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The efficiency of scientific and tourism activity of Polish National Parks with use DEA method

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Abstract: Financial shortfalls are typical for protected areas (PA) in many countries. The data collected in the mid-90s of the twentieth century indicate that globally there is a deficit in the amount of $2.3 billion for efficient protection of PA. Therefore, there is a growing interest in accounting for PA costs and a need to increase the efficiency of using resources. The article described Polish National Parks (NP) and presented the analysis of efficiency of using their resources with DEA method. The research was conducted in the area of tourist and scientific activity, which, along with the protection of biodiversity is the essence of NP.

Keywords: efficiency, Data Envelopment Analysis, nationals parks, protected areas, tourism

1. Introduction

Nature conservation is one of the most important goals of the international community in the twenty-first century, which is manifested by numerous international initiatives. UNESCO declared 2010 to be the International Year of Biodiversity (UN 2006). During the Conference of the Parties to the Convention on Biological Diversity in Nagoya in 2010 the proposal was that by 2020, the world's protected areas (PA) would cover at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas (UNEP 2010). Almost all the countries have established PA within their national territories (Nolte et al., 2010). Current global conservation of land is estimated to cover about 13% of land surfaces and almost 1.5% of oceans (Boucher et al., 2013; Chape et al., 2005), and global land PA is estimated to cover 15–29% of the Earth's surface by 2030 (McDonald, Boucher, 2011).

Financial shortfalls are typical for PA in many countries (James et al., 2001). The data

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collected in the mid-90s of the twentieth century indicate that the world's deficit for the efficient protection of PA amounts to $2.3 billion. It is estimated that in order to ensure efficient protection of the global PA there is a need for about $ 45 billion a year for 30 years, and the current annual financial outlays amount to only about $ 6.5 billion (Balmford et al., 2002). Therefore, there is a growing interest to account PA-related costs (Naidoo et al., 2006; Armsworth et al., 2011). In addition, during the World Summit on Sustainable Development the need to increase the efficient use of financial resources for environmental protection was indicated (UN, 2002).

PA are essential for the conservation activities around the world, since they provide a number of important environmental, economic and social benefits for the society. PA are financed mainly from the limited public resources. For these reasons, the goal is to increase the efficiency of PA-related activities. DEA method has been employed for measuring efficiency. This method was recognized as a valuable instrument for analysis and a practical decision support tool, also including the area of environmental protection (Hof et al. 2004; Dyckhoff, K. Allen 2001, Zhang et al. 2008) and national parks (Bosetti V., Locatelli, 2006).

The objective of the article is to characterize the national parks in Poland and analyze resource use efficiency of national parks using DEA method. The study has been conducted in the area of tourist and scientific activities, which, along with the protection of biodiversity are the essence of the operation of national parks (NP).

2. The national parks in Poland

2.1. Tourism in the national parks

Tourism in environmentally valuable areas, including NP, has been the subject of numerous studies worldwide (Wenjun et al., 2005; Buckley, 2002), as well as in Poland (Dudek, 2003; Poskrobko 2005). In 2009, there were about 11.2 million tourists per annum in Polish NP, which accounted for approximately 35 people per 1 ha of NP (Table 1). That year, most- visited national parks included Tatra NP (2.2 million tourists), Karkonosze NP (2 million tourists) and Wolin NP (1.5 million tourists), while the least- visited national parks were Narew NP (11 thousand tourists), Ujście Warty NP (20 thousand tourists) as well as Polesie NP and Drawno NP (about 24 thousand tourists). The volume of tourist traffic in the least- visited parks, was only 1 - 2 persons/ ha, in contrast to the most- visited parks, in which the volume of tourist traffic ranged from 104 (Tatra NP) to 357 (Karkonosze NP) persons per 1ha of the park per annum. Detailed information on this subject has been presented in Table 1 at the end of the compilation.

In 2009, the tourist infrastructure of NP in Poland comprised: 29 youth hostels, 4 holiday houses, 45 campings and camp sites, 275 rain shelters, 29.1 km of ski pistes, 3 stadiums, 10 cable cars, 14 ski lifts, 6 competitive tracks and 3326.2 km of hiking trails (GUS, 2010). In Tuchola Forest NP, Narew PN and Ujście Warty NP the tourist infrastructure comprised only hiking trails.

In 2004-2009 the number of hiking trails in Poland increased by a quarter, reaching a total length of 3,326.2 km in 2009 (GUS *(CSO)*, 2005 and GUS *(CSO)*, 2010).

As can be seen from data presented in Table 1, the most hiking trails in terms of total length are in the largest NP; in Kampinos NP the total length of trails was 560 km, in Bieszczady NP it was 245 km, and in Biebrza NP it was 473 km.

Taking into consideration the above we can conclude that the basic protective function of NP clearly contradicts the tourist function. This conflict is clearly seen in NP located near large urban centers (Warsaw, Kraków, Poznań with nearby parks: Kampinos NP, Ojców NP and Wielkopolska NP), as well as in the renowned tourist regions, which have good infrastructure - Tatra Mountains, Karkonosze Mountains and the Baltic Sea coast. The NP are the main tourist attractions in these regions, and thus record a huge influx of tourists, mainly seasonal, and the two national parks in the mountains (i.e. Karkonosze NP and Tatra NP) have tourists also in the winter period. Admission of such big tourist traffic in NP with all its consequences (difficulties due to the excessive number of visitors and often aggressive infrastructure) is the result of poor financial condition of the NP. In view of insufficient financial resources for the implementation of the basic protective function, tourism incomes support the budget of NP as well as the local communities. Thus, there is a paradox - on the one hand, an excessive number of tourists and the need to create right infrastructure has specific, often negative effects on nature, on the other hand, the increased attendance improves the financial condition of the parks.

2.2. Educational and scientific activities in the national parks

Educational and scientific activities in the NP may be a preventive and mitigating factor in solving various conflicts. However, it is difficult to measure its efficiency, because it concerns people's attitudes and behaviors, and therefore the effects of education can be seen only in the long run (Partyka, 2010).

NP carry out educational activities in many different forms. The most common activities include:

- Managing ecological education centers, museums,
- Organizing educational events, which are most often directed to groups of children and adolescents and prepared on the reported theme-based demand on the basis of NP's educational materials,
- Giving the access to trails that are usually connected with protection of nature, culture and traditions of the region in a broad sense,
- Issuing information and educational materials, popular science publications,
- Running websites.

The data presented in Table 1 show that all the NP had some educational events, which were held in the form of workshops, seminars and conferences. Many parks organized rallies, festivals, photo and art competitions. Due to nature of educational events, in particular parks and lack of homogeneous criteria, NP activity can be evaluated on the basis of number of completed events. In 2009, the number of educational events in NP amounted to 3059, but there were about 32% fewer events than in 2004 (GUS, 2005). That year, there was a significant quantitative diversity of educational events in NP. The smallest number of educational events was in Stołowe Mountains NP (4), Biebrza NP (12) and Bieszczady NP (14), and the largest number of events, as many as 811, was in Kampinos NP and Słowiński NP (557). The educational activity in NP was also manifested by conduct of museums. In 2009, there were 19 parks with museums (with the exception of Tuchola Forest NP, Drawno NP and Ojców NP). The data from GUS *(Central Statistical Office)* show that in 2009 museums were visited by 1.1 million people, i.e. about 343% more people than in 2004. At the end of 2009, there were 137 educational paths in Polish NP, while in 2004 there were 22% less. Most paths were set out in Biebrza NP (15), Bieszczady NP (12) and Gorce NP (10).

Popular science publications were another example of educational activities conducted in NP. The total number of publications offered by NP amounted to approximately 500 titles (Holly, G. & Gray, B., 2010), and their total circulation in 2009 amounted to 1 020 thousand copies. In 2009, NP issued a total of 127 new titles, i.e. 10% more than in 2004.

Most of new publications in 2009 were published in Tatra NP (29), Kampinos NP (12), Wigierski NP and Słowiński NP (10 each).

The educational activities of NP are complemented by scientific activity. The data in

Table 1 shows that in 2009 a total number of 1,059 scientific works was conducted in 22 NP (with the exception of Ujście Warty NP, in which no scientific works were conducted). The subjects of these works related to, inter alia, inventory and monitoring surveys, as well as complex surveys. These included BA, MA and PhD theses. In 2009, only 43% of NP had scientific laboratories and 41 scientific workers were employed only in 13 parks.

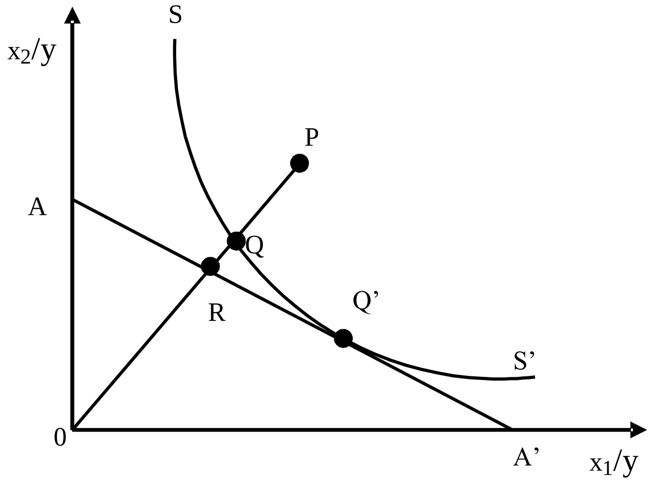
Therefore, NP is an example of important projects, in which their different functions (protection of biodiversity, tourism function, educational function, scientific function) interweave with the multitude and ambiguity of purposes in terms of limited financial resources. Furthermore, the final effects of NP operation are difficult to measure and additionally encumbered by conflicting aspirations of many stakeholders. Thus, research aimed at identification of efficient national parks may be of great importance. These parks can be regarded as benchmarks as well as substitutes of competitiveness in public sector.

3. Materials and methods

The data from report "Protection of Environment 2010" published by GUS (*Central Statistical Office*), series "Statistical Information and Elaborations" as well as the data from the Ministry of Environment were used in this study. 23 NP have been subjected to analysis. Non-parametric Data Envelopment Analysis (DEA) method has been applied to measure technical efficiency (TE). It counts itself among the frontier analysis methods, in which the measurement of efficiency is based on the comparison with the objects recognized as efficient by estimating the correct frontier function. This is a non-parametric method that does not require knowledge of functional frontier efficiency, which in the case of such objects as NP makes measuring of their efficiency somewhat easier. In addition, the data adopted for models can be quantitative and qualitative, and be expressed in different units.

The concept of efficiency measurement on the basis of the production- possibility curve was proposed by M.J. Farrell (1957). The assumptions of this concept have been presented in a simple graphic example (Fig. 1).

Figure 1. The curve of efficiency for two inputs used to produce a unit of output



Source: Farrell (1957).

On the basis of the objects considered as efficient we can estimate the efficiency curve SS'. At the same this curve constitutes a frontier, beyond which all the objects will be characterized by a certain degree of inefficiency. On the basis of the position of the curve we can determine a degree of inefficiency of the objects located beyond the curve. Point P is an inefficient object lying beyond the curve of efficiency. The degree of technical inefficiency for this object is presented on the distance QP, which represents the amount, by which the inputs could be proportionally reduced in order to obtain technical efficiency. This can be expressed by the ratio QP/0P.

The technical efficiency (TE) of point P can be measured by the ratio:

$$TE_n = \frac{0Q}{0P} = 1 - \frac{QP}{0P}$$

If the value of this ratio is equal to one, the object is considered to be technically efficient since it is located on the production curve (an example is the point Q). The value of the parameter in the range between zero and one provides an indicator of the degree of technical inefficiency of the object.

If we know the value of the price ratio of individual inputs (slope of line AA' to the curve), we can define allocative efficiency (AE) of the object located at the point P:

$$AE_n = \frac{0R}{0Q}$$

Reduction of inputs to the point Q means that the object is technically efficient, but it is not cost efficient. By contrast, the point Q' represents the place on the curve, which shows both cost and technical efficiency. The total economic efficiency (EE) can be defined to be the following ratio:

$$EE_n = \frac{0R}{0P}$$

These ratios EE, AE and TE for inefficient objects take a value between zero and one. These measures assume that the function determining the curve of production is known. In practice, this function is not known and must be estimated on the basis of available data in the group of the analyzed objects.

On the basis of the presented concept, DEA method has been proposed, (Charnes, Cooper, Rhodes, 1978) which has been globally used to study the efficiency of various sectors of economy such as power industry, banking, education, health and agriculture. Polish literature has not yet used this method to study the efficiency of national parks.

DEA method is based on the concept of productivity formulated by G. Debreu (Debreu, 1951) and MJ Farrell (Farell, 1957). The concept was developed from a single input and a single output into multi-dimensional arrays as a result of the tests made by A. Charnes, W.W. Cooper and E. Rhodes. The study presented in this article uses a CCR model, which assumes constant returns to scale and a BCC model, which assumes variable returns to scale (Banker, 1984)[1].

Under the assumption of s - effects and m - inputs we can calculate technical efficiency (TE) using the following equation:

$$\frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} = \frac{u_1 y_1 + u_2 y_2 + ... + u_s y_s}{v_1 x_1 + v_2 x_2 + ... + v_m x_m},$$

where y_r - value of output, u_r – weight of output, x_i - value of input, v_i - weight of input.

Solving a linear programme with the objective function subjected to maximization for each object we obtain a coefficient of technical efficiency. The publication (Charnes et al. 1978) presents the way this function has been solved, under the assumption that the

[1] The concept of measuring efficiency applied in CCR and BCC models uses one of the most popular techniques described i.a. in work "Production Frontiers" (Fare et al., 1995).

calculated coefficient is in the form of the above mentioned objective function subjected to maximization, whereas the optimized variables are weights of inputs and weights of outputs. For input- oriented CCR models the dual form of the model takes the following form:

$$\min_{\Theta,\lambda} \Theta,$$

with restrictions:

$$\mathbf{Y\lambda} \geq \mathbf{Y_o},$$
$$\Theta \mathbf{X_o} - \mathbf{X\lambda} \geq 0,$$
$$\boldsymbol{\lambda} \geq 0.$$

where: $\boldsymbol{X_o}$ - the vector of inputs of a given object (dimensions (1 x m));

$\boldsymbol{X}$ - the matrix of inputs of all the objects (dimensions (n x m));

$\boldsymbol{Y_o}$ - the vector of outputs of a given object (dimensions (1 x s));

$\boldsymbol{Y}$ - the matrix of outputs of all the objects (dimensions (n x s));

$\lambda_1,..., \lambda_\sigma$ - coefficients of the linear combination;

Θ - object efficiency coefficient.

This task is solved for all n objects, whereas the goal of optimization is to find the minimum value of Θ at which it is possible to reduce the inputs or the resources used, making it possible to achieve the same level of output. When it is not possible to find such a value, then $\Theta = 1$, which means that favourable combination allowing to achieve the same outputs by the object does not exist. Thus, the object can be considered as economically efficient. By contrast, when $\Theta < 1$, there is a more efficient combination of inputs allowing to achieve the same outputs. The calculated parameter Θ shows the sufficient percentage of inputs in a given object by using efficient objects technology.

In 1984, Banker, Charnes and Cooper proposed to extend CCR model, described above, to BCC model by assuming variable returns to scale (Banker, Charnes, Cooper, 1984). For this purpose, CCR model can be modified by adding convexity constraints, which results in a BCC model in the form of:

$$\min_{\Theta,\lambda} \Theta,$$

with the following restrictions:

$$\mathbf{Y}\boldsymbol{\lambda} \geq \mathbf{Y_o},$$
$$\Theta\mathbf{X_o} - \mathbf{X}\boldsymbol{\lambda} \geq 0,$$
$$\mathbf{1}'\boldsymbol{\lambda} = 1, \; \boldsymbol{\lambda} \geq 0$$

The study has applied a set of variables, which are to be represented by a national park in terms of its educational and scientific activity. The variables adopted for the research with the reference to outputs concern:

Y_1 – a number of completed scientific works (pieces)

Y_2 – a number of tourists (in thousands)

Y_3 – a number of educational events (pieces)

while with the reference to outputs the variables concern:

X_1 – an active protection (ha)

X_2 – a landscape protection (ha)

X_3 – a total budget (PLN)

X_4 – extrabudgetary funds (PLN)

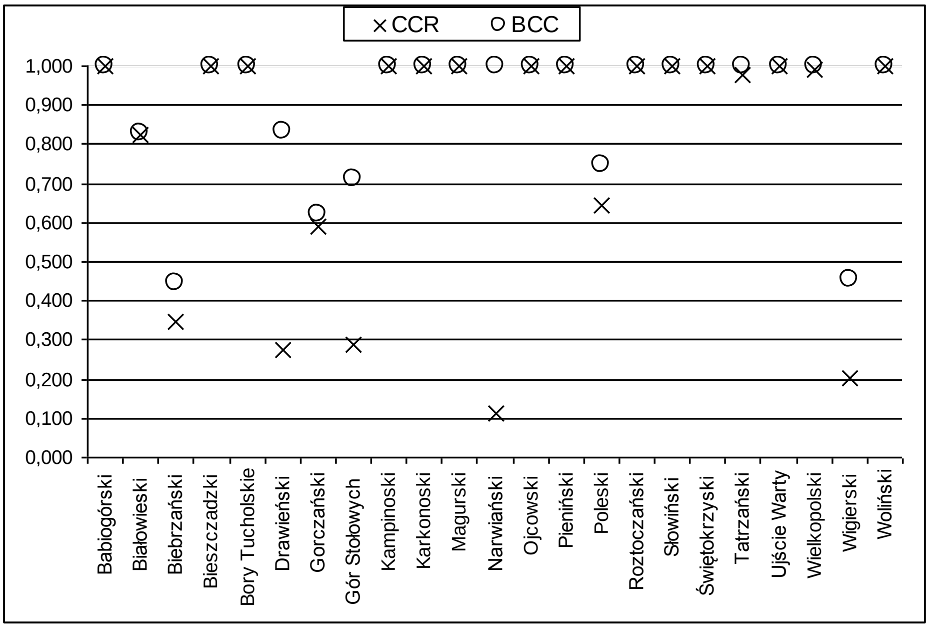
X_5 – household incomes (PLN).

4. Results

With reference to all the parks TE rates were calculated for the model assuming constant returns to scale (CCR) and variable returns to scale (BCC). Fig. 2 shows a graphic representation of the efficiency ratios of individual parks for both analyzed models.

An average rate of technical efficiency for the model assuming constant returns to scale (CCR) amounted to 0,794. There were 13 parks recognized as efficient while the number of inefficient parks amounted to 10. The average rate for the parks recognized as inefficient was 0,526. The parks characterized by the lowest efficiency rates include: Narew NP (0,114), Wigry NP (0,202), Drawno NP (0,276) and Stołowe Mountains NP (0,287). That means that with such a selection of variables it is possible to increase the analyzed outputs in these parks by approximately 70-90% in comparison to the parks recognized as efficient.

Figure 2. Technical efficiency of scientific and tourist education of Polish national parks



Source: own work.

The assumptions for the variable returns to scale for BCC model resulted in increased levels of the average technical efficiency rate to 0,898. In this case, the number of parks recognized as efficient has increased to 16. The average technical efficiency rate for inefficient parks was 0,663. The lowest level of efficiency rates was reported in Biebrza NP (0,448), Wigry NP (0,456) and Gorce NP (0,623). This indicates a possibility of increasing the efficiency by about 45-55% in comparison to the effective parks.

The above analysis shows that most of the parks could be considered as efficient if we assume both constant and variable returns to scale. However, some parks, i.e. Tatra NP, Narew NP and Wielkopolska NP were inefficient in the case of CCR model, whilst in the case of BCC model they were considered as efficient. This particularly applies to Narew NP, in which there was an increase in the efficiency ratio from 0,114 to 1,000.

DEA method applied to measure the efficiency of scientific and tourist activity of national parks showed a large variation in the efficiency. In the case of the model adopting constant returns to scale, which is the model used to compare all the parks, regardless of the scale of their activity resulting from the level of adopted variables, of 23 analyzed parks, 13 parks were recognized as efficient, while the remaining 10 parks showed a certain degree of inefficiency. In the case of the model adopting variable returns to scale, there were 16 parks recognized as efficient. At the same time there was an increase in the overall efficiency level, which is a normal phenomenon. A high percentage of the efficient parks may result from a big variation between individual parks. This is especially visible in the model adopting variable returns to scale. This case pertains to the situation where a park does not have a peer group and it is not possible to find a more favorable combination of inputs, which makes a park an efficient object. This can be confirmed by solving additional models. However, it is not a subject of this article. At all times it needs to be remembered that the calculated efficiency is relative, which means it is calculated in relation to the other objects. By contrast, it is not applied to absolute measure. Nevertheless, the analysis suggests some relations that particularly concern the results obtained in the model adopting constant returns to scale (CCR).

Low values of efficiency ratio were observed in the case of national parks established after 1989. This group includes: Wigry NP (1989), Drawno NP (1990), Biebrza NP (1993), Stołowe Mountains (1993), Narew NP (1996). Furthermore, with the exception of Stołowe Mountains NP these are lowland parks. It is characteristic that as many as 3 out of 4 NP located in north-eastern Poland are featured by low values of efficiency ratio (CCR model), i.e.: Wigierski NP, Biebrza NP and Narew NP. The fourth park - Bialowieża NP - is the exception, not only in terms of efficiency, but also because it covers the last part of old-growth forest in Europe.

5. Conclusions

The analysis of the operation of the national parks in Poland in 2009 showed that the structure of the parks' activity is diverse. In terms of tourism we can separate NP characterized by a very high volume of tourist traffic (e.g. Tatra NP, Karkonosze NP). The volume of tourist traffic in these parks ranged from 100 to 350 persons per 1 ha of the park's area. However, in the parks with low volume of tourist traffic, this ratio amounted to only 1-2 persons/ ha (e.g. Ujście Warty NP, Biebrza NP). There was also a big diversity between the analyzed parks in the field of tourism infrastructure.

The analysis of scientific and educational activity in NP also shows a considerable diversity. In the national parks such as Ujście Warty NP, Narew NP and Tuchola Forest NP a number of completed scientific works amounted to only a few pieces per year, while in the national parks such as Pieniny NP, Bieszczady NP or Roztocze NP the number of completed works was about 80, whilst in Tatra NP it was 141.

There are parks where scientific activity understood as a number of completed scientific works was conducted on a small scale (up to a few works) in 2009. The research on the efficiency of using resources in Polish NP showed that DEA method can be used as a tool to compare the efficiency of NP's operations. However, additional analyses are necessary, especially in terms of selection and sensitivity of variables. DEA method can complement the other analyses, especially if there is a need to take into consideration a few outputs and inputs. The results of research showed a possibility to intensify scientific and tourist activity in inefficient NP without necessity to incur additional costs.

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Robert RUSIELIK, Wojciech ZBARASZEWSKI

Pomiar efektywności naukowej i turystycznej polskich parków narodowych z wykorzystaniem metody DEA

Streszczenie

Niedobory finansowania są wspólne dla obszarów chronionych (PA) w wielu krajach. Dane zebrane w połowie lat 90. XX wieku świadczą, że w skali świata występuje deficyt w kwocie 2,3 mld USD na skuteczną ochronę funkcjonujących PA. Dlatego rośnie zainteresowanie rozliczaniem kosztów funkcjonowania PA oraz potrzeba zwiększenia efektywności wykorzystania środków finansowych. W artykule scharakteryzowano polskie parki narodowe (PN) oraz przeprowadzono analizę efektywności wykorzystania ich zasobów przy zastosowaniu metody *Data Envelopment Analysis* (DEA). Badanie przeprowadzono w obszarze działalności turystycznej i naukowej, które wraz z ochroną różnorodności biologicznej stanowią istotę funkcjonowania PN.

Słowa kluczowe: efektywność, Data Envelopment Analysis, parki narodowe, obszary chronione, turystyka.

Table 1. National parks in Poland in 2009

National park	Year of establishment	IUCN category	Total area (ha)	including:		Number of scientific workers	Number of completed scientific works	Inputs on scientific activity (excluding remunerations (thousand PLN)	Total of tourist trails (km)	Number of tourists (thousands)	Total budget (PLN)
				Strict protection (ha)	Landscape protection (ha)						
Babia Góra NP	1954	II	3390,5	1124,5	184,4	1	63	0,9	53,0	66,7	1748 000
Białowieża NP	(1932)[b], 1947	II	10517,3	5726,1	352,0	2	59	0,5	44,0	190,0	4391 000
Biebrza NP	1993	-	59223,0	4472,2	27532,3	-	53	-	473,5	39,0	5040 900
Bieszczady NP	1973	II	29195,1	18553,6	85,5	4	80	124,0	245,0	350,0	4166 402
Tuchola Forest NP	1996	-	4613,0	324,3	78,9	-	8	-	75,0	60,0	1688 000
Drawa NP	1990	II	11342,0	569,0	504,0	-	11	-	160,0	23,6	2463 000
Gorcza NP	1981	II	7030,8	3610,8	537,1	4	63	28,0	155,3	70,0	3449 216
Stołowe Mountains NP	1993		6340,4	771,0	624,6	3	15	10,0	107,3	366,0	2628 000
Kampinos NP	1959	II	38548,5	4636,0	6636,3	9	78	57,0	560,0	1000,0	9206 000
Karkonosze NP	1959	II	5580,5	1726,1	24,8	1	48	167,0	117,6	2000,0	6254 105
Magura NP	1995	-	19437,9	2407,7	57,0	-	17	-	85,0	50,0	3655 000
Narew NP	1996	-	7350,0	-	-	-	7	-	55,0	11,0	1554 653
Ojców NP	1956	V	2145,7	250,9	491,7	3	45	7,0	39,7	400,0	2342 000
Pieniny NP	(1932)[c], 1954	II	2346,2	748,9	993,1	-	84	56,9	35,2	838,0	2017 000
Polesie NP	1990	II	9764,4	116,0	1490,3	1	66	80,2	75,5	24,6	2466 000
Roztocze NP	1974	II	8482,8	805,9	356,3	4	88	49,1	61,1	100,0	3226 000
Słowiński NP	1967	II	21572,9	5928,9	132,9	-	32		144,3	386,4	2713 000
Świętokrzyski NP	1950	II	7626,4	1715,2	322,8	2	31	13,3	41,0	183,0	3229 000
Tatra NP	(1947)[a], 1954	II	21197,3	12449,1	2774,8	4	141	43,0	275,0	2195,0	6017 000
Ujście Warty NP	2001	-	8074,0	681,9	3376,7	-	-	-	13,2	20,0	1348 000
Wielkopolska NP	1957	II	7583,9	259,7	2328,1	-	24	-	215,0	1200,0	2827 000
Wigry NP	1989	V	14987,9	623,2	2919,1	3	34	30,0	245,4	120,0	4067 591
Wolin NP	1960	II	8133,1	500,2	63,9	-	12	-	50,1	1500,0	2542 000
Total	-	-	31483,6	68001,2	51866,6	41	1059	667,1	3326,2	11193,3	79038 867

[a] State Forests of TANAP. [b] Białowieża National Park Forest District. [c] State Forests of PNP.

Source: own work on the basis of GUS *(Central Statistical Office),* 2010, and "Parki Narodowe w Polsce. Działalność organizacyjna i finansowanie w 2009 r" *("National Parks in Poland. Organizational activity and financing in 2009"),* Warsaw 2010.