

Ding Q. et al. (2017), *Influence of high-latitude atmospheric circulation changes on summertime Arctic sea ice,* "Nature Climate Change" No. 7, p. 289-295

Dobrowsky P.H. et al. (2014), *Distribution of Indigenous Bacterial Pathogens and Potential Pathogens Associated with Roof-Harvested Rainwater, "*Applied and Environmental Microbiology" No. 80(7), p. 2307-2316

Gwenzi W. et al. (2015), *Water quality and public health risks associated with roof rainwater harvesting systems for potable supply: review and perspectives*, "Sustainability of Water Quality and Ecology" No. 6, p. 107-118

Hadaś E., Dera M. (2014), *Pasożyty – zagrożenie nadal aktualne*, "Problemy Higieniczno – Epidemiologiczne" No. 95(1), p.6-13

Kaushik R., Balasubramanian R. (2012), *Assessment of Bacterial pathogens in fresh rainwater and airborne particulate matter using Real – Time PCR, "*Atmospheric Environment" No.46, p. 131-139

Koszelnik P. (2007), *Atmospheric deposition as a source of nitrogen and phosphorus loads into the Rzeszow reservoir, SE Poland*, "Environment Protection Engineering" No. 33(2), p. 157-164

Królikowska J., Królikowski A. (2012), *Wody opadowe – odprowadzanie, zagospodarowanie, podczyszczanie i wykorzystanie,* Warszawa

Leong J. et al. (2018), *Quantification of mains water savings from decentralised rainwater, greywater, and hybrid rainwater-greywater systems in tropical climatic conditions,* "Journal of Cleaner Production" No. 176, p. 946-958

Ludwińska A., Paduchowska J. (2017), *Rainwater harvesting systems in sanitary installation of buildings (in Polish)*, "Rynek Instalacyjny" No. 5, p. 42-46

Mendez C.B. et al. (2011), *The effect of roofing material on the quality of harvested Rainwater*, "WaterResearch" No. 45, p. 2049-2059

Nalwanga R. et al. (2016), *A study of the bacteriological quality of roof-harvested rainwater and an evaluation of SODIS as a suitable treatment technology in rural Sub-Saharan Africa*, "Journal of Environmental Chemical Engineering"DOI: 10.1016/j.jece.2016.12.008

Słyś D., Stec A. (2012), *Analiza LCC wariantów zagospodarowania wód deszczowych w budynku wielorodzinnym,* "Proceedings of ECOpole" No. 6(1), p. 409-415

Wisner B., Adams J. (2002), *Environmental health in emergencies and disasters. A practical guide*, WHO, Geneva

Zawilski M., Sakson G. (2010), *Calibration for digital model of virtual catchment area and water supply / sewage treatment systems done with SWMM software with the use of precipitation and sewage flow measurement data* (in Polish), "Gaz, Woda i Technika Sanitarna" No. 11, p. 32-36

Zdeb M., Zamorska J., Papciak D. (2016), *Studying Microbiology of Rain Water For of Their Use in Economy,*"Journal of Ecological Engineering" No. 17(3), p. 203-208

Zhang Y. et al. 2010), *Alternative Water Resources for Rural Residential Development In Western Australia,* " Water Resour Manage" No. 24, p. 25-36

Zhang Q. et al. (2014), *Quality and seasonal variation of rainwater harvested from concrete, asphalt, ceramic tile and green roofs in Chongquing, China*, "Journal of Environmental Management" No. 132, p. 178-187

Mirosława WITKOWSKA-DĄBROWSKA

SPATIAL VARIABILITY AND ECONOMIC AND ENVIRONMENTAL CONSEQUENCES OF AGRICULTURAL ACIDIFICATION OF SOILS IN THE PROVINCE OF WARMIA AND MAZURY

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ABSTRCT: The aim of this study has been to identify the spatial variability in the acidification of soils and the liming needs as well as the soil availability of fertiliser components in the Province of Warmia and Mazury (województwo warmińsko-mazurskie). The soil spatial variability has been analysed according to the division into administrative districts. The choice of this spatial division pattern was justified by the availability of data and the research subject. The data were obtained from Reports on the Environmental Conditions in the Province of Warmia and Mazury, the database of the Regional Agricultural Chemical Station in Olsztyn and from the Programme for Environmental Protection in the Province of Warmia and Mazury until 2020. The research results showed large differences between the districts, which were mostly due to natural conditions. Because of the high demand for nutrients, it would be advisable to prepare fertilisation plans and to adhere to Good Agricultural Practice recommendations, as this would control the causes and alleviate the consequences of soil acidification induced by farming.

KEY WORDS: soil acidification, consequences, agricultural causes

JEL: Q15, Q56, Q57

Introduction

Soil acidification is affected by both natural and anthropogenic factors. The principal natural conditions include the climate and the type of parent rock. In Poland, including the Province of Warmia and Mazury, over 90% of soil developed on acid rocks transported by glaciers (Hołubowicz-Kliza, 2006, p. 3). The topsoils lying over acid soils are exposed to more intensive leaching of alkaline components, especially in areas where total annual rainfalls are high. The Province of Warmia and Mazury belongs to the coldest regions in Poland, with a short plant growing season and a relatively high, but spatially varied, annual sum of precipitations (400 mm near Ryn and Sępopol, up to nearly 700 mm near Elbląg and Górowo Iławeckie, compared to the Polish average of 600 mm). Also, temperatures across the province are varied. The climate in the western part of the region is shaped under the influence of the Baltic Sea, whereas the eastern parts of the province are exposed to a distinct influence of the continental climate. The plant growing season is 200-201 days long in the west, but shortens to 190-200 days in the north-eastern part of the province, while the yearly average temperature of 6°C in Olecko is by 1°C lower than the average temperature recorded in the environs of Nowe Miasto Lubawskie. The mean annual precipitation reach up to 450 mm. At low temperatures, the CO_2 generated by breathing soil organisms concentrates in soil and adds to soil acidification (Programme..., 2010, p. 10). Another cause of soil acidification is the application of nitrogen fertilisers (Hołubowicz-Kliza, 2006, p. 3). The current predictions up to the year 2050 concerning the consumption of mineral fertilisers in the world implicate a constant growth in their use (Gil, 2013, p. 9).

The Province of Warmia and Mazury is perceived as an agricultural region. Considering the fact that nearly all Poland lies in the so-called sensitive area and the Province of Warmia and Mazury occupies the northern part of Poland, in the vicinity of the Vistula Lagoon, it seemed worth making an analysis to demonstrate how the phenomenon of soil acidification was distributed spatially in the province. Another question was whether the diverse natural conditions observed in the province would be accompanied by the spatial variability in soil acidification, which entails differences in the demand for soil liming and in deficits of mineral components.

Review of literature

Acidity is conditioned by the soil presence of hydrogen ions (H+), which occur either in the soil solution or bound by the soil sorption process.

Depending on what hydrogen ions are present, i.e. in the soil solution or absorbed by the soil complex, two types of acidity are distinguished: active acidity and potential acidity. Acidity fluctuates considerably during an annual cycle, as seasons of the year change. It tends to be the highest in summer, when soil microorganisms are the most active and plants grow most intensively. The natural acidification processes take place all the year and do not pose a threat (Boguszewski, 1980, p. 176; Fotyma, Zięba, 1988, p. 250; Filipek, 2001, p. 5; Filipek, Skowrońska, 2013, p. 284); however, when they coincide with certain anthropogenic measures they can become dangerous to agricultural ecosystems. The anthropogenic source of soil acidification stems mostly from combustion of energy generating resources, mainly coal and crude oil derivatives (Filipek, 2005, p. 67; Filipek, Skowrońska, 2013, p. 284). Another cause that cannot be neglected is the influence of agriculture on soil pH. The main factor of soil acidification related to agriculture is mineral fertilisation. A consequence of this process is the growing fertiliser demand of plant production, that is the increasing consumption of mineral fertilisers per basic crop production unit, such as 100 kg of cereal grain (cereal unit (c.u.)). A direct effect of excessive fertiliser consumption, beside the lowered effectiveness of inputs into the production, is a greater risk to the soil and water environments. A team working at the IUNG Research Institute have calculated from equations (regression functions) developed by Grzebisz et al. (2008, p. 49) the so-called yield loss coefficient, which equals 25% and 15% for very acid and acid soils, respectively (Ochal et al., 2017, p. 5).

Although in the 1990s it was possible to observe a decrease in the consumption of fertilisers in Poland, mostly phosphates and potassium ones, the amount of fertilisers used in agriculture has increased by 31% following Poland's access to the EU, while the total crop prodution has risen by just 5% (Kopiński, 2012, p. 95; Gil, 2013, p. 9).

There is a considerable variability in soil acidity and soil content of available forms of macronutrients across Poland (Kopiński, 2012, p. 95; Ziętara, 2009, p. 190). For years, the share of very acid and acid soils in Poland has been exceeding 50% on average of all farmland and still tends to increase (Siebielec et al., 2017, p. 27).

The highest share of acidified soils (pH<5.5) is in the Provinces of Podkarpacie and Małopolska (*województwo podkarpackie* and *małopolskie*). The least of such soils can be found in the Province of Kujawy and Pomerania (*województwo kujawsko-pomorskie*) (Hołubowicz-Kliza, 2013, p. 5). The results of the studies conducted by the IUNG in 2014-2015 suggest that 28.9% of the analysed soil samples were very acidic in reaction (pH over 4.5), and another 28.3% had acid reaction.

According to Filipek and Skowrońska (2013, p. 283), special attention should be paid to an inadequate N:P:K ratio and a share of nitorgen in NPK fertilisers. Among potassium fertilisers, potassium chloride ones contribute the most to soil acidification due to the ease of Cl-ion leaching. Phosphate fertilisers soluble in water can also favour soil acidification, although to a lesser extent than nitrogen ones. From the point of view of farmers, consequences of soil acidification are extremely grave. They include depressed availability of nutrients, especially phosphorus, magnesium and molybdenum, which leads to a decline in yields (Grzebisz et al., 2005, p. 36; Igras et al., 2010, p. 9) and poses a threat to the soil and water environments. Moreover, the mobility of soil components increases, which can create a hazard of their excessive accumulation, particularly heavy metals and mobile aluminium (Hołubowicz-Kliza, 2013, p. 5). Another consequence is the depressed intensity of the uptake of free nitrogen from the atmosphere and nutrients into deeper soil horizons. As a result, the soil fertility and quality are impaired. Acidity is one of the major soil qualities which decide about the course of soil processes, and the lowered effectiveness of mineral fertilisers can only partially be attributed to worse soil and climate conditions (Blake et al., 1999, p. 400; Kaczor, Kozłowska, 2000, p. 55; Filipek, Skowrońska, 2009, p. 25; Kopiński et al., 2013, p. 53). An in-depth study into the influence of weather conditions and soil acidification on productivity has been conducted by Kopiński et al. (2013 p. 53). In 2006-2011, the plant production potentially lost due to the unregulated soil reaction was 4.3 c.u. per ha^{-1} of arable land in dk on average per year, and tended to be twice as high as the production lost due to unfavourable weather conditions. These data support the opinion expressed by Krasowicz (2009, p. 9), who maintained that organisational factors rather than natural conditions, including the weather, had a greater impact on the economic and production results in farming. Moreover, the inputs into fertilisation constitute a considerable share of total plant production costs. Management of fertilisers in agriculture has both economic and ecological importance. Particularly noteworthy in the context of environmental effects are, according to Gaj (2013, p. 5), nitrogen and phosphorus. In the Province of Warmia and Mazury, the level of mineral fertiliser consumption is lower than the country's average (figure 1).

The consumption of lime as a fertiliser has decreased drastically since 2005, both in Poland and in the Province of Warmia and Mazury. At the same time, according to the IUNG data, around 32.5% of the analysed soil samples are distinguished as the ones which must be limed, 17.2% – should be limed, 12% – need some liming and 25% – do not need any liming (Ochal et al., 2017, p. 11). The provinces where the percentage of soils that require liming is the highest are: *małopolskie* (77.5%), *podkarpackie* (73.4%), łódzkie

(59.7%), as well as *dolnośląskie*, *mazowieckie*, śląskie, *podlaskie*, *lubelskie*, *warmińsko-mazurskie* (from 54.2 to 50.9%).

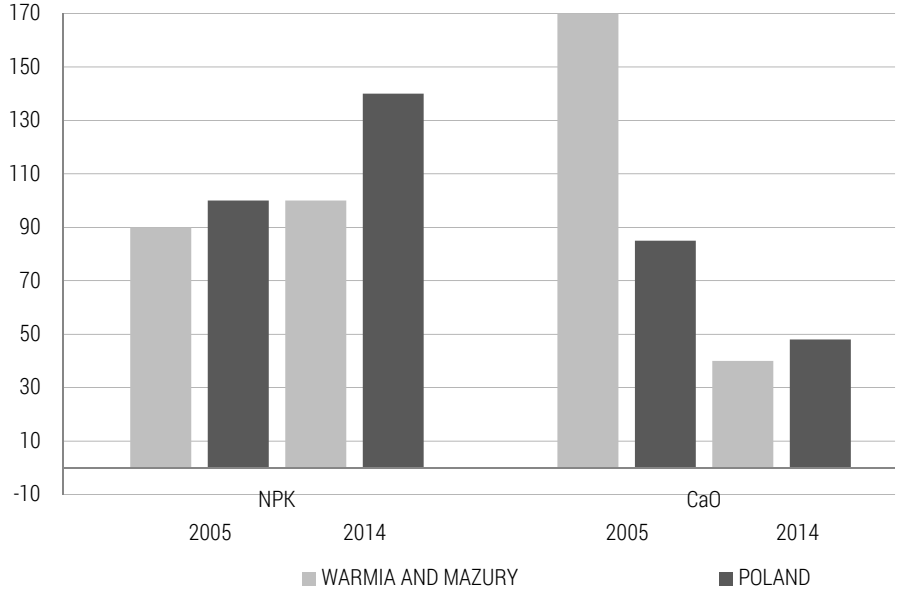

Figure 1. Consumption of mineral fertilisers and lime in the Province of Warmia and Mazury and in Poland in 2005-2014

Source: author's own work based on data of the Main Statistical Office (GUS).

Research methods

The purpose of this study has been to identify the spatial variability in the acidification of soils and their richness in available forms of nutrients in the area covered by the Province of Warmia and Mazury (*województwo warmińsko-mazurskie*). The spatial variability was analysed according to the division into administrative districts (excluding towns with the status of a district). The choice of this spatial division pattern was dictated by the accessibility of data and the research subject. The data were obtained from reports on the condition of the environment in the Province of Warmia and Mazury, the database of the Regional Agricultural Chemical Station (OSCHR) in Olsztyn and from the Programme for Environmental Protection in the Province of Warmia and Mazury until 2020. The assessment of acidifcation of soils performed by the OSCHR was based on pH tests correlated with the agronomic classes of soil. On the basis of the pH in KCl reaction, soils are then divided into 5 classes: very acid pH< 4.5, acid pH 4.6-5.5, slightly acid pH 5.6-6.5, neutral pH 6.6-7.2 and alkaline pH > 7.2. According to the pH value and agro-

nomic class of soil, soil demand for liming was estimated on a five-degree scale: liming is necessary, needed, recommened, limited and useless. Moreover, it was calculated by how many percent points in the time periods analysed the abundance of soils changed with respect of available forms of macronutrients: phosphorus (P_2O_5), potassium (K_2O), and magnesium (Mg). The analyses published in the Reports were made on the basis of analytical results delivered by regional agricultural chemical stations in 2007-2010 and in 2011-2016 in the area covered by the Province of Warmia and Mazury.

Research results

The total area of farmland contained in the farms located in the Province of Warmia and Mazury in June 2015 was 1096.1 thousand ha, of which 87.3% was the farmland owned by family farms. 89.7% of the agriculturally used land belonged to well-maintained farmland.

The variability of soils in the province is due to the variability of partent rock, diverse land relief and various climate and hydrological conditions. It is possible to notice changes progressing through certain zones from the north to the south of the province.

According to the analyses made by the Regional Agricultural Chemical Station in Olsztyn in 2011-2014, 33% of the land used for agricultural purposes in the Province of Warmia and Mazury either had to or needed to be limed. The studies also showed that the share of very acid and acid soils decreased in comparison to the previous research time periods and their distribution in the whole province was uneven.

Figure 2 shows results of the soil analyses in 2007-2010 (the lower bar) and in 2011-2016 (the upper bar) for particular districts. The reaction of over half of the samples (55%) collected from the the area submitted to analyses was very acid or acid. Slightly acid reaction was detected in 26% of the soil samples, while neutral and alkaline reaction was demonstrated in just 19% of the samples obtained from the analysed farmland. Similar results have been reported by Brodzińska (2009, p. 37-42).

However, the spatial variability and changes between the two time periods are evident. In most districts a decrease in the constribution of acid and very acid soils can be noted.

Soil acidification entails the necessity to implement soil liming (figure 3). In the Province of Warmia and Mazury, the highest demand for soil liming was diagnosed in the districts: *braniewski*, *lidzbarski* and *elbląski*.

Soil acidification is also closely connected with the leaching of nutrients, mainly alkaline compounds, to deeper horizons of soils. This leads to deficits

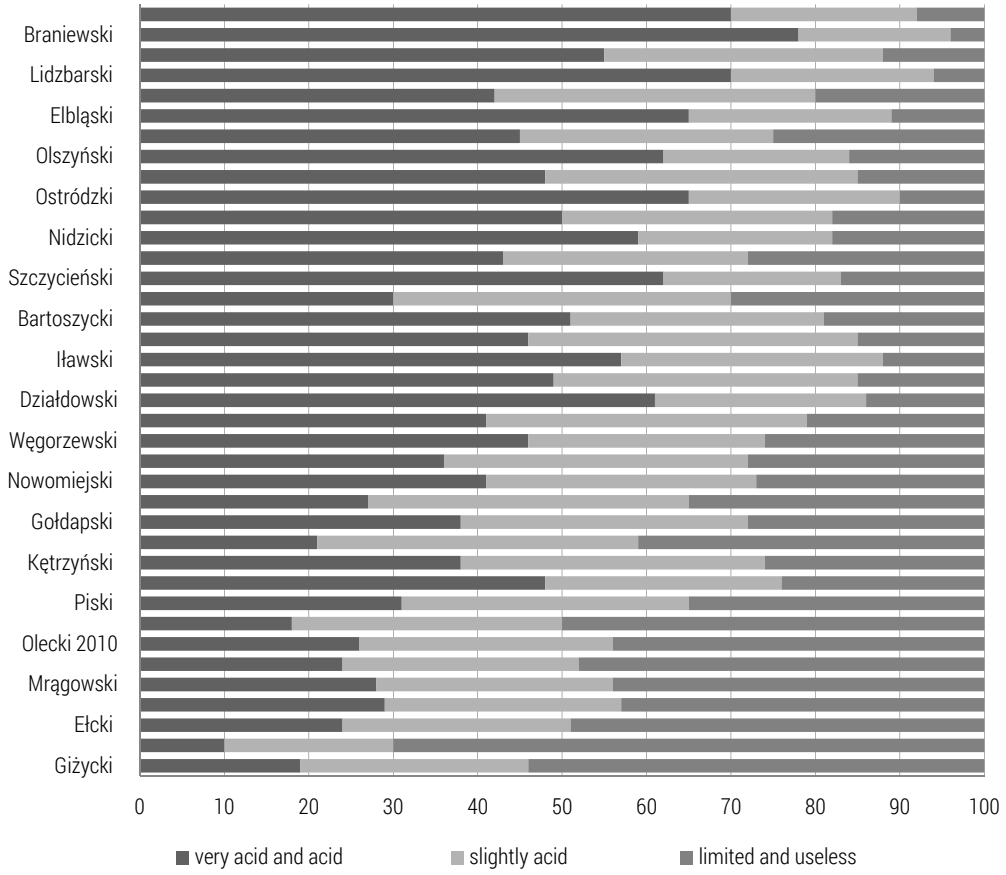

Figure 2. Reaction of soil under farmland in the Province of Warmia and Mazury

Source: author's own work based on data from the Regional Enrvionmental Protection Inspectorate in Olsztyn (WIOŚ) and the Regional Agricultural Chemical Station in Olsztyn (OSCHR).

of nutrients. In the province of Warmia and Mazury, the analysed soils demonstrated large differences in the content of available forms of fertiliser elements (phosphorus, potassium, magnesium), due to the natural conditions or the applied levels of fertilisation. In the case of the districts with the highest demand for soil liming, and particularly the districts *braniewski*, *węgorzewski* and *lidzbarski*, the soils were found to be very low or low in phosphorus (32%, 50% and 46%, respectively, in 2008), and the soil content of this element even declined in the subsequent years, by 7.13 and 2 percent points. The districts where soils have a low content of available forms of nutrients are also characterised by a high share of acid and very acid soils. Same as in the case of climate and soil-related conditions, it is possible to

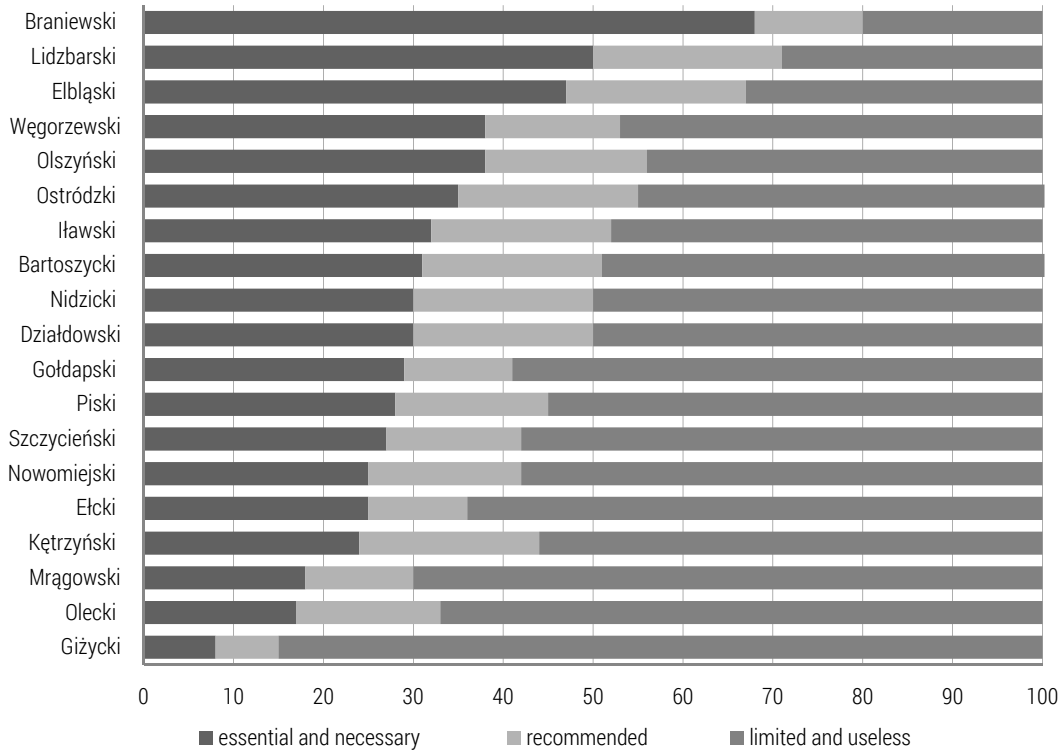

Figure 3. Liming demand in districts of the Province of Warmia and Mazury

Source: author's own work based on data from the WIOŚ in Olsztyn.

observe a certain tendency in the spatial distribution of districts, creating zones along the north-south axis.

The unbalanced richness of soils and the unused nutrients may have a negative influence on the water environment and quality of air. As well as having a negative effect on the maintenance of productive functions of soil, depleted resources of soil humus diminish the role of soils in the sequestration (binding) of carbon from the atmosphere. Polycyclic aromatic hydrocarbons, heavy metals and other harmful substances from polluted soils which are absorbed by plants either poison the yields or deteriorate the quality of agricultural production, have a negative impact on the environment, and via the food chain can accumulate in animal bodies, adversely affecting their condition and health. These substances can cause toxic, cancerogenous and mutagenic pathological conditions in humans (Programme…, 2016, p. 306).

Conclusions

The soil reaction is a principal factor that conditions an efficient use of macronutrients, secondary elements and micronutrients contained in the soil by plants. Various natural and man-made factors can cause an increase in the acidity of soils, reducing the availability of nutrients and deteriorating the conditions for an optimal growth of plants, hence affecting the volume and quality of yields produced by agricultural crops and forestry plants as well as the health of wild plants. In the districts where the share of very acid and acid soils was high and the demand for soil liming was likewise high, a large percentage of soils with low and very low richness in available elements, especially phosphorus, was identified. Another important contributor to soil acidification is agricultural practice, especially unreasonably high fertilisation with nitrogen fertilisers. The variability of soil types, from compact black soils near Kętrzyn through brown soils in Sępopolska Lowland and muddy soils in the environs of Elbląg, to light sandy soils in the south of the province means that different levels of fertilisation and liming are in order.

Literature

Blake L. et al. (1999), *Changes in soil chemistry accompanying acidification over more than 100 years under woodland and grass at Rothamsted ExperimentalStation. UK. European*, "Journal of Soil Science" No. 50, p. 400

Boguszewski W. (1980), *Wapnowanie gleb*, Warszawa, p. 176

Brodzińska K. (2009), *Środowiskowe uwarunkowania konkurencyjności rolnictwa Warmii I Mazur,* „Roczniki Naukowe SERIA" No. 4, p. 37-42

Filipek T. (2001), *Przyrodnicze i antropogeniczne przyczyny oraz skutki zakwaszenia gleb,*„Nawozy i Nawożenie" No. 8, p. 5-26

Filipek T. (2005), *Dynamika antropogenicznych przyczyn zakwaszenia gleb w Polsce w ostatnich latach*, „Nawozy i Nawożenie" No. 23, p. 67-68

Filipek T., Skowrońska M. (2009), *Optymalizacja odczynu gleby i gospodarki składnikami pokarmowymi w rolnictwie polskim*, „Postępy Nauk Rolniczych" No. 1, p. 25-37

Filipek T., Skowrońska M. (2013), *Aktualnie dominujące przyczyny oraz skutki zakwaszenia gleb użytkowanych rolniczo w Polsce,* „Acta Agrophysica" No. 20(2), p. 283-294

Fotyma M., Zięba S. (1988), *Przyrodnicze i gospodarcze podstawy wapnowania gleb*, Warszawa, p. 250

Gaj R. (2013), *Efektywne wykorzystanie nawozów mineralnych we współczesnym rolnictwie*, Centrum Doradztwa Rolniczego w Brwinowie Oddział w Poznaniu, p. 42

Grzebisz W., Szczepaniak W., Diatta J.B (2005), *ABC wapnowania gleb uprawnych,* Poznań, p. 36

Grzebisz W., Szczepaniak W., Diatta J.B. (2008), *ABC wapnowania gleb uprawnych*, Poznań, p. 49

Harasim A. (2006), *Przewodnik ekonomiczno-rolniczy w zarysie*, IUNG-PIB Puławy, p. 171

Hołubowicz-Kliza G. (2006), *Wapnowanie gleb w Polsce,* Puławy, p. 3

Igras J. et al. (2010), *Zużycie nawozów mineralnych w Polsce w układzie regionalnym,* „Studia i Raporty" No. 25, p. 9-19

Kaczor A., Kozłowska J. (2000), *Wpływ kwaśnych opadów na agroekosystemy,* „Zesz. Nauk. AR w Szczecinie", p. 55

Klepacki B. (1997), *Wybrane pojęcia z zakresu organizacji gospodarstw, produkcji i pracy w rolnictwie*, Warszawa, p. 148

Kopiński J. (2011), *Tendencje zmian intensywności produkcji rolniczej w Polsce w aspekcie oddziaływań środowiskowych,* „Zeszyty Naukowe SGGW" No. 11(4), p. 95-104

Kopiński J. (2013), *Stopień polaryzacji intensywności i efektywności produkcji rolniczej w Polsce w ostatnich 10 latach*,„Roczniki Naukowe SERiA" No. 15(1), p. 97-103

Kopiński J., Nieróbca A., Ochal P. (2013), *Ocena wpływu warunków pogodowych i zakwaszenia gleb w Polsce na kształtowanie produkcyjności roślinnej,* „Woda – Środowisko – Obszary wiejskie" No. 2(42), p. 53-63

Krasowicz S. (2009), *Regionalne zróżnicowanie zmian w rolnictwie polskim*, „Studia i Raporty IUNGPIB" No. 15, p. 9-36

Ochal P. et al. (2017), *Środowiskowe aspekty zakwaszenia gleb w Polsce,* Puławy, p. 43

Program Działalności Ośrodka Warmińsko-Mazurskiego Ośrodka Doradztwa Rolniczego w Olsztynie (2010), M. Micińska M (ed.), p. 63

Program Ochrony Środowiska Województwa Warmińsko-Mazurskiego do roku 2020, (2016), Zarząd Województwa Warmińsko-Mazurskiego, Olsztyn, p. 306

Raport o stanie środowiska województwa warmińsko-mazurskiego w 2016 roku, Inspekcja Ochrony Środowiska. Wojewódzki Inspektorat Ochrony Środowiska w Olsztynie, http://www.wios.olsztyn.pl/fileadmin/user_upload/monitoring/raporty/Raport_WIOS_2016_internet.pdf [30-09-2018]

Siebielec G. et al. (2017), *Raport z III etapu realizacji zamówienia monitoring chemizmu gleb ornych w Polsce w latach 2015-2017*, praca finansowana ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej, IUNG, p. 190

Ziętara W. (2009), *Uwarunkowania rozwoju gospodarstw wielkotowarowych w Polsce,*„Roczniki Naukowe SERIA" No. 9(1), p. 490-496

Dariusz STARKOWSKI • Paweł BARDZIŃSKI

MUNICIPAL WASTE TRANSPORT PROCESS ANALYSIS. PRINCIPLES OF WASTE MANAGEMENT, PACKAGING, RULES OF REGISTRATION, STORAGE AND FINES FOR IRREGULARITIES AND INFRINGEMENTS WITHIN THE SCOPE OF MUNICIPAL WASTE MANAGEMENT

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ABSTRCT: The article discussed the process of road transport operation planning connected with municipal waste transport and the organization of mixed waste collection on the example of shipping routes analysis carried out by means of transport of a service company in Wałcz commune in West Pomeranian voivodeship. The article consists of seven parts, all of which present elements of a planning and transport process connected with municipal waste in road transport from legal, technical and economic perspective. Legal information concerning a road transport of goods was provided along with conditions that have to be met in order to perform this kind of transport and business activity. Moreover, technical and legal aspects of municipal waste transport vehicles were approached. The article covered as well the characteristics of: transport process, transport technologies, transport systems, the analysis of work capacity onthe basis of drivers' working time and a description of optimal routes for providing services in the commune taking into consideration a technological process of municipal waste transport step by step. The aim of the article is to present the rules of municipal waste: management, storage, segregation, keeping appropriate records of waste in municipal enterprises.

KEY WORDS: road transport, municipal waste, provisions of law, transport centre, transport operation

JEL: Q001, H41, R11

Introduction

Municipal waste management has become a challenge for local government authorities both in small communes and larger municipalities. Pursuant to revised national legislative provisions, communes are obliged to manage waste. Currently, waste storage is the most popular way of its dealing in Poland. According to data provided by the National Waste Management Plan, there is no sufficient amount of recovery and disposal facilities outside storage places(educational and advertising materials of Altvater Piła Group Eneris). Due to that, not enough waste undergoes biological and thermal treatment. When it comes to household waste treatment, it's the local government authorities that are held responsible for waste collection, keeping records, and lawful management. The article indicates basic types of documents which relate to waste management records that business entities deal with and requirements that need to be met.

Materials

Principles of waste management

Generally, waste management plans are planning and economic documents designed for a specific part of municipal waste management. Act of 12 December 2012 on Waste introduces many changes in ways of waste management. The basic change is creating the hierarchy of waste management, that consists in keeping a precisely determined sequence of waste treatment from waste prevention to its disposal (figure 1) (Starkowski, Bardziński, 2017).

Currently the following rules of waste management shall apply (Kisperska-Moroń, Krzyżaniak,2009):

1. Principle of waste prevention is connected with the scope of responsibilities for waste generation.Everyone who undertakes actions that cause or may cause waste creation, should plan and conduct such activities as to:

- prevent the creation of waste or limit waste and its negative impact on the environment during the creation of products, during and after their use,
- provide a re-use in a manner compatible with protection or improvement of the quality of the environment,
- provide waste disposal compatible with the environment protection in case where waste creation and re-use could not have been prevented.

The she said principle particularly applies in case of business entities (communes, entrepreneurs, property owners). A commune as business

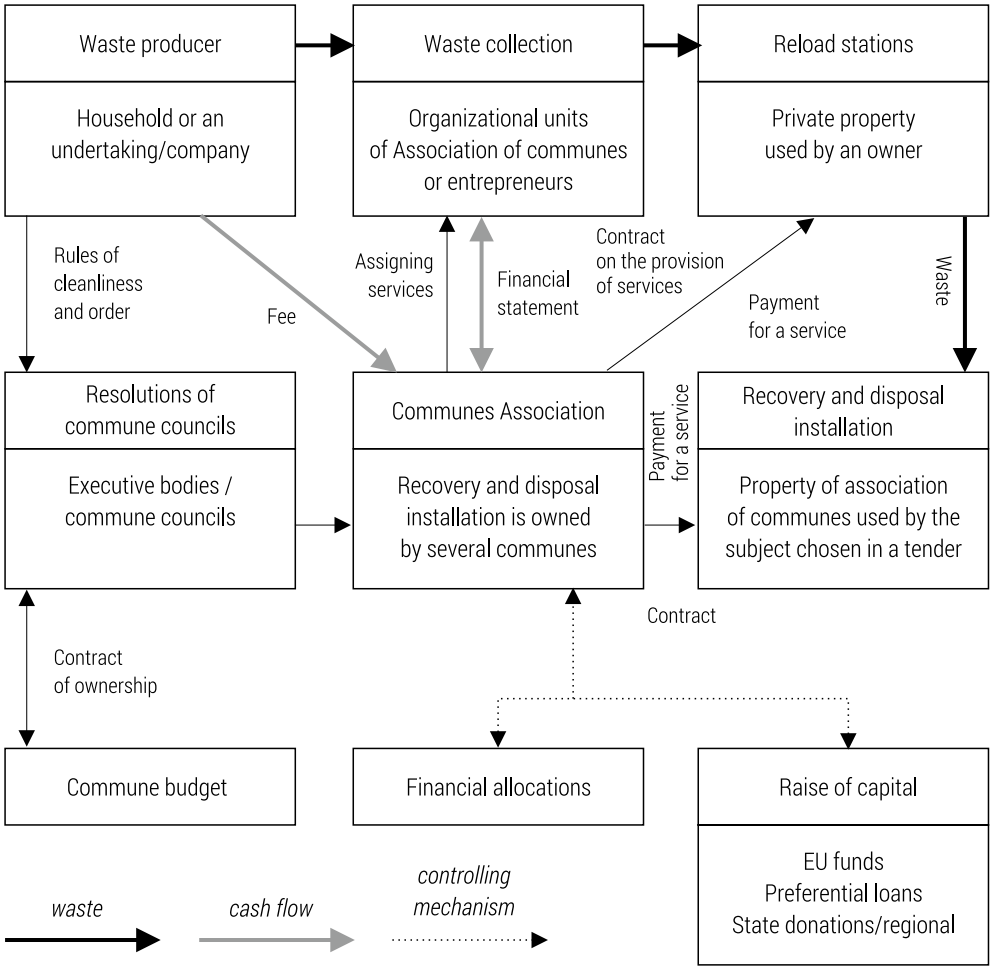

Figure 1. Scheme of responsibility and waste treatment hierarchy

Source: author's own work.

entity may introduce actions that result in waste creation. If however the commune acts as a property owner, all duties for property owners apply. Entrepreneurs – waste producers and other property owners need to abide by the mentioned regulation just as in case of a commune, which is treated as a civil legal entity.The regulation does not apply to entrepreneurs that deal with waste collection (including transport). In situation where an activity results indirectly in waste creation other than the one

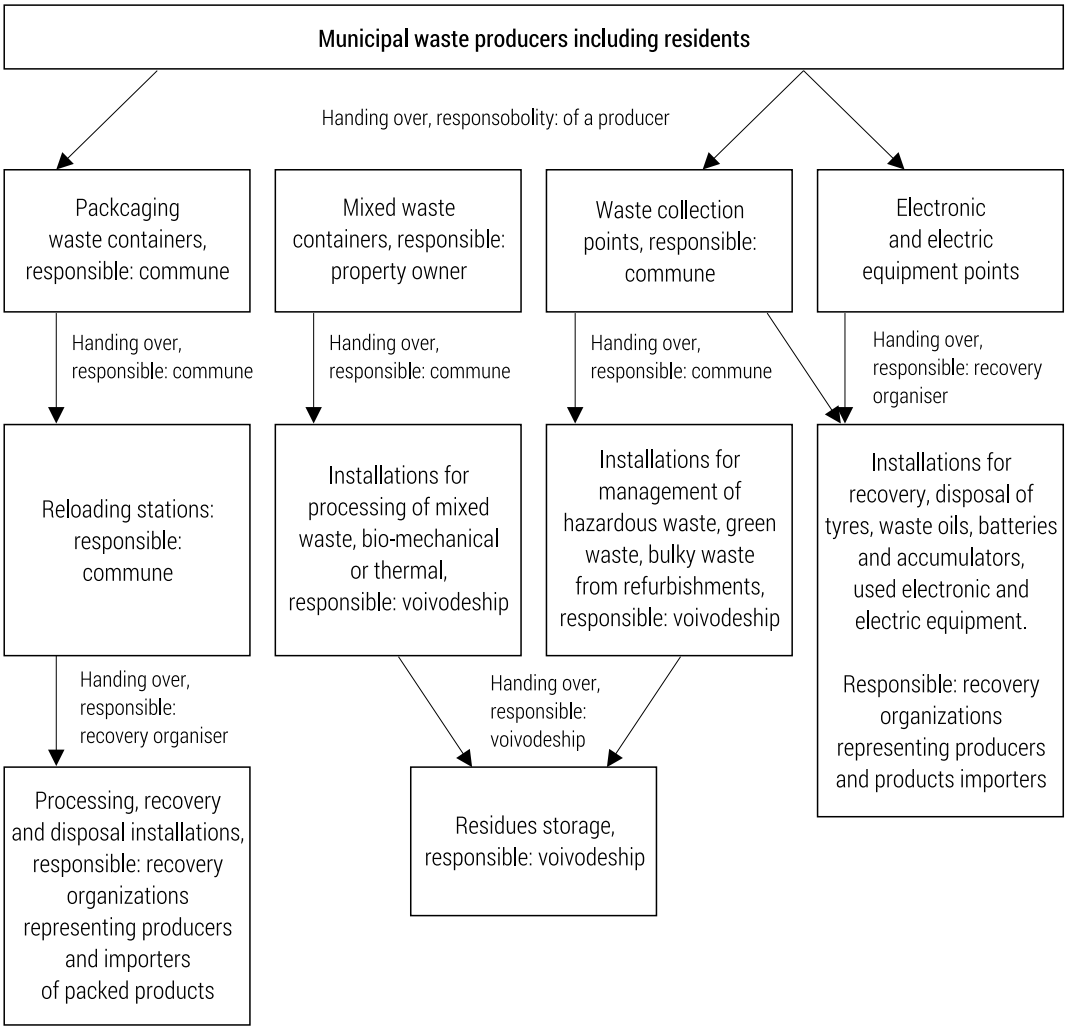

Figure 2. Waste creation responsibility principle

Source: author's own work.

that is collected and transported the said rule applies (figure 2) (Starkowski, Bardziński, 2017).

This information doesn't relate to entrepreneurs that deal with waste disposal and recovery. Basically, the rule applies to waste producers as its main aim is to reduce the amount of produced waste which also made it important for local authorities.

Every property owner, irrespective of the legal form including entrepreneur and commune may be waste producer.

2. Priority of waste recovery principle.The principle refers to communes, entrepreneurs and property owners. Waste holder, which is a commune as a civil legal entity, entrepreneur and an owner of a property, is obliged to deal with waste in a way that conforms to the principles of waste management, environmental protection requirements and waste management plans. First, it is required that waste recovery takes place and if due to technological reasons it's not possible or unjustified ecologically, waste should be disposed of in accordance with environment protection requirements and waste management plans. Where it was not possible to recycle waste it should be disposed of in a way that enables warehousing of waste that couldn't be disposed of in other manner due to technological reasons, or it was either ecologically or economically unjustified. Pursuant to the principle, a commune which a civil law relation subject, needs to abide by the regulations set forth by its authorities and a commune waste management plan. In case of property owner (individual or aggregate) should sort and recover waste and only when these actions are not possible shall he dispose of it. The same rule applies to entrepreneurs (Srokosz et al., 2011).
3. Principle of waste recovery and disposal at the place of its production(-Franczyk et al., 2005).Waste should firstly undergo recovery after its sorting, and then may be disposed of at the place of its production. Waste that can't be recovered or disposed of at the place of production, should be transmitted to the nearest waste management facilities that can deal with its recovery or disposal. Mixed municipal waste, residues of municipal waste sorting and sewage sludge may undergo recovery or disposal in other municipality if a distance between the place of waste production and recovery or disposal facilities which fulfill technological standards, is smaller than a distance to waste management facility within the boundaries of the same municipality.
4. Proximity principle expressed in subjecting waste to recovery or disposal first, at the place of its production or transmitting waste to the nearest plants that provide recovery or disposal at high technological level, according to Environmental Protection Law of 27 April 2001 (Journal of Laws of 2208 No. 25 item 150 as amended).

   Waste producer may manage it using own means or transmit it to other holder as long as the other producer or waste holder meets formal requirements (obtained waste management permit or is released from the obligation to obtain such permit).

   Waste producer or subsequent waste holder is responsible for appropriate waste management as long as it is authorized to perform waste man-

agement or is entered into a register of subjects exempted from authorizations kept by a district mayor.

5. Polluter pays principle – costs of waste management are incurred by primary waste producer, current or previous waste holder. Member states may stipulate that costs of waste management are in whole or in part assigned to goods producer or products dealers.
6. The principle of proximity and self-sufficiency. The relevant local legal act within the territory of commune is rules of cleanliness and order that determines detailed principles of keeping a commune clean and tidy. It is a general act, passed compulsory by a Commune Council, referring to duties of the commune and all subjects performing activities within the commune boundaries. Basic issue that rules of cleanliness and order relates to is defining the scope of selective collection and pick up of municipal waste. Member States shall take appropriate measures (alternatively in cooperation with other Member States) to establish an integrated and adequate network of waste disposal installations that will deal with mixed waste recovery. Network should be designed in a way that would allow the European Union as a whole to become self-sufficient and Member States to reach the same goal gradually. Network needs to enable mixed municipal waste recovery or disposal in the nearest waste management installation by means of the most appropriate methods and technologies in order to ensure a high level of protection for the environment and public health(Srokosz et al., 2011).
7. Principle of selective collection and waste pick up. A legal basis for the said principle is article 4a of the amended Act on Maintaining Cleanliness and Order in Communes of 1 February 2015. The regulation introduced an optional delegation for the Minister of the Environment to set out in a regulation (Starkowski, Bardziński, 2017):

- detailed manner of selective collection of waste fractions and determining when a requirement of selective collection is met,
- municipal waste subject to selective collection among the depicted one in the article 3b paragraph 1 and article 3c paragraph 1. Ministry of the Environment introduced a provision in regulation that sets out in what situations an obligation of selective municipal waste collection is fulfilled. The decisive criteria in this case would be weight of separately collected waste in a month. If such waste constitutes at least 50% of total waste weight, then the said obligation is treated as fulfilled. A legal basis of this principle which is an article 4a of the amended Regulation, excludes any possibility of municipal waste collection at source in a double container system (broken down into “wet” and “dry” fractions). A duty of selective waste collection is met by communes that provide for a duty of separat-

ing the following types of waste from total waste weight in rules of cleanliness and order:

- paper, cardboard and paper, cardboard packaging,
- metals and metal packaging,
- plastic and plastic packaging,
- multi-material packaging,
- glass and glass packaging,
- biodegradable municipal waste including biodegradable packaging and greek waste,
- overdue medicines and chemicals,
- used electronic and electric equipment,
- waste batteries and accumulators
- furniture and other bulky waste,
- used tyres,
- construction and demolition waste which is municipal waste.

Currently there are three models of selective waste collection "at source", among which commune may choose one (Starkowski et al., 2012):

1) **Model I** – collecting the following waste fractions on separate bags and containers:
- paper,
- metals,
- plastic (including multi-material packaging),
- glass.

2) **Model II** – collecting the following waste fractions on separate bags and containers:
- paper,
- metals,
- plastic (including multi-material packaging),
- glass,
- biodegradable vegetable waste.

3) **Model III** – collecting the following waste fractions on separate bags and containers:
- paper,
- metals,
- plastic (including multi-material packaging),
- glass,
- biodegradable vegetable waste,
- ash from households.

Due to that, glass-cardboard, glass-plastic and glass-metal are excluded from an aggregate collection. Paper and glass waste should be collected separately as the Ministry informs. As a consequence every property owner has

4 types of waste collected from: mixed, paper, glass, plastic with metal and multi-material packaging. In case of Model II and Model III the Ministry allows collecting ash from households only during heating season. At the same time, separate ash collection is suggested by the department. Prior to being placed in a container or a bag, packaging waste should be empty but not necessarily cleaned.

Colors of bags and containers

Pursuant to the Regulation, colors of containers and bags intended for selective waste collection are determined (figure 3) (Starkowski et al., 2011):

- BLUE containers and bags labeled: "PAPER AND CARDBOARD",
- GREEN containers and bags labeled "GLASS" – if glass is collected in aggregate,
- GREEN containers and bags labeled "COLORED GLASS" – if collected glass is divided into white and colored,
- WHITE containers and bags labeled "WHITE GLASS if collected glass is divided into white and colored,
- YELLOW containers and bags labeled "METALS" or "PLASTIC" or "MULTI-MATERIAL WASTE" or "DRY WASTE",
- BROWN containers and bags labeled "BIODEGRADABLE VEGETAL WASTE",
- BLACK containers and bags labeled "MIXED WASTE".

Simultaneously, the Regulation allows the Commune Council to introduce additional colored containers intended for collecting other municipal waste fractions" (Rosik-Dulewska, 2010). In municipal waste management the most often used containers are the ones of a capacity 120, 240 and 1100 liters (Starkowski et al., 2012).

Rules of storage (warehousing) and waste sorting

Act of 14 December 2012 on Waste, determines waste storage that is compliant with environment protection and human health safety. The storage of waste in repositories is being gradually replaced with various methods of waste disposal. This transformation is important in order to keep sustainability of waste management. In a short perspective, there are plans of closing all waste landfills, reducing the amount of waste that needs to be stored and increasing scale of waste disposal. Finding a proper location for a landfill is difficult due to the presence of outbuildings. People tend to be scared for their health and the condition of land and soil around. Choosing a location needs to be supported by appropriate economic, operational and environ-

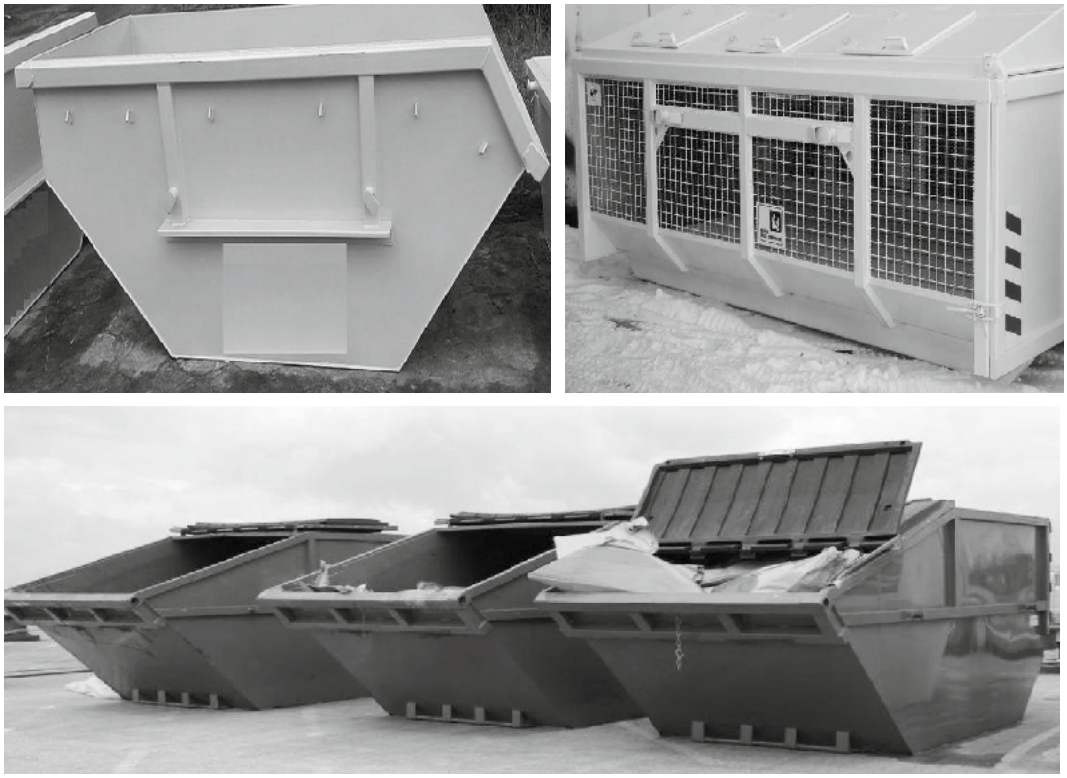

Figure 3. Containers used for selective waste collection

Source: author's own work.

ment protection criteria(Rosik-Dulewska, 2010). Storage has to be carried out in a selective way, however in certain cases there is a possibility of storing waste in a non-selective manner, which is regulated by the legal act (Ordinance of the Minister of Economy on types of waste not subject to selective storage in landfills). Environment protection regulations determine requirements that are to be met in connection with waste storage. The process should be carried out in accordance with environment protection and human health protection rules, in particular in a way that accounts for physical and chemical properties of waste (i.e. physical state, qualities that make waste hazardous and possible treats it may cause). Proper storage has to protect environment from penetration of contamination to water and soil (liquid waste is particularly dangerous).

Penalties for infringements and irregularities in waste management

The State Inspection of Environmental Protection is a basic institution that controls the issues connected with waste management. Activities undertaken by the inspector of SIEP are twofold. It may take place as a planned audit with prior notification of the undertaking or non-scheduled audit performed by the inspector. Pre-audit notification results from provisions of article 79 paragraph 1 of Act on freedom of economic activity of 2 July 2004 (Journal of Laws of 2015 item. 584)and pertains solely to scheduled and non-scheduled audits other that interventions. In case of a scheduled audit (notification sent through registered letter accompanied by an acknowledgment of receipt) an inspector may initiate an audit no sooner than 7 days and not later than 30 days from the receipt of the notice. The said provision can found in article 79 paragraph 4 of the above mentioned Act. The Inspected Entity is obliged to indicate in writing a person authorized to represent the undertaking, especially in the absence of the controlled party (art. 80 par. 3). The audit focuses on complying with provisions and administrative decisions in the scope of environment protection. On the day of an audit the inspector submits a permission to carry out an audit and makes an entry in a control book of an undertaking. The situation looks different in case of an intervention control. It is carried out without notification due to direct life, health or environment threatening or may be indispensible to prevent environmental offences. The audit covers complying with the regulations and administrative decisions in the scope of environmental protection. The inspector of the State Inspection of Environmental Protection makes an entry in a control book of an undertaking and submits the permission to carry out an audit within 3 days.

A period of 5 years may be subject to an audit which checks as well the scope of use of the environment. It refers to waste production, keeping waste records, waste storage, delivery of waste to receivers, collection and transport of waste, waste recovery, possession of procedural legal regulation in the range of waste generation, waste management, extraction of surface and groundwater, sewage disposal, procedural legal regulations of gas and dust emission, noise emission in the environment, dealing with genetically modified organisms, packaging and packaging waste, product fees, dealing with ozone-depleting substances, recycling of end-of-life vehicles, used electronic and electric equipment, using natural fertilizers, timely and reliable submission of data on type and amount of produced waste and list of the environmental use. The findings observed during the inspection are recorded in a protocol. Every act connected with environmental protection provides for

fines. Criminal sanctions may take a form of a custody or a fine or an administrative financial sanction which seems to be the most severe one. A penalty notice is given to an undertaking representative – an owner or an appointed person. Administrative financial sanction is used on the basis ofadministrative proceeding. The inspector is authorized to impose fines by way of a penalty notice for serious environmental offences. A detailed list of offences that are covered by Inspection is included in the Regulation of the President of the Council of Ministers of 13 September 2002 on awarding authority to impose fines by way of penalty notice by inspectors (Journal of Laws No. 151 item. 1253 as amended) (Regulation of the Minister of Economy on types of waste not subject to selective storage in landfills). It is worth noticing that if waste carrier has a permission to transport waste, collection and storage in order to have a full load is impossible. If an undertaking wishes to have waste reload and storage base, it is an obligation to obtain a permission to deal with waste which is waste collection authorization. Ignorance of an entrepreneur may be severely punished and unawareness of provisions does not relieve from the responsibility. In case when an entrepreneur produced waste in a year but did not submit a yearly report on type and amount of waste and methods of waste management, did that in untimely (after 15 March for a previous reporting year) or incorrect manner,the provincial environmental protection inspector levies a financial penalty of 500 PLN. In case where an entrepreneur does not submit a missing yearly report, in spite of being given post-inspection recommendations issued by the State Inspection of Environmental Protection, another fine of 2000 PLN will be imposed. Administrative penalty may be imposed numerous times, however a yearly total amount of fines cannot exceed 8 500 PLN. Data mentioned before indicate how many subjects are given administrative pecuniary sanctions for violations of conditions of the use of the environment.

Conclusions

Currently, the legislator introduced and obligation for the communes to organize waste management and collection from every property owner. Due to that, communes are equipped with legal instruments compliant with the Act of 2012 that enable them to perform the tasks.

Among the instruments, local legal acts are particularly significant, as their aim is to determine principles of waste collection in the commune. Commune residents may use administrative legal instruments and the relation between the commune and an entrepreneur that collect waste is regulated (with inclusion of its civil-legal personality) by an agreement on waste

collection. Provisions concerning waste management in Poland have been binding for a few years so far, however many problematic issues in relation between the commune and municipal company still arise. Another parts of the article will focus on this matter.

The contribution of the authors

Dariusz Starkowski – 50%
Paweł Bardziński – 50%

Literature

Act of 14 December 2013 on waste (Journal of Laws of 2015 item. 87)

Altvater Piła Grupa EnerisSurowce (2017), *Materiały reklamowo-szkoleniowe przedsiębiorstwa*

Bilitewski B., Wagner J., Reichenbach J. (2010), *Sprawdzone metody gospodarowania odpadami komunalnymi*, Opole

Franczyk J. et al. (2005), *Gospodarowanie odpadami i substancjami niebezpiecznymi. Tom 1. Ustawodawstwo, składowanie odpadów, transport towarów niebezpiecznych, dokumentacja,* Kraków

Jerzmański B., (2012), *Gospodarka odpadami komunalnymi – nowe zasady*, „Przegląd Komunalny" No. 9

Kisperska-Moroń D., Krzyżaniak S. (2009), *Logistyka*, Poznań

Notice of the Marshal of the Sejm of the Republic of Poland on 7 November 2016 on announcing a consolidated text of an Act on waste Journal of Laws of 2016 item. 1987

Regulation of the Minister of Economy on types of waste not subject to selective storage in landfills of 16 January 2015 (Journal of Laws 2015 item. 110)

Regulation of the Minister of Health on detailed manner of medical waste treatment of 30 June 2010 (Journal of Laws 2010)

Regulation of the Minister of the Environment of 12 December 2014 on types of waste and quantities of waste for which no obligation to keep waste records (Journal of Laws 2014 item. 1974)

Rosik-Dulewska C. (2010), *Podstawy gospodarki odpadami*, Warszawa

Srokosz T. et al. (2011), *Gospodarka odpadami komunalnymi Raport,* Katowice

Stanisławska I., Bardziński P., Kalka J. (2015), *Od umowy do utylizacji, czyli kompleksowa gospodarka odpadami komunalnymi po nowelizacji ustawy o utrzymaniu czystości i porządku w gminach*, Poznań

Starkowski D., Bardziński P. (2017), *Analiza procesu przewozowego odpadów komunalnych. Część pierwsza – Międzynarodowe przepisy prawne*. „Czasopismo Ochrona Środowiska i Zasobów Naturalnych" No. 1(71) Vol. 28, p. 1-8

Starkowski D., Bardziński P. (2017), *Analiza procesu przewozowego odpadów komunalnych. Część druga – Krajowe przepisy prawne*, „Czasopismo Ochrona Środowiska i Zasobów Naturalnych" No. 1(71) Vol. 28, p. 1-5

Starkowski D., Bardziński P. (2017), *Formal and legal conditions of municipal waste transport planning*, „Inżynieria i Ochrona Środowiska" No. 3, p. 399-420

Starkowski D., Bardziński P. (2017), *Zasady gospodarki odpadami na przykładzie przedsiębiorstwaAltvater Piła Group Eneris*, „Inżynieria i Ochrona Środowiska" No. 20(4), p. 473-495

Starkowski D., Bieńczak K., Zwierzycki W. (2011), *Samochodowy transport krajowy i międzynarodowy. Środowisko pracy kierowcy i logistyka*, Poznań

Starkowski D., Bieńczak K., Zwierzycki W. (2011), *Samochodowy transport krajowy i międzynarodowy. Przepisy w transporcie drogowym*, Poznań

Starkowski D., Bieńczak K., Zwierzycki W. (2011), *Samochodowy transport krajowy i międzynarodowy. Przepisy prawne*, Poznań

Starkowski D., Bieńczak K., Zwierzycki W. (2012), *Samochodowy transport krajowy i międzynarodowy. Transport kołowo – drogowy*, Poznań

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DRYING OF HERBAL PLANTS AS A METHOD OF MANAGEMENT OF WASTELAND

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ABSTRCT: The cultivation of herbs in Poland is one of the newest sectors of plant production despite the centuries-old tradition of using herbs across the world. Contemporary herbal processing in Poland is primarily oriented to the production of herbal medicines, as in many other European countries. The cultivation, harvesting and processing of herbs in small and medium-sized farms require machinery and devices adjusted to the scale of production. The processing of herbal plants involves drying, which is one of the most important stages of herb preservation and the most energy-consuming process occurring in agricultural production. A comprehensive review is presented covering the various methods used in agriculture to preserve herbal plants and the classification of solar-energy and hot-air drying systems. In addition the paper presents examples of the development of solutions using low-temperature herb dryers appropriate to small and medium-sized farms.

KEY WORDS: dryer, herbs, herbal plants, solar collector

JEL: O13, Q16, Q55

Introduction

Herbs are characterised by different contents of biologically active substances and hence they are widely used in various branches of industry. Formerly herbs were used in folk medicine, now they are widely used in the herbal, pharmaceutical and food industries (spices, juices), cosmetics (creams, pastes) and perfumery. The content of biologically active substances in herbal plants includes various types of chemical compounds such as: anthocyanins, flavonoids, glycosides, alkaloids, saponins, and tannins. In the group of herbal raw materials, we can distinguish seeds (*semen*), rhizomes (*rhizoma*), leaves (*folium*), roots (*radix*), flower (*flos*), fruit (*fructus*) and cortex (*cortex*). Herbs include species from which it is possible to obtain one or more types of raw material. For example, nettle (*Urtica dioica L.*) is a source of leaves and roots.

About 130 species of herbal plant are cultivated in Europe on a large-lot scale of production, and the area of herbal plants under cultivation in the European Union countries is about 70,000 ha.On a world scale about 20 thousand species are used for therapeutic purposes (Olewnicki et al., 2015). Herbal plants cultivated in Poland come from field cultivation and natural sites (Seidler-Łożykowska, 2009). There are about 2500 species of herbal plant cultivated in Poland, and the Polish herbal industry uses about 160 species.

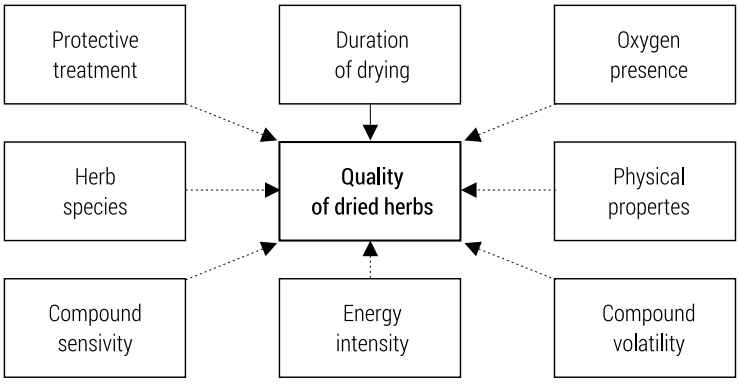

Figure 1. Factors affecting the quality of dried herbs

Source: authors' own work based on (Orphanides et al., 2016).

Drying is the most commonly used method for the preservation of agricultural products. Among the factors affecting the quality of herbs after harvesting, the conditions related to the stabilisation of the raw material and the

process of its storage should be mentioned. Stabilisation is mainly related to the drying process, which should be carried out under appropriate conditions that do not reduce the quality of the raw material. The temperature and drying time should be adapted to the specific plant species. Various factors that influence the final quality of dried herbs are presented in figure 1.

This article discusses the devices available for the mechanisation of herb cultivation and presents examples of proposed solutions for herb dryers destined for small and medium-sized farms. The possibility of using low-temperature heat produced by solar collectors for drying purposes is also presented.

Methods of drying

The methods of drying herbs are presented in figure 2. Traditional methods have been used such as open-air sun and solar drying, with, respectively, direct and indirect use of solar energy, and/or shade drying (Orphanides et al., 2016). On a smaller scale, freeze drying, convection drying with hot air and ultrasound assisted drying methods have also been used. Hot-air drying and shade drying are widely used due to their low cost (Soysal, 2004).

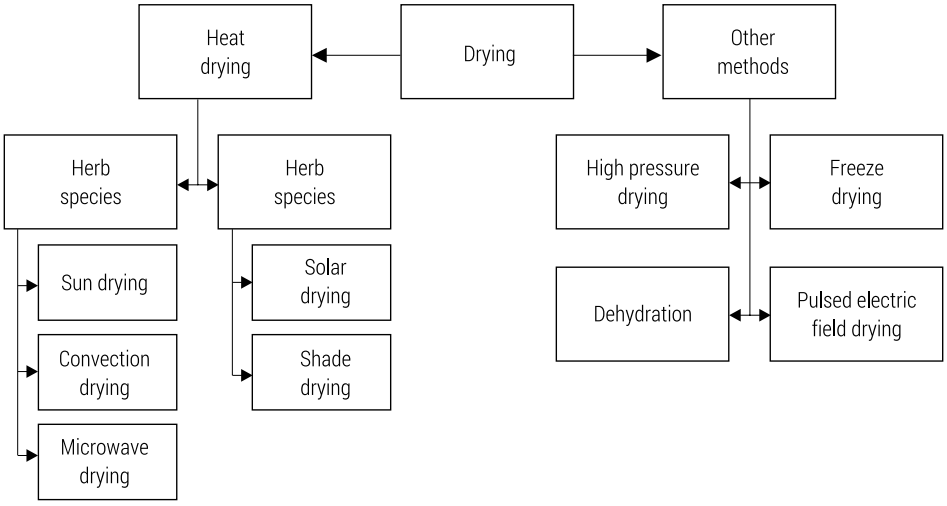

Figure 2. Methods for drying herbs

Source: authors' own work based on (Orphanides et al., 2016).

Drying in the sun is one of the oldest methods of drying utilising solar energy. It is widely used to dry agricultural products, such as medicinal plants, across the whole world (Janjai, Bala, 2012). Solar dryers can be categorised into direct and indirect (Sharma et al., 2009; Shylaja, Peter, 2004).

Both natural methods (active and passive), using the heat of solar radiation and heat contained in the air directly, as well as thermal – mainly convection drying, are used (Argyropoulos, Müller, 2014).

The working principles of drying in the open sun, direct solar drying and indirect solar drying are presented in figure 3. Part of the solar energy is absorbed by the crop surface and the remaining part of the solar energy is reflected back into space (figure 3a). Converted absorbed radiation causes an increase in the crop temperature and its loss to the environment. Blowing a draught through the moist air over the crop surface also contributes to convective heat loss. During direct drying (figure 3b) a part of the solar radiation passes through the transparent cover and is reflected back to the atmosphere. The remaining part of the solar radiation is transmitted inside the dryer and is reflected back from the crop surface. In indirect solar drying (figure 3c) the crop is kept in the drying chamber. The solar air heater is used for solar-energy collection and the heating of air entering into the heater which is connected to the drying chamber. The warm air is transmitted across the crop. The heat from moisture evaporation is provided by convective heat transfer between the warm air and the wet crop (Sharma et al., 2009). The crop is dried by the difference in moisture content between the drying air and the air in the vicinity of the crop.

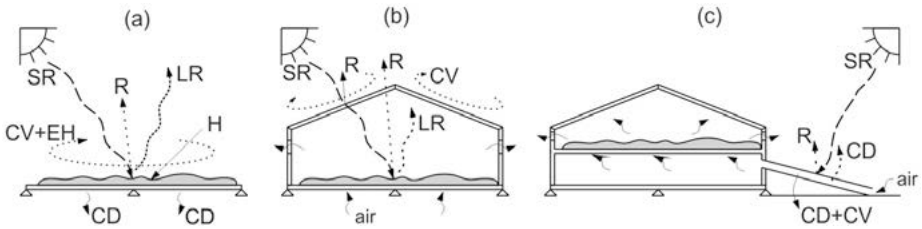

Figure 3. Working principles of (a) open sun drying, (b) direct sun drying and (c) indirect solar drying: CD – conductive losses, CV – convective losses, EH – evaporative heat losses, H – heat absorbed, L – low wavelength radiation, R – radiation, SR – short wavelength solar radiation

Source: authors' own work.

To avoid the direct exposure of herbs to the sun, the shade drying of herbs has been associated with a higher quality product than sun drying. The drying period in shade drying is longer than in the case of sun drying (Pirbalouti et al., 2009). Solar energy is utilised to heat air that then passes through the material by the use of suitable equipment (Sharma et al., 2009). The limitations of solar drying are the climatic conditions. Rainy weather conditions lead to a susceptibility to rehydration of the dried product.

Hot-air drying using convection ovens is a basic technology for postharvest preservation of aromatic and medicinal plants (Müller, 2007; Antal et al., 2011). Infrared and microwave waves enhance conventional drying and reduce the drying time compared to conventional methods.

Proposals of driers for small-scale production

Agriculture is characterised by a significant number of energy-consuming technological processes.This situation is most often caused by the need to maintain the kinetics of the drying process of large amounts of raw material with high humidity.In the case of drying bulk materials, the problem is to construct a dryer to achieve and maintain the desired drying parameters (surface, humidity, temperature) in the dryer, with a minimum amount of drying agent supplied.The classical examples in this area are hay and herb dryers. The years 60-90s of the 20th century formed, among other things, a period of intensive investigation on drying processes in the preservation of agricultural products (Niemiec, 1995; Niemiec, Michna, 1991). The simple field and farmhouse hay dryer constructions (figure 4) used local materials such as waste wood.

The drying of herbs takes place under a so-called low- or medium-temperature convection drying process, with air temperature not exceeding 40°C. Under these conditions, solar collectors may be an alternative to other artificial drying methods (Baniasadi et al., 2017; Janjai, Tung, 2005). Heat demand for drying purposes occurs during the harvest period for herbs and coincides with the period of the highest solar radiation. In air collectors, the air is the working medium. To use solar collectors rationally the following factors should be taken into account:

- structural features that can be used during construction (rafter framing, type of roofing),
- process conditions (location of drying room, dryer size, type and amount of dried material).

Drying equipment can be divided according to different criteria, e.g. taking into account the drying mechanism: convection dryers (moisture from the material is reduced by a stream of drying gas) and contact driers (the material is in contact with the hot surface of cylindrical chambers). Achieving economically justified drying kinetics is, first of all, defining the purpose of drying, knowledge of the physical and chemical characteristics of the dried material and its quantity, and proper selection of the type of dryer and the details of its construction.In the case of the location of the dryer, taking into account the heat source planned to be used in the drying process and land hypsography will permit many errors and hence costly losses in the process to be avoided.

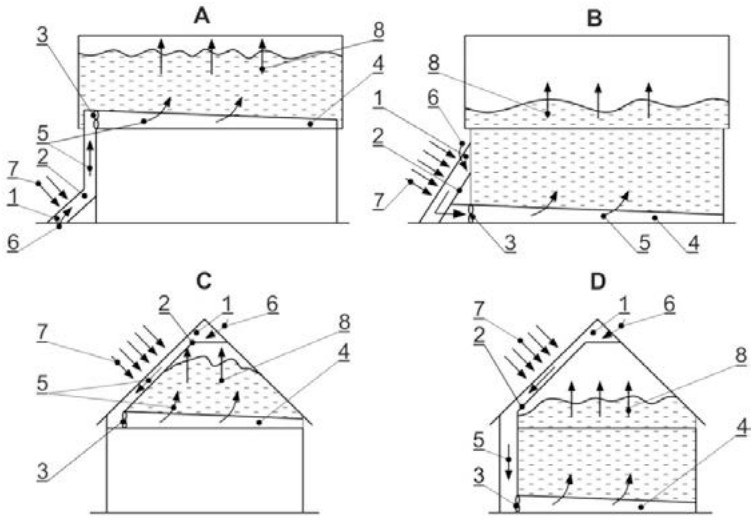

Figure 4. Basic rules for installing solar collectors in farm buildings; A – wall collector with drying room in the loft, B – wall collector with dryer in the barn, C – under floor collector with drying room in the loft, D – under roof collector with drying room in the barn: 1 – air inlet, 2 – collector, 3 – fan, 4 – distribution channel, 5 – heated air, 6 – ambient air, 7 – solar radiation, 8 – humid air

Source: authors' own work.

During the storage of hygroscopic materials and poorly carried out drying processes, conditions fostering spontaneous combustion may occur, e.g. in the case of coal storage, bulky feeds (storage of damp hay in barns) and other cases found in biochemical processes implemented in industry and the processing of agricultural raw materials.In the case of herb drying, the temperature regime and the influence of the intensity of solar radiation (UV) are of particular importance.Looking for ways to reduce energy consumption in crop drying, in particular bulky feeds and herbs, solar collectors have been developed (figure 4) which have a heating unit (figures 5 and 6) for heating the drying air in herb driers. Depending on the atmospheric conditions and the required drying parameters, the dryer is fed from the solar collector or the heating unit. In order to maximise the use of solar radiation energy, the air is always supplied to the heating unit after preheating in the collector (figure 4). After flow through the collector, the air is supplied to the combustion chamber in the heating unit and to the heat exchange chamber located between the combustion chamber and the air inlet into drier. In the case of favourable atmospheric conditions (temperature, humidity), the air heated in the collector can be fed directly to the dryer.

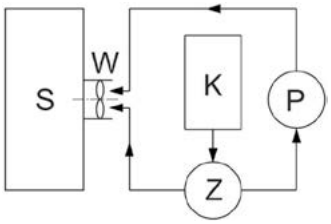

Figure 5. Block diagram of the installation of the equipment in the dryer: S – dryer room, W – fan, K – solar collector, Z – three-way gate valve, P – heating unit

Source: authors' own work.

Improvement of the temperature control of the air supplied to the heat exchanger is obtained by changing the number of sections of the flue. The flue consists of at least two sections connected to each other. The sections are made of a flexible metal tube coiled in conical spirals with at least two coils. The control of the heat exchange surface is possible by changing the number of sections mounted. The biomass stove used in the heating system with a variable heat exchange surface allows the temperature of the heated air to be more easily maintained and, as a result, to be adapted to the weather conditions and the requirements of the dried material. The heating unit for heating the air contains a combustion chamber, with a mounted burner, which is separated by a plate from the heat exchanger (figure 7).

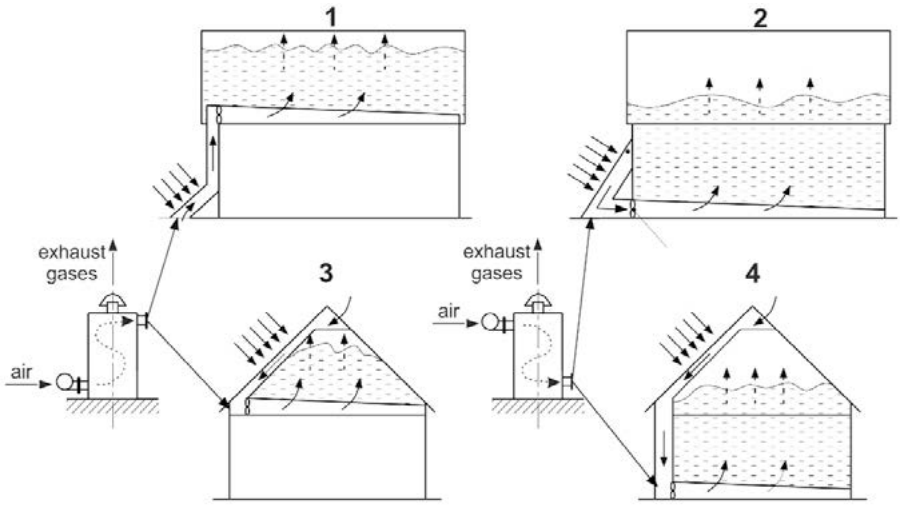

Figure 6. The principle of cooperation of a heating unit with dryers equipped with solar collectors in an attic and in a barn: 1, 2 – wall collectors; 3, 4 – under-roof collectors

Source: authors' own work.

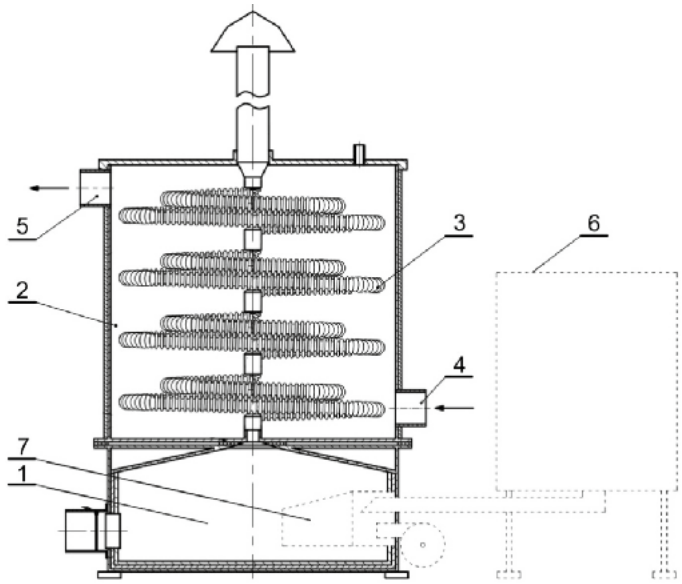

Figure 7. The air heater equipped with biomass stove: 1 – combustion chamber, 2 – heat exchanger, 3 – tubular section of flue, 4 – air inlet, 5 – air outlet, 6 – biomass heating unit with biomass-storage cell, 7 – burner

Source: authors' own work.

The device thus developed is currently under patent procedure. The prototype of the air heater is in the process of manufacture. The combustion chamber is insulated from the walls of the heat exchange chamber by two insulating layers, one of which is a chamotte layer and the second is a vermiculite layer. When the burner is fed with woodchips or pellets, effective combustion of these heating fuels is obtained if the burner is equipped with a fan.

The main advantages of the air heater presented here include the possibility of adjusting the length of the flue by changing the number of spiral sections, as a result of which the heat exchange surface between the flue gas and the heated air is altered. This solution permits the temperature of the heated air to be regulated and thus to be adapted to the needs of the dryer, as well as controlling the value of the negative pressure that causes the flue gas to flow through the heat exchanger.

The heater is particularly useful for drying agricultural products, herbs and spices. In addition, the heater has a simple structure and is cheap to fabricate. The construction of the stove unit enables both forward-current and counter-current heat exchange, and the conical design of individual sections of the flue ensures good gas circulation. The stove permits the combustion of various forms of biomass; the preferred types of biomass are wood chips and pellets.

The air heater presented in this paper is easy to build and inexpensive to operate, which provides the opportunity for its widespread use by herb producers and for the drying of other agricultural crops. The use of a segmented grate permits quick disassembly and, if necessary, an adaptation of the drying chamber for drying other materials such as, for example, grains. There are many opportunities to construct simple and cheap solar collectors. In figure 8, a collector located on a cowshed wall is shown. The collector is constructed with the specification of obtaining the optimal solar radiation on the surface of the foil collector, the roof slope of a barn or a livestock building (Niemiec, Król, 1994a).

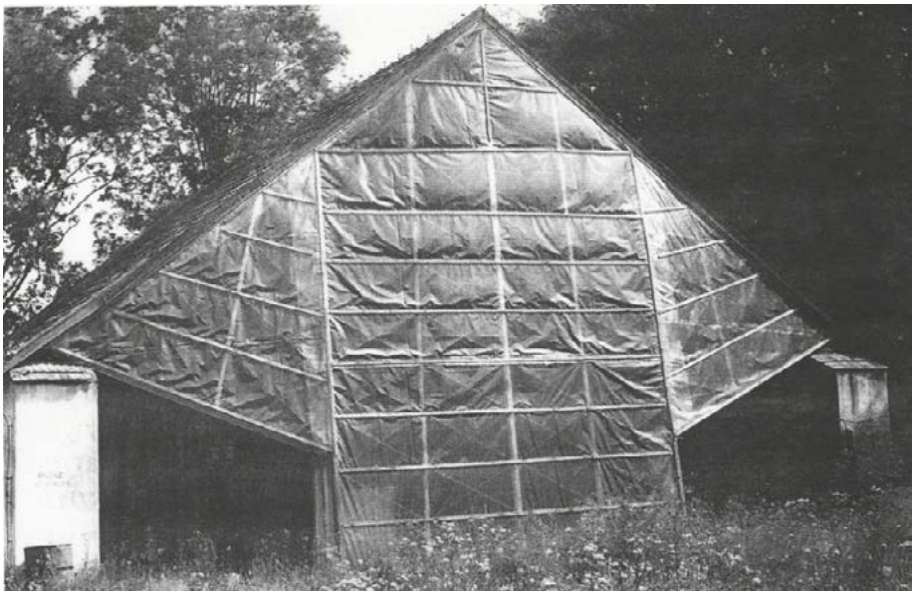

Figure 8. A wall collector for drying agricultural products

Source: (Niemiec, Król, 1994b, p. 1).

Conclusions

In order to obtain high quality herbal raw materials during the drying process, it is necessary to maintain the basic technological parameters (time, temperature) close to the natural conditions prevailing in nature. Under roof solar collectors are recommended for use when there is favourable insolation on roofs covered with sheet metal or tiles. If there is an unfavourable location of the roof surface in relation to the sun, wall collectors can be used effectively. The benefit of drying herbal plants in buildings equipped with

solar collectors is to eliminate the harmful effect of ultraviolet solar radiation and minimise the loss of ethereal oils. The use of collectors in driers also allows farmers to become more independent of weather conditions, and thus to plan work on the farm in a rational manner.

The contribution of the authors

Witold Niemiec conceived and designed the structure of the article. Tomasz Trzepieciński performed the review of literature. Both authors contributed equally to developing the air heater and to the writing of the paper.

Literature

Antal T. et al. (2011), *Effect of drying methods on the quality of the essential oil of spearmint leaves (Mentha spicata L.)*, "Journal of Drying Technology" No. 29, p. 1836-1844

Argyropoulos D., Müller J. (2014), *Changes of essential oil content and composition during convective drying of lemon balm (Melissa officinalis L.)*, "Industrial Crops and Products" No. 52, p. 118-124

Baniasadi E., Ranjbar S., Boostanipour O. (2017), *Experimental investigation of the performance of a mixed-mode solar dryer with thermal energy storage*, "Renewable Energy" No. 112, p. 143-150

Janjai S., Bala B.K. (2012), *Solar drying technology*, "Food Engineering Reviews" No. 4, p. 16-54

Janjai S., Tung P. (2005), *Performance of a solar dryer using hot air from roof-integrated solar collectors for drying herbs and spices*, "Renewable Energy" No. 30, p. 2085-2095

Müller J. (2007), *Convective drying of medicinal, aromatic and spice plants: a review*, "Stewart Postharvest Review" No. 3, p. 1-6

Niemiec W. (1995), *Badanie składu spalin pochodzących z pieca do spalaniatrocin*, "Problemy Inżynierii Rolniczej" No. 2, p. 101-112

Niemiec W., Król K. (1994a), *Poddachowe i przyścienne kolektory do dosuszania* płodów *rolnych*, Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa, Warszawa, p. 1-4

Niemiec W., Król K. (1994b), *Suszarnie do ziół*, Instytut Budownictwa, Mechanizacji i Elektryfikacji Rolnictwa, Warszawa, p. 1-4

Niemiec W., Michna G. (1991), *Wykorzystanie kolektorów słonecznych do dosuszania-siana*, "Przegląd Hodowlany" No. 6, p. 29-30

Olewnicki D. et al. (2015), *Zmiany w krajowejprodukcjizielarskiejiwybranychrodzajach przetwórstwa roślin zielarskich w kontekście globalnegowzrostupopytuna te produkty*, "Zeszyty Naukowe SGGW" No. 15, p. 68-76

Orphanides A., Goulas V., Gekas V. (2016), *Drying technologies: Vehicle to high-quality herbs*, "Food Engineering Reviews" No. 8, p. 164-180

Pirbalouti A.G., Mahdad E., Craker L. (2013), *Effects of drying methods on qualitative and quantitative properties of essential oil of two basil landraces*, "Food Chemistry" No. 141, p. 2440-2449

Seidler-Łożykowska K. (2009), *Hodowla iodmiany roślin zielarskich*,„Hodowla roślin inasiennictwo" No. 3, p. 16-20

Sharma A., Chen C.R., Lan N.V. (2009), *Solar-energy drying systems: A review*, "Renewable and Sustainable Energy Reviews" No. 13, p. 1185-1210

Shylaja M.R., Peter K.V. (2004), *The functional role of herbal spices*, in: P.V. Kuruppacharil (ed.), *Handbook of herbs and spices*, Cambridge, p. 11

Soysal Y. (2004), *Microwave drying characteristics of parsley*, "Biosystems Engineering" No. 89, p. 167-173

STUDIES AND MATERIALS

STUDIA I MATERIAŁY

Agnieszka TRĘBICKA

DYNAMIC MODEL OF THE WATER DISTRIBUTION SYSTEM AS AN ANALYSIS TOOL IN THE MANAGEMENT OF THE ŁAPY WATER SUPPLY NETWORK

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ABSTRCT: The subject of this paper is the analysis of a very common problem of water distribution systems of cities in Poland, which is the concentration of chlorine in water supply networks and the economic aspects of electricity consumption for the supply of pumps. As an example of the analysis, the water distribution system model of Łapy and the available data from the years 2015-2017 was used. As part of the work, an assessment of the existing state of the city water distribution system of Łapy was presented (lying in the Bialystok poviat), conducted with the help of the EPANET computer program, and aimed at improving the efficiency of the examined network. This allowed us to avoid errors during the investment and to assess the condition of the water supply network. This program was chosen because it is publicly available, as well as used by many companies to solve problems with water supply systems in a friendly and clear way.

KEY WORDS: mathematical model, water tower, water supply, dynamical model, computer modeling

Introduction

Having information about the operation of the water supply system is the basis for the proper functioning of the water company. Therefore, it seems advisable to use the water supply model as a tool supporting the process of water supply system operation.

The use of all computer software packages and their implementation as an application allows for organically operating costs of water and sewage systems, increasing the efficiency of business management and supporting the investment process. System modeling is currently the most reliable reproduction of real working conditions, taking into account the variability of water distribution and distribution (Fernandez et al., 2009).

The introduction of more data allows for the reconstruction of the water supply network operating conditions for random events such as water abstraction for fire-fighting purposes, failures as well as their impact on other recipients of the water supply network.

The ability to make the right decisions without a thorough knowledge of the facts, which is commonly used in engineering practice, will be partially enriched in terms of information and model, which will definitely ensure the developed and presented technique, on the behavior of individual elements in dynamic conditions (Boulos, et al., 2009; Darsono, Labadie, 2007).

The analysis was performed for the water distribution system of Łapy lying in the Bialystok poviat. An attempt was made to recreate the actual operating conditions of the water distribution system in a virtual environment.

The demand of Łapy for drinking water and other social, living and economic purposes is covered by three water intakes located in various parts of the analyzed area.Deep water intakes are found in:

- water supply station on Spółdzielcza street (production 523 m^3/d, pressure 3.8 bar),
- water supply station on Płonkowskiej street (production 173 m^3/d, pressure 3.8 bar),
- water supply station on Długiej street (production 667 m^3/d, pressure 3.8 bar).

The obtained results gave a picture of the functioning of the water distribution system and made it possible to improve the existing working conditions.

The problem of distribution and concentration of chlorine in SDW model

Chlorine dissolved in water prevents the growth of bacteria in water supply networks. It acts as a preservative and guarantees the sanitary properties of water supplied to consumers. To maintain quality up to the collection points and to prevent the risk of secondary contamination, it is essential to add chlorine to the treated water as it leaves the water treatment station (Studziński, 2014). In accordance with the requirements set out in the Regulation of the Minister of Health of March 29, 2007 the admissible concentration of free chlorine in drinking water is in the range of 0.1-0.3 mg/l, and the maximum acceptable concentration in stored water is 0.5 mg/l.

The classic method of introducing chlorine into water is based on the dosage of pure or sodium hypochlorite solution. Methods of generating sodium hypochlorite directly on the aqueduct, using kitchen salt or natural chlorides contained in water are also becoming more and more popular. Despite the undisputed technical advantages, these methods are, however, quite expensive today and therefore have to be used in waterworks with a higher capacity.

In this context, there are methods for the classical dosing of hypochlorite, with particular emphasis on the selection of disinfectant dosing pumps.

Thus, in the model chlorine with a concentration of 0.3 mg/l was introduced into the network and a simulation lasting 10 days (240 h) was started. Following this, a report was generated. The medium concentration map is shown in figure 1.

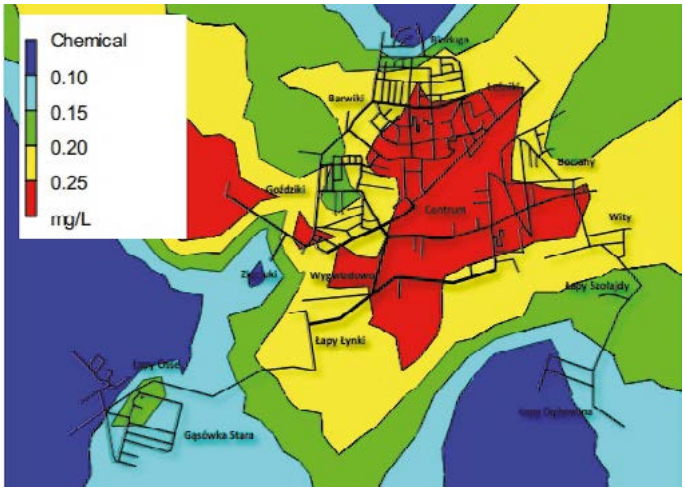

Figure 1. A map showing the average concentration of chlorine of the water distribution system of Łapy created in the program EPANET on a scale of 1:25 000.

Source: author's own work.

Areas where chlorine breaks down and its concentration decreases are the final sections of the network, especially in the North, South and South West. The average concentration for the whole network after 240 h is 0.26 mg/l.

Predictably, the section of the W258 water supply network in Łapy Osse is characterized by the lowest concentration. This is closely related to the stagnation of water. The rate of concentration increase in selected sections is illustrated by graphs of time courses (figure 2).

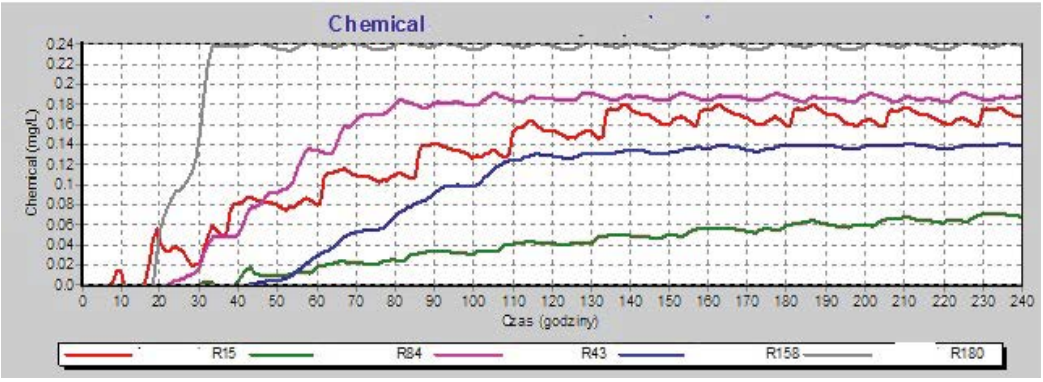

Figure 2. Increase in the concentration of chemicals and the range of variations for the sections of the model: R15, R84, R43, R158, R180

Source: author's own work.

The rate of increase in concentration for R180 is much higher than for the R84 tube. In the first case, the course stabilizes after 40 hours, while in the second case, until the end of the simulation the concentration increases without reaching a clear uniform level.

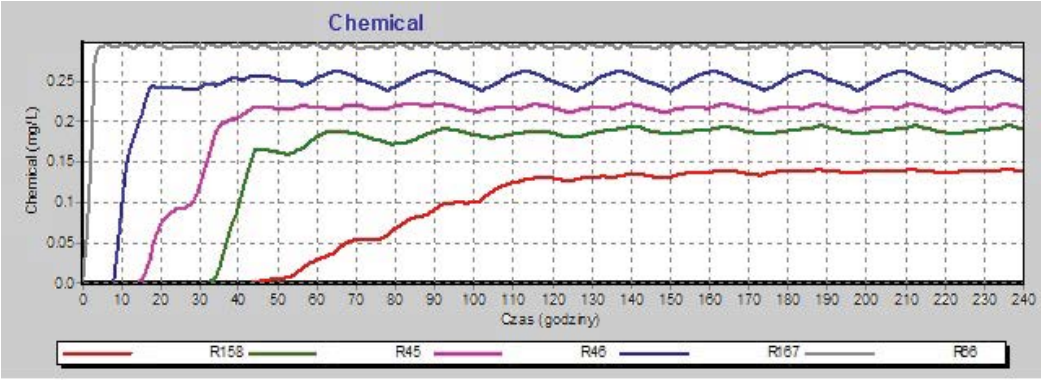

Figure 3. Increase in the concentration of chemicals and the range of variations for the sections of the model: R158, R45, R46, R167, R66

Source: author's own work.

Particular attention should be paid to the characteristics of changes in value after reaching the optimal concentration. In the R66 combination, the size changes several times a day, while in the R167 pipe, it changes only twice.

However, in the R158 connection, the concentration characteristic after reaching the optimal level has a course similar to a continuous line (figure 3).

Based on the obtained results, it can be concluded that the concentration of chlorine on the extreme sections of the model threatens the development of pollution.

The cost of electricity for powering the pumps in the system

Another very important problem that arouses many queries is the cost of electricity to power the pumps in the system. The analysis concerned three pumps located on the tested model of SDW and representing respectively water intake:P – on Spółdzielcza street, S – on Płonkowska street, D – on Długa street. Using EPANET it is possible to calculate this energy with great precision. Thanks to this, each network modification can be compared in terms of energy savings, which will document the legitimacy of the actions taken (Machón, López, 2007). For the calculation of energy consumption, the average energy price of PLN 63.00 per 1 kWh was adopted and the results were obtained as in the table below (table 1). The daily cost of energy used to pump water is PLN 130.80.

Table 1. Energy consumption report

Pump	Percent wear	Average eficiency	KWh/m^3	Average KW	Peak KW	Cost/Day
P	77,5	52,10	0,24	1,24	2,93	14,95
S	100	68,28	0,15	4,76	16,48	74,30
D	75	72,36	0,15	3,55	5,3	41,55
Total cost						130,80

Source: author's own work.

Degree of mixing of water from various sources in the simulation over time

Using the EPANET program, an analysis of the common problem of water distribution systems concerning the mixing of water from several sources were made. The source node can be any node in the network, including the

tank. Simulation in time determines the percentage of water from an indicated source in remote places of the network. Internally, EPANET treats the source node as a permanent source without chemical reactions. Water is treated as an ingredient that is introduced into the network at a concentration of 100%. The traceability is a useful tool for analyzing distribution systems built from two or more water systems. Thanks to this situation, it became possible to indicate the degree of mixing of water from a given source with water from other sources and to observe how the spatial model of this mixing changes over time (Abe, Peter, 2010).

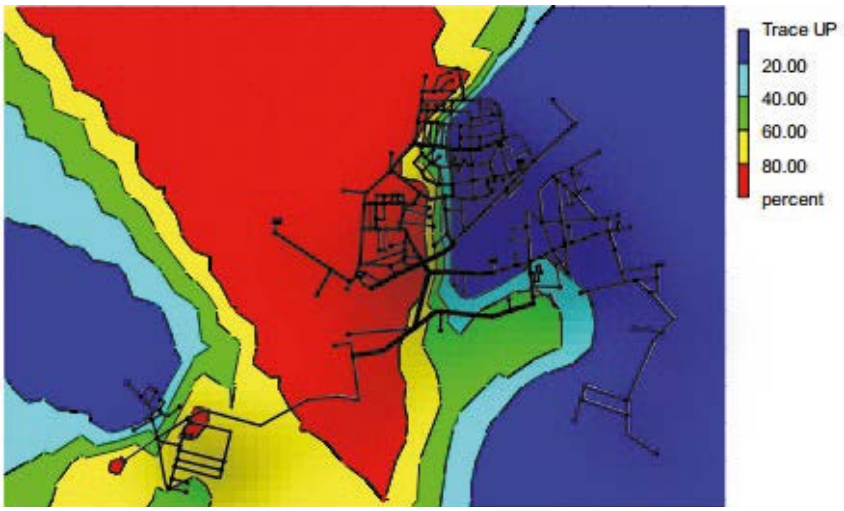

Figure 4. Percentage of water from the water intake on Płonkowska street. in relation to the remaining water intakes in the city of Łapy created in the program EPANET on a scale of 1:25 000

Source: author's own work.

In figure 4 there is one of the simulations carried out with the range of water coming from the intake on Płonkowska street. The water flows to the Łap Osse district. Generally, the pumping station on Płonkowska powers the western part of the city. Figure 5 shows the range of water distribution from the intake of the river Długa. Despite the smaller distance between the river Długa and the district of Łapy Osse, the water pumped there comes from the intake on Płonkowska street. The reason for this situation may be large housing estates with multi-family housing in the south of the network. High demand in this region makes it possible to redirect most of the mass of water from the Długa intake to these areas, giving space in the South-West part of the network to water originating from a more distant angle which is the Płonkowska intake.

Figure 5. Percentage of water coming from the intake on Długa street in relation to the remaining water intakes in the city of Łapy created in the program EPANET on a scale of 1:25 000

Source: author's own work.

The third source – the intake of Spółdzielcza street.The cooperative fills the rest of the network, that is the north and north-east region (figure 6).

Figure 6. Percentage of water coming from the intake on Płonkowska street relation to the remaining water intakes in the city of Łapy created in the program EPANET on a scale of 1:25 000

Source: author's own work.

The percentage of the largest number of connections is served by the shot in Spółdzielcza – on average 34.7% of the entire network; in second place, the entry in Płonkowska 31.6%. The intake on Długa Street is fed by 28% of calls in the catchment network.

The simulation proved that switching the network from three intakes to one can not take place without the modernization of the transmission pipelines.

Conclusions

The simulations carried out make calculations of important parameters of the network operation that have previously been impossible, for example the mixing of water from various sources, the distribution of chlorine concentration in water supply networks and economical aspects of electricity consumption for powering the pumps. The developed and presented technique definitely ensured the most reliable information on the behavior of individual elements in dynamic conditions, where problems were diagnosed and proven, among others, that the concentration of chlorine, so far difficult to study at extreme sections, threatens the development of pollution, and switching networks from three intakes to one can not take place without the modernization of transmission waterworks (Walski, Chase, Sawicki, 2011).

Making the right decisions without knowing the facts is a valuable skill commonly used in engineering practice. Currently, it is becoming more reliable thanks to information and model enrichment, through the variant and mathematical modeling used in the study. The simulations and the construction of the model reflecting the real conditions of SDW Łapy required obtaining a number of data, which ensured correct reproduction in the system machine and brought invaluable benefits in the form of reliable results, indicating problematic network parameters and at the same time enabling new concepts of engineering solutions.

Acknowledgements

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Literature

Abe N., Peter B.C. (2010), *Epanet Calibrator – An integrated computational tool to calibrate hydraulic models,* Integrating Water Systems Boxall & Maksimovic

Boulos P.F., Lansey K.E., Kamey B.W. (2009), *Comprehensive Water Distribution Systems Analysis Handbook for Engineers and Planners*, Pasadena, MWH Soft, California

Fernandez F.J. et al. (2009), *Use of neurofuzzy networks to improve wastewater flow-rate forecasting*, "Environmental Modelling & Software" Vol. 24, pp. 686-693

Darsono S., Labadie J.W. (2007), *Neural-optimal control algorithm for real-time regulation of in-line storage in combined sewer systems "*Environmental Modelling & Software" Vol. 22, pp. 1349-1361

Machón I. et al. (2007), *Simulation of a coke wastewater nitrification process using a feed-forward neuronal net "*Environmental Modelling & Software" Vol. 22, pp. 1382-1387

Studziński J. (2014), *Some algorithms supporting the water network management by use of simulation of network hydraulic model,* Industrial Simulation Conference (ISC), 11-13.06.2014, Hoegskolan, EUROSIS 2014, pp. 33-37

Walski T., Chase D.V., Sawicki D.A. (2011), *Water distribution modeling,* Haestad Press, Waterbury, CT, USA

Marta WIŚNIEWSKA

THERMAL COMFORT ASSESSMENT OF A FLOOD – AFFECTED BUILDING MICROCLIMATE

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ABSTRACT: In 2010, Plock Country, which is located in Poland, was affected by two flood waves that covered approx. 7 hectares of land located in two communes. This paper presents one of the single-family homes affected by the flooding. The aim of the work is to evaluate the building's microclimate, in terms of its thermal comfort, on the basis of a conducted survey. The studies involved measurements of the basic microclimate parameters, including temperature, relative air humidity and temperature on the internal surface of the partition walls. On the basis of the survey results, analyses were made of the variability of the microclimate parameters as well as of the dependencies between these parameters inside the building.

KEY WORDS: flood, microclimate, thermal comfort

Introduction

A flood is a temporal hydrological phenomenon which can be occur by the swelling of river waters in reservoirs. The subsequent occurrence of the water bank overflow leads to flooding of coastal or depressed areas and river valleys (Hu et al., 2018).

In May and June 2010, Płock County (Masovian Voivodship) was affected by two flood waves caused by the swelling of the Vistula River. This paper presents one of the single-family homes affected by both floodings. It also describes results of a survey conducted inside the building aimed at assessing its microclimate in terms of thermal comfort. The survey included the measurement of basic microclimate parameters:

- air temperature,
- relative humidity,
- temperature on the inside surface of the partition walls.

Furthermore, this study identified the factors affecting the microclimate prevailing in the rooms. This paper also presents the optimal conditions for each room to ensure thermal comfort and the reduced occurrence of negative impact on the well-being and health of the inhabitants (Małkowska, 2012).

An overview of literature

The microclimate is understood as a number of meteorological factors that determine directly the living conditions of an organism or a group of organisms. The main parameters that determine the prevailing microclimate are the following:

- air temperature,
- relative humidity,
- air movement,
- surface temperature of the partition walls.

Each of these factors has a significant impact on the well-being, physical and mental efficiency, work efficiency and the overall health of the inhabitants (Żenczykowski, 1987).

One of the main issues involved in building design is thermal comfort. Thermal comfort involves the attainment of optimal temperature of the indoor air as well as of the partition walls that form the rooms. The factors describing the microclimate are, at the same time, the thermal properties of the room; it should be noted, however, that they are independent to the parameters of the human body and, depending on the values of the factors such as temperature, relative humidity, air movement and temperature of the

surrounding walls, can take up various amounts of internal body heat. Moreover, we also distinguish personal factors related to thermal comfort which include the level of individual activity and the thermal insulation of clothing.

The perception of thermal comfort of the environment depends on the extent to which the apparent temperature differs from the comfort temperature associated with the type of job performed and clothing worn by given individuals. The absence of thermal comfort for extended periods of time may underlie functional dysfunction of internal body organs which, in turn, lead to serious threats to life.

The key factor that contributes to thermal comfort is building structure. The habitation zone that it creates is the result of its thermal properties and the devices contained therein which are used for heating, i.e. heating, ventilation and air-conditioning devices. In order to achieve the required thermal comfort in a building or room, it is essential to take into account both its thermal and physical properties (Andjulovic, Georgescu, 1971; Fanger, 1974; Krygier et al., 1991; Małkowska, 2012; Żenczykowski, 1987).

Poland belongs to the temperate climate zone. In this climate zone, the biggest challenge from the point of view of thermal comfort maintenance is the winter period. Not only is this due to the necessity of protecting against atmospheric factors, but primarily of maintaining the appropriate and constant temperature within the building.

In the climate zones in which the temperature of outdoor air varies significantly during the year, such dramatic changes affect the indoor air temperature variation which goes beyond the limits required to ensure thermal comfort. For this reason, during winter heating devices are used to maintain the indoor air temperature within the limits necessary to achieve thermal comfort. This, on the other hand, is not the case during the summer period. In summer, an increased heat transfer is achieved by means of natural (room ventilation) or mechanical (fan) ventilation. The occurrence of the so-called comfortable conditions inside the building requires, apart from maintaining a given air temperature, balancing the temperature vertically and horizontally (Anjulovici, Georgescu, 1971; Małkowska, 2012).

The optimal temperature for people in the habitation area provides the heat balance of the body without any effort on its part. In order to ensure the well-being of inhabitants, the air temperature at floor level should be slightly higher than at head level, but the difference should not exceed °C. This is associated with physiological thermal regulation of humans which can be disrupted due to a stronger temperature variation (Andjulovici, Georgescu, 1971; Krajewska, 2005; Małkowska, 2012; Rokiel et al., 2011).

The required internal temperature values depend on the level of physical activity of given individuals. For example, the air temperature in rooms

intended for intellectual work or recreation should be 20-22°C in winter and 23-26°C in summer (Krajewska, 2005; Krygier et al., 1991; Małkowska, 2012).

In the design calculations for residential buildings, the average value of relative air humidity for the entire heating period is 55%. The actual relative humidity is different from this adopted value, as it ranges from 30 to 70%. However, its effect on the thermal sensation of inhabitants is insignificant. Changes in relative humidity within these limits can reduce the preferred temperature only by 1°C, which proves to be difficult to detect by the human body in temperatures below 23°C (Janowski, Szulc, 1979; Małkowska, 2012; Rokiel et al., 2011; Śliwowski, 2008).

The relative humidity of the indoor air depends primarily on the parameters of the outdoor air as well as the amount of water vapour inside any given room. Emission of water vapour from the people living inside is a characteristic of residential buildings. As a result of breathing, evaporation from the body surface and simple day-to-day activities (e.g. washing, cleaning) the inhabitants become sources of humidity. Humidity begins to have an impact on human well-being only when it is connected with the need to evaporate water from the skin surface (Małkowska, 2012; Rokiel et al., 2011; Żenczykowski, 1987).

Water vapour in the air may condense on the inner surfaces or inner layers of the partition walls. This phenomenon of condensation is determined by the humidity of indoor air and the thermal insulation of the partition (Małkowska, 2012; Żenczykowski, 1987).

Mould is a result of condensation of water vapour on the surfaces of walls. Generally, it appears in the corners of the inner surface of the walls in rooms located in the building corners. It has a negative impact on human health thus deteriorating the indoor thermal comfort. In addition, it also makes the walls look unaesthetic (Andjulovici, Georgescu, 1971; Małkowska, 2012). A method of preventing the formation of humidity, or at least of its reduction, is room airing. Airing is based on the phenomenon of thermal exchange which is caused by a periodical opening and closing of windows or other openings in the wall partitions (Krygier et al., 1991; Małkowska, 2012).

The speed of the air movement inside a closed room largely influences the well-being of the inhabitants. In the case when the room temperature is low, even slight air movements experienced by a person are unpleasant. Similarly, when the room temperature is high, the air movements felt on the body are perceived as unpleasant.

Nowadays, the greatest challenge in the design of ventilation and air-conditioning devices is the adoption of the right balance of temperature and air

speed in order not to cause the sensation of draught in the inhabitants (Rokiel et al., 2011).

Considering the partition walls in terms of their thermal properties, the greatest influence on the thermal comfort in the room is attributed to the floor. This is due to the fact that inhabitants have a direct and almost continuous contact with the floor. While the indoor air temperature is a parameter that can be adjusted using the heating or air-conditioning appliances, this is not the case of the surface temperature of the partition walls. Partition walls are scarcely affected by heating or cooling since these actions do not eliminate the negative effects of cold walls. Raising the air temperature of the room using such devices reduces the heat flux transferred convectively from the entire surface of the human body, while the radiation heat flux remains unchanged (Małkowska, 2012).

In order to maintain the human body in good health condition, it is necessary to ensure constant body temperature. In view of this, the energy obtained from the oxidation of food must be balanced by the heat losses to the environment and the activity-related energy expenditures.

The heat emitted by the human body is the result of its physiological functions. The heat flux emitted by a person consists of:

- the sensible heat emitted by a person as a result of such processes as convection and radiation,
- the latent heat emitted by means of respiration and radiation of water vapour from the body surface (Krajewska, 2005; Krygier et al., 1991; Małkowska, 2012; Rokiel et al., 2011).

One of the available methods for practical assessment of given environments is the thermal sensation index which determines the average evaluation of thermal sensation. The main variable parameters affecting the thermal comfort include:

- energy expenditure (amount of heat generated in the body),
- resistance of heat conduction through the clothing (Clo value),
- air temperature,
- average radiation temperature,
- relative air flow speed,
- partial pressure of water vapour in the surrounding room.

The thermal sensation index can be studied for any combination of the above four variables. The formula for the calculation of the 'Predicted Mean Vote' (PMV) is complicated, which renders it impractical; therefore, tables and diagrams facilitating the determination of PMV are more frequently used. The factors responsible for the thermal sensation of persons inside given rooms can be divided into the elements of microclimate defining the microenvironment and the so-called personal elements describing activities

and clothing. In cases when the activity of human body is higher, a lower indoor air temperature is defined as comfortable. It is worth noting that the increased thermal insulation of clothing results in a similar experience (Castaldo et al., 2018; Fanger, 1974; Małkowska, 2012).

One of the most widely used thermal sensation measurement systems is the 7-point ASHRAE scale (from –3 = cold to +3 = hot) (ASHRAE standard, 2013). In the conditions of comfort, thermal load is zero. Conditions different from comfortable will affect the average human skin temperature, but also the amount of sweat generated to maintain the thermal balance of the body.

Table 1 presents the proposed permissible ranges of values of thermal microclimate elements in the heating period (Śliwowski, 2008).

Table 1. Proposed technical standards for the room microclimate elements in the heating period

The elements of microclimate	Limit values
Air temperature, °C	
* in rooms, kitchens, hallways	20–22
* in toilets and bathrooms	above 22
Temperature of partition wall, °C	
*in all spaces below the air temperature accordingly, not more than by	3
Air speed, m/s	
* in all spaces	below 0.15
Relative humidity, %	
* in rooms, kitchens, hallways	40–60
* in toilets and bathrooms	below 70

Source: author's own work based on (Śliwowski, 2008).

In order to ensure the state of thermal comfort, the average temperature of thermal radiation should be close to air temperature. The phenomenon of thermal radiation in rooms is largely determined by the type and location of radiators, the size and thermal quality of windows, the level of thermal insulation of the building envelope as well as the existence of thermal bridges in given rooms.

The necessity to generate appropriately high surface temperatures of the surrounding partition walls, particularly the exterior walls and windows, is caused by the influence of cold surfaces on the thermal sensations of the human body.

The air movement in habitable rooms is the least variable parameter affecting the human thermal comfort. It is widely assumed that air speed up to 0.3 m/s is actually non-detectable for people. This is due to the existence on the skin surface of a static boundary layer of air that is dissipated when air speed exceeds 0.3 m/s (Śliwowski, 2008).

Research methods

In May 2010 in Poland, the amount of precipitation ranged from 123 to 200% of the norm. The highest precipitation totals were observed in the Vistula basin. The flood wave formed on the Vistula River reached the peak of 780 cm. On the 22 May 2010, the stream gauge located in Kępa Polska indicated 738 cm, which meant that the water level was exceeded by 1 metre.

On the 23rd May 2010, the swelled waters of the Vistula River broke the levee located in the town of Świniary in the Płock Country. The flood affected the locations belonging to the Słubice and Gąbin communes.

On the 6th June 2010 came the second flood wave. After the wave, flood water stagnation lasted for about three weeks, with the flood continuing for six weeks. The time between the first and second flood wave was too short to drain the water from the first flooding. Water drainage was additionally slowed down by the temporary flood barrier in the village of Dobrzyków constructed for the purpose of protection from flooding of subsequent locations (Małkowska, 2012; Struzik, Subotowicz, 2010; Zaborowska 2011).

The 2010 flood in the Płock Country affected about 7,000 hectares of land belonging to the Słubice and Gąbin communes inhabited by 3714 persons. Some locations that were completely flooded in this period include:

- Korzeniówka Stara,
- Nowy Troszyn,
- Troszyn Polski,
- Nowy Wiączemin,
- Wiączemin Polski,
- Świaniary,
- Sady,
- Nowosiadło,
- Zysk Polski,
- Rybaki.

Cleanup works in the affected area started in early July 2010. In August and September 2010, drying of the flooded areas using special blowers was performed (Małkowska, 2012; Struzik, Subotowicz, 2010; Zaborowska, 2011).

The subject of the survey was a family home situated in the village of Nowy Wiączemin in the Słubice commune belonging to the Płock Country. The village area was affected by two flood waves in May and June 2010.

After the flood, the building underwent a renovation. The plaster layer inside the building was removed up to the ceiling height and replaced with a new layer. Also, the floor was replaced. On the outer side of the walls up to the height of the flood water, polystyrene insulation was removed and replaced by a new reinforced one with a structure covering. Despite the flooding, the walls of the building remained intact. Analysing the layers of the building partitions, we may conclude that the floor of the surveyed room meets the condition for minimum insulation resistivity ($R_{min.\ of\ insulation}$). The outer wall, however, does not meet the conditions for the maximum thermal transmittance ($U<U_{max}$), but remains close to the permitted limit. The ceiling neither meets the condition (Małkowska, 2012; PL, 2008). The building inspection in one of the rooms discovered an area of mould in the zone of a thermal bridge under the ceiling.

The conducted survey included measurements of some microclimate parameters: indoor air temperature, indoor air relative humidity and temperature of internal surfaces of partition walls. The survey was conducted in the room functioning as the living room. The intended temperature of the room in the design phase was estimated at 20°C (Śliwowski, 2008). The building is heated using a central heating system powered by a solid fuel (coal) boiler. The boiler room is located in the basement the entrance to which is outside the building. The area of the surveyed room is 32.46 m^2.

For the measurements of temperature and relative humidity of indoor air, the LABEL LB 486 converter-logger was used. The device has three sensors: 2533, 2547 and 2625 which were placed in the room at the height of 1.8 m and at a distance of 50 cm from one another.

Surveys were conducted in four series in the following time periods:

- first series: 1-15 November 2011,
- second series: 16-22 January 2011
- third series: 28-29 November 2011,
- fourth series: 5-6 December 2011.

Measurements were read and recorded by the equipment in 20 minute intervals (Małkowska, 2012).

In order to determine the microclimate parameters in the surveyed building, which consisted in measuring the surface temperature of the walls, four TESTO 177-T3 measuring devices were used. Each of the devices is equipped with three probes. One probe is located inside the device and serves to measure air temperature, while the other two measure the surface temperature of partition walls. For the survey purposes, the second probe

was situated at the floor level, and the third above it, at the height of 1 meter. Three devices were located by the outer walls and one by an inner wall. The wall surface temperature measurements were taken from 29th October to 6th December 2011. The measurement results were recorded by the devices in five-minute intervals (Małkowska, 2012).

Results of the research

In the surveyed room, air temperature should fit in the range of 20÷22°C (table 1). Table 2 shows the percentage of temperature measurements that meet one of the conditions of thermal comfort (temperature greater than or equal to 20°C), and the percentage of measurements failing to meet the thermal comfort conditions (temperature below 20°C).

The analysis indicates that during most of the surveyed period the temperature was below 20°C, which means that for most of the time the conditions for thermal comfort were unfulfilled.

The analysis of the temperature measurements of indoor air during the first series of studies (1-15.11.2011) found that, as a rule, the temperature of indoor air increased in the afternoon and decreased around 11 p.m. The temperature increase was caused by the firing up of the boiler, while the decrease was the result of the boiler cooling down during the night. Figure 1 shows an example distribution of daily temperatures of indoor air in the surveyed room.

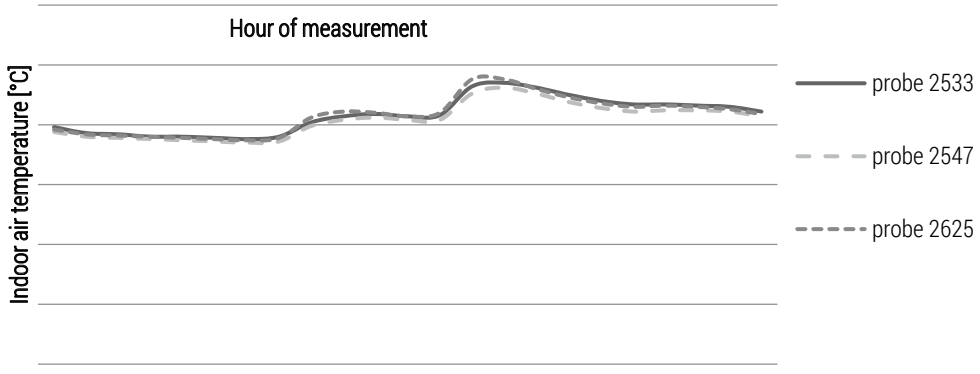

Figure 1. Daily distribution of indoor air temperature on 2.11.2011

Source: author's own work.

Table 2. Percentage of measurements of temperatures that meet/fail to meet the conditions of thermal comfort

Series 1	Survey period		1-15.11.2011	Average Value [%]
	Amount of measurements		1087	
	% measurements below 20°C	probe no. 2533	65.2	74.2
		probe no. 2547	78.7	
		probe no. 2625	78.7	
	% measurements equal or greater than 20°C	probe no. 2533	34.8	25.8
		probe no. 2547	21.3	
		probe no. 2625	21.3	
Series 2	Survey period		16-22.11.2011	
	Amount of measurements		413	
	% measurements below 20°C	probe no. 2533	37.2	50.1
		probe no. 2547	61.5	
		probe no. 2625	51.6	
	% measurements equal or greater than 20°C	probe no. 2533	62.8	49.9
		probe no. 2547	38.5	
		probe no. 2625	48.4	
Series 3	Survey period		28-29.11.2011	
	Amount of measurements		91	
	% measurements below 20°C	probe no. 2533	64.8	70.0
		probe no. 2547	74.7	
		probe no. 2625	70.3	
	% measurements equal or greater than 20°C	probe no. 2533	35.2	30.0
		probe no. 2547	25.3	
		probe no. 2625	29.7	
Series 4	Survey period		5-6. 11 2011	
	Amount of measurements		88	
	% measurements below 20°C	probe no. 2533	29.6	40.9
		probe no. 2547	50.0	
		probe no. 2625	43.2	
	% measurements equal or greater than 20°C	probe no. 2533	70.5	59.1
		probe no. 2547	50.0	
		probe no. 2625	56.8	

Source: author's own work.

The next studied parameter in the room was the relative air humidity. Its value must fit in the range of 40÷60% (table 1) to ensure thermal comfort for the inhabitants. Table 3 presents the percentage of relative air humidity in the room. The table involves the measurements of humidity in the range from 40 to 60%, i.e. those which satisfy the condition of thermal comfort, and the measurements that are outside the limits, thus failing to meet the conditions of thermal comfort.

Based on the above information, we can conclude that high indoor air humidity (above 60%) is present for most of the time in the surveyed room. There are also measurements below 40% (very low-humidity air). These are, however, incidental situations that were not taken into consideration in the further part of the study.

In the case of the surface temperature of partition walls, it should not be lower than the indoor air temperature by no more than three degrees (table 1). In the surveyed room, the air temperature should be in the range of 20÷22°C; therefore, the surface temperature of the walls enclosing the room must be greater than or equal to 17°C. The figures 2 and 3 show the percentage of measurements of the surface temperature of the walls at the height of 1 m and by the floor that meet the condition of thermal comfort for individual measurement points.

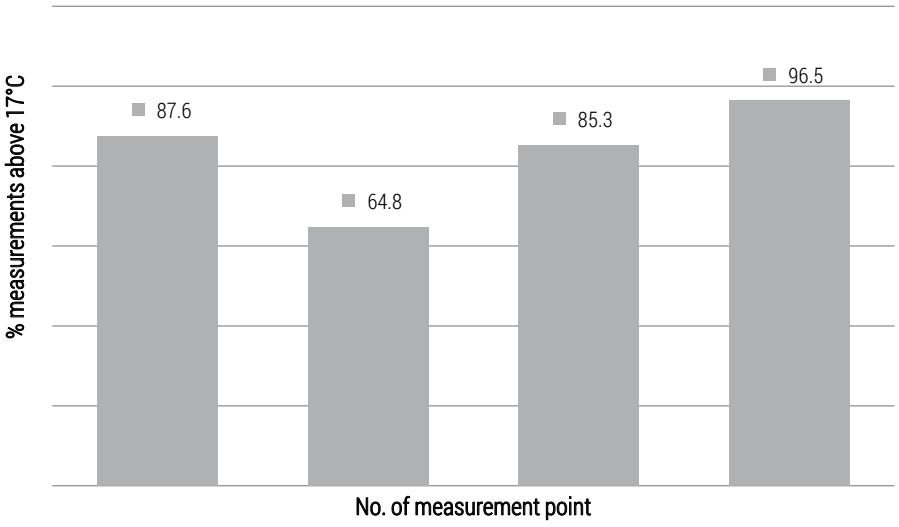

Figure 2. Percentage of measurements of the surface temperature of the partition walls at the height of 1 m that satisfy the condition of thermal comfort

Source: author's own work.

Table 3. Percentage of measurements of relative humidity that meet/ fail to meet the conditions of thermal comfort

series 1	Survey period		1-15.11.2011	Average Value [%]
	Amount of measurements		1087	
	% measurements within 40÷60%	probe no. 2533	68.3	63.3
		probe no. 2547	54.7	
		probe no. 2625	66.9	
	% measurements above 40%	probe no. 2533	0.0	0.2
		probe no. 2547	0.0	
		probe no. 2625	0.6	
	% measurements below 60%	probe no. 2533	31.7	36.6
		probe no. 2547	45.4	
		probe no. 2625	32.6	
series 2	Survey period		16-22.11.2011	
	Amount of measurements		413	
	% measurements within 40÷60%	probe no. 2533	61.3	55.7
		probe no. 2547	50.9	
		probe no. 2625	55.0	
	% measurements below 40%	probe no. 2533	0.0	0.5
		probe no. 2547	0.0	
		probe no. 2625	1.5	
	% measurements above 60%	probe no. 2533	38.7	43.8
		probe no. 2547	49.2	
		probe no. 2625	43.6	
series 3	Survey period		28-29.11.2011	
	Amount of measurements		91	
	% measurements within 40÷60%	probe no. 2533	0.0	2.2
		probe no. 2547	0.0	
		probe no. 2625	6.6	
	% measurements above 40%	probe no. 2533	0.0	0.0
		probe no. 2547	0.0	
		probe no. 2625	0.0	
	% measurements below 60%	probe no. 2533	100.0	97.8
		probe no. 2547	100.0	
		probe no. 2625	93.4	

series 4	Survey period		5-6. 11 2011	
	Amount of measurements		88	
	% measurements within 40÷60%	probe no. 2533	18.2	16.3
		probe no. 2547	6.8	
		probe no. 2625	23.9	
	% measurements above 40%	probe no. 2533	2.3	3.0
		probe no. 2547	3.4	
		probe no. 2625	3.4	
	% measurements below 60%	probe no. 2533	81.8	83.0
		probe no. 2547	92.1	
		probe no. 2625	75.0	

Source: author's own work.

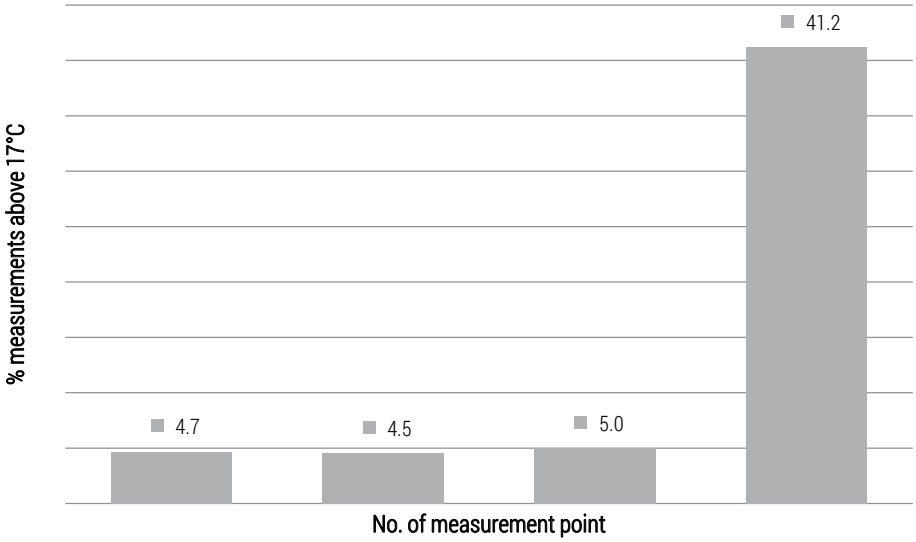

Figure 3. Percentage of measurements of the surface temperature of the partition walls at floor level that satisfy the condition of thermal comfort

Source: author's own work.

Figure 3 shows that, for most of the time, the surface temperature of the partition walls at the height of 1 m exceeded 17°C. The situation is different in the case of the surface temperature of the partitions measured by the floor (table 4). Here, the temperature in most cases is less than 17°C. Particularly noteworthy are the results of the measurement analysis of the device 4. In this case, the measurements involved the inside wall. We observe a large dif-

ference in the measurements of this wall and the external walls (other measuring devices). In the case of device 4, the sensors placed at the height of 1 m and at the floor level mostly indicated temperatures equal to or greater than 17°C (from 64,8% to 96.5%, depending on the measurement point) (Małkowska, 2012).

Conclusions

Referring the obtained results to the requirements of thermal comfort outlined by Professor Śliwowski (2008), it turns out that the surveyed room does not meet the conditions of thermal comfort, since the 58.8% of temperature measurements were lower than 20°C, and in 63% of cases the 60% of relative humidity was exceeded. What is more, lower surface temperatures of the outer walls measured by the floor level were observed (95.3% of cases below 17°C), while at the height of 1 metre, the surface temperature of partitions was greater than or equal to 17°C (79.2% of the cases).

After surviving two flood waves and despite the renovation and drying processes, the building does not create comfortable conditions for its inhabitants.

This study demonstrates that the surface temperature of partition walls measured at the floor level changes together with the surface temperature of the partition walls measured at the height of 1 m, but remains permanently lower by 2°C. Moreover, while the room floor satisfies the $R_{min\ of\ insulation}$ condition, the outer wall does not satisfy the condition of U_{max} ($U > U_{max}$), but remains close to the permitted limit. The ceiling neither meets this condition. The study also demonstrates the significance of the influence of heating appliances on the changes of air temperature and humidity in the room (boiler heating).

During building inspection, areas of mould were found in the thermal bridge zone of one of the rooms, which, apart from its unaesthetic appearance, causes negative effects on the health of the family.

Further actions should involve the improvement of the existing conditions in the building towards the achievement of the all-year-round thermal comfort.

Literature

Andjulovici A., Georgescu S. (1971), *Komfort cieplny w budynkach*, Warszawa

ASHRAE standard (2013), *Thermal Environmental Conditions for Human Occupacy,* No. 55

Castaldo V. et al. (2018), *How outdoor microclimate mitigation affects building thermal-energy performance: A new design-stage method for energy,* "Renewable Energy" Vol. 127, p. 920-935, DOI: 10.1016/j.reneme.2018.04.090

Fanger P. (1974), *Komfort cieplny*, Warszawa

Hu P. et al. (2018), *Flood – inducted mortality across the globe: Spatiotemporal pattern and influencing factors, "*Science of The Total Environment" Vol. 643, p. 171-182, DOI: 10.1016/j.scitotenv.2018.06.197

Janowski M, Szulc J. (1979), Fizyka *cieplna budowli. Materiały do ćwiczeń*, Warszawa

Krajewska A. (2005), *Wpływ kształtu budynku oraz właściwości termicznych przegród na parametry mikroklimatu w budynkach wielkokubaturowych*, praca doktorska, Płock

Krygier K., Klinke T., Sewerynik J. (1991), *Ogrzewnictwo. Wentylacja. Klimatyzacja*, Warszawa

Małkowska M. (2012), *Ocena mikroklimatu i właściwości termicznych przegród w budynku po powodzi*, praca inżynierska pod kier. dr inż. A. Krajewskiej, Płock

PL (2008) Norma PN EN ISO 6946:2008 *Komponenty budowlane i elementy budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczania*

Raish J., *Thermal Comfort. Designing for people*, Centre of Sustainable Development

Rokiel M. et al. (2011), *Jak skutecznie osuszyć budynek, Poradnik, Sposoby usuwania wilgoci oraz zagrzybienia w budynku po powodzi*, Warszawa

Struzik M., Subotowicz E. (2010), *Powiat Płocki, Biuletyn Samorządowy*, No. 44-45, Rada i Zarząd Powiatu w Płocku, Płock

Śliwowski L. (2008), *Mikroklimat wnętrz,* in: P. Klemm (ed.) *Budownictwo ogólne*. *Fizyka budowli*, p. 53-103, Warszawa

Zaborowska J. (2011), *Wpływ powodzi na jakość wody przeznaczonej na cele bytowo-gospodarcze w powiecie płockim*, praca inżynierska, Płock

Żenczykowski W. (1987), *Budownictwo ogólne, t. 3. Problemy fizyki budowli i izolacje*, Warszawa

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USE OF THERMOGRAPHY FOR DETERMINING PLACES IN DANGER OF THE MOLD GROWTH IN RESIDENTIAL BUILDINGS

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ABSTRACT: The mold present in buildings is a factor causing, among others, threat to the health of residents, degradation of building materials, destruction of wall surfaces and furniture adjacent to molded partitions. This article examines the usefulness of thermography to identify areas at risk of mold growth in homes. For this purpose, a thermal imaging camera was used to create thermograms of building partitions. The thermograms were processed to determine the possibility of mold appearance and the extent of its development. The presence of moisture on barrier surface is one of the preconditions for mold growth. Thermogram analyses were carried out using three methods for determining critical temperature below which moisture condensation occurs on the surface of the barrier. A method based on the surface temperature factor proved to be the most useful one to determine the extent of mold development f_{Rsi}. The usefulness of the thermovision method to determine the area of mold growth has been verified practically through visible traces of mycelium on the examined walls and ceilings. When analyzig thermograms, it is required to take many factors into account. Therefore, a person interpreting thermograms must have appropriate knowledge in the field of thermovision and building physics.

KEY WORDS: building physics, thermography, humidity, biological degradation, microclimate

JEL: Y90, I19, Q49

Introduction

The problem of biodegradation of materials from which a building is built has been known for a long time. It is caused, for instance, by bacteria, fungi and molds. Their spores are present in the air of practically every building. Moreover, the adequate thermal and humidity conditions, as well as a suitable substrate, will suffice for their development. They appear as a mildew bloom spoiling the aesthetics of rooms and destroying the attacked material. Mold also affects the health of people and animals inhabiting the attacked rooms of a building. Their mycotoxins are the cause of many diseases e.g. allergies, and can even cause cancer. The impact of such microorganisms on the health of people in the building is one of the factors of the so-called Sick Building Syndrome; SBS for short. As early as in the 1990s, WHO reported that SBS occurs in as many as 30% of new and modernized buildings (WHO, 1990).

Problems with increased humidity usually appear in buildings where windows have been replaced with new and airtight ones. The tenants of these buildings, due to ill-conceived thermal energy savings, do not ventilate the rooms during periods of increased moisture emissions, causing mold growth. Building regulations existing since 2008 (WT, 2013) have introduced the need to use more airtight windows. At the same time, in the case of natural ventilation, the necessity to use diffusers in windows, balcony doors or in external walls was emphasized. Unfortunately, it happens quite often that the ventilators are sealed during the winter because, in the minds of the residents, the rooms are much colder, resulting in increased heating bills.

Even periodically increased indoor air humidity can cause surface condensation and deep-water vapor condensation in the partition, which supports mold growth. The deposition of mold spores in such places initiates the development of mold colonies. Condensation is caused by lowering the surface temperature below the so-called dew point. A significant reduction in the temperature of the partition surface in a building takes place when constructional and technological mistakes were present in the design process. They may also occur at the stage of building completion.

With the help of thermovision, the presence of mold cannot be directly detected. It can be used to find damp places where mold may or has already been formed.

Causes and effects of fungi and mold appearance in the building

Mold spores can be found in many places, including house dust, contaminated building materials, and – in autumn in – the outdoor air. For their development, a temperature of approximately 18°C, air humidity exceeding 60% and a nutrient-rich substrate are sufficient (Charkowska, 2005; Gawin, 2007). Such conditions occur most often in closed, warm and humid spaces, such as attics, basements, closed underfloor spaces or poorly ventilated flats. In those cases, in the air with the moistened surface, a specific ecological niche that allows the growth of mold colonies is created (Wołejko, 2011; Gutarowska, 2010).

The increase in the humidity of the substrate – the surface of the partition – may take place as a result of leaks in the external partitions (roofing, wall cracks), moisture rising from the ground and condensation on the surface of a building partition (Hyun-Hwa Lee, et al., 2016).

Hot air with a relative humidity RH of approximately 80% and a temperature of 22°C contains enough water vapor to allow condensation of water vapor to start in contact with partition surface at the temperature of approximately 18°C. Such a temperature reduction of 4 degrees can take place in the winter on the surface of thermal bridges in the building (Sedlbauer, 2002; Ickiewicz, 2015-2017). These are places in the construction of partitions, where there is a discontinuity in the thermal insulation or in the material with a high thermal conductivity coefficient λ. In addition to thermal bridges, the temperature drops in sites where, with a combination of several external partitions, the outflow of heat from the outer surface occurs in two or three directions. This causes the cooling of the internal surface of such a connection, resulting in a drop in its temperature. Such sites, referred to as geometrical bridges, include – for example – building corners, connections roofs or roofs of unheated lofts with corners of the building, connecting the walls with the ceiling above the passage in the building. Covering these places with furniture or curtains creates a zone where humidity, due to weaker air circulation, can last for a long time (figure 1). Therefore, especially in the above-mentioned sites, mold infestation occurs (Hyun-Hwa Lee, et al., 2016; Gawin, 2007).

Other places where, under high indoor air humidity, water vapor condensation may occur, are the surfaces of cold water pipes in the sanitary installation and the surfaces of the ventilation risers (Wołejko, 2011). Wall surfaces of ventilation pipes can cool down due to the reverse air draft. This is particularly the case on the last floors of buildings, where gravitational ventilation is very poor. Then it is enough to turn on the exhaust fans in the bathroom or

kitchen for a reverse sequence to be created through the remaining ventilation ducts.

The presence of fungi and mold in the building, in addition to the unpleasant musty smell, may be accompanied by symptoms, such as:

- layers of varying intensity and color on the surface of the partition,
- discoloration of building materials,
- decomposition of molded wallpaper or drywall,
- flaking paint coatings,
- softening the structure of wood and wood-based materials, e.g. fibreboards on the back of furniture,
- increase in soil moisture (some types of fungi can synthesize water from the air).

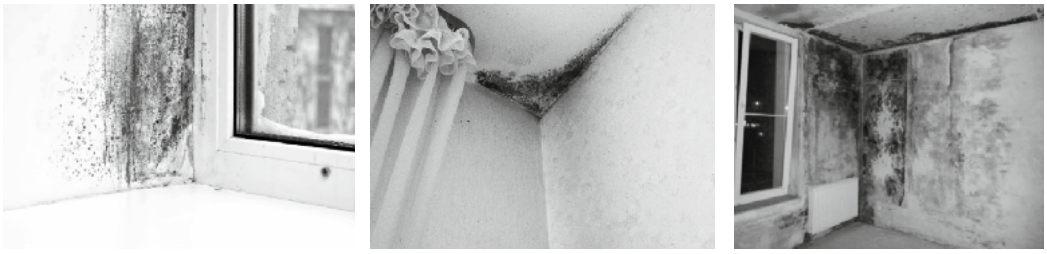

Figure 1. Examples of mold locations in apartments (window reveal, upper corner of the room, behind the curtains and furniture)

Source: author's own work.

In flats, the most common forms of mold present in the air are spores and parts of hyphae. The most common molds in this environment are fungi assigned to the classes *Deuteromycetes* and *Zygomycetes* (Gutarowska, 2010). These classes may include mold fungi, which are classified as inside home: *Aspergillus*, *Penicillium*, *Alternaria*, *Cladosporium*, *Mucor*. They are the main causes of allergies and other more serious diseases.

The growth of microorganisms, including molds and bacteria, contributes to the destruction of organic and inorganic materials used in construction. This process is complex and, as a consequence, there is a decline in the quality of materials, which in the literature is called "biodeterioration". This is related to the reduction of aesthetic and hygienic features and often deterioration of the mechanical properties of building materials (Charkowska et al., 2005). Organic materials attacked by fungi are mostly: wood, paper, wallpapers, paint coatings. The deterioration of these materials is caused by the exoenzymes produced by these microorganisms.

Inorganic materials on which molds can develop are: ceramics, plasters, concretes, stone materials, glass and even construction products from metal

alloys. The molds developing on these materials give off the radicals of acids and other substances that cause the process of chemical destruction of materials. This interaction resembles a corrosive process and that is why it is called biological corrosion.

Research methodology

Thermography was used for studying the possibility of surface condensation and mold growth. With its help, areas on the surface of baffles where the temperature drops below critical levels, which, in turn, causes condensation (dew point) were determined.

The unquestionable advantages of the thermovision method are the non-destructive nature of tests and the speed of measurement. The thermal image camera registers the distribution of infrared radiation on the observed surface. The apparent temperatures corresponding to this distribution without any corrections are not an accurate representation of real temperatures.

To precisely determine the temperature of the tested surface using the thermovision method, it is necessary to take into account the influence of several factors. It is obligatory to enter the parameters of the object and the measurement environment (PN-EN 13187, 2001; Nowak, 2012; Walker, 2004; Więcek, 2011). The parameters are:

- air temperature (atmosphere),
- ambient temperature (reflected apparent temperature),
- object's emissivity Ɛ,
- distance between the object and the camera,
- relative humidity *RH*.

Thermovision tests conducted inside the building make it possible to reduce the impact of some of the above-mentioned factors. For example, the correction of attenuation of infrared radiation by the water vapor contained in the air is not so important due to the small distance between the camera and the object. In addition, in the case of external examinations, the influence of radiation temperature of the horizon and the half-space around the building should be additionally determined (Walker, 2004; Kruczek, 2015).

Equally important is the large difference in temperatures between the exterior and interior environment of the building, changes in air temperatures before and during testing, wind speed, solar radiation and no precipitation. The angle at which we observe the examined surface is also significant, because more than 50°, the emissivity of the surface ε is highly reduced (Nowak, 2012; Więcek, 2011). For this reason, the observations should be carried out preferably perpendicularly to the surface of the partitions.

Moisture detection on the surface of partitions is possible due to three factors. The first is the evaporation of water causing the cooling of the surface. The second effect of moisture is the increase in thermal conductivity of the moist material, resulting in a reduction in the surface temperature inside the building. The last consequence of moistening is the change of the thermal inertia of the material of the building envelope, which affects the slower "thermal response" of the material at a rapid change in air temperature in the room.

The first method used in the research was calculating the dew point, the temperature at which the moisture contained in the air reaches saturation and begins to condense. On the basis of thermovision measurements and hygrothermal conditions, areas with temperatures lower than the dew point temperature increased by 1°C were determined on the thermogram.

Assumptions for this method are similar to those in the PN-91/B-02020 standard (PN-91/B-02020, 1991). The dew point temperature is calculated according to formula:

$$\theta_s = \sqrt[8]{\frac{RH}{100}} \cdot (112 + 0{,}9 \cdot \theta_i) + 0{,}1 \cdot \theta_i - 112 \quad (1)$$

where:
RH – relative humidity of the internal air in %,
θ_i – air temperature in the room in °C.

The second method is about determining the temperature factor f_{Rsi} and the temperature of the internal surface of the building component at which condensation will occur, according to the calculation method included in PN-EN ISO 13788 (PN-EN ISO 13788, 2003). According to the standard, the risk of mold growth due to condensation on the inner surface of the partition can occur when in given external climate conditions the value of the temperature factor $f_{Rsi,min}$ in the critical month will be greater than the value of f_{Rsi} factor for the partition. The temperature factor on the inner surface is calculated for the relative air humidity in the building of 80% – possible mold growth.

$$f_{Rsi,min} = (\theta_{si,min} - \theta_e)/(\theta_i - \theta_e) \quad (2)$$

where:
$\theta_{si,min}$ – the minimum allowable surface temperature determined for a given location dependent on the temperature and humidity of the outdoor air and the load class of the indoor humidity in the building in °C,
θ_e – outside air temperature in °C,
θ_i – internal air temperature in °C.

For the partition, the temperature factor on the internal surface f_{Rsi} is calculated from the formula below, having the computed value of the heat transfer coefficient U of the partition.

$$f_{Rsi} = \left(\frac{1}{U} - R_{si}\right) / \frac{1}{U} \tag{3}$$

where:
U – heat transfer coefficient of the partition in W/(m²·K),
R_{si} – resistance to the heat transfer on the inner surface for the walls equals 0,25 m²·K/W.

With a thermovision camera, it is possible to determine from the thermograms, without calculating the heat transfer coefficient U, the critical temperature factor f_{Rsi} of the tested partition from the formula 4. For new buildings it can be assumed that the appropriate critical value for comparisons will be f_{CRsi}=0.75 (Walker, 2004). This coincides with the required temperature factors in Switzerland and the United Kingdom, for which f_{Rsi} is also 0.75. In Polish legislation (WT, 2013) it is allowed that when the indoor temperature in the room is at least 20°C, and the average monthly humidity RH = 50%, the limit value f_{CRsi} is 0.72. In Europe, the requirements for the critical value of the temperature factor to avoid mold growth are different. In Germany and Belgium, the minimum values for the maximum relative humidity RH = 80% are f_{Rsi} =0.70. In Finland, for new buildings, the required value for f_{Rsi} for floors is 0.97 and for external walls 0.87.

In order to check the condition for the temperature factor, three surface temperatures should be determined thermographically: within the thermal anomaly θ_{sia}, in a nearby area with good thermal insulation located on the inside θ_{si} and outside θ_{se} of the partition.

$$f_{Rsi} = (\theta_{sia} - \theta_{se}) / (\theta_{si} - \theta_{se}) \tag{4}$$

where:
θ_{sia} – temperature of the surface at the place of thermal anomaly, e.g. thermal bridge in °C,
θ_{se} – temperature of the external surface outside the anomaly, with good insulation and temperature factor $f_{Rsi,min}$ greater than the critical for a given location of the building in °C,
θ_{si} – temperature of the internal surface outside the anomaly, with good insulation and temperature factor $f_{Rsi,min}$greater than the critical for a given location of the building in °C.

By converting the above equation, we can determine critical temperature θ_{sia}, below which there will be a risk of moisture condensation and mold growth. For this purpose, an isotherm for the temperature θ_{sia} from the formula 6 should be set on the thermography. Below this temperature critical

surface humidity will occur, creating the risk of condensation and mold growth. The limit value of f_{CRsi}recommended in the literature for thermal imaging tests (Walker, 2004) equals 0.75.

$$\theta_{sia} = f_{CRsi} \cdot (\theta_{si} - \theta_{se}) + \theta_{se} \quad (5)$$

where: symbol translation as above.

Results of thermovision inspections

The Flir T450sc and SC660 cameras were used for thermovision inspections. The thermal resolution on both cameras was not worse than 0.03°C (T450sc) and 0.045°C (SC660). The optical resolution of the obtained thermograms was 640x480 (T450sc in UltraMAX mode). The examination took place on February 18, 2016 and January 13, 2014, in both cases with the clouded sky and no precipitation.

In order to check the possibility of mold growth and for correct temperature indications on thermograms, during the measurements, the humidity of the air at the measurement site was recorded using Extech's electronic psychrometer MO297 cooperating with the cameras.

Both cameras used have a measurement mode, which in assumptions is consistent with the dew point. It enables the isotherm to be set below which the water vapor condenses on tested surface (RH=100%). During measurements using this mode, the parameters described in the paragraph 3 of the article, should be entered into the camera. On the screen of the camera, you can observe sites where condensation takes place.

The first test site where a risk of moisture condensation and mold formation may exist is the connection of a non-insulated cantilever balcony slab with an insulated external wall. Such a situation occurs quite often with "economical thermomodernization" and improper thermal insulation of a thermal bridge in the external wall with balconies or loggias. The author of this article encountered such a situation in 78 buildings in north-eastern Poland when making thermograms of buildings insulated with the ETICS (Ickiewicz, 2015-2017).

During local inspection, a building insulated with 15 cm polystyrene, made in the OWT-67N technology was tested. In the field of insulation works, the insulation of the balcony support plate was omitted (figure 2). The effect of the board not being warmed is visible on the thermograms (figures 3, 4 and 5).

Figure 2. Balcony with the uninsulated plate

Figure 3. Thermogram of uninsulated balcony plate with visible thermal bridge

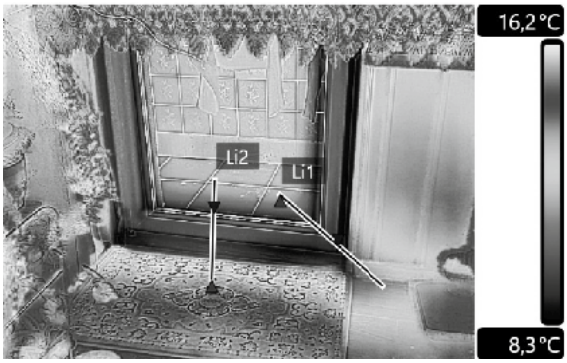

Figure 4. Thermogram of temperature distribution at the balcony door

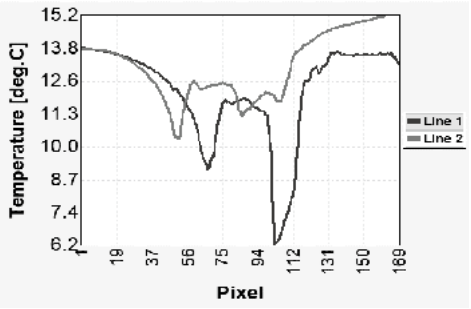

Figure 5. Temperature distribution in the profiles Li1 and Li2 at the threshold of the balcony door

Source: author's own work.

From the conditions for water vapor condensation in room temperature θ_i = 18.5°C and indoor air humidity RH = 62%, the dew point temperature was calculated as θ_s = 11°C. On the thermogram (figure 6), the surface with a dew point temperature increased by 1°C and below was marked with arrows. In this area, according to the assumption in the Regulation (PN-91/ B-02020, 1991), condensation of water vapor may occur. This method, however, has limitations, as the camera will indicate the place of condensation, with a one degree reserve, only in the current conditions of the external climate and the heat-humidity conditions prevailing inside the room.

After determining the temperature of the internal and external areas and the area of the thermal anomaly at the threshold of the balcony door, critical temperature for the factor f_{CRsi} = 0.75 was θ_{sia} = 9.9°C. On the thermogram

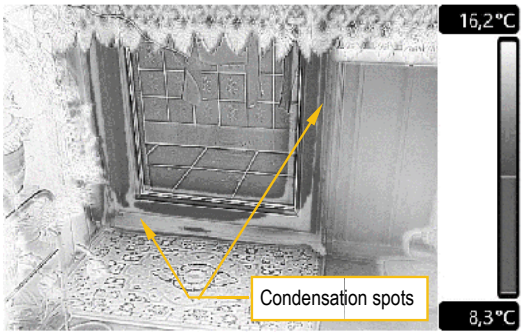

Figure 6. Thermogram of the surface condensation site at the balcony door – a condition for dew point θ_s

Source: author's own work.

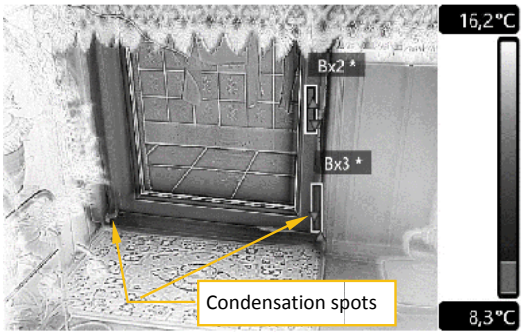

Figure 7. Thermogram of surface condensation site at the balcony door – a condition for critical temperature to prevent the growth of mold θ_{sia}

(figure 7), an area with a temperature lower than 9.9°C was marked with arrows.In these places condensation and the development of mold may occur. Mold will develop when dirt is found on the PVC window profile as a nutrient for fungi. The hard PVC from which the window is made is resistant to biological corrosion, while the wooden parquet at the threshold is not, moreover it can be biodegradable.

The next site analyzed in the article is the connection of the gable wall with the longitudinal (shielding) wall and the ceiling of the last storey in the insulated building in the OWT-67N technology (figure 8). In this connection, condensation is quite common, because the place is usually covered by curtains that limit air circulation. This situation took place in the apartment where the thermogram visible in figure 9 was performed. Analyzing the possibility of condensation of water vapor on the surface of the thermal bridge from the condition to the dew point, at room temperature of θ_i=19°C and humidity *RH* = 55%, surface condensation does not occur (figure 10). It does not exclude water vapor condensation on under other thermal and humid conditions. It can take place when the humidity inside the apartment increases due to cooking, bathing or drying.

This situation was confirmed on the next thermogram, assuming – as in the previous example – a temperature factor equal to 0.93. The condensation zone (mold infestation), after determining the isotherm for critical temperature θ_{sia} = 14.6°C is shown with arrows in figure 11. The range of possible condensation was confirmed by traces of mold visible in the thermogram (figure 8).

Figure 8. Photograph of upper corner connection gable wall – curtain wall with mold traces visible on the wallpaper

Figure 9. Thermogram of the upper corners with a visible temperature reduction in the corner

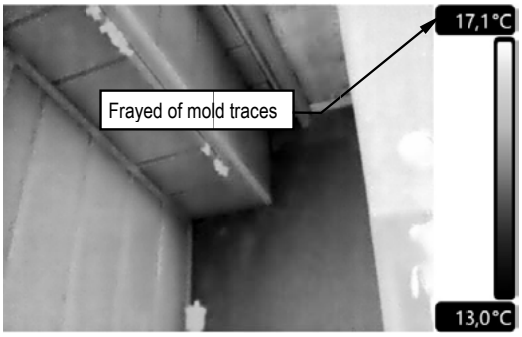

Figure 10. Thermogram of the site endangered by surface condensation in a room corner – a condition for dew point

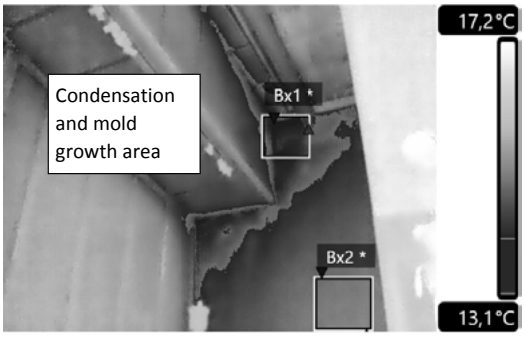

Figure 11. Thermogram of the site endangered by surface condensation in a room corner – a condition for critical temperature

Source: author's own work.

Another example of a place where moisture condensation and mold development can occur is the surface of the gravity ventilation duct in the room on the top floor (figure 12). As a result of the small chimney draft on the top floors, especially pronounced when the windows are tight, during fan operation in the kitchen hood or in the bathroom, the draft can be reversed in the channels without a fan (Wróbel, 2011). Such a case took place in the apartment on the top floor through which the ventilation duct ran in a reverse sequence. What is more, the analyzed flat had airtight windows without ventilators and was poorly ventilated. Outside air, with a temperature of – 2°C, flowing through the ventilation duct to the below apartment cooled the surface of the wall considerably (figure 13). This resulted in condensation of water vapor and mold growth. Such situations are quite frequent and take place when the windows are tight without efficient ventilators (Janińska, 2000).

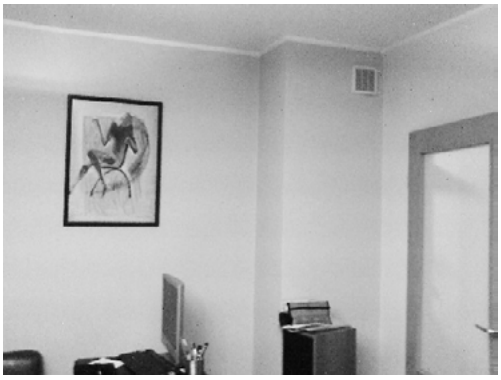

Figure 12. The natural ventilation channels in the room on the top floor of the building

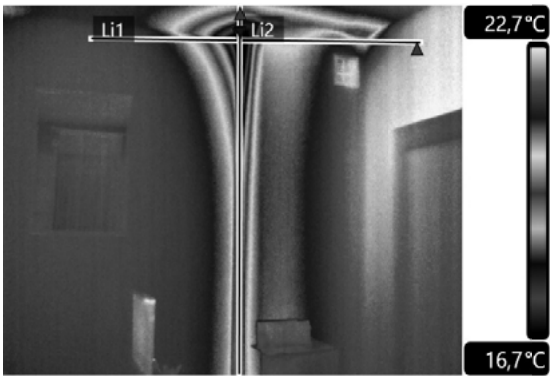

Figure 13. Thermogram of natural ventilation channels in the room on the top floor of the building

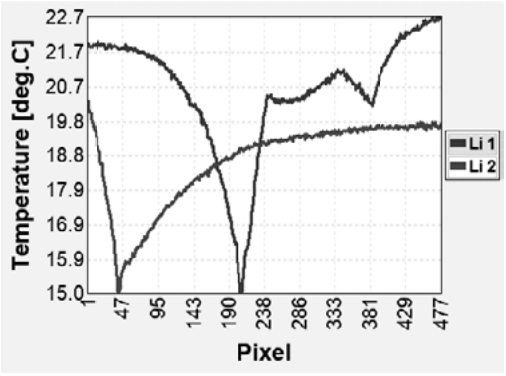

Figure 14. Temperature drop in the Li1 and Li2 profiles on the ventilation duct from Fig. 12

Source: author's own work.

Figure 15. Thermogram of the place endangered by surface condensation in a room corner – a condition for dew point

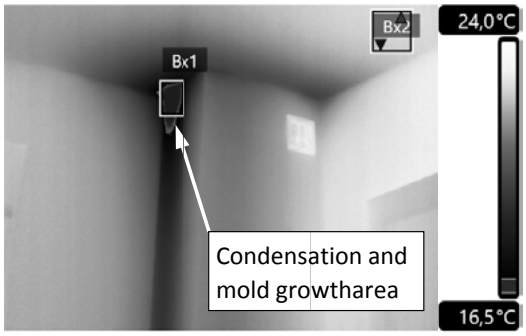

Figure 16. Thermogram of the place endangered by surface condensation in a room corner - a condition for critical temperature

The reach of the wall mold contamination zone with the ventilation duct coincided with the condensation zone (figure 15) determined from the condition for the dew point temperature (θ_s + 1°C) and the critical temperature resulting from the f_{CRsi} temperature factor (figure 16).

Different ranges of water vapor condensation zones shown on the thermograms (figures 6, 7, and 10, 11) result from the thermal and humidity conditions which occurred during the test. When changing the relative humidity *RH* or indoor air temperature θ_i, the range of moisture condensation zone and mold growth, determined from the condition on the dew point temperature, will be different.

Conclusions

Thermovision as a tool for detecting sites at risk of mold development has many advantages. It is a quick and non-invasive method. The advantages also include visual and graphical representation of the results of a large surface examination. The disadvantages include the need to take into account many factors affecting the interpretation of thermograms. In addition, suitable climatic conditions are necessary for correct measurements. The tests should be carried out with the possible temperature difference between the internal and external environment of minimum temperature 15°C. When registering and interpreting maps, knowledge about the construction of building partitions of the building being investigated and the experience of the thermal imaging camera operator is also important.

On the basis of calculations and processing of thermograms made, it can be stated that thermovision enables the detection of sites threatened by the development of mold fungi upon the determination of water vapor condensation areas. During field tests, it was confirmed that the most frequent places for mold development in dwellings are the partitions, where – as a result of temperature decrease and high humidity (no ventilation) – surface condensation occurs. Covering such places with furniture or curtains at the windows further increases the risk of mold infection by reducing air circulation.

During the site inspection of the buildings in industrialized technology, it was found that the improvement in "thermal quality" of housing estates by various thermomodernization treatments is not a sufficient measure to avoid the development of mold on the surfaces of partitions. The behavior of residents, who should take care of periodic airing of apartments has a huge impact, especially after the emission of a large amount of moisture. Ventilation can be facilitated by window ventilators, which should be installed in new windows.

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Literature

Charkowska A., Mijakowski M., Sowa J. (2005), *Wilgoć, pleśnie i grzyby w budynkach*, Warszawa

Gawin D., Kosecka E. (2007), *Program komputerowy WUFI i jego zastosowanie w analizach cieplno-wilgotnościowych przegród budowlanych*, Łódź

Gutarowska B. (2010), *Grzyby strzępkowe zasiedlające materiały budowlane, Wzrost oraz produkcja mikotoksyn i alergenów*, „Zeszyty naukowe Politechniki Łódzkiej" No. 1074, Łódź

Hyun-Hwa Lee et al. (2016), *Evaluation of the thermal environment for condensation and mold problem diagnosis around built-in furniture in Korean apartment buildings during summer and winter*, "Energy Procedia" No. 96, p. 601-612

Ickiewicz I. et al. (2015-2017), *Opinie techniczne 78 budynków dot. prawidłowości przeprowadzonych prac termomodernizacyjnych w wielorodzinnych budynkach mieszkalnych*, Białystok

Janińska B. (2000), *Wpływ cyrkulacji powietrza na rozwój grzybów pleśniowych*, Materiały XLVI Konferencji LILiW PAN i KN PZITB „Krynica '2000" Vol. 3, p. 123-130

Kruczek T. (2015), *Conditions for the use of infrared camera diagnostics in energy auditing of the objects exposed to open air space at isothermal sky*, "Archives of Thermodynamics" Vol. 36 No. 1, p. 67-82

Nowak H. (2012), *Zastosowania badań termowizyjnych w budownictwie*, Wrocław

PN-91/B-02020 *Ochrona cieplna budynków. Wymagania i obliczenia*

PN-EN 13187:2001, *Właściwości cieplne budynków – Jakościowa detekcja wad cieplnych w obudowie budynku – Metoda podczerwieni*

PN-EN ISO 13788:2003, *Cieplno-wilgotnościowe właściwości komponentów budowlanych i elementów budynku – Temperatura powierzchni wewnętrznej konieczna do uniknięcia krytycznej wilgotności powierzchni i kondensacja międzywarstwowa – Metody obliczania*

Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 5 lipca 2013 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie, Dz.U. 2013 poz. 926

Sedlbauer K., Krus M. (2002), *Mold growth on ETICS as a result of "bad workmanship"?*, "Journal of Thermal Envelope and Building Science" No. 2, p. 117-121

Walker N., Nowicki A.N. (2004), *Infrared Thermography Handbook*, Vol. 1&2, The British Institute of Non-Destructive Testing

Więcek B., De Mey G. (2011), *Termowizja w podczerwieni. Podstawy i zastosowania*, Warszawa

Wołejko E., Matejczyk M. (2011), *Problem korozji biologicznej w budownictwie*, „Budownictwo i Inżynieria Środowiska", p. 191-195

WHO Regional Office for Europe Copenhagen (1990), *Indoor air quality: biological contaminants – Report on a WHO meeting*, WHO Regional Publications European Series No. 31

Wróbel A. (2011), *Ilościowe określanie cieplnych właściwości przegród budowlanych z wykorzystaniem techniki termograficznej*, Kraków

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AFFORESTATION FUNDED BY RPD IN THE PERIOD 2007-2013: THE EXAMPLE OF PODLASKIE AND WIELKOPOLSKIE VOIVODSHIPS

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ABSTRACT: The objective of this study is to identify differences between the afforestation subsidies from European Union (EU) obtained by beneficiaries from Podlaskie and Wielkopolskie Voivodships (918 and 618 beneficiaries respectively) as part of RDP 2007-2013. The survey results showed faster increase of forest rate growth in Podlaskie Voivodship, which is classified as a less economically developed region. When compared to Wielkopolskie Voivodship, Podlaskie Voivodship received higher subsidies; nevertheless, the average sum obtained (in thousand EURO) per beneficiary was lower in Podlaskie than in Wielkopolskie.

KEY WORDS: European Union funds, afforestation, private land

Introduction

The economic diversification of different regions of the world, continents, and countries is largely due to historical conditions. This is also true in the case of Poland, whose heritage is connected with the period of partitions (division of the state between Prussia, Austria, and Russia in the 18th century), the westward shift of Polish boundaries after WW2, the country's planned economy in the post-war communist period and, finally, the transition towards a market economy in the 1990s (Ministerstwo Rozwoju Regionalnego, 2008). The trends in institutional development and social capital building grew out of the need to push for restructuration of rural areas, including through effective use of European Union (EU) funds (Bober et al., 2007).

The forest ratio is a component of the category of land use ratios. Its role is to ensure sustainable development through providing environmental governance and to exert a positive influence on the shaping of climate and water balance, whilst serving productive and social functions (GUS, 2015). In 2013, the forest ratio in Poland equalled 29.4% (GUS, 2017). In 2013 the forest ratio equalled 30.7% in Podlaskie Voivodship and 25.7% in Wielkopolska (GUS, 2017). According to the Raport o stanie lasów (State of Forest Report) (Centrum Informacyjne Lasów Państwowych, 2013), based on the standard used in international assessment, which includes lands designated for forest management, Poland is listed among those countries with the largest forest acreage in the region (next to France, Germany, and Ukraine). Forestation share in Poland is an indicator which, starting from 1945 when it amounted to 21%, has been steadily increasing, enabling the implementation of sustainable development of rural areas (Central Statistical Office, Indicators of the sustainable development of Poland, 2015).

The process of afforestation of arable lands was subsidised by EU funds, distributed by the Agency for Restructuring and Modernisation of Agriculture (ARiMR) as part of the Rural Development Programme (RDP) 2007-2013. The tasks performed under axis 2 concerned "improvement of natural environment and rural areas". One of the objects of the tasks was to ensure sustainable use of arable lands. Axis 2 covered measures 221 and 223 (i.e. "afforestation of agricultural and non-agricultural land") which encompassed expansion of forest areas through afforestation (Ministerstwo Rolnictwa i Rozwoju Wsi, 2015). Land use and land cover (LUCC) modifications have become an important matter in studies on worldwide environmental changes in recent years (Fan et al., 2017). Populations face the challenge of a trade-off between current needs and assuring the ability of the biosphere to provide goods in the long period (Foley et al., 2005). In Poland, the area of agricul-

tural land has been declining over time. Moreover, modifications in land cover show a decrease in agricultural land, and an increase in the forest area (Cegielska et al., 2018). The abandonment of traditional agricultural lands has been happening in many regions of the world (Janus, Bozek, 2018). Land abandonment influences mainly areas characterized by the least favorable conditions for cultivation and the lowest soil fertility (Hatna, Bakker, 2011).

After accession to the EU, Poland was also included in operational programmes intended for elimination of regional differences caused, among others, by historically rooted tensions. The new conditions created an impulse to undertake research in the field of determining the level of subsidies in the selected voivodships located in the eastern and western part of the country. The voivodships in Eastern Poland were covered by the Operational Programme for Development of Eastern Poland (OPDEP-PORPW) 2007-2013, the intent of which was to inhibit stagnation that is a cause of the marginalisation and peripheral significance of voivodships. The objectives are achieved through "acceleration of the pace of social and economic development in accord with the principle of sustainable development" (PORPW 2007-2013, 2012). The Programme encompassed construction of approx. 9,500 km of broadband infrastructure, funded by both domestic funds and funds from the European Regional Development Fund for 2007-2013. Central and Western Poland, including Wielkopolskie Voivodship, in turn, focused mainly on ensuring growth in employment and social cohesion in the region as part of the European Social Fund. In the years 2007-2013, Wielkopolskie Voivodship benefited from the Wielkopolskie Regional Development Operational Programme and the Human Capital Operational Programme, the major elements of which were investments in transport infrastructure, competitiveness of companies, natural environment, and HR infrastructure.

Overview of literature

The dominant types of land use changes have been the alterations in the area of forest distribution, which has been the result of complex historical, social, and economic processes in Poland (Poławski, 2006). Increasing the acreage of forests is the main objective of eco-policy and forestry (Polna, 2017). Moreover, afforestation programs strengthen the profitability of environmental policy (Łonkiewicz, 1994; Fonder, 2002). Forest growth rate in Poland grew from 28.4% in 1995 to 30.6% in 2016 because of afforestation of agricultural and non-agricultural land. Research shows concentration of forest mainly in rural areas (Polna, 2017). The National Programme for the Augmentation of Forestation Share (Krajowy Program Zwiększania Lesistości,

KPZL) supported afforestation in Poland since 1995. Klepacka et al. (2017) state that afforestation of agricultural land (referring to research of selected districts of Podlaskie Voivodship) increases the share of privately owned forested land and heavily impacts goal attainment for the KPZL. Since the growing share of private forests plays a large role in the rapid reduction of land area owned by the State Treasury that could be afforested, EU funds can be applied exclusively to private land owners, stressing their importance for reaching the desired share of afforested land in total land area in Poland. Kaliszewski (2016) noted that since 2004, the ability of farmers to obtain payments under the Common Agricultural Policy (CAP) has led to increased agricultural use of land, as such areas were classified unsuitable for profitable farming. As unsuitable for farming such areas were included in the earlier proposed pool of land intended for afforestation under the KPZL.

Moreover, afforestation is supported in line with the Act of June 8, 2001 regarding shifting agricultural land to forest (Dz.U. nr 73, poz. 764) (Polna, 2017). Funds for afforestation distributed through RDP 2007-2013 are considered in this study. Since May 1, 2004, Poland has adopted the tools of the EU CAP. The main funding source for agriculture and rural area support in the EU member states is the European Agricultural Guidance and Guarantee Fund. In Poland, the Agency for Restructuring and Modernization of Agriculture allocates funds supporting afforestation of low quality agricultural land, both arable and non-arable. Axis 2 covered measures 221 and 223, i.e. "afforestation of agricultural and non-agricultural land", which encompassed expansion of forest areas through afforestation, maintenance and strengthening of the ecological stability of forest areas by way of reducing fragmentation of forests, creation of ecological corridors, increasing the share of forests in the global carbon balance, and curbing climate change (Ministerstwo Rolnictwa i Rozwoju Wsi, 2015). Implementation of measures 221 and 223 "afforestation of agricultural and non-agricultural land" in axis 2 "improvement of natural environment and rural areas" provides the opportunity to improve forest rate by afforestation of areas which are economically inefficient and undeveloped agricultural land (GUS, 2015).

Afforestation is a tool for carbon sequestration to manage climate change. Consequently, there is a need for a rational approach to afforestation. Carbon sequestration, biodiversity conservation and forest and timber sector should be considered in a balanced way (The World Conversation Union, 2004). The annual amount of CO_2 absorbed by one hectare of a forest amounts to $39m^3/CO_2$ or 10 tons of carbon (Klepacka, Florkowski, Revoredo-Giha, 2017). Increasing forest resources is one of the major principle of forest management in Poland (Budnica-Kosior, Kwaśny, Szymański, 2016). The cooperation between the economic sectors and various countries can make an effective use of forests

resources (Wysocka-Fijorek, 2016). The gradually growing area of re-forested agricultural land contributes to changes in the agricultural landscape, increasing both the economic and environmental value of land (Sioma, Szymański, 2008). Forest performs various functions in European Union member countries, that is productive and non-productive, and compatible with the concept of sustainable development (Ossowska, Janiszewska, 2016).

The 2009 Report on implementation of afforestation implemented under the rural development regulation 1698/2005 for the period 2007-2013 shows the improving competitiveness of agriculture and forestry sectors, including the addition of value to forestry products. The afforestation rate varies across voivodships in Poland. However, afforestation allows rational management of agricultural land poorly suited for agricultural production (Kurowska et al., 2014). Forests are important element of environment and spatial economy (Kurowska, Kryszk, 2017). Forests are recognized as an irreplaceable, lacking alternative social goods and contribute to the preservation of balance and self–regulation of the natural environment, while generating revenues from wood and forest resources (Zamelski, 2018).

Research methods

The objective of the study is to identify the rate of subsidies for afforestation of arable and non-arable lands received by beneficiaries based in Podlaskie and Wielkopolskie Voivodships as part of RDP 2007-2013. The temporal frames of the programme encompassed the years 2007-2013. During that time, EU support was received by 918 beneficiaries from Podlaskie Voivodship (natural persons: 98.6%) and 623 beneficiaries (natural persons: 96.6%) from Wielkopolskie. The analysis was carried out on the level of districts within the Voivodships in question. The source of data used for the analysis was information provided by the Agency for Restructuring and Modernisation of Agriculture and the Central Statistical Office of Poland (GUS), Local Data Bank (BDL). The Voivodships have been presented with the use of a descriptive and comparative method. The study contains selected survey results.

Results of the research

Characteristics of voivodships covered by the study

The differentiation of economic levels of individual regions has been a significant feature of Poland's territorial development (Przeglądy terytorialne OECD Polska, 2008). According to Przegląd Geograficzny (The Geo-

graphic Review, 2012), Poland was divided in two parts: the "eastern part with a very low development level, and central/western part with a mosaic-like distribution of development". NUTS Classification (Classification of Territorial Units for Statistics), officially introduced by the EU in 2005 for analyses of social and economic development levels in regions, shows Poland divided into northern, north-western, central, eastern, south-western, and southern regions (Eurostat).

The disproportion in development of regions is shown by the sustainable development indicators used for monitoring the achievement of objectives of the EU Sustainable Development Strategy. Among them is the factual GDP per capita (Eurostat). In 2010-2012, the economic growth measure (factual Polish GDP per capita) indicated Mazowieckie, Dolnośląskie, Wielkopolskie, Śląskie, and Pomorskie Voivodships as leaders – the voivodships were characterised by high investment attractiveness when compared to other voivodships, mainly due to diversified structure of the economy – whilst naming eastern voivodships, i.e. Podkarpackie, Lubelskie, Warmińsko-Mazurskie, Podlaskie, and Świętokrzyskie as those with the lowest GDP (Regional development in Poland, 2009). In 2015, the factual GDP per capita equalled 7,764 EURO (based on exchange rates NBP table of 2018-01-12 (1 EURO – 4,1669 PLN),http://www.nbp.pl/homen.aspx?f=/srodeken.htm [12-01-2018]) in Podlaskie Voivodship and 11,517 EURO in Wielkopolskie. Podlaskie Voivodship (2,018,702 ha) is located in the north-east of Poland, while Wielkopolskie Voivodship (2,982,650 ha) lies in western Poland (based on the prevalent climate of the two, it is clear that Podlaskie Voivodship is located in the climatic region of Masuria and Podlaskie, while Wielkopolska Voivodship lies within the climatic region of Central Wielkopolska, Southern Wielkopolska and Central Poland) (Woś, 1994). Podlaskie Voivodship is divided into 14 districts, 3 cities with district rights (Białystok, Łomża, Suwałki), 118 urban and rural municipalities, 40 towns and 3,859 rural settlements. Wielkopolskie Voivodship, in turn, encompasses 31 districts, 4 cities with district rights (Kalisz, Konin, Leszno, and Poznań), 226 urban and rural municipalities, 111 towns and 5,450 rural settlements (GUS, 2015). In 2013, arable lands in Podlaskie Voivodship amounted to 1,064,000 ha, while in Wielkopolskie Voivodship, the number reached 1,733 ha. In 2010, agricultural holdings with an area of 1-5 ha (25%) and 5-10 ha (21.4%) prevailed in Podlaskie Voivodship, while in Wielkopolskie, holdings of 0-1ha (23.8%) and 1-5ha (29.2%) were the most common (Urząd Statystyczny w Białymstoku – Statistical Office in Białystok, Urząd Statystyczny w Poznaniu – Statistical Office in Poznań, 2010). Between 2007 and 2013, forested areas grew by 1.4% (increase in the area of private forests by 3.8%) in Podlaskie Voivodship and by 0.6% (increase in the area of private forests by 5.1%) in Wielkopolskie Voivodship. Accord-

ing to the data of FADN (Klepacka et al., 2017), a potentially forested area (a private forest in particular) in Poland corresponds to approximately 27% out of 159,300 ha of land in the period from 2001-2014. In 2013, the area of private forests in Podlaskie Voivodship exceeded 201,600 hectares. The highest forest ratio (between 56% and 82%) was reported in the urban and rural municipalities of Mielnik (Siemiatycze District), Hajnówka, Narewka (Hajnówka District), Gródek, Supraśl, Czarna Białostocka (Białystok District), Giby (Sejny District), Płaska, and Nowinka (Augustów District) (GUS, 2017). In Wielkopolskie, the area of private forests in 2013 was lower by more than 188.2 ha than in Podlaskie. The greatest forest cover, above 50%, was reported in the following urban and rural municipalities: Jastrowie (Złotów District), Miedzichowo (Nowo Tomyśl District), Wieleń, Drawsko (Czarnków-Trzcianka District), and Wronki (Szamotuły District). More than half of the urban and rural municipalities had a forest ratio below the average for Wielkopolskie Voivodship.

Funds for afforestation as part of RDP 2007-2013 in the selected voivodships

For the years 2007-2013, the RDP granted funds for afforestation (measures 221 and 223, afforestation of agricultural and non-agricultural land) in the form of a one-off reimbursement for the costs incurred in relation to the establishment of crops of 998-1502 EURO per hectare (ha), fencing of silvicultural lands with a metal mesh of 622 EURO per ha or 1,56 EURO per linear metre of the fencing, a carer's bonus for private persons granted for up to 5 years (except for plantations of fast-growing species) of 233-326 EURO per ha, and an afforestation bonus for land conversion from agricultural use granted for up to 15 years from the forest crop establishment of 379 EURO per ha. Additionally, the following subsidies were available for entities: funds for afforestation (i.e. works related to the establishment of a forest crop of 430-1502 EURO per ha and 622 EURO per ha of a fenced plantation) carer's bonuses paid once a year for 5 years for processes connected with treatment of the crops of 233 to 492 EURO per ha, and allowance for crop protection against animals of 46-168 EURO per ha. All in all, 129,304,759 EURO was paid from the budget of RDP 2007-2013 for 10,058 beneficiaries (ARiMR, 2015). 1,794 decisions to grant afforestation allowances were issued in the calendar year 2014, for the overall sum of 5,399,698 EURO. The budget distributed 34,078,091 EURO, of which 21,742,782 EURO was paid to 8,043 beneficiaries as part of RDP 2007-2013 and 12,335,309 EURO was distributed among 7,326 beneficiaries by virtue of liabilities resulting from RDP 2004-2006 (ARiMR, 2017). As part of EU subsidies for afforestation of arable and non-arable lands, Podlaskie Voivodship received 4,380,580 EURO (including cities with district rights) and Wielkopolskie received 3,660,330 EURO. Subsidies

obtained by Podlaskie and Wielkopolskie Voivodships, exclusive of cities with district rights, equalled 3,434,688 EURO and 3,154,815 EURO respectively. In Podlaskie Voivodship, the average subsidy per capita reached 3,960 EURO for afforestation of arable lands (ALA) and 1,776 EURO for afforestation of non-arable lands (NALA), while in Wielkopolskie, the numbers equalled 5,280 EURO (ALA) and 1,800 EURO (NALA).

Table 1. Sum received for afforestation of arable and non-arable lands by Voivodships as part of RDP 2007-2013

Forest ratio 2007-2013	Voivodships			
	Podlaskie		Wielkopolskie	
	Number of beneficiaries	Amount obtained in thousand EURO	Number of beneficiaries	Amount obtained in thousand EURO
Arable land (AL)	826	3271,4	584	3084
Non-arable land (NAL)	92	163,3	39	70,6
Total	918	3434,7	623	3154,6

Source: author's own work based on (ARiMR, 2017).

Based on the data presented in table 1, it may be concluded that the funds for afforestation of arable and non-arable lands obtained by Podlaskie Voivodship were 279,872 EURO higher than those received by Wielkopolskie, but the number of beneficiaries in the former in the years analysed was higher as well. This can be justified by a higher acreage of lands to be afforested (713.48 ha of lands designated for afforestation in Podlaskie Voivodship in 2007-2013, compared to 555.65 ha in Wielkopolskie). As a result, the forest growth rate was lager in Podlaskie Voivodship and reached 1.3% (1.4% for Poland; 0.6% for Wielkopolskie Voivodship). In the course of further considerations, data concerning the sums (in EURO) obtained for afforestation of arable and non-arable lands in selected districts of Podlaskie and Wielkopolskie Voivodships as part of RDP 2007-2013 have been presented (figures 1 and 2).

Analysis of the data shown in figure 1 leads to the conclusion that the highest subsidies for afforestation of arable land were obtained by Hajnowski District (19% of the overall subsidy for ALA), with 166 beneficiaries (20.1% of all ALA beneficiaries). Sokółka District, in turn, received the highest subsidy for afforestation of non-arable land (37% of the overall subsidy for NALA), with 42 beneficiaries (45.7 of all NALA beneficiaries). In 2007-2013 the forest growth rate in Hajnowski District was high and reached 2.3%, with 2% in Sokółka District. For comparison, the forest growth rate in Suwałki District (the lowest obtained ALA subsidy) equalled 1.1%. In Sokółka District, the analysis also included the forest growth rate in individual urban-ru-

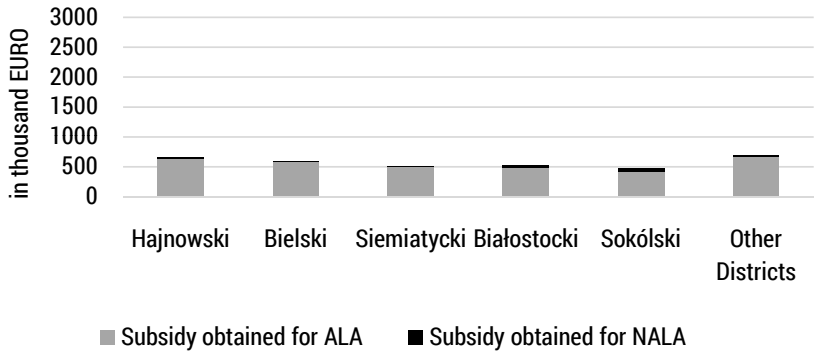

Figure 1. Share of the sum [in EURO] obtained for afforestation of arable land (ALA) and non-arable land (NALA) in selected districts of Podlaskie Voivodship as part of RDP 2007-2013

Source: author's own work based on (ARiMR, 2017).

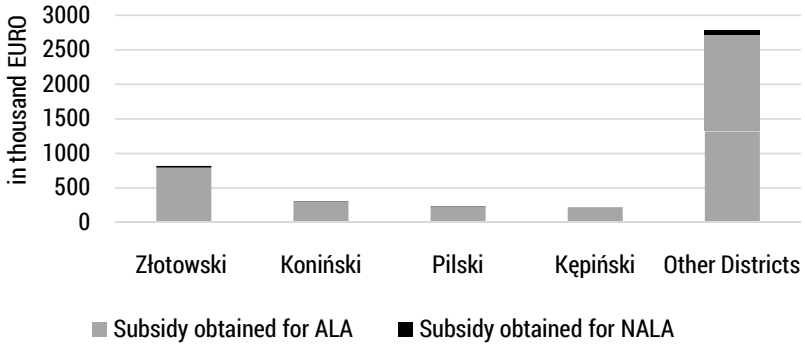

Figure 2. Share of the sum [in EURO] obtained for afforestation of arable land and non-arable land in selected districts of Wielkopolskie Voivodship as part of RDP 2007-2013

Source: author's own work based on (ARiMR, 2017).

ral municipalities. The results indicated two of them, i.e. Sokółka and Suchowola. In the municipality of Sokółka, afforestation of arable land constituted 48%, and afforestation of non-arable land 26% of the overall afforestation in the district. In Suchowola municipality, in turn, the numbers were 0.3% and 6%, respectively. In addition, the Pearson correlation coefficient value was very high (1) (Cohen, 1998) for both municipalities, and indicated a dependency between the sum obtained for afforestation in the years 2007-2013 and the amount received for biogas installation (utilisation of biomass as fuel).

In Wielkopolskie Voivodship (figure 2), the highest subsidies for afforestation of both arable and non-arable lands was obtained by Złotów District (25.75% of the overall ALA subsidies, with 102 beneficiaries – 16.11% of all ALA beneficiaries and 34.67% of the overall NALA subsidies, with 11 beneficiaries – 25.0% of all NALA beneficiaries. In the years 2007-2013 the forest growth rate in Złotów District equalled 1.5%. For comparison, the slowest forest growth rate was recorded in Krotoszyń District, which amounted to 0.2% (the lowest ALA subsidy obtained). Despite the slow growth of the forest rate, Krotoszyń District had a high total industrial production – 634,884,446 EURO and a low unemployment rate – 5.8% in 2015, compared with 179,509,947 EURO of industrial production and an unemployment rate of 12.1% in Złotów District. A high share of total industrial output could have caused a reduction of afforestation in Krotoszyń District. In general, in Wielkopolskie Voivodship a large majority of the subsidies were transferred to the remaining districts suggesting a greater territorial distribution of the amounts allocated under the ALA. This distinction is shown in the distribution of subsidies especially between the districts of the Podlaskie (figure 1) and Wielkopolskie Voivodships (figure 2).

Conclusions

In accordance with the National Forest Improvement Programme (KPZL), afforestation in Poland after 2050 is expected to reach 33%. Therefore, certain actions were undertaken to increase the acreage of forests, among others, though the use of EU subsidies granted under RDP 2007-2013. By using the EU subsidies for afforestation, Podlaskie and Wielkopolskie Voivodships contributed to the growth of arable land afforestation in Poland (GUS, 2015).

Selected (location-specific) survey results showed the following differences in private land afforestation in the years 2007-2013:

- Podlaskie Voivodship had a larger area of land to be afforested when compared to Wielkopolskie Voivodship. This translated, among other things, into a faster forest growth rate in Podlaskie Voivodship.
- At the level of districts in Podlaskie Voivodship, the fastest and the slowest forest growth rates were reported in Hajnówka and Sokołów Districts, respectively. In Wielkopolskie Voivodship, the fastest forest growth rate was noted in Złotów District and the slowest in Krotoszyn District.
- When compared to Wielkopolskie, Podlaskie Voivodship received higher subsidies, with a higher number of beneficiaries. Nevertheless, the average amount (in EUROs) obtained per capita in Podlaskie was lower than in Wielkopolskie Voivodship. It seems that this is due to the predomi-

nance of a number of farms in the range 0-1ha (23.8%) in the Wielkopolskie Voivodship.

- At the level of districts in Podlaskie Voivodship, the highest subsidies for arable land afforestation were granted to Hajnówka District, while Sokołów obtained the greatest support for afforestation of non-arable lands. In Wielkopolskie, in turn, it was Złotowski District that received the greatest support for afforestation of both arable and non-arable lands. In Wielkopolskie Voivodship, in Złotów District the greatest support was given to afforestation of arable land (ALA) and non-arable land (NALA). However, in the Wielkopolskie Voivodship spatial concentration of funds allocated to afforestation was lower than in the Podlaskie Voivodship.

The contribution of the authors:

Anna M. Klepacka – conception of framework, literature review, acquisition of data, analysis and interpretation of data – 50%
Patrycja Szmulewicz – literature review, data collecting, analysis and interpretation of data – 50%

Literature

ARiMR, *Sprawozdanie z działalności ARiMR za rok 2014*, http://www.arimr.gov.pl/fileadmin/pliki/zdjecia_strony/223/Sprawozdanie_ARiMR__2014.pdf [09-09-2017]

Bober J. et al. (2004), *Instytucjonalny program rozwoju instytucjonalnego. Poradnik dla samorządów terytorialnych*, Kraków

Budnica-Kosior J., Kwaśny Ł., Szymański P. (2016), *The role of spatial planning in shaping the afforestation rate on the level of district*, „Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" Vol. 18

Cegielska K. et al. (2018), *Land use and land cover changes in post-socialist countries: Some observaions from Hungary and Poland*, "Land Use Policy" No. 78, p. 1-18

Centrum Informacyjne Lasów Państwowych (2013), *Raport o stanie lasów w Polsce 2012*, Warszawa

Cohen J. (1998), *Statistical power analysis for the behavioral sciences* (2nd ed.), Hillsdale, NJ, Lawrence Erlbaum Associates

European Commission Directorate – general for agriculture and the rural development (2009), *Report on implementation of forestry measures under the rural development regulation 1698/2005 for the period 2007-2013*

Eurostat, Wskaźniki zrównoważonego rozwoju SDI, https://stat.gov.pl/wskazniki-monitorujace/ [22-10-2017]

Fan Y. et al. (2017), *Entropies of the Chinese Land Use/Cover change from 1990 to 2010 at a County level*. "Entropy" No. 19(2), p. 51

Foley J.A. et al. (2005), *Global consequences of land use*, "Science" No. 309(5734), p. 570-574

Fonder W. (2002), *Stan i perspektywy realizacji programu zwiększania lesistości kraju*, in: A Grzywacz (ed.), *Rola leśnictwa w ekorozwoju regionalnym*, Orzechowo, p. 93-113

GUS (2015), *Wskaźniki zrównoważonego rozwoju Polski 2015*, Katowice

GUS, BDL (2017), http HYPERLINK https://bdl.stat.gov.pl/BDL"s://bdl.stat.gov.pl/BDL [22-10-2017]

Hatna E., Bakker M.M. (2011), *Abandonment and Expansion of Arable Land in Europe*, "Ecosystems" No. 14(5), p. 720-731

Instytut Geografii i Przestrzennego Zagospodarowania im. Stanisława Leszczyńskiego PAN (2012), Przegląd Geograficzny

Janus J., Bozek P. (2018), *Using ALS data to estimate afforestation and secondary forest succession on agricultural areas: An approach to improve the understanding of land abandonment causes*, "Applied Geography" No. 97, p. 128-141

Kaliszewski A. (2016), *Krajowy program zwiększania lesistości – stan i trudności realizacji z perspektywy lokalnej*, „Studia i Materiały CEPL w Rogowie" Vol. 18. No 49B/5, p. 7-19

Klepacka A.M., Florkowski W.J., Bagińska M. (2017), *Zmiany w użytkowaniu ziemi – ilustracja skutków wsparcia programów regionalnych w zwiększaniu udziału lasów na przykładzie województwa podlaskiego*, „Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu" Vol. 19. No 5, p. 106-112

Klepacka A.M, Florkowski W.J,Revoredo-Giha C. (2017), *Farmers and their groves: Will cost inefficiency lead to land use change?*, "Land Use Policy" Vol. 61, p. 329-338

Kurowska K. et al. (2014), *Spatial analysis of afforestation in Poland under rural development programme 2001-2013 Forestry and Wood processing*, "Research for rural development" Vol. 2

Kurowska K., Kryszk H. (2017), *Profitability of the farm land afforestation within the Rural Development Programme*, Sylwan Vol. CLXI (12), p. 1035-1045

Łonkiewicz B. (1994), *Przestrzenne modele kształtowania lesistości kraju*, „Człowiek i Środowisko" No. 18(1), p. 97-113

Ministerstwo Rolnictwa i Rozwoju Wsi (2017), http://www.minrol.gov.pl/Wsparcie-rolnictwa/Program-Rozwoju-Obszarow-Wiejskich-2007-2013/Dzialania-PROW-2007-2013/Os-2-Poprawa-srodowiska-naturalnego-i-obszarow-wiejskich/Zalesianie-gruntow-rolnych-oraz-zalesianie-gruntow-innych-niz-rolne [22-10-2017]

NBP (2017), http://www.nbp.pl/homen.aspx?f=/srodeken.htm [12-01-2018]

Ossowska L., Janiszewska D. (2016), *The Diversification of Forestry Function in European Union Contries*, Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie, Problemy Rolnictwa Światowego, Vol. 16 (XXXI) No. 3, p. 292-300

Polna M. (2017), *Zmiany lesistości obszarów wiejskich w latach 1995-2016*, „Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu" Vol. XIX (2), p. 197-199

Poławski Z. (2006), *Zmiany powierzchni i przestrzennego rozmieszczenia lasów w Polsce w II połowie XX wieku*, „Leśne Prace Badawcze" Vol. 3, p. 57-70

Program Operacyjny Rozwój Polski Wschodniej 2007-2013 (2012), *Narodowe Strategiczne Ramy Odniesienia 2007-2013*, dokument opracowany na podstawie Pro-

gramu Operacyjnego Rozwój Polski Wschodniej 2007-2013, zatwierdzonego wydanym w dniu 28 czerwca 2012 r. przez Komisję Europejską sprostowaniem nr C(2012)4173 do decyzji z dnia 23 grudnia 2011 r. nr K (2011) 9789 zmieniającej decyzję Komisji z dnia 1 października 2007 r. nr K (2007) 4568

Przeglądy terytorialne OECD (2008), *Polska*, Ministerstwo Rozwoju Regionalnego, opublikowane w uzgodnieniu z OECD, Paryż

Rozwój regionalny w Polsce, Raport 2009 http://mazowsze.hist.pl/42/Mazowsze_Studia_Regionalne/895/2009/34265/ [22-10-2017]

Sioma S., Szymański L. (2008), *Przestrzenno-powierzchniowy aspekt zwiększania lesistości kraju zrealizowanego w ramach planu rozwoju obszarów wiejskich w latach 2004-2006*, Zarządzanie ochroną przyrody w lasach

The World Conversation Union (2004), *Afforestation and Reforestation for Climate Change Mitigation: Potentials for Pan-European Action*, Warsaw

Urząd Statystyczny w Białymstoku (2010), *Powszechny Spis Rolny 2010. Raport z wyników województwa podlaskiego*

Urząd Statystyczny w Poznaniu (2010), *Powszechny Spis Rolny 2010, Raport wyników województwa wielkopolskiego*

Woś A. (1994), *Klimat Niziny Wielkopolskiej*, Poznań

Wskaźniki Zrównoważonego Rozwoju Polski, Katowice 2015, p. 269, https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5501/5/2/1/wzr_2015_-_publikacja.pdf [27-11-2017]

Wysocka-Fijorek E. (2016), *The Role of Forestry in the Creation of Gross Domestic Product*, Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie Problemy Rolnictwa Światowego Vol. 16 (XXXI), No. 2, p. 363-371, Zakład Zarządzania Zasobami Leśnymi, IBL

Zamelski P. (2018), *Principles of the forest management in the context to concern for the common welfare and public health in Poland*, Sylwan Vol. CLXII (8), p. 658-663

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ASSESSMENT OF ECONOMIC FUNCTIONS AND TOURIST ATTRACTIONS OF "KORZENIOWY DÓŁ" IN KAZIMIERZ DOLNY IN THE LIGHT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT: The purpose of this study is to determine the way of tourism management of the loess ravine "Korzeniowy Dół" in Kazimierz Dolny on the Vistula river, taking into account the principles of sustainable development. This report uses secondary results obtained from the City Hall of Kazimierz Dolny. These were electronic measurements of the tourist traffic on the Vistula Boulevard and the number of tickets sold to the Castle and the Tower as well as Góra Trzech Krzyży. In addition, diagnostic survey was conducted using the questionnaire and direct interview. "Korzeniowy Dół" is one of the products that create the image of Kazimierz Dolny as a tourist town and should be developed in such a way that erosion processes are maximally slowed down. This ravine should be completely closed for traffic.. The bottom of the ravine should be drained and water should be drained through a pipe to the ditch. The bottom of the ravine should remain a ground road used only for pedestrian traffic, as it is only possible way to this tourist and natural attraction preserve for other generations. Visiting the ravine should be paid, like the entrance to Góra Trzech Krzyży, which will contribute to the protection of attractions and will help raise funds for the expansion of accompanying tourist infrastructure. The originality of the work consists in indicating the way of commercialization of the loess ravine in Kazimierz Dolny.

KEY WORDS: Kazimierz Dolny, tourism,nature protection, commercialization

Introduction

From an economic point of view, tourism is a form of economy in the service sector, but in the national economy, it is no homogenous part (Panasiuk, 2007, p. 50); it is often defined as a socio-economically and spatially complex phenomenon, and therefore affects the economy as well as resources such as natural and cultural values (Brelik, 2009, p. 267; Sawicka, p. 188). In spite of the important role of tourism in the economy, it is necessary to mention also its dysfunctional impact both in the social and spatial dimension connected with the destruction of the landscape and degradation of natural and cultural environment (Chojnacka, Wilkaniec, 2010, p. 81). Niezgoda (2006, p. 5) stresses that the dysfunctional nature of tourism is expressed as a result of the lack of human control over development processes in space. It is therefore necessary to implement the principles of sustainable development in the tourist reception area (Jalinik, 2017, p. 205-213), which refers to the management and protection of natural resources, reduction of anthropopression and public access to environmental information and participation in decision-making process (Piątek, 2002, p. 179). The local authorities have a great role in shaping and promoting the region of the tourist reception area, and local communities have territorial connections.

The purpose of this study is to determine the way of tourism management of the loess ravine "Korzeniowy Dół" in Kazimierz Dolny on the Vistula river, taking into account the principles of sustainable development.

An overview of literature

Civilization changes have a significant impact on the development of tourism and growth of tourist movement around the world. In addition, there are changes in the behavior of tourists, whose preference is changed from passive to active individual tourism. The area of tourist destination is also changing, because more and more often the increase of interests in the direction of valuable natural areas, is observed (Panfiluk, 2011, pp. 60-72). It can be thus concluded that tourism development is related to the resultant of processes undertaken in the economic, social and environmental spheres.

The essence of sustainable development is equal treatment of three spheres of real processes, i.e. economic, social and ecological spheres. Tourism should, therefore, develop and function in accordance with the paradigm of sustainable development (Poskrobko,2009, pp. 110-113). The trend based directly on the sustainable development model gives the concept of sustain-

able tourism a broad dimension that can be defined as a form of tourism development, management and tourist activity that maintains the ecological, social and economic integrity of areas, and preserves natural and cultural resources for future generations in an unchanged state (Kiryluk, Borkowska-Niszczota, 2006, p. 110), hence it must be a form of tourism development that respects the environment, ensuring a long-term protection of natural resources (Recommendation of the Council of Europe No. R. 95-10).

An important issue in promoting the sustainable development is the ecological awareness of society, which is currently low. General behavior of tourists usually contradicts the knowledge of ecology principles and the need to protect the environment (Willis, 2010, pp. 1-16).

Nowadays, the need to consciously plan and manage the environment is becoming stronger at the level of municipalities, as well as the appropriate confrontation of environmental resources with their users (Leask, 2016, pp. 344-361). Management of visitors in valuable natural areas should ensure an appropriate relationship between the economy, tourism and environment (Hu, Wall, 2005, pp. 617-635). The increase in tourism should be compatible with the ecological, natural and sustainable development system, understood both as a theoretical category and normative model of economic development and tourism policy (Cheng et al., 2013, pp. 314-320). Sustainable development of tourism in valuable natural areas minimizes the negative effects of tourist impact in the economic, socio-cultural and natural spheres, and at the same time maximizes the benefits of these areas (Kaczocha, Sikora, 2017, pp. 29-38). Local government units should supervise the tourist movement in places particularly vulnerable to destruction and places of natural value. At the same time, they should organize the sharing of tourist attractions in such a way that the places and objects earn on themselves, thus providing funds for their own protection (Wray et al., 2010, pp. 272-290). It should be remembered that caring for the state of nature is to ensure the future generations living in an environment that is unpolluted and friendly to humanity (Marciniuk-Kluska, 2013, pp. 129-140).

When commercializing tourist attractions, an attention should be paid to the Rio de JaneiroDeclaration on Environment and Development, in particular (Sawicki, 2007, p. 25):

- Principle 1. Human beings are the center of interest in the process of sustainable development. They have the right to a healthy and creative life in harmony with nature.
- Principle 3. The right to development must be enforced so that the developmental and environmental needs of present and future generations are fairly taken into account.

Characteristics of the studied area

Kazimierz Dolny is located on the Naleczowski Plateau and is a "pearl" of the tourist cities of the Lublin region and even the country. It is located about 60 km from Lublin, 25 km from Nałęczów and 15 km from Puławy. It has particularly valuable tourist, natural and cultural attractions. In the seventeenth century, it served as a Vistula river port playing an important role in the transport of grain to Gdansk. It is adjacent to the oldest landscape park in the Lublin region. It is a town particularly loved by artists, writers and people related to the broadly understood culture (Sawicki, Mazurek-Kusiak, 2009, p. 1087-1095).

From the point of view of the soil science, Kazimierz is situated in a geographic land made of loess soils that are subject to water erosion and hence many ravines are formed, which favors the roads that run down the water. Road gorges have a negative impact on the local economy as they act as drainage ditches; they carry soil to the roads, make it difficult to access and require continuous maintenance. On the tourist side, however, they are interesting and attractive. The ravine "Korzeniowy Dół" has slopes of up to 85° and a height of about 4 m, above which there are trees and roots. The slopes and bottom of the ravine do not have a vegetal cover, and tourists destroy the surrounding nature by swaying on the roots, digging the cavities in the slopes and drawing them with sticks. Nowadays, it is difficult to get to the fields through this ravine, and the owners of the surrounding allotment gardens are demanding to harden the road leading there. However, there are protests in many circles. The situation is socially and economically difficult, which is becoming a media sensation, not always well used.

Mayor of Kazimierz Dolny asked for expertise on hardening the bottom of the ravine to the Lublin Landscape Park Team and the District Office in Puławy and received two negative comments. This situation is triggering the conflict between different interest groups.

Research methods

This report uses secondary results obtained from the City Hall of Kazimierz Dolny. These were electronic measurements of the tourist traffic on the Vistula Boulevard and the number of tickets sold to the Castle and the Tower as well as Góra Trzech Krzyży.

It is worth noting that the number of tourists enjoying walks along the Vistula Boulevard and those visiting the Castle with Baszta and Góra Trzech Krzyży is a measure of the demand for using the tourist attractions in Kazimierz Dolny.

The research was carried out by means of a diagnostic survey using the direct questionnaire technique, which concerned the popularity of "Korzeniowy Dół" (Korzeniowy Down). These studies were conducted among 428 tourists in Kazimierz Dolny and Nałęczów, and they were an indicator for forecasting the tourists' interest in "Korzeniowy Dół".

"Korzeniowy Dół" is a natural monument and all forms of development should be subject to public consultation, hence additional direct interviews were conducted.

The direct interview focused on the ways to solve the traffic problem in the ravine discussed by three target groups: tourists (276 people), tourism workers from Lublin region (28 people), inhabitants of Kazimierz Dolny (64 people). There were also many free interviews with officials, residents and tourists in the studied ravine. As a supplement to the study, the observation method was used.

Analysis of such compared results of secondary and primary research is a very reliable way to determine the forecast of commercialization of a tourist product commonly known as "Korzeniowy Dół".

Results

The loess ravine "Korzeniowy Dół" is a 360-meter section of a 520-meter road connecting Dolna and Górna Streets. The observation shows that due to water erosion and lack of maintenance work, the road at the bottom of the ravine is not passable but merely piled up by tourists. There are many trash leftovers and drawings on the slopes. Currently, the road belongs to the city and from the legal point of view, it should be widely available.

Tourist traffic has never been professionally surveyed in the ravine, but the observation shows that it is quite large. For this reason, data on the intensity of tourist traffic on Vistula Boulevard (electronic measurement), Castle and Tower (tickets) as well as on Góra Trzech Krzyży (tickets), have been used, as presented in tables 1 and 2. It follows that the average number of tourists in 2014-2016 on the Vistula Boulevard was 362,088 and the standard deviation was 13.057. In this case, the tourist traffic has fluctuated more in months than through years. What seems understandable, it was dependent on the time of the year and months. The largest traffic was recorded in May, June, July and August, and the lowest in December and January each year.

Table 1. Number of people using the tourist infrastructure of the Vistula Boulevard in Kazimierz Dolny in 2013-2016 (electronic measurement)

Months	2014	2015	2016	average
January	3 048	8 977	4 246	5 424
February	9 224	14 460	13 524	12 403
March	18 417	15 452	11 032	14 967
April	27 794	20 199	16 565	21 519
May	44 311	45 255	53 678	47 748
June	39 575	51 265	36 578	42 473
July	60 043	66 952	62 391	63 129
August	74 530	71 673	81 411	75 871
September	45 260	27 926	35 990	36 392
October	32 854	19 844	16 633	23 110
November	12 895	7 209	9 130	9 745
December	7 630	11 957	8 337	9 308
Total	**375 581**	**361 169**	**349 515**	**362 088**

Source: author's own work based on data provided by the City Hall.

By analyzing the number of tickets sold to Castle and Tower, it turned out that, on average, 146,422 tickets were sold here, which accounted for 50.2% of people registered on the Vistula Boulevard, and generated an average of 732,110 PLN in revenue. It is worth mentioning that the tickets have only been sold here for three years. In the case of Góra Trzech Krzyży, the data was only available in 2016. It turned out that the tickets were purchased by 175,560 people, which generated revenues of 351,120 PLN, and the tourist traffic accounted for 41.2% of traffic on the Vistula Boulevard (table 2).

On the basis of the above-mentioned measurements of tourist traffic in the Castle and Tower and on Góra Trzech Krzyży, approximately the same level of tourists can be assessed in the mentioned ravine (Piontek, 2012). The ticket price for Góra Trzech Krzyży is currently PLN 2,therefore the same price has been accepted for the entry ticket to "Korzeniowy Dół". Both tourist attractions are similar.

Table 2. The number of tickets sold and cash receipts in the tourist facilities of Kazimierz Dolny: Castle and Tower as well as Góra Trzech Krzyży

Months	Castle and Tower (ticket 5 PLN, average for 2015-2016)		Góra Trzech Krzyży (ticket 2 PLN – 2016)	
	Number of tickets sold (average for 2015-2016)	Cash receipts in zloty	Number of tickets sold	Cash receipts in zloty
January	1 239	6 195	-	-
February	3 215	16 075	-	-
March	3 428	17 140	3 759	7 518
April	7 029	35 145	6 549	13 098
May	26 729	133 645	42 684	85 368
June	25 098	125 490	14 775	29 550
July	23 243	116 215	26 613	53 226
August	28 109	140 545	50 378	100 756
September	15 470	77 350	12 406	24 812
October	10 225	51 125	15 600	31 200
November	1 701	8 505	2 796	5 592
December	936	4 680	-	-
Total	**146 422**	**732 110**	**175 560**	**351 120**
% share in tourist traffic on Vistula Boulevard	**50,20%**	-	**41,20%**	-

Source: author's own work based on data provided by the City Hall.

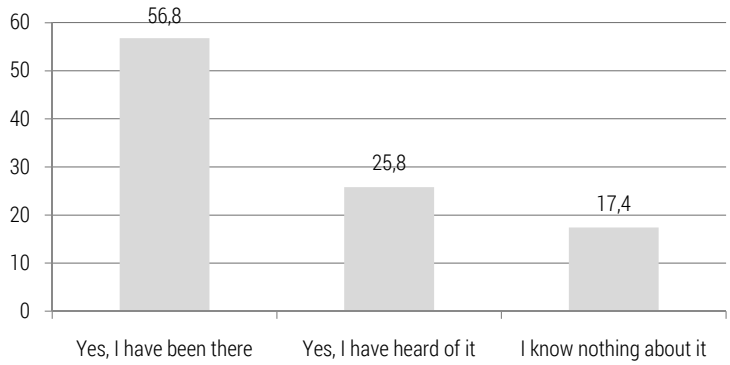

Figure 1. The popularity of the loess ravine "Korzeniowy Dół" in Kazimierz Dolny in the opinion of tourists from this place and from Nałęczów [%]

Source: author's own work based on study.

With regard to the marketing evaluation of the popularity of "Korzeniowy Dół", surveys were conducted among tourists, 56.8% of which were here in person, 25.8% only heard of this tourist attraction, and 17.4% had no knowledge of the above (figure 1). In this way, the popularity of this object was very high among tourists, therefore it can be assumed that "Korzeniowy Dół" will visit 56.8% of tourists walking around the Vistula Boulevard. Visitors to the Castle with Baszta and Góra Trzech Krzyży are usually the same people as those walking around Boulevard. Thus, on average, around 206,000 tourists a year can visit it annually (362,088 people x 56.8% = 205,666 people), which should bring the expected revenue to 412 thousand PLN in the case of ticketing.

This money could give a job to guides who would explain the phenomenon of karst formation to the tourists and make sure they behave properly in the areas of natural beauty. Car parks and toilets could also be provided. Interviews with tourists indicated that this infrastructure was lacking, and their knowledge of erosion and ravines was very negligible.

It is worth pointing out that there are several road ravines less impressive than "Korzeniowy Dół" in Kazimierz Dolny, which in the past years were hardened with concrete slabs, which was faced both by the approval of residents and officials. For the purpose of this study, a poll was conducted among three target groups on how to tackle the road problem (table 3).

Table 3. Opinion of tourists, tourism industry workers and inhabitants of Kazimierz Dolny on the hardening of the road leading through the loess ravine "Korzeniowy Dół"

L.P	Target group of respondents	Way to solve the road problem [% of respondents]			
		cobblestones	concrete slabs	other forms of cure	leave the ground road
1	Tourists	0,0	0,0	3,8	96,2
2	Employees in the travel industry	0,0	0,0	0,0	100,0
3	Residents of Kazimierz Dolny	20,0	51,7	15,0	13,3

Source: author's own work based on study.

It turned out that none of the respondents recruited from tourists or travel industry employees was for fixing the bottom of ravine with pavement or concrete slabs. The cobblestones was approved only by 20%, and the concrete slabs by 51.7% of residents of Kazimierz Dolny. Other forms of hardening was allowed only by 3.9% of tourists and 15.0% of the population, while 96.2% of tourists, 100% of workers and 13.3% of inhabitants stood for leaving the ground road (table 3).

By analyzing the above presented research results, they should be interpreted taking into account the qualitative characteristics of tourist products, creating the image of Kazimierz Dolny – city with the tourist function as well as cooperation of tourist entities (Balińska, 2012, p. 223; Glińska, 2010, p. 130; Wiatrak, 2014, p. 179).

It is also worth noting the usefulness of the "Korzeniowy Dół" for natural and educational tourism, including leisure walks, and Chojnacka, Wilkanca (2010, p. 81) research shows that this latter feature is particularly favored by tourists rushing in protected areas.

Conclusions

"Korzeniowy Dół" is one of the products that create the image of Kazimierz Dolny as a tourist town and should be developed in such a way that erosion processes are maximally slowed down.

The bottom of the ravine should be drained and water should be drained through a pipe to the ditch. The bottom of the ravine should remain a ground road used only for pedestrian traffic, as it is only possible way to this tourist and natural attraction preserve for other generations.

Visiting the ravine should be paid, like the entrance to Góra Trzech Krzyży, which will contribute to the protection of attractions and will help raise funds for the expansion of accompanying tourist infrastructure. The traffic forecasts here are optimistic, because, assuming that the ticket price will be PLN 2, and "Korzeniowy Dół" will be visited by 206,000 people, the average annual income will be at the level of PLN 412,000.

Literature

Balińska A. (2012), *Zarządzanie jakością w turystyce,* in: J. Ozimek (ed.), *Współczesna turystyka i rekreacja – nowe wyzwania i trendy,* Warszawa, p. 223

Brelik A. (2009), *Społeczno-ekonomiczne aspekty rozwoju turystyki,* in: W. Deluga (ed.), *Turystyka we współczesnej gospodarce,* Koszalin, p. 267

Cheng Q., Su B., Tan J. (2013), *Developing an evaluation index system for low carbon tourist attractions in China,*"Tourism Management" No. 36, p. 314-320

Chojnacka M., Wilaniec A. (2010), *Wpływ ruchu turystycznego na przekształcenia krajobrazu chronionego na przykładzie Lednickiego Parku Krajobrazowego,* „Problemy Ekologii Krajobrazu", t. XXVII, Polska Asocjacje Ekologii Krajobrazu, p. 81

Glińska E. (2010), *Kreowanie wizerunku miasta o funkcji turystycznej*, „Zeszyty Naukowe – Ekonomiczne Problemy Usług" No. 519(53), p. 130

Gorzym-Wilkowski W.A. (2014), *Koncepcja systemu planowania przestrzennego obszarów chronionych,* in:B. Sawicki, M. Harasiumiuk (eds*), Rola obszarów chronionych w rozwoju edukacji, turystyki i gospodarki,* Warszawa, p. 216

Hu W., Wall G. (2005), *Environmental management, environmental image and the competitive tourist attraction,* "Journal of Sustainable Tourism" No. 13(6), p. 617-635

Jalinik M. (2017),*The Attractiveness of Białowieża Forest,* "Economics and Environment" No. 2(61), p. 205-213

Kaczocha W., Sikora J. (2017), *Ethical Values and Norms in theManagement of Attractive Natural Areas,* "Ekonomia i Środowisko" No. 4(63), p. 29-38

Kapera J. (2012), *Polityka turystyczna organów samorządu województwa małopolskiego waspekcie działań stymulacyjnych popyt turystyczny,* „Zeszyty Naukowe – Ekonomiczne Problemy Usług" No. 697(8)2, p. 372

Kiryluk H., Borkowska – Niszczota M. (2006),*Koncepcja turystyki zrównoważonej w teorii i praktyce,* in:A. Nowakowska, M. Przydział (eds), *Turystyka w badaniach naukowych,* Rzeszów,p. 110

Leask A. (2016), *Visitor attraction management: A critical review of research, "*Tourism Management" No. 57,p. 334-361

Marciniuk-Kluska A. (2013), *Environmental Management in the Scope of Economic Sustainable Development*,„Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach, Seria: Administracja i Zarządzanie" No. 96, p. 129-140

Niezgoda A. (2006), *Obszar recepcji turystycznej w warunkach rozwoju zrównoważonego*, Poznań, p. 5

Panasiuk A. (2007), *Ekonomika Turystyki*, Warszawa p. 50

Panfiluk E. (2011), *Problems of the sustainable development of tourism,* "Economy and Managemen" No.2, p. 60-72

Piontek B. (2002), *Koncepcja rozwoju zrównoważonego i trwałego*, Warszawa, p. 179

Piontek B. (2012), *Economic valuation of the natural environment – selected problems, "*Ekonomiai Środowisko"No. 1(41), p. 47-69

Poskrobko B. (2009),*Współczesne trendy cywilizacyjne a idea zrównoważonego rozwoju,* in: B. Poskrobko (ed.), *Zrównoważony rozwój gospodarki opartej na wiedzy,* Białystok, p. 110-113

Rekomendacja Rady Europy no R. 95-10 Komitetu Ministrów dla państw członkowskich w sprawie polityki zrównoważonego rozwoju turystyki na obszarach chronionych, dokument elektroniczny, www.eko.org.pl/lkp/prawo_html/recomend_turist.pl [10-05-2018]

Sawicka A.H. (2014), *Influence of public space development on the quality of life,* in: B. Sawicki (ed.)*, Promotion of Healthy lifestyle in European countries*, Lublin, p. 188

Sawicki B. (2007), *Agroturystyka w aktywizacji obszarów wiejskich*, Lublin, p. 25

Sawicki B. (2014), *Rola obszarów chronionych w rozwoju edukacji, turystyki i rekreacji w opinii mieszkańców Lubelszczyzny,* „Zeszyty Naukowe ALMAMER" No. 4(73), p. 47

Sawicki B., Mazurek-Kusiak A. (2009), *Rola dóbr kulturowych i przyrodniczych w rozwoju turystyki w gminie Kazimierz Dolny*, „Zeszyty Problemowe Postępów Nauk Rolniczych"No.542(II), p. 1087-1095

Wiatrak A.P. (2014*), Determinations and forms of cooperation i tourism, "*Scientific Journal" No. 836, "Economic Problems of Tourism" Vol. 4(28), p. 179

Willis K.G. (2010), *Assessing visitor preferences in the management of archaeological and heritage attractions: A case study of Hadrian's Roman Wall,*"International Journal of Tourism Research" No. 12, p. 1-16

Wray K., Espiner S.,Perkins H.C. (2010),*Cultural clash: Interpreting established use and new tourism activities in protected natural areas,* "Scandinavian Journalof Hospitality and Tourism" No. 10(3), p. 272-290

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

PROBLEMATYKA OGÓLNOEKOLOGICZNA I SPOŁECZNA

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OWN INVESTMENT CAPACITY OF COMMUNES IN NATURALLY VALUABLE AREAS AND LOCAL CONDITIONS OF TOURISM DEVELOPMENT

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ABSTRACT: The aim of the research was to identify the level of the Polish municipality's own investment capacity with the most significant share of naturally valuable areas in the years 2014-2016 and the level of tourism development of these areas. The methods of economic analysis – comparative, indicative and tools of taxonomic analysis were used here, which allowed for ranking of the surveyed units in terms of the level of naturally valuable, tourism function, the level of local development and own investment potential. The surveyed entities had their own investment capacity, however, due to the scope of infrastructure needs, it should be assessed as low. The conducted research indicates a small scope of development of tourism in communes with the with the highest naturally valuable areas. In results, it can be concluded that this development opportunity has not been effectively used. In the authors' opinion, the development of the tourist function in the most naturally valuable areas which ensures that tourism will be the basis of local development of these areas is not possible without external support in the form of subsidies from the national budget and the implementation of knowledge on how to manage these areas.

KEY WORDS: local development, legally protected areas, communal investments, synthetic measure, tourist function

Introduction

Development of infrastructure on the naturally valuable areas is difficult because of some legal and financial obstacles. For these reasons, tourism is seen as a desirable course of local development. Local development strategies based on tourism activity not require the creation of large objects of economic, and technical infrastructure. Some investments in energy, road or water networks are, of course, necessary. Therefore, it is important to describe whether the level of the Polish municipality's own investment capacity with the most significant share of naturally valuable areas is significantly differ from others. The second question is whether tourism activity on the naturally valuable areas is higher than others.

An overview of literature

Naturally valuable areas are an important element of the environment in the policy of sustainable development, which requires special attention from the creators of local and regional development. These are either legally protected areas, such as national parks, landscape parks, nature reserves, protected landscape areas, Natura 2000 sites, or unprotected environmental elements that should be preserved for future generations. The most important resources include forests and waters, due to their important role in maintaining biodiversity and the cleanliness of the natural environment (Cieszewska, 2008, p. 239-250; Steiner, 2000; Dobrzańska, 2007, p. 61; Zielińska, 2007, p. 168). Poland is a country with a high forest cover, the area of the forests increases, and the number of species of animals endangered with extinction increasing due to various protection forms. High environmental values predispose these areas to the development of tourist functions (Dębniewska, Skorwider-Namiotko, 2015, p. 169). However, their development may be difficult due to legal and financial restrictions in the area concerning creation of new infrastructure (Puciato, 2009, p. 228). Tourism can also have a negative impact on the environment (Jurkiewicz-Karnkowska, 2016, p. 70; Skorwider-Namiotko, Skorwider-Namiotko, 2016, p. 311-317; Jalinik, 2016, p. 227). It should also be taken into account that the high share of naturally valuable areas with insufficiently developed tourist function reduces the economic base of the local economy and thus becomes an additional barrier to development that cannot be overcome without the support of external resources. On the other hand, there are examples indicating that sustainable development of tourism in these areas is possible (Dedeke, 2017, p. 161-172).

Local development is a process that aims to improve the quality of life of inhabitants. The stream of local public expenditures should improve the infrastructure (first of all technical, which creates the economic base) and the investment climate, which will induce entrepreneurs to develop new economic activities and thus increase the income and assets of residents. This higher activity should be reflected in the higher own budget revenues of communes (in particular due to the share in income from PIT and CIT income taxes and in real estate, agricultural and forest tax) (Warczak, 2015, p. 111-122; Kołodziejczyk, 2014, p. 198-206).

The possibilities of financing investments in municipalities to a large extent depend on the amount of operating surplus in the budget. According to the current law, the structure of the budget is to ensure surpluses on financing current operations consisting in satisfying the current needs of residents through communal and social services. Thanks to these surpluses, it will be possible to repay the existing debt and allocate part of the funds for new investments. Lack of operating surplus significantly reduces or prevents investment activities (Gubernat-Ulatowski, 2016, p. 48-54; Zawora, 2014, p. 554). Investment potential can be determined at various levels (Skorwider, Garbowski, 2012, p. 233). From the point of view of the conducted research, the study of own investment capacity of communes was considered the most important.

Research methods

The aim of the research was to identify the level of the Polish municipality's own investment capacity with the most significant share of naturally valuable areas in the years 2014-2016 and the level of tourism development of these areas. The methods of economic analysis – comparative, indicative and tools of taxonomic analysis were used here, which allowed ranking of the examined units and measurement of statistical relationships between the studied phenomena. Those methods were used commonly in works of Krakowiak-Ball (2005), Nowak (1975), Skorwider-Namiotko and Skorwider-Namiotko (2016), but sometimes with different tool of taxonomy analysis. In order to identify communes with the predominance of naturally valuable areas, three indicators were used which, in the opinion of the authors, reflect the nature of the phenomenon under investigation in the best way. These included: the share of the legally protected area, the share of forest areas and the share of the surface underwater (including the area of sea waters within the boundaries of communes) (Dębniewska, Skorwider-Namiotko, Wojtowicz, 2016, p. 27). In Poland, the most of natural naturally valuable areas are legally protected but forests and water areas are important to develop flora

and fauna and touristic activity as well. On the other hand, mountains areas were partially omitted because some of them are in one of the previous groups. Some mountain areas are attractive to development of tourism but are not so naturally valuable if there are few or common plants and animals or are even barren, like some mountain peaks. These indicators were not separable, as some forest and water areas also had the status of legally protected areas.

The synthetic measures illustrating the level of naturally valuable, tourism function, the level of local development and own investment potential was built on the basis of the Perkal index (Karmowska, 2011, p. 87), so an equal influence of particular variables on the studied phenomenon was assumed. The data was obtained from the Online Local Data Bank of the Central Statistical Office and information from the Ministry of Finance regarding long-term financial plans of communes. Data was collected for all communes in Poland, after which they were subject of the normalization procedure, using the method of zero unitarization (Jarocka, 2015, p. 113-125; Walesiak, 2014, p. 365-369; Kukuła, Bogocz, 2014). All variables were stimulants. They were characterized by an appropriate level of differentiation, as the coefficient of variation was above 10%. Variables were not correlated significantly. The value of R=0.81 was assumed as the correlation limit because this value gives an explanation of the variability of one feature in 2/3 (R^2=0.66). In the second stage, diagnostic variables were transformed to eliminate their titer. For this purpose, the method of zero unitarization was applied in accordance with the following formula:

$$z_{ij} = \frac{x_{ij} - \min_i\{x_{ij}\}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}} \tag{1}$$

where:
z_{ij} – normalized value of the *j* variable for the *i* object,
x_{ij} – value of the *j* variable for the *i* object,
min – maximum value of the variable,
max– the minimum value of the variable.

As a result of the transformation applied, normalized variables adopted values from the interval [0,1]. In the next stage, previously normalized variables were aggregated according to the following procedure:

$$z_i = \sum_{j=1}^{k} w_j \cdot z_{ij} \tag{2}$$

where:
k – number of variables,
w – variable weight.

In that way, three synthetic measures: the level of naturally valuable, the level of tourism function, and the level of local development were calculated. Then they were compared with the indicators of own investment potential i.e. relative investment capacity (% of current revenues) and investment capacity per capita (PLN/person) with the use of Pearson correlation index.

Results of the research

Identification of communes with the predominance of naturally valuable areas and their tourist functions

Based on the distance of a synthetic measure of a given commune from the average and a multiple of the standard deviation, five types of communes have been distinguished (table 1). Conducted research indicates that in Poland dominate communes in which naturally valuable areas are an important element of the local economy. In over 84% of Polish communes, the synthetic measure of the level of naturally value has exceeded 0.05, and in over 42% it exceeded 0.20. Although the level of 0.05 is low, compared to other surveyed units, it already indicates that areas are an important element of the natural and economic environment of the commune, and thus this resource will require appropriate management.

Table 1. Types of communes by the level of naturally valuable areas in Poland

Type of commune	Division criteria	Synthetic measure interval	Number of communes
1 – the highest share of NVA	higher than x + 2s	higher than 0.505	108
2 – high share of NVA	higher than x + s	(0.353 – 0.505>	348
3 – average share of NVA	higher than x	(0.202 – 0.353>	585
4 – low share of NVA	higher than x – s	(0.051 – 0.202>	1045
5 – the lowest share of NVA	till x – s	<0.000 – 0.051>	392

x – mean, s – standard deviation, NVA – naturally valuable areas.

Source: author's own work based on data of Central Statistical Office in Poland [17-11-2017].

Municipalities from the group number one were chosen as subjects of research. These were municipalities for which the value of the synthetic measure was higher by two standard deviations from the average. They constituted 4.35% of the total population. Their list is presented in table 2. In the identified entities with the highest level of naturally valuable, the average share of the legally protected area exceeded 93%, forests accounted for over 62% of the communes area (more than twice the national average), and water approx. 3% (so 1.5 times more than average for the country).

Table 2. Communes with the highest level of naturally valuable areas by voivodships

Voivodship	Number of communes	Synthetic measure interval	List of communes
Dolnośląskie	1	0.549	Stronie Śląskie (3)
Kujawsko-pomorskie	5	0.510-0.596	Osie (2), Śliwice (2), Wielka Nieszawka (2), Bobrowniki (2), Solec Kujawski (3)
Lubuskie	3	0.511-0.584	Dobiegniew (3), Kłodawa (2), Drezdenko (3)
Małopolskie	18	0.505-0.612	Rytro (2), Łabowa (2), Sękowa (2), Szczawnica (3), Muszyna (3), Piwniczna-Zdrój (3), Uście Gorlickie (2), Kamienica (2), Ochotnica Dolna (2), Czorsztyn (2), Krynica-Zdrój (3), Poronin (2), Bystra-Sidzina (2), Kościelisko (2), Krościenko nad Dunajcem (2), Kamionka Wielka (2), Lipnica Wielka (2), Bukowina Tatrzańska (2)
Mazowieckie	8	0.506-0.619	Podkowa Leśna (1), Izabelin (2), Zielonka (1), Wilga (2), Celestynów (2), Nowy Duninów (2), Nieporęt (2), Maciejowice (2)
Opolskie	7	0.508-0.601	Tułowice (2), Murów (2), Lasowice Wielkie (2), Zębowice (2), Kolonowskie (3), Turawa (2), Ozimek (3)
Podkarpackie	19	0.509-0.669	Cisna (2), Lutowiska (2), Krempna (2), Komańcza (2), Baligród (2), Solina (2), Krasiczyn (2), Jaśliska (2), Czarna (2), Ustrzyki Dolne (3), Bircza (2), Tyrawa Wołoska (2), Horyniec-Zdrój (2), Narol (3), Olszanica (2), Krzywcza (2), Adamówka (2), Fredropol (2), Niwiska (2)
Podlaskie	8	0.506-0.647	Białowieża (2), Narewka (2), Mielnik (2), Nowinka (2), Płaska (2), Czarna Białostocka (3), Zbójna (2), Giby (2)
Pomorskie	5	0.584-0.633	Osieczna (2), Osiek (2), Hel (1), Lipusz (2), Dziemiany (2)
Śląskie	9	0.511-0.622	Kuźnia Raciborska (3), Boronów (2), Ujsoły (2), Wisła (1), Herby (2), Szczyrk (1), Janów (2), Nędza (2), Czernichów (2)
Świętokrzyskie	12	0.506-0.608	Brody (2), Bliżyn (2), Suchedniów (3), Wąchock (3), Zagnańsk (2), Daleszyce (3), Stąporków (3), Ruda Maleniecka (2), Smyków (2), Raków (2), Bodzentyn (3), Łączna (2)
Warmińsko-mazurskie	6	0.512-0.612	Jedwabno (2), Stawiguda (2), Janowo (2), Kruklanki (2), Ruciane-Nida (3), Łukta (2)
Wielkopolskie	3	0.509-0.561	Powidz (2), Sośnie (2), Wronki (3)

(1) – urban commune, (2) – rural commune, (3) – urban-rural commune.

Source: author's own work based on data of Central Statistical Office in Poland [17-11-2017].

In order to determine the tourist function of the studied areas, five indicators were used (Szromek, 2013, p. 91-103; Hendel, 2016, p. 159-168), which were then normalized and used to construct a synthetic measure of the level of tourism function development using the Perkal indicator (table 3):

- Baretje-Defert indicator expressed in the number of tourist beds per 100 permanent residents,
- Defert indicator expressed in the number of tourists using accommodation per 1 square km of the area,
- Schneider indicator, expressed by the number of tourists using accommodation, per 100 inhabitants of the area,
- Charvat indicator expressed in the number of overnight stays per 100 inhabitants of the area,
- accommodation density indicator expressed in the number of beds offered to tourists per 1 square km of the area.

Table 3. Indicators of the level of tourism function development in the analysed communes in 2014

Item	Baretje-Defert indicator [pc./100 p.]	Defert indicator [pc./sq. km]	Schneider indicator [pc./100 p.]	Charvat indicator [pc. /100 p.]	Accommodation density indicator [pc./sq. km]	Synthetic measure of the tourism function development level
Communes with the highest naturally valuable areas						
Average	12.6	159.5	249.8	986.9	7.8	0.029
Median	2.5	17.2	43.5	93.1	1.1	0.004
Standard deviation	32.2	423.4	514.1	2 471.2	25.6	0.067
Coefficient of variation	2.6	2.7	2.1	2.5	3.3	2.3
Min	0.0	0.0	0.0	0.0	0.0	0.000
Max	292.7	2 751.9	2 798.9	19 598.0	239.4	0.535
Communes in Poland overall						
Average	2.7	129.9	55.8	196.1	4.5	0.008
Median	0.3	3.1	5.2	12.0	0.3	0.001
Standard deviation	16.1	666.1	237.0	1115.3	29.4	0.038
Coefficient of variation	6.0	5.1	4.2	5.7	6.6	4.7
Min	0.0	0.0	0.0	0.0	0.0	0.000
Max	374.2	16540.9	5656.0	22467.8	619.7	0.691

Source: author's own work based on data of Central Statistical Office in Poland [17-11-2017].

Based on the data form table 3 it can be stated that the communes in the most naturally valuable areas were characterized by low level of development of the tourist function, because of the low average value of the synthetic measure (0.029). Most of them were classified in the fourth or fifth category

of tourism function development (and therefore the lowest ones). Only the commune of Mielno was in the first category and the commune of Międzyzdroje in the third category, i.e. above the average for all communes. Despite such low results, the analysed communes were characterized by a higher than average for Poland level of development of the tourist function – in total as well as in each of the variables used for its construction. The obtained results indicate that the surveyed municipalities failed to build adequate accommodation infrastructure. This lack of touristic facilities partially was the result of legal system in which are some restriction related with building process in naturally protected areas (Kistowski, 2008; Zielińska, 2007, p. 165-166). Sometimes tourist activity was not shown in the official statistics of the Central Statistical Office. To a large extent, this situation concerned agritourism farms. It can also be said that the authorities of these municipalities did not manage to stop the tourist for longer than a one-day stay.

Determinants of investment capacity in the communes with the highest level of naturally valuable areas

The larger economic base gave larger own revenues of these communes. The five most important indicators referring to the level of local development are presented in table 4. There were: own income per inhabitant, percentage users of the public water and sewage network, users of gas system and number of companies registered in REGON system per 100 000 inhabitants. On the basis of their normalized values, a synthetic measure of the level of local development was built (also using the Perkal indicator). The average values of own revenues and the average number of enterprises from 2014-2016 were used in the analyses due to their volatility in analysed years. Data about the availability of infrastructure simultaneously illustrate the scope of investment needs.

Table 4. Average values of indicators of the level of local development in the analysed communes in 2014-2016

Item	Own income per inhabitant [PLN/person]	Users of the public water network [%]	Users of the public sewage network [%]	Users of gas network [%]	Entrepreneurial level [pcs./10,000 people]	Synthetic measure of local development level
Communes with the highest naturally valuable areas						
Average	1 751.9	75.8	55.0	18.0	880.7	0.319
Median	1 407.4	87.5	56.5	0.7	725.7	0.319
Standard deviation	1 092.0	26.5	27.6	27.0	426.2	0.121
Coefficient of variation	0.62	0.35	0.50	1.50	0.48	0.38
Min	547.5	0.2	0.0	0.0	419.7	0.086
Max	6 787.8	100.0	99.9	95.8	2 902.1	0.611
Communes in Poland overall						
Average	1 566.3	87.6	48.6	25.4	787.7	0.342
Median	1 382.3	93.5	47.2	7.4	716.9	0.322
Standard deviation	1 223.8	17.4	28.5	31.0	346.3	0.121
Coefficient of variation	0.78	0.20	0.59	1.22	0.44	0.35
Min	482.6	0.0	0.0	0.0	277.6	0.014
Max	46 844.8	100.0	100.0	98.5	7 919.5	0.764

Source: author's own work based on data of Central Statistical Office in Poland and Ministry of Finance [17-11-2017].

The analysed communes were characterized by a slightly lower average level of local development than all communes in the country. There was a low population density in the majority of studied areas (about 61 people per square km, while the country's average is 123 people per square km). Approx. 25% of inhabitants of these areas have not had access to public water system, 45% to sewage system, and 82% to gas network.

The level of own income per capita was higher than the average for Poland by approx. 12%; higher level of public sewage system by just over 6 percentage points (although it should be noted that this level was low – around 55%) and a higher level of entrepreneurship, also by approx. 12%. However, these units were characterized by lower access to public water supply infrastructure (by about 12 percentage points) and lower access to gas infrastructure (by about 7 percentage points). These results indicate the existence of an infrastructure gap in the studied area. It is the effect of dispersed settlement and dispersed economic activity. However, such conditions cause the necessity to increase investment expenditures.

Own investment capacity is the difference between current income and current expenses less repayment of instalments of credits, loans and redemption of municipal bonds in a given year, increased by income from the sale of assets, budget surplus from previous years and revenues from privatization and returns of previously granted loans. Therefore, the received subsidies and debts incurred – old (in the form of free funds) or new debts – are funds coming from outside the municipality. They were compared to current income and per capita (table 5).

Table 5. Average values of indicators of the level of local development in the analysed communes in 2014-2016

Item	Relative investment capacity [%]	Investment capacity per capita [PLN/person]
Communes with the highest naturally valuable areas		
Average	7.84	302.15
Median	6.20	216.16
Standard deviation	8.15	353.93
Coefficient of variation	1.040	1.171
Min	-24.38	-900.81
Max	48.47	2 302.35
Communes in Poland overall		
Average	7.54	310.8
Median	6.30	207.6
Standard deviation	9.34	2 312.8
Coefficient of variation	1.24	7.44
Min	-53.19	-6 655.3
Max	229.47	113 709.corr

Source: author's own work based on data of Ministry of Finance [17-11-2017].

Municipalities in Poland, on average, had a small own investment capacity. Funds that can be used for investments accounted for approximately 7.5% of current revenue, i.e. approx. PLN 300 per year per capita. Such investment potential will not allow quick elimination of the emerging infrastructural gap. However, there is a large variation in this potential, both in percentage and per capita terms. A disturbing phenomenon, however, is the occurrence of negative indicator values in some communes. Such situation occurred in 193 communes, of which only three (communes: Janów, Płaska

and Krempna) were in the studied group. Municipalities with the highest naturally valuable areas were characterized by slightly better than average ratio of relative investment capacity and a slightly lower index of investment capacity per capita. In the studied group, the lower variability of the analysed phenomena was also observed.

Analysis of the coexistence between the analysed factors and the level of naturally valuable areas suggests the lack of significantly statistical connections both in the studied group and in the whole population. Pearson correlation coefficients ranged from –0.12 to 0.14, and among synthetic measures from –0.03 to 0.06.

Conclusions

The vast majority of local government authorities are struggling with the proper development and protection of naturally valuable areas. The greater the share of naturally valuable areas is, the more difficult building of a local development strategy is, as development processes will require intensive support. Most of the analysed communes in the naturally valuable areas were rural one, but the level of entrepreneurship development was higher than the national average, which should be assessed positively. The existing infrastructural gap must have been fulfilled independently by the inhabitants. The researched communes had own investment capacity, but due to the scope of those needs, it was too low. The most widespread method of using naturally valuable areas is the development of tourism. However, the surveys carried out among Polish communes, indicate the limited scope of tourism development in the communes with the largest share of these areas. This development opportunity has not been effectively used.

In the authors' opinion, the obtained results indicate that a significant development of the tourist function in the most naturally valuable areas, i.e. such a level of development that will make tourism the economic base of the local economy, is not possible without external support. The appropriate financial resources in the form of non-repayable subsidies and grants are necessary here. Without this, there is a real threat that the level of protection of these areas will be reduced, and some of them will degrade. Secondly, it is necessary to implement in communes know-how to show how effectively manage these areas. Creating a catalogue of good practices combined with financial support for their implementation gives better results than waiting for bottom-up development, it was proved by the absorption of funds from the European Union. However, support should be provided firstly from

national budgets and government agencies, as the negative effects of abandoning such activities will have a national dimension, not just a local one.

The contribution of the authors

Jarosław Skorwider-Namiotko – conception, literature review, acquisition of data, analysis and interpretation of data – 60%
Anna Skorwider-Namiotko – conception, acquisition of data, analysis of data – 20%
Marianna Dębniewska – conception, interpretation of data – 20%

Literature

Bank Danych Lokalnych GUS (2017), https://bdl.stat.gov.pl/BDL/start; [30-09-2017]

Cieszewska A. (2008), *Zachowanie terenów cennych przyrodniczo w kształtowaniu struktury krajobrazu na poziomie miejscowego planu zagospodarowania przestrzennego*, "Problemy Ekologii Krajobrazu" Vol. XXI, p. 239-250

Dedeke N. (2017), *Creating sustainable tourism ventures in protected areas: An actor-network theory analysis*, "Tourism Management" No. 61, p. 161-172

Dębniewska M., Skorwider-Namiotko J. (2015), *Poziom rozwoju turystyki na obszarach przyrodniczo cennych powiatów Warmii, Mazur i Podlasia*, "Ekonomia i Środowisko" No. 4(53), p. 165-174

Dębniewska M., Skorwider-Namiotko J., Wojtowicz K. (2016), *Obszary przyrodniczo cenne jako potencjał turystyczny gmin województwa warmińsko-mazurskiego*, in: M. Jalinik, S. Bakier (eds), *Turystyka na obszarach przyrodniczo cennych*, Białystok. p. 20-42

Dobrzańska B. (2007), *Planowanie strategiczne zrównoważonego rozwoju na obszarach przyrodniczo cennych*, Białystok

Gubernat-Ulatowski E. (2016), *Potencjał finansowy i inwestycyjny a aktywność inwestycyjna jednostek samorządu terytorialnego*, "Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach" No. 294, p. 47-58

Hendel M. (2016), *Przydatność wskaźników funkcji turystycznej w ocenie rozwoju turystycznego obszaru na przykładzie gminy Ustroń*, "Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie" No. 87, p. 157-170

Jalinik M. (2016), *Zarządzanie turystyką na obszarach przyrodniczo cennych*, "Zeszyty Naukowe Turystyka i Rekreacja" No. 1(17), p. 227-238

Jarocka M. (2015), *Wybór formuły normalizacyjnej w analizie porównawczej obiektów wielocechowych*, "Economics and Management" No. 1, p. 113-126

Jurkiewicz-Karnkowska E. (2016), *Potencjalna rola obszarów cennych pod względem przyrodniczym w turystyce wiejskiej i agroturystyce na przykładzie gminy Konstantynów*, in: S. Graja-Zwolińska, A. Spychała, K. Kasprzak (eds), *Turystyka wiejska. T. 2, Zagadnienia przyrodnicze i kulturowe*, p. 70-78

Karmowska G. (2011), *Badanie i pomiar rozwoju regionalnego na przykładzie województwa zachodniopomorskiego*, "Roczniki Nauk Rolniczych. Seria G" Vol. 98, No. 2, p. 85-93

Kistowski M. (2008), *Problemy lokalizowania inwestycji na terenach cennych przyrodniczo*, "Studia BAS" No. 10

Kołodziejczyk D. (2014), *Infrastruktura w rozwoju społeczno-gospodarczym gmin w Polsce*, „Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" No. 360, p. 198-207

Krakowiak-Bal A. (2005), *Wykorzystanie wybranych miar syntetycznych do budowy miary rozwoju infrastruktury technicznej*, „Infrastruktura i Ekologia Terenów Wiejskich" No. 3, p. 71-82

Kukuła K., Bogocz D. (2014*), Zero unitarization method and its application in ranking research in agriculture*, "Economic and Regional Studies" Vol. 7 No. 3

Nowak Z. (1975), *Zastosowanie metody skalowej i agregatowej do waloryzacji regionu (na przykładzie regionu krakowskiego)*, "Zeszyty Naukowe WSE w Krakowie" No. 62, Kraków

Puciato D. (2009), *Turystyka i rekreacja na obszarach przyrodniczo cennych na przykładzie Parku Krajobrazowego Góry Opawskie*, "Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej" Vol. II No. 4 (23), p. 227-231

Skorwider J., Garbowski M. (2012), *Zmiany w potencjale inwestycyjnym gmin wiejskich i miejsko-wiejskich w Polsce*, "Studia Obszarów Wiejskich" Vol. XXIX, p. 231-246

Skorwider-Namiotko A., Skorwider-Namiotko J. (2016), *Poziom rozwoju gospodarki odpadami na obszarach atrakcyjnych turystycznie*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" No. 418, p. 311-317

Steiner F.R. (2000), *The Living Landscape: An Ecological Approach to Landscape Planning*, McGraw-Hill Professional Publishing

Szromek A. (2013), *Pomiar funkcji turystycznej obszarów za pomocą wskaźników funkcji turystycznej na przykładzie obszarów państw europejskich*, in: J. Mika, K. Zeug-Żebro (eds), *Zastosowania metod matematycznych w ekonomii i zarządzaniu*, Katowice, p. 91-103

Walesiak M. (2014), *Przegląd formuł normalizacji wartości zmiennych oraz ich własności w statystycznej analizie wielowymiarowej*, "Przegląd Statystyczny" No. 4, p. 363-372

Warczak M. (2015), *Endogeniczne i egzogeniczne czynniki rozwoju gospodarczego z perspektywy finansów gminy*, "Współczesna Gospodarka" No. 6, p. 111-121

Zawora J. (2014), *Możliwości finansowania inwestycji gmin wiejskich w Polsce*, "Stowarzyszenie Ekonomistów Rolnictwa i Agrobiznesu. Roczniki Naukowe", tom XVI, zeszyt 6, p. 554-560

Zielińska A. (2007), *Konkurencyjność obszarów przyrodniczo cennych*, in: T. Bernat (ed.), *Przedsiębiorstwo i państwo – wybrane problemy konkurencyjności*, Szczecin, p. 162-172

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TOURIST TRAILS AS AN ELEMENT OF A RURAL TOURIST PRODUCT AND THEIR POPULARITY AMONG THE INHABITANTS OF POLAND

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ABSTRACT: The article presents the results of the research on the familiarity and popularity of selected tourist trails, which are located in rural areas of Podlaskie and Mazowieckie provinces, among the inhabitants of Poland. The research (using the diagnostic survey method) covered 459 adult Poles. The selection of respondents had quota-random character. The survey sample reflects the structure of the Polish population in terms of gender and main age groups. The conducted research proved that the familiarity and popularity of tourist trails located in rural areas is very small. Therefore it is necessary to intensify the promotional activities for this type of attraction.

KEY WORDS: tourist trail, thematic trail, rural tourism

JEL: L83, Z32, Q26

Introduction

Rural tourism is a type of tourism currently developing fast and widely promoted. Besides Polish Tourist Organization high activity in this area demonstrates the Ministry of Agriculture and Rural Development, as well as the Polish Federation of Rural Tourism "Gospodarstwa Gościnne". However, it is worthy of note that rural tourism, until recently viewed through the prism of "peace and quiet", is dynamically changing its shape. The country becomes a place to perform many other functions of tourism, not only a holiday one. Increasingly accentuated and used in rural tourism products is their cognitive value. Cultural sphere of the country, with its folklore, rituals, customs and habits, remains unknown to most city inhabitants, but more and more often is something increasing curiosity and desirable. One of the more appreciated traditions of the village are often the unique and unusual regional dishes.

One of the most attractive ways to explore the cultural and natural resources of the rural areas in the author's opinion is through the thematic tourist trails. Regional and local tourist organizations are especially active in this field, because in the design, marking and promotion of particular trails and objects they see the chance of developing tourism in the area of their functioning. This process results in lot of themed hiking trails existing in rural areas.

The concept and essence of the tourist trail

In the former Polish lands, the first tourist trail, marked by signs in 1880 by Leopold Wajgel, was a trail from Krasny Łuh (Ług) to Howerla in the Czarnohora mountain range in the territory of today's Ukraine. Seven years later (1887) Walery Eliasz Radzikowski, using the cinnabar stripes, marked (first in the Tatry mountains) trail to Morskie Oko, going from the village of Zakopane through Polana Waksmundzka and Psia Trawka (Midowicz, 1986). Nowadays in Poland there are more than 79 thousand kilometers of marked hiking trails (Tourism..., 2017). In fact, there are many more, as in recent years many municipalities and various social organizations, active in the field of tourism and recreation, undertook actions to mark new tourist trails (Gospodarek, 2008).

The history of marking the tourist trails in Poland is almost 140 years old and has a tremendous impact. Despite this, there is no single and universally accepted definition of a tourist trail in scientific literature. Moreover, there is also no specific legislative act regulating this issue. For the few years, thanks

to the Ministry of Sport and Tourism, the work on the project of draft assumptions for the Act on tourist trails is in progress, however it is still a long way to sign the relevant legislation.

The most frequently cited definition of the tourist trail was suggested by the Polish Tourist and Touring Association (PTTK) in the "Guide to marking tourist trails" (2014), where it was specified that the tourist trail is path set in terrain and marked with homogenous signs (symbols), equipped with devices and informative signs, allowing tourist with average level of skills and experience its crossing regardless of season, but except extreme weather conditions. As noted by Stasiak (2006), the activists of this organization are eager to narrow the meaning of this term only to trails determined according to PTTK standards.

In a similar way the idea of tourist trail defines many other authors. Pawlusiński (2007) states that the trail is a guided tourist path, marked in the field with tables or informative signs, connecting places and objects that are attractive in terms of sight, nature or culture. Werner (2010) defines this element of the tourist space as paths being traced, uniformly marked and of adequate width, ensuring a safe passage for visitors of any skill level. Another author proposing the definition referring to PTTK's findings is Kotarski (2007), who states that the hiking trail is a path set in the field with special, unified signs placed on posts, fences, trees, buildings and other objects, which facilitates mountain, kayak, cycling, horse riding, skiing or hiking trips. Among the authors who proposed the definition of a tourist trail corresponding to the PTTK's meaning can be presented Potocki (2004), Rogalewski (1977), Rogowski (2012), Świnicka (1979), Wyrzykowski and Marak (2010), as well as Lijewski, Mikułowski and Wyrzykowski (2002) and others who, in their definitions, emphasize the necessity of marking tourist trails with appropriate signs and symbols. In a similar way, the essence of tourist routes is presented in foreign literature (e.g. Moore, Ross, 1998; Moore, Shafer, 2001; Jensen, Guthrie, 2006; Timothy, Boyd, 2014; MacLeod, 2017).

At this point mention should be made of the proposition of the definition formulated by the authors of the presuppositions to the draft law on tourist trails, who defined tourist trails as marked paths with accompanying objects, designed and adapted for a specific form of tourism, combining places, objects, natural and cultural values, settlements and other elements of space, as well as trails intended for practicing specific physical and active recreation (Assumptions to the draft of the Act on Tourist Trails 2010 after: Stasiak, Śledzińska, Włodarczyk, 2014). It should be emphasized that the existence of a trail due to those regulations is not dependent on its tracing in the field.

Similarly the tourist trail is defined by Kruczek (2005), who claims that it is every trail (not always marked), which was set in the tourist area for pur-

poses of visitors, leading to the most attractive places (sites) with a number of regulations, including, among others, those about security and values protection. Stasiak (2006) also notes that the current dynamic development of tourism is accompanied by new, previously unknown solutions. Increasingly popular are becoming the so-called virtual trails – trails not marked in the real space, but existing on tourist maps, in guides and information and promotional materials, as well as on the websites. The existence of such trail is stated only by the information boards functioning next to the particular objects. The popularity of such system is due to the fact that motorized travelers do not need the continuity of marking and the marking of long-distance trails is very expensive. Moreover, in urban space, saturated with various information carriers (signs, advertisings, posters etc.), the standard signs of the trail may easily become imperceptible. Thanks to the rapid development of mobile satellite navigation technology (GPS), traditional marking of hiking trails is often replaced by navigation systems, commonly used by mobile phones and recently even by watches. In this approach, without taking into account the necessity of marking a trail, a virtual trail is a set of places (attractions) suggested to be visited by a tourist, and the trail, order and way of travel are dependent only on the visitors' preferences. Trails organized in such way Stasiak (2006) defines as thematic ones, which serve primarily cognitive tourism, while marked tourist trails, accompanied by special signs (pictograms placed in visible for tourists spots, in a sight distance one from another) are inseparable elements of qualified tourism.

As Tomczak (2013a) notes, defining a thematic trail is possible with use of the enriched definition of a tourist trail. It is necessary to take into account the factual content, which stands as a thematic core. Such trail should create an integral whole that allows the tourist to focus on a coherent theme, through which traveler begins to perceive the crossed space. Thus, the thematic trail can be understood as an integrated and managed linear system of recreational penetration (the concept of linear systems of recreational penetration was used by Styperek (2002), who, apart from the tourist trails, also includes to this group didactic, health and walking paths.), consisted of objects representing a given subject in space, connecting them trail and elements of the accompanying offer that may be related to the subject in different ways (events, characters, stories, genius loci of the place etc.). This type of trail should make possible to cognize and understand the essence of the subject, as well as to facilitate the visitor traveling through appropriate land development (Tomczak, 2013b).

Due to the analyzed further thematic trails located in the rural areas, whose core are mostly cultural values, it is necessary to characterize here the concept of the cultural trail. In Polish literature quite broad definition of it

was presented by Gaweł (2011), who identifies such trail as a set in field and marked trail combining objects and places selected according to a clear criteria of them atisation, which moreover are an unique and representative example of the cultural heritage of a given region, community, ethnic group, national minority or nation. Through presenting the material heritage, the trail should enable cognizance and popularize the intangible heritage, treating both areas as an integral whole. It should be noted, however, that unmarked cultural trails are not included in this definition. It seems to be very debatable nowadays, as the exclusion from the circle of cultural trails of designed, but unmarked trails, which aim is to present tourists the anthropogenic values of a given area, seems to be an unreasonable action, especially due to the analysis of many existing paths.

The problem of the cultural trail was more widely defined by Puczko and Ratz (2007, p. 133), who understood it as a thematic (not necessarily marked) trail, which has a focusing point – cultural value or element of cultural heritage, with crucial role of the cultural attractions. This definition seems to be much more comprehensive and consistent with the current direction of development of this type of trails.

Functions of the thematic trails

Tourist trails are an important component of tourist infrastructure. They are considered as an element of internal communication accessibility. Stasiak (2006) notes that the tourist trail can't be seen only as a road or path with signs painted on rocks or trees. Crucial here is an additional infrastructure located along the trail and facilitating (or sometimes even enabling) visitors to penetrate the area. It consists of, among others, signposts and tables with time of passage (in the mountains) or distances (in the lowlands), information boards with a description of the trail and a topographic map of the area, places to rest or shelters in case of bad weather conditions. In many places (especially in mountain areas) there are also various types of artificial facilities, like stairs, handrails, ladders, buckles, chains etc.

Tourist trails have many functions, however among them two basic can be distinguished. The first one is realized for tourists and consists in allowing and facilitating them to visit the most interesting tourist attractions of the area. The trails are usually traced to make possible reaching the most valuable sightseeing sites (sacred and secular monuments, natural peculiarities etc.). Their course should enable to cognize interesting phenomena and participate in unusual events (e.g. related to folk culture or unique religious events). Mikos v. Rohrscheidt (2009) adds that the structure and composi-

tion of the services of a large group of trails is an important component of creating the opportunity of adventure in authentic sites, which undoubtedly has a huge impact on the overall feelings and experiences of tourists. The path of trail should also be designed in a way giving visitors a chance for aesthetic experience (e.g. the possibility to admire beautiful landscapes). It should also be noted that the important role of tourist trails should be to bring tourists to attractions important for sightseeing, but, for various reasons, less known and under-promoted. From the tourist point of view there is also another great advantage – sense of security from walking along the marked trail, with the awareness of the time of reaching the final destination. Those aspects are very comfortable for the visitors, who usually are traveling in an unknown area.

The second basic function of the tourist trails is the protective one (ecological), which means reducing the negative impact of tourism on the natural environment of the area. As noted by Stasiak (2006), it is a way of channeling tourist traffic along the traced paths, limiting or even preventing (e.g. in national parks) the penetration of tourists in areas of particular value or with little resistance to anthropopressure. Such actions allow to avoid the risk of exceeding the tourist absorbency limits of an area, what most often has a negative impact on its environment. Apart from the protective function, the trails also have another significant influence on the area, where they are located. They make local tourist offer more concrete, creating a new tourist brand for a group of places and objects located on the path of the trail (Mikos v. Rohrscheidt, 2010), which can result in controlled increase in dynamics of tourism development in a particular place. This process can be especially important for rural trails, which mostly are lacking the popular attractions that generate mass tourism, thus should attract visitors with authenticity, originality and high quality of well-promoted offer.

Purpose and research methods

The purpose of the article is to present the familiarity and popularity of selected tourist trails located in rural areas of Podlaskie and Mazowieckie provinces. The research method was a diagnostic survey with use of the survey technique. The research covered 459 adult Poles. The selection of respondents had random character. For this reason, the sample is not representative. The research tool was the survey questionnaire, filled in during the direct interviews with the respondents. The pollsters were students of full-time and part-time studies of Tourism and Recreation at WULS (SGGW) in Warsaw. They conducted the research among their families, friends and

neighbors in their hometowns in the spring of 2017. The survey consisted of 30 questions, and its structure was reflected in the analytical part of the article. The survey questionnaire was tested during pilot studies conducted among WULS-SGGW students.

Respondents' characteristics

Among the 459 respondents 52.3% were women. The largest age group was between 30 and 45 years old (29.3%). The majority of respondents were people with secondary education (42.3%). 39.2% of the respondents were residents of cities with over 200 thousand inhabitants. Details on this subject are presented on the figure 1.

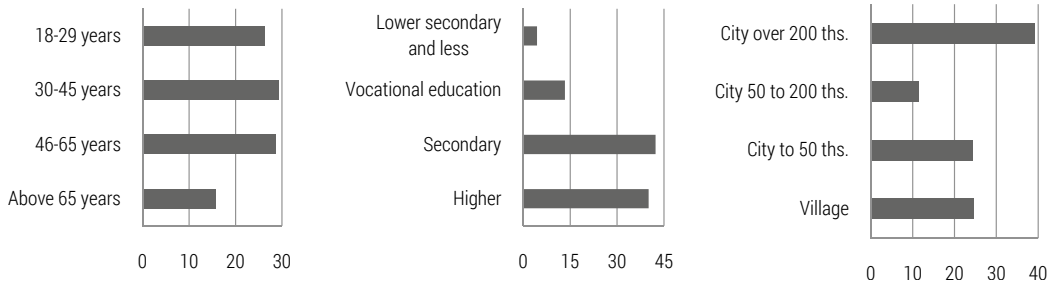

Figure 1. Age, education level and place of residence of the respondents

Source: author's own work.

Residents of all provinces were among the surveyed. However, people from Mazowieckie (43.4%), Podlaskie (12.4%) and Lubelskie (9.8%) provinces were dominant.

Results of the research

The familiarity and popularity of tourist trails in the rural areas of Mazowieckie and Podlaskie provinces among the respondents was quite diversified. The most popular trail in Mazovia was Chopin Trail, visited by almost one third of the surveyed. Also in case of this particular trail the smallest number of people, who were not aware of the existence of such trail, was observed (table 1).

Table 1. Familiarity and popularity of selected tourist trails in Mazowieckie province among the respondents [%]

	I have not heard	I heard something, but I do not know what it is	I know this trail, but I was not there	I visited this trail
Drewniane Skarby Mazowsza / ***Wooden Treasures of Mazovia***	63.0	20.9	12.0	4.1
Mazowiecki Szlak Tradycji / ***Mazovian Trail of Tradition***	68.2	18.7	10.2	2.8
Mazowsze na Filmowo / Mazovia in the film	68.4	17.9	10.0	3.7
Sakralne Perły Mazowsza / ***Sacred Pearls of Mazovia***	61.4	19.4	11.8	7.4
Szlak Bitwy Warszawskiej / ***Trail of Warsaw Battlefield***	29.8	26.8	30.3	13.1
Szlak Chopinowski / ***Chopin's Mazovia***	25.5	19.0	23.7	31.8
Szlak Folkloru i Smaków Mazowsza Mazowiecka Micha Szlachecka / ***Trail of Folklore and Taste of Mazovia Mazowiecka Micha Szlachecka***	72.3	13.9	8.7	5.0
Szlak Książąt Mazowieckich/ ***Trail of Dukes of Mazovia***	34.0	23.7	25.3	17.0
Szlak Papieski na Mazowszu / ***Papal Trail in Masovia***	42.7	24.0	20.7	12.6
Szlakiem Mazowieckich Skarbów / ***Trail of Mazovian Treasures***	67.3	18.5	10.2	3.9
Average	53.3	20.3	16.3	10.1

Source: author's own work.

Quite popular were also trails of the Mazovian Dukes and the Warsaw Battle. It is worthy of note that these three most visited trails are the projects of the Mazovian Regional Tourist Organization. realized within the framework of the Mazovian Heritage Project. The high recognition and popularity of these trails is probably a result of the extensive and intensive promotion. The remaining trails.whose originators are subjects with smaller financial capacities. were significantly less familiar and not so frequently visited.

Much less familiarity and popularity among the respondents had the trails in Podlasie province. The most frequently visited one was the Royal Oak Woods Trail in Białowieża. Its popularity is probably a result of location in the well-known and often visited Białowieża Forest. The Podlaski Stork Trail was comparatively popular to the Royal Oak Woods. while other trails had a minimal popularity among the respondents (table 2).

Less familiarity and popularity of the trails in Podlasie can be explained in some way by the peripheral position of the province. In the opinion of the author it is not without significance that on the website of the Podlaska Regional Tourist Organization (PROT) people can find information only about the Podlaski Stork Trail. This is not the only negligence on the PROT site. At the beginning of August 2017, the last change in one of the 4 main links titled Tourist Product Catalog is dated on October 2014, and the newest inscription

in the Discover Podlasie link (another of the four main links on the home page) is from November 2016. Therefore the question should be asked: what is the idea of displaying these links...? Another example of negligence in the field of promotion of the analyzed trails may be the fact that despite the two prizes awarded by PROT in the regional stage of the competition for the Best Tourist Product – POT Certificate Fairy Tale Trail of Suwalszczyzna was the least popular among the respondents. It should not surprise though, because on the official website of the trail, in the tab marked "news" there are only 2 items (both from February 2015) and one of them, named Offer of trips and green schools for 2016 is still in preparation.

Table 2. Familiarity and popularity of selected tourist trails in Podlaskie province among the respondents [%]

	I have not heard	I heard something. but I do not know what it is	I know this trail. but I was not there	I visited this trail
Baśniowy Szlak Suwalszczyzny / ***Fairy Tale Trail of Suwalszczyzna***	79.1	13.9	4.8	2.2
Carska Droga na Bagnach Biebrzańskich / ***Tsar's Road in the Biebrza Marshes***	66.9	17.9	8.7	6.5
Kraina Otwartych Okiennic / ***The Land of Open Shutters***	72.1	14.6	10.7	2.6
Kresowe Wędrówki po Podlasiu / ***BorderHiking in the Podlasie Region***	76.5	15.3	5.7	2.6
Podlaski Szlak Bociani / ***Podlaski Stork Trail***	49.9	20.3	21.8	8.1
Podlaski Szlak Kulinarny / ***PodlasieCulinaryTrail***	69.5	17.2	10.9	2.4
Podlaski Szlak Tatarski / ***Podlasie Tatar Trail***	54.2	20.7	20.7	4.4
Szlak Dębów Królewskich w Białowieży / Royal Oak Woods Trail in Białowieża	49.7	18.5	15.9	15.9
Szlak Frontu Wschodniego I Wojny Światowej / ***Trail of the Eastern Front World War I***	61.4	18.1	13.9	6.5
Szlak Tradycji Rękodzieła Ludowego Województwa Podlaskiego / ***Trail of FolkCrafts of Podlaskie Voivodship***	73.6	14.8	8.7	2.8
Szlak Walk Partyzanckich / ***Trail of PartisanFights***	64.7	19.6	12.0	3.7
Average	65.3	17.3	12.2	5.2

Source: author's own work.

Of course comment about the promotion of these trails in the web was made with reason. As it is clear from the research conducted (figure 2), the Internet for a significant majority of the respondents was a main source of information on the discussed trails.

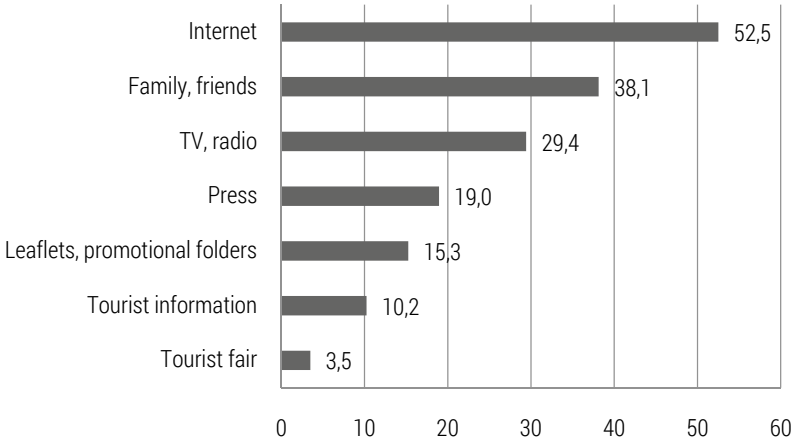

Figure 2. Sources of information on analyzed trails indicated by the respondents [%] (respondents could choose more than one answer)

Source: author's own work.

It can also be assumed that regardless of the source from which the interested groups will obtain the first information on any of the trails, for more details they will turn to the Internet. Taking into account the trails administrators care of websites, with which trails should be promoted, the chance to find the desired information, as well as to visit a particular trail by tourists, is unfortunately very low.

Conclusions

Rural areas are increasingly more attractive for tourists. Natural and cultural values of the country are eagerly discovered and visited by the inhabitants of the cities. Interesting and increasingly used form of presentation of the countryside are thematic trails, thanks to which visitors have the opportunity to get acquainted with the most interesting places or objects of visited area. However, it should be noted that despite the efforts of many organizations active in the development of rural tourism, the familiarity and popularity of this type of tourist trails is low. On average over half of the respondents were not aware of the existence of the analyzed trails in Mazowieckie prov-

ince. In case of Podlasie trails it was 2/3 of the surveyed. These results indicate the necessity to undertake extensive and intensive promotional activities to popularize such attractions in rural areas. It should also be stressed that the most accessible and widely used promotion channel, the Internet, is neglected in many cases with no particular reason. This was proven for example by checking the content of the websites of certain trails and finding the out-of-date information presented in the Internet.

As emphasized by Bogacz-Wojtanowska, Gaweł and Góral (2016), it is very important to manage trails. It should be conducive to strengthening their ties with the social environment (impact of the trail on building the cultural identity of the local community) and their professionalization (the trail treated as a tourist product, enabling the use of tangible and intangible cultural heritage). The basic task of people creating the cultural heritage trail (or entities trying to strengthen such structures) is to develop appropriate management, having a real impact on the operation of objects on the trail – the lack of such a management entity prevents any of the roles described above.

It is also worth taking into account the latest trends in creating and satisfying the needs – experience marketing and experience economy. It is precisely the emotions, sensations, impressions that a modern cultural tourist is looking for, and the heritage trails are perfectly adapted to their creation. The multitude and diversity of trails allow to create attractions that will not compete with each other and will contribute to increasing the tourist attractiveness of the region and the growth of tourism in its area.

It should be noted that the research was only aimed at recognizing the popularity and knowledge of selected trails. It seems necessary to conduct more detailed research on tourist trails in the countryside. It should be included in them elements that may increase interest in such trails, as well as to get suggestions from interested ones, that is tourists.

The contribution of the authors

Jan Zawadka –conception, literature review, analysis and interpretation of data – 50%
Joanna Pietrzak-Zawadka –conception, literature review, analysis and interpretation of data – 50%

Literature

Bogacz-Wojtanowska E., Gaweł Ł., Góral A. (2016), *Szlaki kulturowe jako medium zmian w kulturze*, Stowarzyszenie Gmin i Powiatów Małopolski

Gaweł Ł. (2011), *Szlaki dziedzictwa kulturowego. Teoria i praktyka zarządzania*, Kraków

Gospodarek J. (2008), *Bezpieczeństwo na szlakach turystycznych*, in: P. Cybula, J. Raciborski (eds), *Turystyka a prawo. Aktualne problemy legislacyjne i konstrukcyjne*, Sucha Beskidzka-Kraków, p. 275-295

GUS (2017), *Turystyka w 2016 r.*, Warszawa

Jensen C.R., Guthrie S. (2006), *Outdoor recreation in America*, Champaign

Kotarski M. (2007), *Szlaki turystyczne istotnym elementem infrastruktury turystycznej*, „Zeszyty Naukowe Almamer" No. 6(50), p. 17-23

Kruczek Z. (2005), *Polska. Geografia atrakcji turystycznych*, Kraków

Lijewski T., Mikułowski B., Wyrzykowski J. (2002), *Geografia turystyki Polski*, Warszawa

MacLeod M. (2017), *The role of trails in the creation of tourist space*,"Journal of Heritage Tourism" No. 12(5), p. 423-430

Midowicz W. (1986), *Z historii znakowania szlaków w Tatrach Polskich*, Warszawa-Kraków

Mikos v. Rohrscheidt A. (2009), *Tematyczne podróże po szlakach jako forma turystyki kulturowej*, in: K. Buczkowska. A. Mikos v. Rohrscheidt (eds), *Współczesne formy turystyki kulturowej*, Poznań, p. 384-402

Mikos v. Rohrscheidt A. (2010), *Regionalne szlaki tematyczne. Idea.potencjał. Organizacja*, Kraków

Moore R.L., Ross D.T. (1998), *Trails and Recreational Greenways: Corridors of Benefits*, "Parks & Recreation" No. 33(1), p. 69-79

Moore R.L., Shafer C.S. (2001), *Trails and Greenways: Opportunities for Planners, Managers, and Scholars*, "Journal of Park and Recreation Administration" No. 19(3), p. 1-16

Pawlusiński R. (2007), *Transport w turystyce*, in: W. Kurek (ed.), *Turystyka*, Warszawa

Potocki J. (2004), *Rozwój zagospodarowania turystycznego Sudetów od połowy XIX w. do II wojny światowej*, Jelenia Góra

Program prac legislacyjnych Rady Ministrów – lipiec-grudzień 2009 r. Założenia projektów ustaw

PTTK (2014), *Instrukcja znakowania szlaków turystycznych*, Warszawa

Puczko L., Ratz T. (2007), *Trailing Goethe. Humbert and Ulysses; cultural routes in tourism*, in: G. Richards (ed.), *Cultura tourism. Global and local perspectives*, New York

Rogalewski O. (1977), *Zagospodarowanie turystyczne*, Warszawa

Rogowski M. (2012), *Atrakcyjność turystyczna szlaków pieszych – metoda oceny*, in: B. Włodarczyk (ed.), *Turystyka – moda na sukces*, Łódź, p. 221-234

Stasiak A. (2006), *Produkt turystyczny – szlak*, „Turystyka i Hotelarstwo" No. 10, p. 9-40

Stasiak A., Śledzińska J. Włodarczyk B. (eds) (2014), *Szlaki turystyczne. Od pomysłu do realizacji*, Warszawa-Łódź

Styperek J. (2002), *Linearne systemy penetracji rekreacyjnej*, Poznań

Świnicka H. (1979), M*odele zagospodarowania turystycznego pojezierza (na przykładzie woj. koszalińskiego)*, „Miasto" No. 29(4), p. 16-19

Timothy D.J., Boyd S.W. (2014), *Tourism and Trails Cultural, Ecological and Management Issues.Channel View Publications*, Bristol

Tomczak J. (2013), *Kulturowe szlaki tematyczne Warszawy*, Warszawa

Tomczak J. (2013a), *Szlak kulinarny jako przykład szlaku tematycznego*, „Prace i Studia Geograficzne" No. 52, p. 47-62

Werner Z. (2010), *Wykorzystanie i zagospodarowanie turystyczne różnych typów środowiska geograficznego*, in: J. Wyrzykowski. J. Marak (eds), *Turystyka w ujęciu interdyscyplinarnym*, Wrocław, p. 371-410

Wyrzykowski J., Marak J. (2010), *Turystyka w ujęciu interdyscyplinarnym*, Wrocław

Małgorzata **RAUBA** • Szymon **WYSZTYGIEL**

SOCIAL PERCEPTION OF FOREST FUNCTIONS ON THE EXAMPLE OF THE MUNICIPALITY OF CZARNA BIAŁOSTOCKA

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ABSTRACT: Nowadays, forest perception is multi-layered and often very subjective. Forest can have three basic functions: economic, social and protective. These functions are of varying importance for local communities. The paper analyses the significance of particular forest functions for the inhabitants of Czarna Białostocka commune. Factors that motivate respondents to visit the forest were analyzed. The evaluation assessed, among other things, the purpose and frequency of visits to forests, the type of resources extracted from forests and for what purposes they are used. The research tool was a questionnaire consisting of 11 questions. The research was conducted in autumn 2016 among 100 inhabitants of towns and villages adjacent to the forest areas of Czarna Białostocka commune. According to the conducted interviews, for the residents of Czarna Białostocka commune, the forest is used primarily for harvesting ground vegetation such as mushrooms, fruits and herbs. To a lesser degree, it is a place of rest and recreation.

KEY WORDS: functions of the forest, ground vegetation, side forest usage, Czarna Białostocka commune

Introduction

The area of forests in Poland is 105.3 thousand ha. They are primarily public property (81%). Forest land accounts for 30.8% of the country's land area. The forest cover in Podlasie voivodeship is of similar proportions.

At the UNCED conference in Rio de Janeiro (1992) by-products of forest use were considered as a very important component of sustainable development due to their role in forest management. The great diversity of these raw materials has been taken into account, both in terms of their production and their use. It was stressed that the use of these resources, on the one hand, should be a measurable source of revenue, and on the other hand, it should be implemented in accordance with the principles of sustainable forest management.

The document issued by the Ministry of Environmental Protection, Natural Resources and Forestry, which was accepted by the Council of Ministers in 1997 under the title the Forest Policy of the State, indicates, among other things, important features of the social functions of the forest, serving the development and maintaining health, recreation and tourism in society (Polityka Leśna Państwa, 1997). Raw materials that have been sourced from the forest undergrowth for hundreds of years were and are still used by humans as food. In addition, medical properties of some raw materials have enjoyed interest and application in folk medicine. The harvested fruits of the forest served not only their own needs, but also were a source of additional income (Ankudo-Jankowska, Glura, 2013, p. 99). The Forest Law, which guarantees universal access to forest areas, also contains information on logging, the primary and dominant element of forest management. The most difficult to regulate is the side usage of forest, also known as non-timber forest use. The problem arises because harvesting often takes uncontrollable form. Non-timber forest use is also closely related to the forest's recreational function (Staniszewski, Janeczko, 2012, p. 162). Environmental pollution has increased as cities, technology and science have developed rapidly and progressively. As a result, interest in forest areas has increased in our society, especially in places with tourist attractions in the area, and it is tourism, according to Pascalias-Jakubowicz (2009), that is one of the most significant factors influencing forestry in 21st century. Forests are the main natural and landscape values in Poland, thus they constitute tourist destinations and also add attractiveness to areas located in the vicinity of forest stands (Janeczko, Woźnicka, 2014, pp. 40-41). Forests attract both the elderly and the youngest due to their social and economic functions. Everyone uses natural values in a way that suits them the most, from obtaining raw materials to landscape admira-

tion. It is undoubtedly a big advantage of forests, which makes that charming places in them will attract people for a long time.

The aim of the study was to assess what forest benefits, whether tangible or intangible, are most likely to be used by society and what is their importance in everyday life. The above objective was achieved on the basis of the analysis of surveys conducted among the residents of Czarna Białostocka commune.

Forest functions

Forest is one of the most complex terrestrial ecosystems and it is a source of ecosystem services necessary to improve human well-being, capable of meeting different needs, both material and non-material. Over the last three centuries, the global forest land has decreased by about 40% and three quarters of this loss has occurred over the last two centuries. Forest have already disappeared in 25 countries, and further 29 countries have lost more than 90% of their afforestation. Although forest cover in Europe and North America is growing after a dramatic decline in the past, deforestation of natural forests in the tropics remains at an annual rate of more than 10 million hectares per year. It is the area larger than Greece, Nicaragua or Nepal and four times larger than Belgium. In addition, the degradation and fragmentation of forest areas further aggravates the functioning of this ecosystem (MEA, 2005, p. 587). Forests play an important cultural, spiritual and recreational role in many communities. In some cases, they area a factor for the survival of entire cultures and nations.

The State Forest Policy (1997, Chapter I, p. 4) divides forest functions into ecological (protective), productive (economic) and social functions.

The ecological functions of forest consist in stabilizing the water cycle in nature, protection soils from erosion and the landscape from turning into steppe, shaping the global and local climate, stabilizing the composition of the atmosphere and its purification, creating conditions for maintaining the biological potential, enriching the diversity and complexity of the landscape, as well as improving the conditions for health and life of the population and agricultural production (Miura et al., 2015, p. 36).

Production (economic) functions are based on the fact that forest is a source of certain tangible goods, which are taken from the forest and become material natural benefits of the forest. They are aimed at maintaining the renewable and sustainable use of wood, non-wood products obtained from forests and hunting economy, the development of tourism and its related profits from the sale of aforementioned goods, as well as at creating jobs and

providing tax-funded state budged and local government budgets. Material benefits of the forests are also functions resulting from the production of by-products, that is natural non-timber benefits, such as wild game meat or hunting trophies, mushrooms, forest fruits, herbs, other parts of the undergrowth, needles, brushwood, resin, bark, Christmas trees and stump wood, which satisfy the personal needs of the population and other social, including economic, needs (Pilli, Pase, 2017, p. 82).

Social functions serve to shape favorable health and recreation conditions, enrich the labor market, foster the management of degraded areas and help create various forms of forest management by the local community, as well as contribute to the development of culture, education and science and ecological education of the society. They represent the benefits human populations derive, directly or indirectly, from forest ecosystem functions. Social functions are particularly important for rural communities living closely to forest and coastal ecosystems and for urban dwellers experiencing the impact of urban environment (Lagbas, 2018, p. 2).

All these functions depend on each other. The interest of the public in staying in forests and using their resources depends on the diversity of the forest landscape and the biodiversity of species, and this enhances the development of tourist infrastructure, which is conducive to the creation of new jobs. Studies show that forests account for about 5000 different commercial products and the forest sector brings about 2% of the global GDP (MEA, 2005, p. 588). It is estimated that forests support the livelihood of 1.6 billion people in the world and are a source of their income, for example by harvesting fruit, nuts, mushrooms, honey and medicinal plants, harvesting wood, grazing farm animals and hunting. Forests are also a source of genetic material for garden crops and trees, which can make a significant contribution to household income (www.cpfweb.org). The forest environment is therefore a perfect place not only for relaxation for people craving for contact with nature, but also for the acquisition of fruits of the forest.

The management of forest undergrowth resources is the main direction of side forest use in Poland. It is connected with non-productive forest functions, such as protective, landscape and recreational functions. The development of the recreational function of the forest is mainly related to such side effects of forest use as the collection of mushrooms and forest fruits, which apart from increasing the attractiveness of being in presence of nature, may also constitute an additional source of income (Ankudo-Jankowska, Glura, 2013, p. 100).

Legal bases for the use of forests in Poland

The basic legal act regulating the use of forests in Poland is the Act of 28 September 1991 on Forests (Dz.U. No. 101 item 444). In Poland, forest management is carried out according to a forest management plan or a simplified forest management plan. Forest management is primarily aimed at the preservation of forests and their beneficial effects on climate, air, water, soil, living conditions and human health. It is also intended to contribute to the preservation of natural balance and forest protection.

Proper forest management also leads to the protection of soils and the areas particularly vulnerable to pollution or damage and of special social importance, as well as to the protection of surface and deep-water bodies, and the retention of catchment areas, in particular in watershed areas and groundwater reservoirs. The act also stresses the productive role of forests in relation to the harvesting of wood and raw materials, as well as by-products of forest use.

Forests owned by the State Treasury are mostly accessible to the public. It is possible to harvest the forest undergrowth for own use and for industrial purposes. The harvesting of the forest undergrowth for industrial purposes requires the conclusion of an agreement with the forest inspectorate. The forest inspectorate may refuse to conclude a contract if the harvesting of the forest undergrowth threatens the forest environment. Apiaries can be set up in forests owned by the State Treasury free of charge.

Public roads in the forest can be used by motor vehicles, harnessing vehicles and mopeds. As for forest roads, road traffic is permitted only if they are marked with road signs allowing it on these roads. Horse riding in the forest is permitted only on forest roads designated by the forest inspectorate.

On the other hand, in a forest that is not our property it is forbidden:

- extracting resin or birch sap, picking cones, stripping the bark, cutting a tree or otherwise damaging it,
- collecting moss or litter,
- collecting branches, bark, wood shavings, grass, heather, cones or herbs, as well as stripping turf,
- picking mushrooms or forest fruit where it is prohibited.

In accordance with the Offences Code, a person who does not comply with these prohibitions is subject to a fine of up to 250 PLN or a reprimand. Wood in the forest may not be taken out without the consent and knowledge of the forester.

Research methods

The area of research was Czarna Białostocka commune, located in Białystok county, Podlasie voivodeship (figure 1).

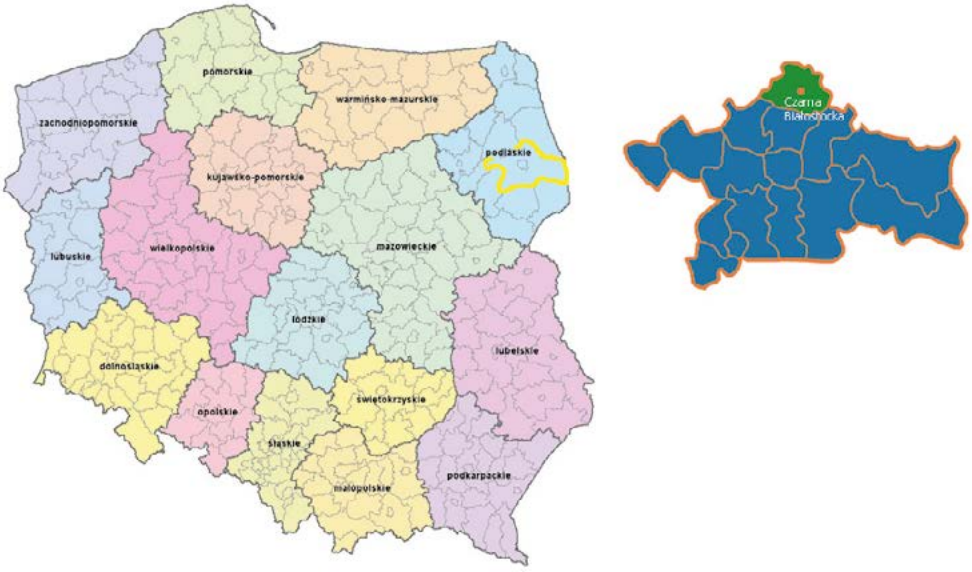

Figure 1. The location of Czarna Białostocka commune in Białystok county and on the map of Poland

Source: e-podlasie.pl, gis-support.pl [31-10-2017].

The area of the commune is 206 km^2.There are 42 localities in the commune. The population of the commune is around 12,000 people, of whom woman make up about 6,000. The largest age group are women aged 55-59. Among men the largest age group is that of those who are aged 25-34. In the commune there are many natural tourist attractions, including famous Czapielówka dam, an old guerilla camp, and the narrow-gauge railway. The commune is located in Knyszyn Forest, with nature reserves such as Budzisk, Jesionowe Góry, Karczmisko, Taboły and Krzemianka (the Central Statistical Office, data from 2014-2016).

In order to obtain data for the research, a questionnaire was conducted at the turn of September and October 2016 among the inhabitants of Czarna Białostocka commune. The research tool was a survey questionnaire consisting of 11 questions. The research was conducted using a direct interview method, in which the interviewer contacted the respondent, gave instructions to the respondent, could also supplement the questionnaire and ask supplementary questions. Open and closed questions provide information

on the reasons why respondents visit the forest, the forms of activity and the significance of forest functions in the functioning of the household. The research was conducted in the localities adjacent to forest areas such as Czarna Białostocka, Złota Wieś, Czarna Wieś Kościelna, Horodnianka, Wólka Ratowiecka, Klimki, Złotoria and Krzyżyk. 100 people participated in the survey, 58% of whom were women and 42% men.

The results of the research

The basic material benefits, which the forest gives to the inhabitants of Czarna Białostocka commune, is obtaining food, i.e. the collection of mushrooms, forest fruits and herbal raw materials. These raw materials are obtained by as much as 95% of the respondents. Mushrooms are collected by 82%, fruits by 78%, and herbs by 31% of the respondents. The inhabitants of the commune are not limited to collecting only one raw material. Depending on the season, they pick mushrooms as well as fruit and herbs. The results of these studies differ from the results obtained in the Forest Promotion Complex of Beskid Sądecki, which showed that the main motive of visits to the forest was the willingness to interact with nature, and only in the second place to obtain crops of the forest undergrowth (Janusz, Pochopień, www.humanitas.edu.pl/resources/upload/dokumenty/.../janusz%20pochopien.pdf, p. 67). The aim of the visits changes with age. Surveys conducted in Mazowiecki Landscape Park indicate that over 65 years of age, the proportion of respondents who prefer picking mushrooms is increasing (Janeczko, Woźnicka, 2014, p. 41). In the case of studies in Czarna Bialostocka commune, the age groups most likely to use this form of spending their free time are those under 20 years of age – 23% of respondents and over 60 years of age – 25% of respondents. To a large extent, the interest in picking fruits of the forest undergrowth is related to the low income in the local community. Monthly income below 1000 PLN was declared by 52% of respondents. 61% of people participating in the survey are inactive, and they are mainly pensioners. Most of the respondents use the collected raw material for their own purposes. Of the 92% of respondents who declare that they use crops of forest undergrowth for their own subsistence, 28% admit that they sell some of them. Andrzej Grzywacz in his article wrote about the utilization purpose of the mushroom picking. It turns out that individual collection and for their own use of mushrooms is carried out by 59% of pickers, and only less than 10% of them sell the gathered mushrooms at roads and in market places (Grzywacz, 2015, p. 76). This is also in line with research done in the area of Bory Tucholskie (Janeczko, Woźnicka, 2014).

According to the survey, 34% of respondents indicate that apart from the main purpose of visiting the forest, that is to pick the crops of forest undergrowth, they eagerly take advantage of attractiveness of the forest landscape and the possibility of resting in nature. Every day the forests of Czarna Białostocka commune are visited by 22% of its inhabitants. Most of them are people over 51 years of age. Twice a week the number of the inhabitants visiting forest even reaches 46%. They are people aged between 10 and over 60 years of age.

The preferences for the use of services provided by forests are also dependent on the level of education. In the group of people surveyed in Czarna Białostocka commune, 48% have primary education, 13% vocational education, 31% secondary education, and only 8% have higher education. The perception of forest functions for the group of respondents with primary, vocational and secondary education is mainly to obtain the crops of forest undergrowth – 47% in the group of people with primary education, 12% with vocational education and 30% for people with secondary education. All people with higher education indicated that the main motivating factor for them to visit the forest environment was the need for relaxation and desire to relax. On average, they use these forest benefits once or twice a week. The gender of respondents is not negligible in the perception of forest functions. The recreational function of the forest is more often used by men – 48%, than women – only 28%. On the other hand, the collection of forest undergrowth goods is carried out by both women (91%) and men (100%).

The occurrence and the possibility of obtaining of mushrooms and forest fruits also contributes to the increase of the significance of non-productive functions, and in particular of recreational function of forests. According to the survey, 38% of respondents combine the function of obtaining the crops of forest undergrowth with the recreational function provided by forest areas.

Current legal conditions guarantee the right to obtain to harvest all subsistence forest goods free of charge (the Law of 28 September 1991 on forests, article 27). One of the questions in the questionnaire concerned the opinion on the introduction of restrictions on the use of forest undergrowth resources. More than half of the respondents, as much as 68% believe that the tightening the law in that direction would lead to systematic breaking of them and public expression of dissatisfaction. For people selling those goods, the introduction of restrictions on obtaining forest undergrowth goods would limit the possibility of obtaining additional or sometimes the only possibility to earn money, as stated by 34% of respondents. A smaller part, 25% of respondents believe that it would not change anything, and people would continue to harvest forest resources they need, regardless of the current law, which could have a negative impact on the condition of forests.

Conclusions

The side use of forest, i.e. the extraction of non-wood raw materials from forests, is the most common among people living near forest areas. They extract practically everything: the crops of the forest undergrowth, animals and wood. The survey conducted in Czarna Białostocka commune, located near the forests, showed that the inhabitants visit the forest mainly in order to obtain raw materials. As much as 95% of respondents declared this form of the forest use. Only 34% of respondents use forest for purely recreational purposes. It can therefore be said that the local community by visiting forests is focused mainly on obtaining raw materials. The purely recreational function is only an added value. Due to such a high percentage of people who procure raw materials, legal restrictions on forest use become important. 34% of respondents said that this would limit the possibility of additional or sometimes the only possibility to earn money. However, 25% of respondents believed that people would continue to use the forest the same way, regardless of the fact that it is illegal.

It is therefore important that the forest use is truly sustainable. The protection of forest environment should be in line with the needs of local communities. Restrictions on forest use should be implemented in a reasonable way that allows for the coexistence of nature and humans.

The contribution of the authors

Małgorzata Rauba – conception – 100%; literature review – 50%; analysis and interpretation of data – 70%
Szymon Wysztygiel – acquisition of data – 100%; literature review – 50%; analysis and interpretation of data – 30%

Literature

Ankudo-Jankowska A., Glura J. (2013), *Znaczenie produktów ubocznego użytkowania lasu dla gospodarki narodowej*, „Prace KomisjiNauk Rolniczych i Komisji Nauk Leśnych" Tom 104, Poznań, p. 99, 100

Ecosystems and Human Well-Being, Millennium Ecosystem Assessment (2005), p. 587, 588

Główny Urząd Statystyczny (2016), *Leśnictwo*, Warszawa

Grzywacz A. (2015), *Prawne aspekty zbioru grzybów w lasach*, „Studia i Materiały CEPL w Rogowie" R. 17. Zeszyt 45/4, p. 76

Janeczko E., Woźnicka M. (2014), *Użytki leśne w zagospodarowaniu rekreacyjnym* lasu, „Studia i Materiały CEPL w Rogowie, R. 16" zeszyt 38/1, p. 40-41

Janusz A., Pochopień J. *Funkcje lasu w świetle preferencji konsumentów*, www.humanitas.edu.pl/resources/upload/dokumenty/.../janusz%20pochopien.pdf, p. 67 [31-10-2017]

Lagbas A.J. (2018), *Social valuation of regulating and cultural ecosystem services of Arroceros Forest Park: A man-made forest in the city of Manila, Philippines,* "Journal of Urban Management", https://doi.org/10.1016/j.jum.2018.09.002

Ministerstwo Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa (1997), *Polityka Leśna Państwa* Warszawa, p. 4

Miura S. et al. (2015), *Protective functions and ecosystem services of global forests in the past quarter-centur, "*Forest Ecology and Management" No. 352, p.36

Paschalis-Jakubowicz P. (2009), *Leśnictwo a leśna turystyka i rekreacja. Turystyka w lasach i na obszarach przyrodniczo cennych*, „Stud. i Mat. CEPL w Rogowie" No. 23(4), p. 29-35

Pilli R., Pase A. (2017), *Forest functions and space: a geohistorical perspective of European forests, "*iForest – Biogeosciences and Forestry" No. 11, p. 82

Staniszewski P., Janeczko E. (2012), *Problemy udostępniania lasów w kontekście użytkowania zasobów runa*, „Studia i Materiały CEPL w Rogowie, R. 14" zeszyt 32/3, p. 162

Ustawa z dnia 28 września 1991 r. o lasach, Dz.U. nr 101 poz. 444

www.cpfweb.org, SFM and the multiple functions of forests [31-10-2017]

Katarzyna ASANOWICZ

CULTURAL HERITAGE OF PODLASIE AS A FACTOR OF SOCIO-ECONOMIC DEVELOPMENT

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ABSTRACT: This paper is devoted to the cultural heritage of the Podlasie region and in particular, the intangible heritage of culinary art. Changes in the definition of "intangible heritage" and the definitions related to culinary tourism are also discussed. The area of research has been defined as the Hajnówka county. On the basis of authors research examples of traditional dishes and products and the possibility of their use in order to increase the value of economically under-invested areas are considered. In addition, the paper presents cases of similar activities undertaken in Italy and Great Britain. To conclude, a comprehensive approach of combining tangible and intangible cultural heritage is proposed.

KEY WORDS: intangible heritage, culinary tourism, culinary route

Introduction

Inhabitants of Polish cities have long been interested in the countryside, but it was only in the first half of the 19th century that architecture and folklore were systematically studied (e.g. Oskar Kolberg's research), thanks to which rural culture gained importance. According to Majewski (2000), rural tourism is a form of tourism taking place in the rural environment and using its advantages.

The main attraction is the countryside itself (its nature, culture, buildings) (Majewski, 2000). Living in a rural homestead, participating in the daily activities of its residents and observing nature can be a rich and diverse experience. An important aspect is also learning about the culture of a given region, because both elements of material and non-material legacy make up the area's "spirit". Products and dishes characterized by being prepared in traditional ways, which reach back to the distant past, can be part of this heritage. Those products are made on a small local scale, using specific skills and technologies. In rural areas, different towns usually specialise in the production of specific regional dishes. Tasting, often combined with sales of those products, may take place on an agritourism farm, at a production plant or during special events, such as festivals, fairs and farmers' markets. Thanks to this, it may be possible to preserve or recreate the methods of production of local products that promote the region. In the European Union, regional cuisine products are covered by special protection: they are seen as an important element of cultural heritage, but are also a major development factor of rural areas. In Poland, the Ministry of Agriculture and Rural Development has in 2005 initiated a list of traditional products. Products entered into this list must be of excellent quality or have exceptional features and properties which result from the use of small-scale traditional production methods and natural ingredients, over the past 25 years.

Cultural heritage protection

According to the official UNESCO definition, the term "cultural heritage" covers material heritage, which consists of immovable and movable monuments, and intangible heritage, transmitted primarily by the means of oral communication and tradition. However, at the present the scope of this concept is expanding rapidly – the largest changes are related to intangible heritage.

The origin of protecting intangible cultural heritage is the UNESCO 25th Session of the General Conference in 1989 in Paris, where a "Recommendation on the Safeguarding of Traditional Culture and Folklore" was adopted, as it was decided that the 1972 "Convention Concerning the Protection of the World Cultural and Natural Heritage" was insufficient. Traditional and folk culture was defined as a collection of products of a certain cultural community, derived from tradition, as an expression of its cultural and social identity. It has been pointed out that values are passed verbally, through imitation or by other means. In 1996, UNESCO began to develop guidelines to create national lists of "living cultural goods" to protect folk spaces or cultural areas. An important element of this work was defining the concept of the "oral heritage of humanity", which was understood as the entire intangible heritage. This led to the proclamation of Masterpieces of the Oral and Intangible Heritage of Humanity (by 2005, 90 proclamations were announced). In 2003, during the 32nd Session of the General Conference of UNESCO in Paris the "Convention for the Safeguarding of the Intangible Cultural Heritage" was adopted. Intangible heritage has been defined as practices, customs, traditions, oral communication, knowledge and skills related to nature and any associated objects or cultural spaces, which are considered by a given community as part of their heritage. This type of heritage is passed down from generation to generation and recreated by communities and groups in relation to their environment and their attitude to nature. Intangible heritage is also a source of a sense of identity and continuity for the given community (Konwencja UNESCO, 2011). As the 2003 Convention was adopted, all previous proclamations were transferred to the "Representative List of the Intangible Cultural Heritage of Humanity". Poland ratified the Convention in 2011 and the first entries to the national list of intangible cultural heritage were made in 2014. There are now 17 items on this list and only one, honey harvesting, can be related to the culinary aspect if the term was expanded to cover honey products. Currently, honey harvesting is defined as a set of practices, knowledge and traditions concerning the honey bee. Honey harvesting does not refer to the production of honey in man-made beehives, but to the traditional collecting of honey from tree hollows ("wild beehives").

Definition of culinary tourism

Researchers studying the aspects of culinary tourism point out that although it has always been an integral part of travel, there is now a growing interest in this form of leisure. There are various definitions of culinary tourism in the literature on the subject.

According to Kowalczyk, the term culinary tourism can be used to describe "all trips whose main reason is the desire to taste dishes and drinks, visit well-known restaurants and other gastronomic establishments, participate in gastronomic events, learn recipes and ways of preparing dishes, purchase products and ingredients necessary to preparing specific dishes, as well as trips to visit regions and towns that stand out in the context of culinary traditions, including the specific cultural landscape, etc."(Kowalczyk, 2016, p. 32).

On the other hand, Dominik and Zadrożna believe that culinary tourism "is not only new experiences, new tastes, learning about cultures and traditions. It is mainly the transformation of culture, nature, way of life, handicrafts and local delicacies made according to traditional recipes into a network of innovative offers in accordance with the principles of sustainable development."(Dominik, Zadrożna, 2014, p. 23). According to Wysokińska, culinary tourism is based on "domestic or foreign travelling, where the main aim is eating and enjoying the food, learning about culinary traditions and even buying local foods" (Wysokińska, 2014, p. 53-54). If we consider culinary tourism as one of the forms of cultural tourism, according to Kowalczyk, the existence of specific geographical and cultural resources is important: this includes places where food products can be produced, places for offering fresh and processed food products and a place for maintaining culinary traditions (Kowalczyk, 2016).

For tourists interested in gastronomy, places related to the cultivation of plants, the possibility of tasting products, familiarizing with production methods may be particularly attractive. With tourism come many "products", which cover a number of aspects related to meeting the needs of travellers. One such product is a tourist trail that can consist of a number of locations or facilities connected with each other by a predefined marked route (Stasiak, 2007). The growing interest in regional cuisine has resulted in the creation of many culinary routes in rural areas. These routes allow not only to preserve and protect the heritage of a given area, but they can also stimulate local development, fostering the creation of new jobs and additional sources of income. Promoting regional cuisine and traditional products increases the touristic appeal of the area and favours the influx of travellers, preventing the economic stagnation of peripheral areas.

In Poland, many culinary routes have recently been created to promote regional cuisine or products. At the initiative of the Polish Tourist Organization, a consortium of "Polish Culinary Routes" was established that promotes culinary traditions and regional products based on the values of the natural environment, culinary and cultural heritage of each region.

General characteristics of the Hajnówka county

The historical heritage of the Podlasie region has created a specific cultural landscape that is formed by urban and architectural layouts of cities, palace and garden complexes, forestry and court gardens as well as wooden rural architecture. An extremely important element of this landscape is the richness of nature, which consists of large woodlands, varied postglacial terrain as well as marshes and primeval forests unique in the European scale. Podlasie has always been a borderland area of the country and as such, to this day it is the most ethnically, culturally and religiously diverse region. Under the influence of long-term political movements, settlers arrived from the west (Catholic) and from the east (Orthodox, mainly Ukrainian and Belarusian).

Hajnówka county ("powiat") is located in the south-eastern part of the Podlasie province. From the west it borders with the Bielsko county, from the south-west with the Siemiatycze county, from the north with the Białystok county, while the eastern border is with the Republic of Belarus. The county is divided into nine municipalities: seven rural, one urban-rural (Kleszczele) and one urban (Hajnówka). The county is relatively small, with an 1624 km^2 (8% of the area of the Podlasie province) and a population of 44,600 (3.7% of the total population in the province). The average population density is 27 people per 1 km^2 (59 people for the province) and varies between the individual municipalities. The smallest density in the municipalities of Białowieża, Dubicze Cerkiewne and Narewka is only 11 people per 1 km^2. The land usage has a large impact on the wide range of population density in the area. In the north-eastern municipalities (Białowieża, Narewka and Hajnówka) forests and woodlands, part of the Białowieża Forest, cover more than half of its area (in the Białowieża area, 87.7%). The south-western part of the county is agricultural in nature.

There are many legally protected areas in the county: the Białowieża National Park, 23 nature reserves, ecological lands, and 1,164 nature monuments. In addition, large fragments of many municipalities are part of Protected Landscape Areas "Dolina Narwi" and "Puszcza Białowieska", the UNESCO Biosphere Reserve "Białowieża" and Natura 2000 "Puszcza Białowieska". The legally protected areas amount to 58.8% of the total area of the county (31.8% of the province), while forests cover 53.3% of the county (30.8% of the province).

The area that includes the Hajnówka county is characterized by low spatial diversity. For the most part it is a lowland area, with few hills, crisscrossed by river valleys and marshes. The forest complexes located in the eastern part of the area exert a significant influence on the landscape, whereas the western section is characterized by the presence of arable fields and mead-

ows. In addition to the large Białowieża Forest, there is a water and swamp complex created by the artificial Siemianówka reservoir and the upper Narew basin. The Białowieża Forest complex together with the Białowieża National Park enjoys great tourist appeal, as it is the only Polish natural area included in the UNESCO World Heritage List in 1979.

In the discussed area, the natural and cultural spaces co-exist alongside each other, and the preserved elements of cultural space testify to the historical richness of the settlement of these lands. The character of the development of the Polish-Belarusian borderland is visible in the spatial layout, which was created as a result of the planned settlement action and determined the shapes of the villages and buildings. After the land reform started in the 16th century, the buildings which quite dispersed in the past were concentrated along the street. This resulted in a very compact, rhythmic layout of the gable walls of each building facing the street, with a row of buildings on each property, often under a shared roof (i.e. the elongated farm building of the Bielsko-Hajnowski type). The traditional one-story houses were covered with Dutch gablet roof covered with straw (Żarnowiecka, 2004). Few 19th century buildings remain (although the property locations are sometimes visible to this day), as most were transformed in the interwar period and immediately after the war. At the beginning of the 20th century most of the houses were destroyed. As a result of land consolidation, the existing plots sizes have changed, which allowed for a different house orientation relative to the street and the separation of the main house from the farm buildings. The roof structure, shape and materials also changed, with the houses now being covered with tiles, contributing to the creation of a new type of homestead.

In this period, buildings were decorated on an unprecedented scale with wood boards cut into complex patterns. The greatest surge of ornamentation took place in the 1930s and later in the 1950s. Ornamental motifs appeared in the gables, on building corners, around windows, and were gradually becoming richer. Gables were decorated by laying boards at various angles; the windows – by carving top and bottom frames and adding shutters, either painted white or in two/three colours. Intricate ornaments with floral and animal motifs and genre scenes of the Podlasie cottage windows led to initiatives aimed at renewing and preserving these decorations as part of the multicultural heritage of these areas (e.g. The Land of Open Window project covers villages with unique ornamentation from the Hajnówka county: Puchły, Soce, Trześcianka).

Tourist infrastructure of the Hajnówka county

The tourist draw of the region is determined not only by the natural values and rich material culture but also by the tourist infrastructure, i.e. the tourist routes. There are 10 hiking routes and 13 bicycle routes (bicycle routes are all connected), which run along forest roads, through nature reserves, peat bogs, nature and educational paths, in river valleys and through the old forest settlements. One 25 km route connects Hajnówka and Białowieża, running through the Szafer Landscape Reserve and can be followed by car. In addition, there are routes for Nordic walking in the forest: The Białowieża Nordic Walking Park has more than 30 km across four routes along the forest paths and roads of the Białowieża Forest, with varying degrees of difficulty.

Due to the specificity of this area (national park, reserves), the limited rules for making them available to the general public mean that not all forms of tourism can be practiced in this territory. Tourist infrastructure is usually limited there to the minimum infrastructure in the form of information boards, nature paths, lookout towers. In the Hajnówka municipality the "Forest and Bison" Nordic Walking trail, a network of seven loop routes of various lengths, was laid out. The Narewka municipality also offers seven routes of over 40 km in total ("Green Land of Good Winds" Nordic Walking Park).

The cultural heritage of the area can be explored by car through the "Cultural Beauty of the Region" trails passing through picturesque villages:

- Orthodox Temples trail (164 km between Białystok and Michałowo), which promotes the Orthodox religious culture: wooden churches, chapels and votive crosses, located in the Narew (Łosinka, Chrabostówka, Narew, Trześcianka), Czyże and Hajnówka (Nowoberezowo, Dubiny) municipalities,
- Tsar's trail (35 km between Bielsk Podlaski and Hajnówka),
- "Tree and Sacrum" trail (leading through villages in the Bielsko and Hajnówka counties),
- "Land of Open Shutters" trail (16.2 km), which includes three towns with unique architecture (Puchły, Soce, Trześcianka).

Another interesting initiative is a network project called the Ethnographic Bicycle Trail of the Kleszczele municipality, leading through the villages of Dasze, Dobrowoda, Saki and Toporki. The goal of the project is "reviving life in the countryside, the use of the potential of the older generation, rebirth of tradition and its cultivation. Passing on to the younger generation (...), what life in the village looked like, as well as creating a tourist offering." (www.etnoszlak.pl). This project is implemented under the "Micro-Grants Program", conducted by the Center for the Implementation of Projects at Białowieża National Park, and funded by the European Fund for the Development of Pol-

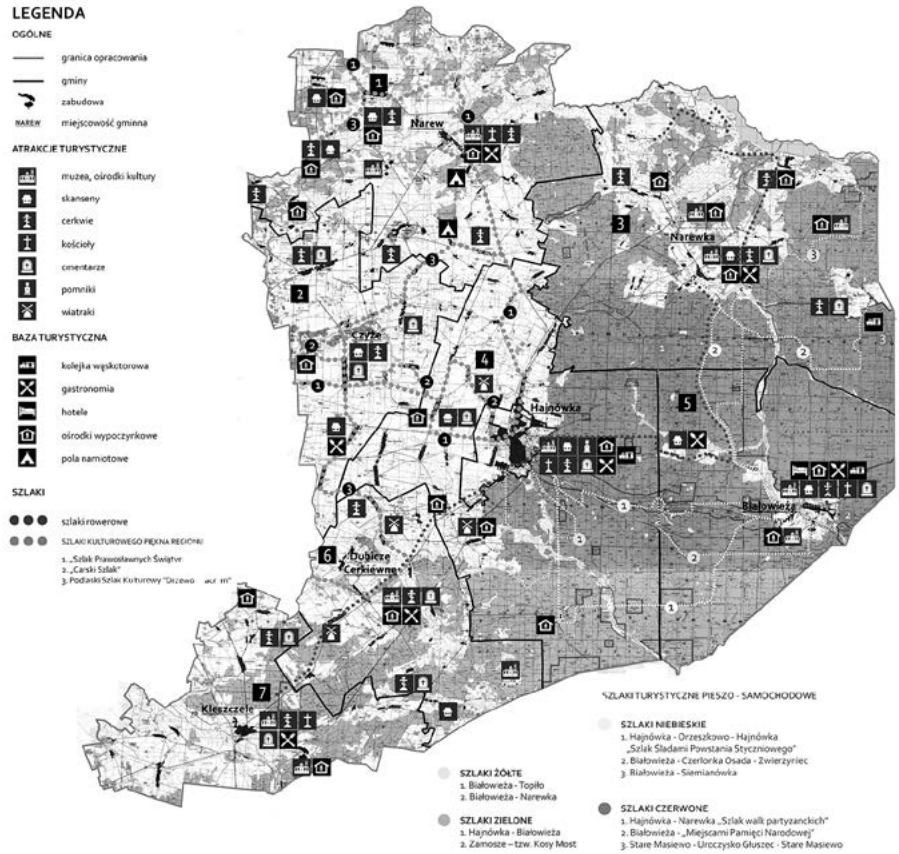

Figure 1. Culture-touristic analysis of Hajnówka County

Source: student's work Gryniewicki, Illicz, Jurak (supervisor Asanowicz).

ish Villages. As part of the project, workshops showing old traditions, including culinary traditions, are organized.

The tourism base in the region consists of 37 facilities with a total of 1383 beds (including 1164 available all-year-round). According to the data of the Białowieża Forest Tourism Centre, the number of rural tourism lodgings is relatively high. Most are in close proximity to the Białowieża Forest and there are fewer in the villages. Most of the accommodation offer beds only, but sometimes entire houses can be rented. The accommodation usually includes: a bonfire place, barbecue, playground. Gardens, orchards and presence of farm animals are rare and few facilities provide meals. In general, the gastronomic base is poorly developed. The largest number of dining options are located in Hajnówka and Białowieża. Data from the Białowieża Forest Tourism Centre shows that there is a lack of catering infrastructure in the Czeremcha and Czyże municipalities.

Culinary traditions

Some of the important traditions of the Hajnówka region include the rules and customs associated with the preparation and consumption of bread, which have been passed on from generation to generation. In this area, bread is made from coarsely ground rye flour but quite often, a mixture of boiled and riced potatoes, as well as flour made from beans, lentils or split peas was added in to increase the volume. Bread dough is usually placed on top of horseradish, sweet flag or cabbage leaves and baked in special bread ovens. The same bread dough was often used to make flat breads (e.g. "podpłomyki") or "wychopieńki", which were baked in the oven on a greased pan.

There are also many baked goods associated with the region. One of those is a "Białowieża cinnamon cake", a type of cake similar to cinnamon rolls or twisted doughnuts without any icing of filling. Another product characteristic to the Hajnówka area is "marcinek", a multi-layered cake with cream, which is a must at any large occasions or gatherings, such as weddings, baptisms or birthdays. Marcinek has been entered onto the government's traditional products list. "Busłowe Łapy", buns in the shape of stork's feet which traditionally symbolized the arrival of spring – this ritual is still observed in the village of Saki in the Kleszczele municipality.

A special regional product is the ceremonial cake – a wedding loaf ("korowaj") always served at wedding receptions. In the village of Dobrowoda (Kleszczele municipality), wedding songs and chants are sung while producing the large and small cylinder-shaped "korowaj" cakes. The cakes are usually decorated with a braid and the larger cake is also adorned with twelve rose and twelve geese shapes, surrounding a bigger rose placed in the middle, under which a coin is placed.

Many dishes of the eastern borderland of the region were also made of vegetables, initially mainly pickled cucumbers and cabbage, but later on of potatoes. Now, potato dishes, such as "potato babka" (a cake-like dish of baked grated potatoes, flour, eggs, onions and bacon, often served with double cream) and "potato kiszka" (a mixture of grated potatoes, lardons, onions and spices, produced similarly to sausages and then baked) are the most widely known. Slightly less popular are "kraszanka" (a dish of sliced potatoes with onions and spices, sautéed with lardons and then stewed), "tołkanica" (boiled and mashed potatoes with spices and bacon, baked in a clay tray) or "haluszki" (small fried dumplings – kopytka (literally "little hooves") – served with sugar and cream). Buckwheat, barley and proso millet were also common, eaten with lardons or used in various types of stuffing.

Regional meat dishes include "kumpiak", a type of cured ham which is salted and seasoned with herbs, which give it a unique taste and aroma, and

cabbage rolls ("gołąbki"), made of a mix of sauerkraut and shredded cabbage leaves.

Traditional drinks include "sołoducha" (a refreshing beverage made from rye flour), Białowieża sour-flavoured forest fruit tea and the "spirit of the forest" – moonshine of over 55% ABV, brewed in the forest.

Examples of culinary tourism solutions outside of Poland

Great Britain, Isle of Wight: "Taste Round the Island" trail

The Isle of Wight is the largest and the second most populated island in England, located on the English Channel and is 2 miles away from England's south coast. The area of the island is 384 km^2 and the length of the coastline is 92 km. Slightly more than half of the island is an area of protected landscape. Due to the very diverse landscape, it is called "England in miniature". The island's west is predominantly rural. The mild climate, beautiful landscapes and the short distance from the coast of England influenced the island's popularity and in Victorian times it started to serve as a place of leisure. It was Victorian fashion that contributed to the development of the island in the 19th century, when Queen Victoria built her summer residence, Osborne House, in East Cowes.

The Isle of Wight is an area with a great variety of local products such as beer, wine and cider, organic fruit and vegetables, and even home-made ice cream and desserts. For those who want to become more familiar with authentic culinary flavours, the "Taste Round the Island" bicycle trail has been prepared (there are over 320 km of cycle routes on the island). The theme "Taste" was added to the popular Round the Island Cycle route in 2014 as part of the Bicycle Island cycling initiative. The route begins and ends at the ferry port in Yarmouth.

Along the route there are numerous restaurants, pubs and cafes, and many of these places serve regional products. Local food producers and gastronomic stops along the route are marked as "Taste Locations", which are special gastronomic offers only available to those arriving by bike, such as free cappuccinos and cookies in the shape of a bicycle wheel or free wine tastings. The most interesting places located on the cycling route include the following:

- Freshwater, Dimbola Lodge Tearooms – the home and studio of the well-known Victorian photographer Julia Margaret Cameron, which is now a museum with an attached tea room and a gift shop.
- Fish Farm, located between the villages of Brighstone and Shorwell – a trout farm with a fishing complex, which includes a B&B.

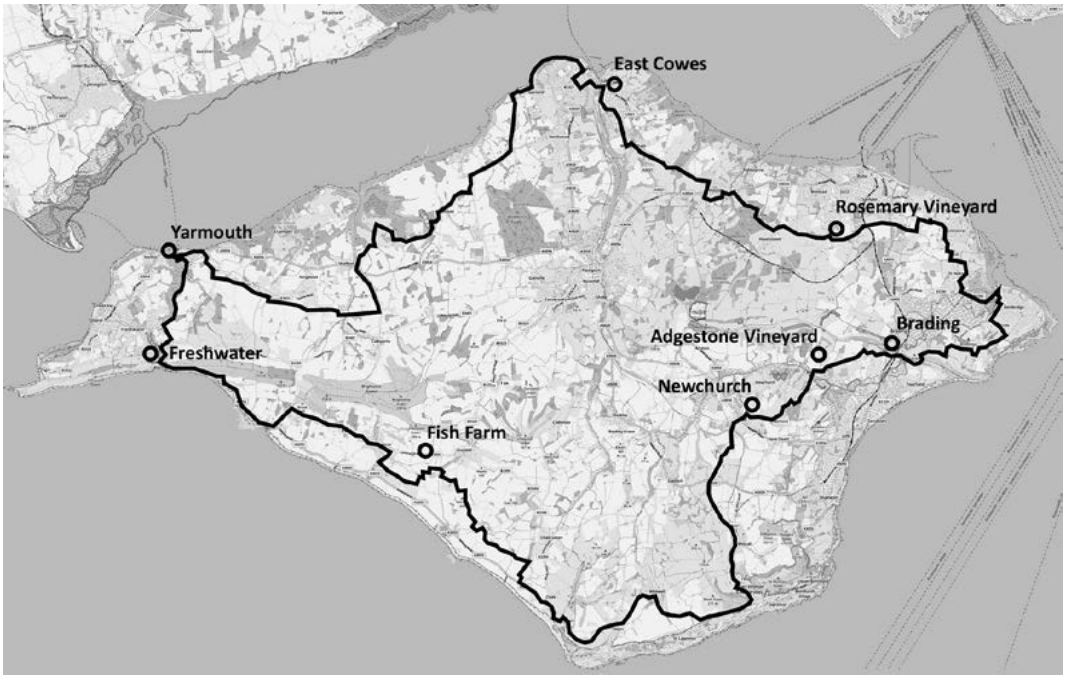

Figure 2. Cycle route on the Isle of Wight

Source: author's own work based on Open Street Map [30-11-2017].

- Garlic Farm in Newchurch – the largest garlic producer in the United Kingdom. At the farm there is a licensed restaurant and a shop that offers products made on the farm.
- Adgestone Vineyard – the oldest vineyard on the island (founded in 1968) and the only one in England with wine cellars. In the vineyard you can learn about wine production. The resort has a shop, a cafe and holiday cottages on the farm. Guests can visit vineyards and cellars as well as take part in wine tastings for free.
- Brading Station Tea Rooms in Brading Village, halfway between Ryde and Sandown stations, where the Railway Heritage Centre information point and a tea room are located.
- Rosemary Vineyard – a vineyard founded in 1986, covering an area of 12 ha. It is one of the largest producers of English wine. Tourists can visit the vineyard and learn about the process of wine production, as well as taste local products. There are also eight 8 camper stands and a shop serving lunches.
- Mrs Jones Tea Depot in East Cowes – a 1940s style cafe, serving breakfasts and lunches. As part of "Taste Locations", cyclists receive a free cake when buying a hot drink.

Italy, Marche region, Pesaro e Urbino province: "Strada del gusto"

"The Road of Flavours" (Route 26 – Strada Provinciale 26) is a project based in the province of Pesaro e Urbino, which focuses on the integration of tourism policies to promote the principles of agri-food excellence developed by the Food and Wine Department. Along the 28 km long trail, there are over 90 companies and facilities recommended by the Unione Nazionale Pro Loco d'Italia di Pesaro e Urbino. The trail connects the towns of Saltara and Sant'Angelo in Lizzola, running through the ancient villages of Cartoceto, Serrungarina, Mombaroccio and Montecicardo among olive groves, vineyards and orchards. Old customs are still strong here and traditional products are common. This tourist route not only promotes the area, but also offers an excellent gastronomic journey through places known for outstanding organically produced food and wine. Thanks to these local products, the well-being of residents increases, while fully respecting local environmental resources.

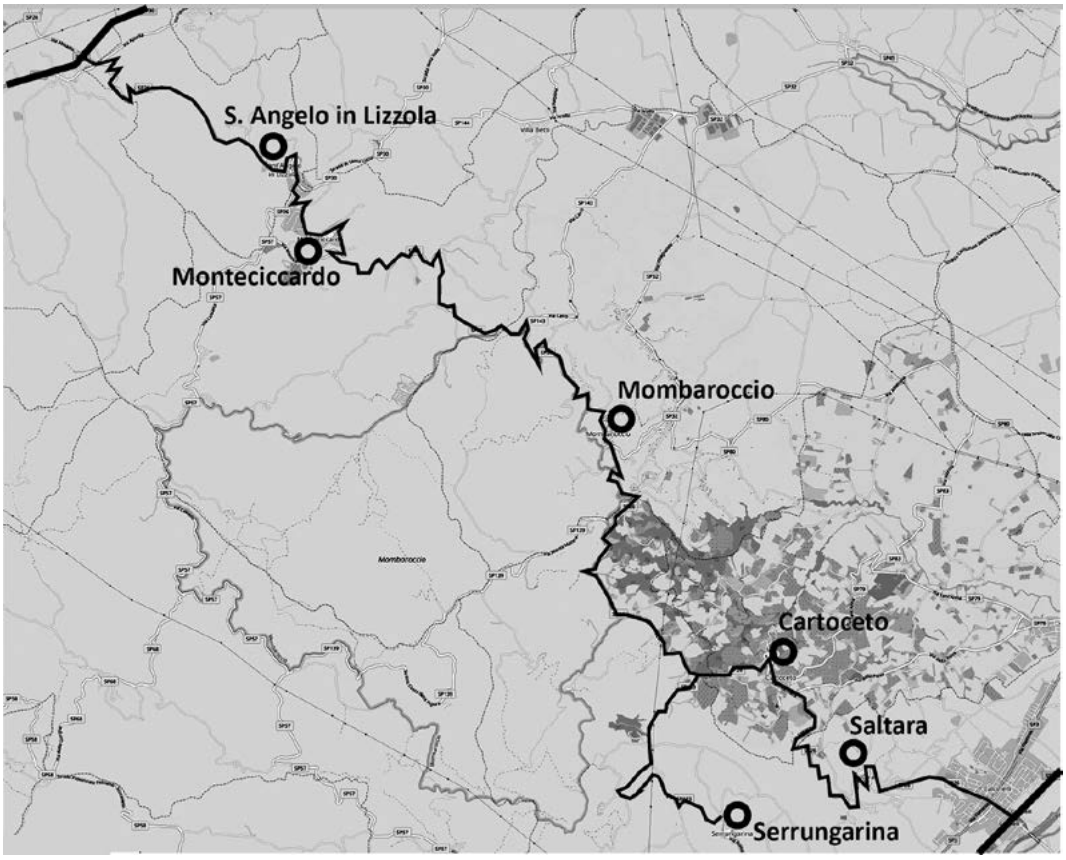

Figure 3. Strada del gusto

Source: author's own work based on Open Street Map [30-11-2017].

The region offers traditional products such as olive oil (Cartoceto DOP – the only Denominazione di Origine Protetta oil in the Marche province), cured ham (Gran Riserva dei Coli Pesaresi), cured sausages (lonzino from Sant 'Angelo in Lizzola), goat and sheep cheeses in Montecicccardo, chestnut and sunflower honey in Mombaroccio and Pera Angelica pears in Serrungarina. In addition, various events take place in the area's villages, e.g. the Mushroom Fair in Saltara, the Oil and Olive Fair in Cartoceto, the Pera Angelica Festival in Serrungarina, the Festa d'la Crescia sai Cucon festival in Mombaroccio, the Conventino festival and the Calici di Stelle wine festival in Montecicccardo.

Conclusions

An important element of rural culture is regional cuisine, as it is in rural areas that there are traditional raw materials, products made from them, dietary habits and specific ways of preparing food. The growing interest of tourists in gastronomy and food characteristic of a given region has influenced the development of culinary tourism, which as researchers note is a new phenomenon within the rural tourism market in Poland. The goal of the economic and social development of rural tourism should be to stimulate the development of farms that offer tourism services, create attractive leisure opportunities, develop the infrastructure and provide an additional source of income for farmers.

The culinary tourism examples from outside of Poland presented in this article clearly show that it is possible to use local intangible cultural resources very intensively. It is necessary to undertake actions aimed at increasing the use of local resources. While the existing network of tourist routes can be considered satisfactory, the analysis shows that special attention should be paid to the development of a gastronomic base serving regional products. Rural tourism farms should enrich their offer with regional cuisine and on the farms "thematic" crops (fruit orchards, vegetable plantations, and herbal crops) could be established. As a model, solutions such as those presented earlier in this article should be adopted, where in the settlements located on the tourist route various products, characteristic only for that location, are offered. It would greatly encourage further tourist activity in the area. In many cases, this was planned in an artificial way, creating a basis for founding new traditions.

A comprehensive approach seems to be a desirable, with a mixture of tangible and intangible heritage. In connection with the above, it is necessary to organize the action of submitting the traditional products from the

Hajnówka county onto the official government list. During the interviews conducted by the author with the inhabitants of Hajnówka, Dubiny and Narewka, eighteen characteristic culinary products were identified. Of those, only five are currently on the list of traditional products, which is due to both a low engagement of the area's municipalities and a lack of coordination at the province level.

Acknowledgements

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Literature

Centrum Turystyki Regionu Puszczy Białowieskiej, www.powiat.hajnowka.pl/ctrpb/node [30-11-2017]

Cycling on the Isle of Wight,www.nationaltrust.org.uk/features/cycling-on-the-isle-of-wight [30-11-2017]

Dominik P., Zadrożna D. (2014), *Szlak kulinarny jako produkt turystyczny*, in: P. Dominik (ed.), *Szlaki kulinarne jako element turystycznej atrakcyjności regionu Mazowsze*, Warszawa, p. 11-30

Dziedzictwo niematerialne, www.unesco.pl/kultura/dziedzictwo-kulturowe/dziedzictwo-niematerialne/ [30-11-2017]

Informacja o Projekcie Sieciowym Etnograficzny Szlak Rowerowy Gminy Kleszczele, www.etnoszlak.pl [30-11-2017]

Konwencja UNESCO w sprawie ochrony niematerialnego dziedzictwa kulturowego sporządzona w Paryżu dnia 17 października 2003 r. (2011), Dz.U. nr 172 poz. 1018

Kowalczyk A. (2016), *Turystyka kulinarna – podejścia „geograficzne" i „niegeograficzne"*, „Turystyka kulturowa" No. 5, p. 29–59

Lista produktów tradycyjnych, www.minrol.gov.pl/Jakosc-zywnosci/Produkty-regionalne-i-tradycyjne/Lista-produktow-tradycyjnych [30-11-2017]

Łapińska H., Stepaniuk M. (eds) (2003), *Dziedzictwo kulturowe. Region Puszczy Białowieskiej – wybrane zagadnienia,* Białowieża – Kamieniuki

Majewski J. (2000), *Agroturystyka to też biznes*, Warszawa

Marconi-Betka A., Sadowska-Mazur K., Włodarczyk J. (2015), *Niematerialne dziedzictwo kulturowe*, Warszawa

Orłowski D., Woźniczko M. (2015), *Turystyka kulinarna na wiejskim rynku turystycznym*,in: W. Kamińska (ed.), *Innowacyjność w turystyce wiejskiej a nowe możliwości zatrudnienia na obszarach wiejskich*, PAN, Warszawa, Vol. MCLXIII, p. 121-142

Stasiak A. (2007), *Gastronomia jako produkt turystyczny*, "Turystyka i hotelarstwo" No. 11, p. 103-132

Stasiak A. (2015), *Rozwój turystyki kulinarnej w Polsce,* in: *Kultura i turystyka – wokół wspólnego stołu*, Łódź, p. 119-149

Strada_del_gusto, www.turismo.pesarourbino.it/fileadmin/grpmnt/1177/Allegati/Strada_del_gusto.pdf [30-11-2017]

Taste Round the Island Cycle Route, www.my viewranger.com/route?details/Mjc-4MTg= [30-11-2017]

Ustawa z dnia 17 grudnia 2004 r. o rejestracji i ochronie nazw i oznaczeń produktów rolnych i środków spożywczych oraz o produktach tradycyjnych, Dz.U. nr 10 poz. 68

Województwo Podlaskie – podregiony, powiaty, gminy (2016), Urząd Statystyczny w Białymstoku, Białystok

Wysokińska B. (2014), *Elementy historyczne w tworzeniu i rozwoju szlaków kulinarnych Mazowsza*, in: P. Dominik (ed.), *Szlaki kulinarne jako element turystycznej atrakcyjności regionu Mazowsze*, Warszawa, p. 51-71

Żarnowiecka J. (2004), *Zróżnicowania regionalne zabudowy wsi jako oferta turystyczna Podlasia*, in: *Europa region turystyka. Specyfika przestrzeni regionalnej – jej ochrona, zachowanie i rozwój*, Materiały Międzynarodowej Konferencji Naukowej Białowieża 2004, p. 182-186

DISCUSSION AND REVIEWS

RECENZJE OMÓWIENIA, PRZEGLĄDY

Sławomir **SNARSKI** • Marek **MARTYNIUK**

ANALYSIS OF APPEAL PROCEDURE FOR CO-FINANCING OF ENVIRONMENTAL PROJECTS UNDER REGIONAL OPERATIONAL PROGRAMME FOR PODLASKIE VOIVODESHIP 2007-2013

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ABSTRACT: The purpose of the paper was to examine the effectiveness of the appeal procedure for co-financing of environmental projects within the framework of the Regional Operational Programme for Podlaskie Voivodeship 2007-2013. The analysis was based on the secondary data of the Podlaskie Voivodeship Marshal's Office and the literature covering the research area. The results of research indicated that the appeal procedure concerning the process of application for the co-financing of projects under Priority Axis V. Development of infrastructure for environmental protection of the programme proved to be a low effective mechanism of verification of the correctness of projects' assessment.The paper comprises the first detailed analysis in the existing body of literature of the effectiveness of the appeal procedure concerning environmental projects, which may constitute a valuable diagnostic tool in defining the scope of the evaluation of other EU-funded regional programmes in future financial perspectives.

KEY WORDS: European funds, environmental projects, appeal procedure

Introduction

A significant increase in investments for environmental protection constituted one of the direct consequences of Poland's accession to the European Union. In the 2007-2013 programming period, European funds were the main source of financing for environmental projects in the country (Barczak, Kowalewska, 2014; Karpińska, 2007). An inherent part of the implementation of the EU cohesion policy in Polish regions were regional operational programmes (Kornberger-Sokołowska, 2012). Efficient use of financial resources from these programmes was determined by the establishment of effective procedures of the assessment and selection of submitted project proposals. Of particular importance in this regard was the establishment of a proper appeal procedure forming a mechanism for verifying the correctness of the assessment of submitted documents (Perkowski, Martyniuk, 2017). Therefore, in order to contribute to a reduction of the development disparities between Podlaskie Voivodeship and other regions of Poland, as well as to make environmental infrastructure conform with the legal constraints of the European Union, the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 (hereinafter referred to as "the programme") was introduced.

The programme was approved by the Board of Podlaskie Voivodeship on 9 November 2007 through Resolution No. 46/599/07. It was one of the instruments for achieving the goals of the National Strategic Reference Framework 2007-2013 – a document defining national priorities and the allocation of a substantial part of European funds under the cohesion policy in the 2007-2013 financial perspective (Perkowski, 2010a). According to the teleological provisions of the Podlaskie Voivodeship Development Strategy 2020 of 30 January 2006, the preservation of the natural environment was recognized as one of the main strategic objectives of the region's development. Therefore, the Board of Podlaskie Voivodeship, performing the function of the Managing Authority of the programme, established Priority Axis V. *Development of infrastructure for environmental protection* and allocated an amount of PLN 484.2 million to support the maintenance and improvement of the quality of the natural environment by part-financing the eligible costs of 249 projects in this field. However, in accordance with the information disclosed by the Podlaskie Voivodeship Marshal's Office in Bialystok, within the same priority axis as many as 205 grant applications of a total value of PLN 1,137.9 million were rejected by the Managing Authority. Taking into consideration the amount of funds disbursed on environmental protection in the region and the rejection of such a considerable number of project proposals,

the purpose of this paper was an attempt to verify the effectiveness of the appeal procedure for co-financing of environmental projects under the programme.

An overview of the literature

The paper comprises the first in the existing body of literature detailed analysis of the effectiveness of the appeal procedure for co-financing of environmental projects under the programme. While an analysis of the availability of European funds is a popular subject matter in the scientific literature, numerous questions with respect to the principles for evaluation, and the selection and award criteria concerning environmental projects in Poland remain unanswered. Therefore, the research was conducted in order to bridge the gap in this regard. The existing scientific studies relevant to environmental protection or the support for environmental projects under the programmes financed from the budget of the European Union do not constitute a detailed analysis due to their general nature or introductory character. For instance, Lejcyk andPoździk performed a general assessment of the complexity of procedures for obtaining EU financial support in the period 2007-2013 in Poland, including projects aimed at increasing environmental protection (Lejcyk, Poździk, 2010). Perkowski, in turn, dealt with only theoretical aspects of the appeal procedure employed under the European financial instruments, including the programme, mainly in the context of the Polish implementation system (Perkowski, 2010b). As for Szubiakowski, it should be indicated that in his study concerning the proceedings on allocation of funds under the EU development policy and judicial review in such matters, he did not use any examples of specific operational programmes (Szubiakowski, 2009). Considering the idea of the third-generation administrative procedures, based on the example of proceedings for co-financing of projects under operational programmes, Kmieciak in his research completely omitted the impact of the appeal procedure on the implementation of environmental projects (Kmieciak, 2015). Suwaj and Perkowski discussed, among others, the practical aspects of the appeal procedure under the structural funds. However, they focused primarily on the concept of prevention of inactivity in administrative proceedings in Poland (Suwaj, Perkowski, 2010). Łacny, on the other hand, focused on largely theoretical study of protection of fundamental rights in the field of spending European funds within operational programmes in general (Łacny, 2015).

Research methods

The disbursement of significant funds from the EU budget under the programme in Podlaskie Voivodeship, accompanied by the rejection of a large number of applications for co-financing of environmental projects, raised the following research questions: Did the process of selection of submitted applications provide the applicants with an effective appeal procedure in order to objectively assess project proposals and to select the best of them? How many of the submitted protests and applications for reconsideration were approved? Did the appeal procedure constitute an effective instrument of verification of the quality assessment of submitted project proposals, or was it intended to affirm the earlier decisions made in the interest of the Managing Authority? These questions and dilemmas prompted an analysis of the effectiveness of the appeal procedure in the field of applying for funding of environmental projects within the framework of the programme.

Therefore, the paper contains a description of general rules and conditions governing the implementation of environmental projects under the programme's Priority Axis V. *Development of infrastructure for environmental protection.* Moreover, it describes the appeal procedure within the programme applicable to competitive calls for proposals conducted in the field of the environment in an attempt to determine the degree of its effectiveness. In the paper nonreactive research methods were followed, consisting of an analysis focusing on the contents of the existing documents. The analysis was based on the literature covering the research area and the secondary data collected by the Podlaskie Voivodeship Marshal's Office in Bialystok – mainly in the form of programme documents, aggregated reports on the implementation of the programme, as well as the data disclosed in accordance with art. 10§1 of the Act of 6 September 2001 on Access to Public Information (Journal of Laws of 2016 item 1764 as amended). Despite the generally deductive character of the deliberations undertaken in this paper, the analysis of detailed information was performed using inductive inference.

Results of the research

The core objective of the programme was to increase economic growth and create new non-agricultural workplaces while preserving the natural and cultural heritage of the region. The aforementioned objective was being achieved by means of three specific objectives, including the third specific objective, *id est* the development of tourism with the use of natural and cultural heritage. With respect to the programme's assumptions, the practical

implementation of this specific objective was ensured by supporting investments inenvironmental infrastructure for regional or local impact (Sierak et al., 2016). The total indicative budget of the programme amounted to EUR 792.2 million, including EUR 672.5 million from the European Regional Development Fund. The programme was comprised of seven priority axes covering the scope of intervention at the regional level (table 1).

Table 1. Indicative financing plan for the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 for the whole programming period [EUR]

Priority axis No.	Title of priority axis	% of financial resources allocated to implementation of priority axis	Financial allocation [EUR]
Priority Axis I	Increase of innovation and support of entrepreneurship in the region	23	156 965 734
Priority Axis II	Development of transport infrastructure	32	216 279 961
Priority Axis III	Tourism and culture development	15	99 263 261
Priority Axis IV	Information society	8	50 896 631
Priority Axis V	Development of infrastructure for environmental protection	11	75 455 876
Priority Axis VI	Social infrastructure development	8	50 896 631
Priority Axis VII	Technical assistance	3	22 784 877
Total		**100**	**672 542 971**

Source: authors' own work based on www.rpowp.wrotapodlasia.pl [06-06-2017].

The priority axis, which to the greatest extent focused on the maintenance and improvement of the quality of the natural environment was Priority Axis V. *Development of infrastructure for environmental protection*. It comprised two measures: 5.1. *Development of regional infrastructure for environmental protection* and 5.2.*Development of local infrastructure for environmental protection*. The main beneficiaries of the aforementioned measures were: regional and local authorities, state administration, the State Forests National Forest Holding, national and landscape parks, non-governmental organizations, as well as entrepreneurs.

In compliance with the provisions of the Detailed Description of Priority Axes of the Regional Operational Programme for Podlaskie Voivodeship 2007-2013, under Measure 5.1 preference was given to investments related to improving solid waste management, including landfill reclamation and installations for the disposal of hazardous waste. Moreover, the measure promoted initiatives aimed at the preservation of biodiversity, ecological educa-

tion, monitoring of environmental conditions and preventing environmental threats, as well as the purchase of equipment for the services responsible for the liquidation of the consequences of natural hazards and major accidents (Snarski, Martyniuk, 2016). During the period of the implementation of the programme, within the framework of the measure 11 calls for proposals were conducted under which 54 projects were approved for implementation of a total value of PLN 231,683,876.77, including PLN 155,582,768.42 of the contribution from the programme, as shown in table 2.

Table 2. Project proposals selected for co-financing under Priority Axis V. *Development of infrastructure for environmental protection* of the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 [PLN]

Measure	Number of applications	Total value	Eligible expenditure	Total public contribution
5.1	54	231,683,876.77	210,365,773.93	155,582,768.42
5.2	195	544,696,652.93	487,865,096.49	328,624,293.76
Total for Priority Axis V	**249**	**776,380,529.70**	**698,230,870.42**	**484,207,062.18**

Source: authors' own work based on the data from the Podlaskie Voivodeship Marshal's Office in Bialystok of 22 March 2017, reference DEFRR-VI.1431.4.2017.

The scope of support of Measure 5.2.*Development of local infrastructure for environmental protection* covered investments focusing on the development of water and sewage management, with particular emphasis on the extension of the sewerage network and water distribution systems, providing agglomerations below 15 thousand PE (population equivalent) with sewage systems and sewage treatment plants, as well as protection of municipal water intakes. In addition, support could be granted for projects related to the development of renewable energy sources and thermo-modernisation of public buildings (Snarski, Martyniuk, 2016). In the years 2007-2015, the Managing Authority launched 14 competitive calls for proposals within the measure, while 1 grant application was classified as an individual key project and received support outside a competitive tendering procedure in the form of a direct grant. In the reference period, as many as 195 grant applications were approved for co-financing by the Managing Authority. The total amount of funding provided within the measure amounted to PLN 328,624,293.76 (table 2).

Table 3. Project proposals rejected under Priority Axis V. *Development of infrastructure for environmental protection* of the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 [PLN]

Measure	Number of applications	Total value	Eligible expenditure	Total public contribution
5.1	43	169,333,756.12	142,640,421.53	102,788,456.24
5.2	162	968,580,567.91	792,371,777.05	490,786,191.69
Total for Priority Axis V	**205**	**1,137,914,324.03**	**935,012,198.58**	**593,574,647.93**

Source: authors' own work based on the data from the Podlaskie Voivodeship Marshal's Office in Bialystok of 22 March 2017, reference DEFRR-VI.1431.4.2017.

Interestingly, according to the Interim Implementation Report of Regional Operational Programme for Podlaskie Voivodeship 2007-2013 for the 1st Half of 2015, Priority Axis V, as compared to other axes of the programme, had one of the lowest levels of fulfilment of obligations towards the European Union in the implementation period, *id est* 99,21%. Nevertheless, the Managing Authority rejected as many as 205 project proposals of a total value of PLN 1,137,914,324.03, as presented in table 3.

The scope of the appeal procedures within the implementation system of the EU cohesion policy in Poland, including Podlaskie Voivodeship, was regulated by the Act of 6 December 2006 on the Principles of the Development Policy Making (Journal of Laws of 2016 item 383 as amended). On this basis and in accordance with the relevant guidelines of the Minister of Regional Development, the Managing Authority of the programme specifically identified the types of legal remedies available to the applicants during the conduct of assessment of their project proposals and the appeal procedure (Suwaj, Perkowski, 2010). It is noteworthy that the appeal procedure within the programme, aimed at ensuring the possibility of verifying the accuracy of the assessment of projects, was applicable only to the projects selected through competitive calls for proposals. The procedure consisted of two stages: the pre-trial stage and the stage of the proceedings before the administrative courts.

In accordance with the rules of the programme's implementation system, in the case of a negative assessment of a project, at the pre-trial stage an applicant was entitled to lodge to the Managing Authority the following legal remedies: a protest (the first pre-trial stage) and an application for reconsideration (the second pre-trial stage). In the initial phase of the implementation of the programme, protests were dealt with by the Governor of Podlaskie Voivodeship and were lodged through the Department for Regional Operational Programme Management of the Podlaskie Voivodeship Marshal's Office. In the case of calls for proposals announced after 20 December 2008

under the provisions of the Act of 7 November 2008 on Amending Certain Acts in Connection with the Implementation of the Structural Funds and the Cohesion Fund (Journal of Laws No. 216 item 1370), the Department for Regional Operational Programme Management of the Podlaskie Voivodeship Marshal's Office was the institution responsible for considering protests, and applications for reconsideration were considered by the Department of Regional Policy of the aforementioned office.

The negative assessment of the project could involve both formal and quality assessments. If at any stage of the appeal procedure the allocation for the implementation of the measure was exhausted, the Managing Authority simply left a protest or an application for reconsideration of the case without consideration. An appeal by the applicant did not result in holding the contract procedures concerning the applicants whose projects were recommended for co-financing (Perkowski, 2010b). If the result of the re-assessment of an application for funding was positive, *id est* entitling to qualify for implementation, the project was placed on the list of positively assessed projects. This meant, however, only a conditional declaration of its co-financing by the Managing Authority (Perkowski, Martyniuk, 2017). Furthermore, if at any stage of the proceedings regarding the appeal procedure the allocation for the implementation of the measure or priority was exhausted, the Managing Authority left a legal remedy without consideration.

After the exhaustion of the pre-trial appeal procedure, the applicant could lodge a complaint to a competent administrative court, *id est* in the case of the programme – to the Voivodeship Administrative Court in Bialystok. The possibility of lodging a complaint depended on exercising the available legal remedies at the pre-trial stage of the appeal procedure. As a result of consideration of the complaint, the court could: uphold the complaint, dismiss the complaint or discontinue the proceedings.

From the judgment before the Voivodship Administrative Court, both the applicant and the Managing Authority could bring a cassation complaint to the Supreme Administrative Court in Warsaw. The statement by the court during the appeal indicating that the assessment of the project was carried out in a way that violated the law resulted in the need of repeating the assessment (Łacny, 2015). In such a situation, the Managing Authority was obligated to re-review the assessment procedure. The final judgment of the administrative court, involving the dismissal of complaint, rejecting the complaint or leaving the complaint without consideration, ended the appeal procedure and the procedure for the selection of projects (Kmieciak, 2015). Of great importance was the fact that the scope of the judicial review exercised by the administrative courts concerned only examining whether the assessment of the application for funding was carried out in compliance with

the law (Szubiakowski, 2009). The review did not address the quality assessment of a project according to the selection criteria approved by the Monitoring Committee of the programme.

The scope of the appeal procedure, especially in the initial phase of its implementation, put the applicants in a situation of the lack of experience, limited allocations and the lack of clear guidance on the interpretation of the applicable regulations (Perkowski, 2009). All these negative factors were reflected in the practical application of the appeal procedure by the Managing Authority in terms of setting up the system for selection of environmental projects within Priority Axis V. *Development of infrastructure for environmental protection* of the programme. Figure 1 below illustrates the effectiveness of protests and applications for reconsideration lodged under the priority axis for the whole programming period, broken down by measures.

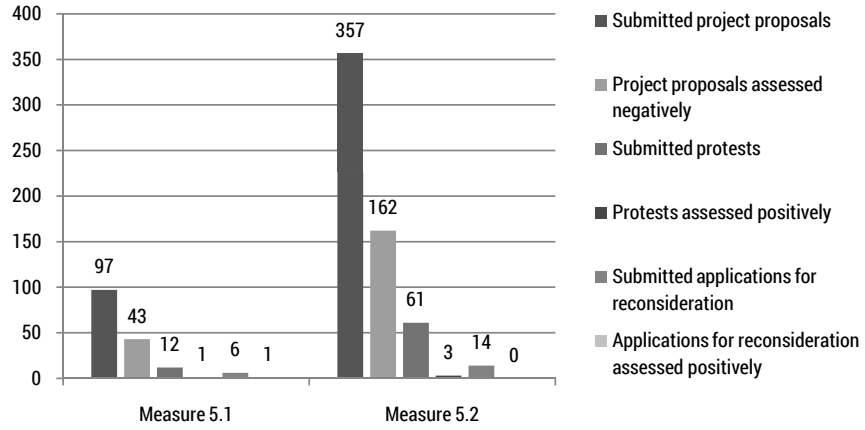

Figure 1. Effectiveness of protests and applications for reconsideration lodged under Priority Axis V. Development of infrastructure for environmental protection of the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 (breakdown by measures)

Source: authors' own work based on the data from the Podlaskie Voivodeship Marshal's Office in Bialystok of 22 March 2017, reference DEFRR-VI.1431.4.2017.

According to the data presented in figure 1 above, within Measure 5.1.*Development of regional infrastructure for environmental protection* 43 project proposals (of a total value of PLN 169,333,756.12) failed to pass the formal and quality assessment thresholds. In this regard, the applicants lodged 12 protests, which resulted in the decision of the Managing Authority to include only 1 of them (of a total value of PLN 1,747,909.04) on the list of projects assessed positively. Detailed information obtained from the Podlasie Voivodeship Marshal's Office in accordance with the procedure stipulated by

the Act on Access to Public Information indicates that within the framework of 11 calls for proposals conducted in the programming period as few as 6 applications for reconsideration (of a total value of PLN 16,469,768.41) were submitted by the applicants and only 1 of them (of a total value of PLN 3,401,954.09) was positively assessed by the Managing Authority.

A slightly worse situation in terms of the efficiency of the appeal procedure was noted in the case of Measure 5.2. *Development of local infrastructure for environmental protection*. During 14 calls for proposals, the Managing Authority considered that as many as 162 projects (of a total value of PLN 968,580,567.91) did not correspond to the formal and quality assessment criteria. Within the framework of the appeal procedure, 61 protests were lodged (of a total value of PLN 379,594,526.65), of which only 3 (of a total value of PLN 3,337,575.00) were considered eligible by the Managing Authority. As far as the second pre-trial stage of the appeal procedure was concerned, the applicants submitted 14 applications for reconsideration, none of which ended in putting a project proposal on the list of projects assessed positively (figure 1).

According to the information provided by the Podlaskie Voivodeship Marshal's Office, neither of the applicants under Priority Axis V. *Development of infrastructure for environmental protection*, who initiated the pre-trial stage of the proceedings, decided to submit a complaint to the Voivodeship Administrative Court in Bialystok. Therefore, it can be concluded that the judicial phase of the appeal procedure was not applicable in the case of co-financing projects in the field of environmental protection from the resources available under the programme.

Conclusions

As a rule, the appeal procedure within the programme aimed at ensuring the possibility of verifying the accuracy of the assessment of project proposals. Hence, the main objective of the procedure, functioning in the form of specific provisions of the system of implementation of the programme, was to provide the applicants with sufficient legal protection against a non-objective conduct of assessment of their project proposals. The protection under this instrumentwas also applicable to environmental projects selected through competitive calls for proposals. On the basis of the results of the analysis of the appeal procedure within Priority Axis V. *Development of infrastructure for environmental protection* of the programme it can be stated that it proved to be a low effective mechanism of verification of the correctness of projects' assessment.

Taking due account of the appeal procedure, the applicants were entitled to use the mechanism of verification consisting of two stages: the pre-trial

stage and the stage of the proceedings before the administrative courts. In the case of failure of the provisions for appeal, the Managing Authority could finance subsequent projects from a reserve list. A significant disadvantage of the appeal procedure consists in the fact that even in the case of a positive outcome of the remedy, an applicant had no guarantee that his project would be involved in the distribution of the European Union funds under the programme. In such cases the project was put on the list of projects assessed positively, receiving only a conditional declaration of its co-financing (Perkowski, Martyniuk, 2017). Furthermore, an appeal by the applicant did not result in holding by the Managing Authority the contract procedures concerning the other applicants, whose projects were recommended for co-financing. In a situation where at any stage of the appeal procedure the funds for the implementation of a measure were exhausted, the Managing Authority simply left a legal remedy without consideration.

Importantly, none of the applicants under Priority Axis V. *Development of infrastructure for environmental protection* of the programme decided to exercise their right regarding the use of the judicial stage of the appeal procedure involving the proceedings before the competent administrative courts. However, there is still a degree of uncertainty in relation to the potential effectiveness of this mode of appeal for the reason that the eventual judgment would not concern the issue of the quality assessment of a project proposal, which basically constitutes the essence of the assessment process. The efficiency of the procedure of assessing applications for funding could not yet be considered to be of superior importance compared to the fairness and objectivity of the assessment itself. For these reasons, the appeal procedure in the field of applying for co-financing of environmental projects within the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 was largely ineffective.

The contribution of the authors

Sławomir Snarski – concept and objectives, literature review, research – 50%
Marek Martyniuk – concept and objectives, literature review, research – 50%

Literature

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

Karpińska J. (2007), *Finansowanie ochrony środowiska w Polsce ze źródeł europejskich w aspekcie okresu programowania 2007-2013*, „Zeszyty Naukowe SGGW w Warszawie – Problemy Rolnictwa Światowego" No. 2(17), pp. 342-351

Kmieciak Z. (2015), *Idea procedur administracyjnych trzeciej generacji (na przykładzie postępowania w sprawach dofinansowania projektów w ramach programów operacyjnych)*, „Państwo i Prawo" No. 5, pp. 3-18

Kornberger-Sokołowska E., Zdanukiewicz J., Cieślak R. (2012), *Jednostki samorządu terytorialnego jako beneficjenci środków europejskich*, Warszawa

Lejcyk M., Poździk R. (2010), *Fundusze unijne. Zasady finansowania projektów ze środków unijnych w Polsce w latach 2007-2013*, Lublin

Łacny J. (2015), *Ochrona praw podstawowych w wydatkowaniu funduszy Unii Europejskiej*, „Państwo i Prawo" No. 12, pp. 25-45

Perkowski M. (ed.) (2009), *Monitoring procedury odwoławczej w systemie wdrażania funduszy europejskich*, Białystok

Perkowski M. (ed.) (2010a), *Prawo zarządzania projektami finansowanymi z funduszy europejskich*, Warszawa

Perkowski M. (ed.) (2010b), *Procedura odwoławcza w systemie wdrażania funduszy europejskich*, Warszawa

Perkowski M., Martyniuk M. (2017), *Niedoskonała procedura odwoławcza w systemie realizacji unijnej polityki spójności w Polsce. Ocena wykonania wyroku Trybunału Konstytucyjnego z 12 grudnia 2011 r. (P 1/11)*, „Zeszyty Naukowe Sądownictwa Administracyjnego" No. 3, pp. 37-60

Sierak J. et al. (2016), *Efekty wykorzystania dotacji unijnych w ramach regionalnych programów operacyjnych w latach 2007–2013. Część 2. Województwa Polski Wschodniej i Centralnej*, Warszawa

Snarski S., Martyniuk M. (2016), *Efekty wsparcia projektów z zakresu ochrony środowiska w ramach Regionalnego Programu Operacyjnego Województwa Podlaskiego na lata 2007-2013*, in: M. Jalinik, S. Bakier (eds), *Turystyka na obszarach przyrodniczo cennych. Potencjał obszarów przyrodniczo cennych*, Białystok, pp. 136-147

Suwaj R., Perkowski M. (2010), *Koncepcja zapobiegania bezczynności w postępowaniu administracyjnym*, Białystok

Szubiakowski M. (2009), *Postępowanie w sprawie rozdziału środków w ramach polityki rozwoju oraz sądowa kontrola w tych sprawach*, „Zeszyty Naukowe Sądownictwa Administracyjnego" No. 4, pp. 31-39

Urząd Marszałkowski Województwa Podlaskiego (2016), *Regionalny Program Operacyjny Województwa Podlaskiego na lata 2007-2013*, Załącznik Nr 1 do uchwały Nr 149/1923/2016 Zarządu Województwa Podlaskiego z dnia 19 lipca 2016 r., http://www.rpowp.wrotapodlasia.pl/private/upload/tinymce/File/zalacznik_1_program_po_decyzji.pdf [28-05-2017]

Urząd Marszałkowski Województwa Podlaskiego (2015), *Sprawozdanie okresowe z realizacji Regionalnego Programu Operacyjnego Województwa Podlaskiego na lata 2007–2013 za I półrocze 2015*, http://www.rpowp.wrotapodlasia.pl/private/upload/file/e270232dc8ea51619323c845f19d3194.pdf [06-06-2017]

Urząd Marszałkowski Województwa Podlaskiego (2006), *Strategia Rozwoju Województwa Podlaskiego do 2020 roku*, Załącznik do Uchwały Nr XXXV/438/06 Sejmiku Województwa Podlaskiego z dnia 30 stycznia 2006 r., http://www.strategia.wrotapodlasia.pl/pl/strategia/wa_ne_dokumenty.htm [06-06-2017]

Zarząd Województwa Podlaskiego (2016), *Szczegółowy opis priorytetów Regionalnego Programu Operacyjnego Województwa Podlaskiego na lata 2007-2013*, Załącznik Nr 1 do Uchwały Nr 119/1409/2016 Zarządu Województwa Podlaskiego z dnia 23 lutego 2016 r., http://www.rpowp.wrotapodlasia.pl/dokumenty/dokumenty-programowe,3.html [06-06-2017]

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