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ORIGINAL RESEARCH ARTICLE

Opportunity costs of establishing nature reserves in selected forest districts of the Mazowieckie Province

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Abstract. The article presents the results of research on the opportunity costs related to establishing nature reserves in four randomly-selected forest districts located in the Mazowieckie Province: Celestynów, Grójec, Płońsk and Zwoleń.

Our analysis included calculation of profits forgone by forest districts due to the cessation of timber harvesting in nature reserves and an estimation of work places lost as a result of introduction of new limitations, as well as the expenses incurred by municipalities related to their establishment of forest tax concessions in nature reserves.

The establishment of nature reserves incurred losses related to timber harvest of about 246 thousand m^3 during the period of 10 years, which is equivalent to between 4.1% and 19.8% of the planned timber harvest stated in the forest management plans of the studied forest districts. Total opportunity costs were equal to 25.5–27.2 million PLN during these 10 years or 1502–1605 PLN/ha of nature reserve annually. Annual opportunity costs calculated per unit of forest area were equal to 56–60 PLN/ha. The estimated loss in work places was 98.8 working days annually per 1000 ha of forest area in forest districts. Total expenses incurred by municipalities related to establishment of forest tax concessions in nature reserves reached about 18.1 thousand PLN in 2011.

The research results show that the economic and social costs of nature protection activities are concentrated in their places of their origin. Those costs are felt the most by the owners of the affected forests and local communities. We recommend that possibilities are explored for the introduction of instruments to allow the mitigation of negative effects resulting from restrictions in forest use. Restructuring of forest and nature protection policy, to take into account the interests of all stakeholders would provide an improved model for the use of these forests.

Key words: biodiversity conservation, public forests, local labour market, tax concessions

1. Introduction

Protection of forests and ecosystems with special values because of their natural biodiversity and landscape values is one of the goals of forest management. Such a goal could be reached through various management activities such as management planning, silvicultural activities, and forest protection and use. Especially valuable natural forest sites are covered by different types of conservation, such as nature reserve establishment. Creating protected areas with high protection level, with the regime limiting or completely excluding timber harvesting has, however, negative economic consequences. In economics, profits lost when resources such as timber are not being used for the best alternative choice are described as opportunity costs (Begg et al. 1998).

For enterprises, analysis of opportunity costs for various types of activities helps in selecting the most profitable activity, which maximises revenues. In forestry, such an approach could not be used due to the fact that selection of the best economic option means the return to the resource-driven model that is centred exclusively on

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timber production. The analysis of opportunity costs can, however, be used in shaping the goals of forest policy and policy related to protection of biodiversity as well as selection of instruments, such as economic and financial, which would facilitate reaching stated goals.

The opportunity cost analysis for establishment of nature reserves in forests is characterised by multiple aspects because cessation of timber harvesting results in many various consequences. From the perspective of forest owners and managers, limitations related to nature protection can lead to loss or restriction of timber harvesting rights and also to the increase in expenditures related to protection activities. For local communities, limitations due to nature protection can mean smaller number of workplaces in forests (and also in timber processing) as well as decreased profits from taxes received by the units of local municipalities.

This article presents research results related to opportunity costs of nature reserve establishment in selected forest districts of the Mazowieckie Province. The research estimates opportunity costs of forest districts associated with the cessation of timber harvesting in nature reserves, establishes number of lost workplaces in timber harvesting and skidding, and also evaluates financial losses from decreased profits related to forest taxes.

2. Methods

The research was conducted in four randomly selected forest districts located in the Mazowieckie Province: Celestynów and Płońsk of the Warsaw Regional Directorate of the State Forests, and Grójec and Zwoleń of the Radom Regional Directorate of the State Forests (Figure 1). The general information on these organisational units is presented in Table 1.

The opportunity costs analysis related to nature reserve establishment covered the following tasks:

– determining profits lost by forest districts due to cessation of timber harvesting on the area of nature reserves,

– estimating the number of workplaces lost because of limitations in timber harvesting in nature reserves (social costs), and

– evaluating losses of municipalities tied with lower forest taxes in forests located within nature reserves.

The research covered forest stands in nature reserves located on the state owned lands and managed by the State Forests National Forest Holding. Current research adopted the assumption that forest stands located within nature reserves are not economically usable due to low

Figure 1. Location of the studied forest districts within the Mazowieckie Province (elaborated by Marcin Mionskowski)

volumes of harvested timber within them (Grzywacz 2012). The research also excluded financial benefits obtained by forest districts from timber sales harvested in nature reserves during incidental fellings related to natural calamities and protective cuttings.

Forest management plans (Plan urządzenia lasu) of the analysed forest districts served as major source of information. The following forest management plans were studied during the continuation of given research:

– for Celestynów Forest District – from 01.01.2009 to 31.12.2018,

– for Grójec Forest District – from 01.01.2004 to 31.12.2013, and

– for Płońsk and Zwoleń Forest Districts – from 01.01.2003 to 31.12.2012.

Estimation of opportunity costs related to cessation of timber harvesting included assessment of potential economic benefits, which would be received by forest districts when timber harvesting would be conducted according to rules relevant to commercial forest stands. It was assumed that forest stands having dominant tree species at harvest age during the time of management plan preparation would be qualified for timber harvesting while forest plan is in use, i.e. during 10-year period. For young timber stands that potentially qualify for intermediate cutting, it was assumed that during the time covered by management plan these stands would have one pre-commercial or commercial thinning.

Table 1. Forest area, number and area of nature reserves, and the level of the allowable cut in the studied forest districts

Forest district	Forest area	Number of nature reserves in forests	Years of establishment of the oldest and the youngest nature reserves	Total area of nature reserves	Share of the area of nature reserves within a forest district	Allowable cut according to forest management plan
	ha		year	ha	%	'000 m^3/10 years
Celestynów	8 723	7	1952–1994	235	2.7	375.2
Grójec	16 024	9	1959–1995	992	6.2	689.9
Płońsk	10 621	2	1964–1977	79	0.7	414.4
Zwoleń	14 054	7	1980–2001	391	2.8	604.1

Source: Forest management plans (Plan urządzenia lasu) for Celestynów (2009–2018), Grójec (2004–2013), Płońsk and Zwoleń (2003–2012) Forest Districts

The analysis did not cover forest stands with tree density lower than 0.7. Tree harvesting is usually not conducted in such stands (Jabłoński, personal communication 2012), and therefore inclusion of such stands into nature reserves practically does not decrease harvested timber volumes of forest district.

Forest stands with tree density ≥0.7 were divided into two groups: tree stands potentially suitable for final felling and tree stands potentially suitable for pre-commercial thinning. It was done based on the age of major tree species in each forest stand. According to currently valid 'Instruction on forest management planning' (Instrukcja 2011), tree stands potentially qualified for final felling have major tree species in the age:

n – 20 years – for species with harvest age *n* accepted in forest management plan ≥ 80-years-old,

n – 10 years – for species with harvest age *n* equal to 70-years-old.

Tree stands potentially suitable for intermediate cutting included stands, with major tree species below the age established for the group of stands qualified for final felling.

2.1. Opportunity costs related to exclusion of stands from pre-commercial cutting

Volumes potentially available for cutting during thinnings conducted at the time of 10-year period of forest management plan validity were calculated for every tree stand qualified to the group of pre-commercial stands. Intensity of pre-commercial cuts was estimated based on 'Yield tables for pre-commercial cuts' (Tablice wydajności 1975), current tree age, stand volume and density (m^3 without bark/ha). The total potential volume available for pre-commercial harvesting was calculated by summing all volumes established for every qualified stand.

Opportunity costs related to exclusion of tree stands from pre-commercial cutting were established separately for each tree stand based on estimated volumes available for harvest during pre-commercial thinning as well as average price of 1 m^3 of timber in a given forest district in 2011. Calculated worth of timber was reduced by timber felling and skidding costs using average unit costs of these activities in various forest districts in 2011. The sum of calculated values in every analysed tree stand gave the total amount of opportunity costs related to exclusion of forest stands from pre-commercial cutting.

2.2. Opportunity costs related to exclusion of stands from final cutting

Opportunity costs related to exclusion of stands from final cutting were calculated in two ways: 1) based on real standing volume of stands qualified for final cutting (method I); 2) based on tables of tree stand values (method II). The results of such calculations are approximate and using both of the methods for a given goal allowed comparing the differences in received outcomes.

In the first case, timber volume available for harvesting was calculated based on measurements done for preparation of the forest management plan. It was assumed that opportunity costs equal the total value of standing timber in mature timber stands suitable for final felling reduced by costs of timber felling and skidding.

Value of standing timber was calculated for every stand as a product of multiplication of stand volume and average price of cubic metre of timber in given forest district in 2011. Costs of timber felling and skidding were estimated based on average unit costs of these activities in analysed forest districts in 2011.

The second method of opportunity cost calculation was based on the table of tree stand values included in the annex of the Decree of the Minister of Environment on single compensation for early stand felling of 2002 (Dz. U. z 2002 Nr 99 poz. 905; Rozporządzenie 2002). It was presumed that compensations calculated based on the above decree correspond to the net timber market value. Current study used the average timber price of the first three quarters of 2011 (Komunikat Prezesa 2011).

The calculations used the age of each timber stand during the time of forest management plan preparation increased by the number of years, which passed from the beginning of plan validity period to the year 2012, when current research was conducted. Selection of tree stand value tables was done according to the accepted method by each forest district harvest age of a given species. In case when stand age was higher than the maximum age used in value tables, value corresponding to the maximum age in tables was used.

Both methods used an assumption that according to the 'Principles of silviculture' (Zasady hodowli lasu 2011), fragments of old growth would be left in stands qualified for final felling until the time of natural downfall of these fragments. Share of the remaining old growth fragments constitutes 5% of the area of stands qualified for final cutting.

2.3. Lost workplaces

The number of lost workplaces was estimated based on the volume of possible timber harvest in nature reserves and labour intensity of timber cutting and skidding established from the 'Catalogue of work-hours for activities implemented during timber logging' and 'Catalogue of work-hours for activities related to timber felling by forestry machines'. Both of the above documents are included in the annex to the Decree of the Director General of the State Forests nr 99/2003 (Zarządzenie nr 99).

Timber qualified for possible harvesting was grouped according to species based on structure used in the 'Catalogue…'; so group I includes pine, larch, aspen, poplar, lime tree and willow; group II spruce, fir and Douglas fir; and group III oak and other broadleaved species. The grouping was done with the division on commercial and pre-commercial cutting. It was assumed that large-diameter timber (W) consists 60% and medium-diameter timber (S) consists 40% of the commercial cutting total volume. For pre-commercial cutting, the share is the opposite (W 40%, S 60%).

Total labour intensity of timber cutting is calculated as a sum of labour intensity of the following activities: preparation for felling and stump debarking, tree felling, delimbing, log bucking, pulp wood bucking, and stacking. For the activities related to logging process, the second degree of difficulty was used (as it is suggested for clear cutting in multiple-layer stands or stands with undergrowth as well as shelterwood cutting in lowlands). For pre-commercial cutting, the third degree of difficulty was used (as it is suggested for thinning of ≥60-years-old tree stands). The calculations were based on the standard average hours spent on specific activities necessary for the production of various timber grades (W and S).

Labour intensity of timber skidding was estimated using standard working hours necessary for transporting logs and small-diameter coniferous posts (M1) by skidders up to 300 m, while using average values for clear cutting and selective cutting.

2.4. Decreased profits of municipalities due to lower forest taxes in nature reserves

The calculations of losses in profits of municipalities due to changes in forest taxes for stands located in nature reserves were done according to rules stated in the Act on forest tax of 2002 (Dz. U. z 2002 Nr 200 poz. 1682; Ustawa 2002). The Act specifies that forests included into nature reserves are covered by forest tax 50% lower than tax related to forests outside nature reserves.

Forest tax from 1 hectare per financial year equals to monetary value of 0.220 m^3 of timber calculated from average price of timber sold by forest districts during the first three quarters of the year preceding the tax year using the annually published Statement of the Head of the Central Statistical Office. The research used the average price of timber sold during the first three quarters of 2010 in the calculation of forest tax for 2011 (Komunikat Prezesa GUS 2010). Forest tax calculated in such a manner was later reduced by 50%. The analysis was done for all tree stands above 40 years of age, because stands below 40 years of age are excluded from forest taxation

irrespective of their protective state (Act on forest tax, Dz. U. z 2002 Nr 200 poz. 1682; Ustawa 2002).

3. Research results

The area of tree stands potentially qualified for pre-commercial and commercial cutting with stand density above 0.7 in the studied forest districts is presented in Table 2.

The area of tree stands included into the analysis consists 92.2% of the total area of nature reserves. This ratio for Płońsk and Celestynów Forest Districts equals to 75.9% and 76.6%, respectively, which is lower than in the other two forest districts. In the majority of forest districts, besides Płońsk Forest District, potentially dominating method of forest use was pre-commercial cutting (at about 2/3 of analysed reserve area). In the Płońsk Forest District, tree stands qualified for pre-commercial cutting consisted less than a half of stand area located within nature reserves.

Volume of timber potentially eligible for pre-commercial and commercial harvesting in nature reserves during the 10-year period of forest management plan validity is presented in the Table 3. Volume available for harvest was calculated based on the real volume of stands qualified for commercial cutting (method I).

As a result of forest protection within nature reserves in studied forest districts, about 245.6 thousand m^3 of timber would not be harvested during the 10-year period of forest management plan validity. Greater part of potential timber harvest (93.7%) could be available from commercial felling due to domination of older tree stands in nature reserves.

In absolute values, the largest timber volume available for harvest is located in the Grójec Forest District (136.8 thousand m^3), while the lowest volume is in the Płońsk Forest District (17.0 thousand m^3). It could be explained by the difference in areas of nature reserves in these districts. When calculated per 1 hectare of nature reserve area, the average hypothetical volume available for harvest lies in the interval from 109.1 m^3/ha (Celestynów) to 215.1 m^3/ha (Płońsk), with the average for the four studied forest districts being equal to 144.7 m^3/ha. The high volume in Płońsk Forest District could be explained by significantly higher than in other districts share of tree stands available of commercial cutting.

Overall results for opportunity costs based on timber volumes available for pre-commercial and commercial cutting in nature reserves located in four studied forest districts are presented in Tables 4–7.

Opportunity costs related to exclusion of tree stands from pre-commercial cutting in four forest districts are equal to 2341.4 thousand PLN during the 10-year period of forest management plan validity. The highest costs were estimated for the Grójec Forest District, which equal to 1347.1 thousand PLN, while the lowest were in the Płońsk District, equal to 86.3 thousand PLN (Table 4).

When calculated per unit area suitable for pre-commercial cutting, values of opportunity costs varied from 2072 PLN/ha (Grójec) to 3196 PLN/ha (Płońsk) (with coefficient of variation equal to 19.2%). The average opportunity cost for all areas available for pre-commercial thinning was 2228 PLN/ha.

The average opportunity cost per unit area of nature reserve varied from 1092 PLN/ha in the Płońsk Forest District to 1520 PLN/ha in Zwoleń Forest District, while the average for the total area of nature reserves in

Table 2. Area of tree stands potentially eligible for harvesting in nature reserves during 10 years

Forest district	Total area of nature reserves	Area of tree stands potentially eligible for						Share of the analysed area in the total area of nature reserves
		intermediate fellings		final felling		total		
	ha	ha	%	ha	%	ha	%	%
Celestynów	235	116	64.5	64	35.5	180	100.0	76.6
Grójec	992	650	68.8	295	31.2	945	100.0	95.3
Płońsk	79	27	45.0	33	55.0	60	100.0	75.9
Zwoleń	391	258	67.9	122	32.1	380	100.0	97.2
Sum	1 697	1 051	67.2	514	32.8	1 565	100.0	92.2

Table 3. Volume of timber potentially eligible for harvesting in nature reserves in the studied forest districts

Forest district	Type of felling						Average felling per 1 ha within nature reserves
	intermediate		final		total		
	m^3	%	m^3	%	m^3	%	m^3/ha
Celestynów	2 611	10.2	23 039	89.8	25 650	100	109.1
Grójec	9 614	7.0	127 235	93.0	136 849	100	138.0
Płońsk	700	4.1	16 295	95.9	16 995	100	215.1
Zwoleń	2 384	3.6	63 760	96.4	66 144	100	169.2
Sum	15 309	6.2	230 329	93.8	245 638	100	144.7

Table 4. Opportunity costs due to termination of intermediate felling in nature reserves in the studied forest districts during 10 years

Forest district	Value of timber	Potential costs of timber harvesting and skidding	Opportunity costs		
			total	per 1 ha of the harvest area	per 1 ha of forest within nature reserves
	’000 zł	’000 zł	’000 zł	zł/ha	zł/ha
Celestynów	445.3	131.6	313.7	2 707	1 335
Grójec	1 767.2	420.1	1 347.1	2 072	1 358
Płońsk	118.4	32.1	86.3	3 196	1 092
Zwoleń	693.7	99.4	594.3	2 303	1 520
Average	×	×	×	2228	1380

four studied forest districts equals to 1380 PLN/ha. The coefficient of variation for the above results was quite low and equals to 13.3%, which is significantly lower than in case of opportunity costs related to areas potentially suitable for pre-commercial thinning.

Opportunity costs of exclusion of timber stands from commercial cutting in the studied forest districts calculated by the methods I and II are presented in Table 5.

The total opportunity costs in four studied forest districts calculated based on real standing timber volume were equal to about 25.5 million PLN (Table 5). Such a result is very close to opportunity costs calculated based on tables of tree stand values (27.2 million PLN), which is 6.8% lower. For individual forest districts, differences in results based on methods I and II varied from -28.0% to +26.2%.

The highest opportunity costs related to commercial cutting and calculations based on method I were found in the Grójec Forest District and equal to 14398.9 thousand PLN, while the lowest were found in the Płońsk Forest District – 1787.7 thousand PLN. Calculations based on the method II produced results that varied from 1319.9 thousand PLN in the Płońsk Forest District to 14773.4 thousand PLN in the Grójec Forest District.

The average opportunity costs per unit area of nature reserves under the method I varied from 11069 thousand PLN/ha in the Celestynów Forest District to 22629 PLN/ha in the Płońsk Forest District. The average for the total area of nature reserves in four studied forest districts was equal to 15021 PLN/ha (Table 6), while the coefficient of variation was equal to 29.8%. The results received using method II varied from 10862 PLN/ha (Celestynów) to 21949 PLN/ha (Zwoleń) with coefficient of variation being similar to the method I and equal to 28.6%. The average opportunity costs in four forest districts were equal to 16045 PLN/ha. These values were calculated for the 10-year period of forest management plan validity (Table 6).

Table 7 presents the summary of annual average opportunity costs related to forest protection in nature reserves in the discussed forest districts. When calculated per unit area of nature reserve, the lowest average opportunity costs related to pre-commercial and commercial cutting were found in the Celestynów Forest District. Depending on calculation method used, these costs were equal to 12.2 thousand PLN or 12.4 thousand PLN per 1 hectare of nature reserve area. The highest opportunity costs per unit area of nature reserve were almost identical regardless of the method used. Opportunity costs calculated based on the method I for commercial cutting were the highest in the Płońsk Forest District (23.7 thousand PLN/ha) and based on the method II – in the Zwoleń Forest District (23.5 thousand PLN/ha). The average costs for all four studied forest districts were 16.4 thousand PLN/ha or 17.4 thousand PLN/ha depending on the calculation method used.

The average annual opportunity costs calculated per unit of forest area were found in the Grójec Forest District (Table 7). Depending on the method used, they were equal to 98 PLN/ha or 101 PLN/ha. The lowest opportunity costs were in the Płońsk Forest District. The received results have very high coefficient of variation equal to about 70%. The average opportunity costs related to exclusion of tree stands in nature reserves from commercial cutting for all four forest districts were equal to 56 PLN/ha based on the method I and 60 PLN/ha based on method II.

Table 5. Opportunity costs due to termination of final felling in nature reserves in the studied forest districts during 10 years, calculated based on the real standing volume (method I) and based on tables of tree stands value (method II), in thousand PLN

Forest district	Method I				Method II		
	Value of standing volume	Potential costs of timber harvesting and skidding	Value of old growth (not felled)	Opportunity costs	Value of tree stands	Net value of timber of old growth (not felled)	Opportunity costs
Celestynów	3 960.4	1 161.2	198.0	2 601.2	2 686.9	134.3	2 552.6
Grójec	20 188.3	4 779.9	1 009.4	14 398.9	15 550.9	777.5	14 773.4
Płońsk	2 634.3	714.9	131.7	1 787.7	1 389.4	69.5	1 319.9
Zwoleń	10 391.6	3 168.8	519.6	6 703.2	9 033.6	451.7	8 581.9
Total	37 174.6	9 824.8	1 858.7	25 491.0	28 660.8	1 433.0	27 227.8

Table 6. Opportunity costs due to termination of final felling in nature reserves during 10 years, calculated per 1 ha based on the real standing volume (method I) and based on tables of tree stands value (method II)

Forest district	Opportunity costs per 1 ha, zł/ha			
	of felling area		of nature reserves area	
	method I	method II	method I	method II
	zł/ha	zł/ha	zł/ha	zł/ha
Celestynów	40 644	39 884	11 069	10 862
Grójec	48 810	50 079	14 515	14 893
Płońsk	54 173	39 997	22 629	16 708
Zwoleń	54 944	70 343	17 144	21 949
Average	49 594	52 972	15 021	16 045

Evaluation of timber volume that potentially could be harvested in nature reserves in four studied forest districts allowed estimating labour intensity of timber felling, bucking and skidding. The results are presented in Table 8.

Total potential labour intensity was 390.5 thousand man-hours. Calculated per 8-hour working day, it is about 48.8 thousand working days during 10 years or 4882 working days per year, which is equal to 21.7 standard workplaces (assuming 225 working days during the year). The loss of workplaces per 1000 hectares of forest area was 98.8 working days annually, which equals to 0.44 workplaces.

The last studied element of opportunity costs was the value of revenues lost by municipalities due to lower forest tax in forests located within nature reserves. In 2011, the decrease in tax due to establishment of nature reserves varied from about 1.0 thousand PLN in the Płońsk Forest District to more than 10.2 thousand PLN in the Grójec Forest District. The decrease in forest tax received by municipalities from all studied forest district was about 18.1 thousand PLN (Table 9).

4. Discussion and conclusions

The goal of the research was to estimate opportunity costs related to establishment of nature reserves in selected forest districts of the Mazowieckie Province. Opportunity costs can be viewed from different angles, such as financial costs carried by forest managers, costs faced by local communities due to loss of workplaces or the decrease in profits received from forest tax by municipalities. It should be mentioned

Table 7. Average annual opportunity costs due to termination of intermediate and final felling in nature reserves in the studied forest districts during 10 years

Forest district	Average annual opportunity costs, zł/ha			
	per 1 ha of nature reserves		per 1 ha of a forest district area	
	method I	method II	method I	method II
Celestynów	1 240	1 220	33	33
Grójec	1 587	1 625	98	101
Płońsk	2 372	1 780	18	13
Zwoleń	1 866	2 347	52	65
Average	1 640	1 743	56	60

Table 8. Potential labour intensity of timber harvesting, cutting into length, and skidding during intermediate and final felling in nature reserves during 10 years in the studied forest districts (in man-hours)

Operations or activities	Intermediate felling	Final felling	Total
Preparing for felling and stump debarking	3 109	30 941	34 050
Tree felling	6 297	67 774	74 071
Delimbing	10 314	103 033	113 347
Log bucking	4 023	45 345	49 368
Pulpwood bucking	4 130	34 069	38 199
Stacking	4 765	39 455	44 220
Skidding	2 725	34 549	37 274
Total	35 363	355 166	390 529

Table 9. Estimated value of revenues lost by municipalities due to forest tax concessions in nature reserves

Forest district	Total area of nature reserves	Area of tree stands covered by forest tax concessions	Value of forest tax concessions in 2011
	ha	ha	zł
Celestynów	235	146	2 483
Grójec	992	602	10 240
Płońsk	79	60	1 021
Zwoleń	391	254	4 321
Total	1697	1062	18 065

that the above listed areas of opportunity cost origin appear simultaneously.

From the point of view of forest possessor (manager or owner), creation of nature reserves results in discontinuation of commercial forest use. In the analysed forest districts, establishment of nature reserves generated the estimated decrease in timber harvesting of about 246 thousand m^3 during the 10-year period. For each forest district, the estimated unharvested volume comprised from 4.1% (Płońsk) to 19.8% (Grójec) of total harvest stated in the forest management plan.

The above volume is approximate due to certain assumptions used. One of them is the assumption that mature tree stands would be harvested during the time of management plan validity. In practice, such situation would not always be true. Nature reserves were established in different years during a long period of time. In case when nature reserves would not be established, forest management activities would continue within the borders of present reserves and tree stands would be harvested gradually at the time of stands reaching their harvesting age. It would not be also possible to establish such a large-scale clear cutting sites at the place of reserves. However, timber harvesting would still occur (as well as financial profit from it) on the sites occupied by reserves, but it would not be so intensive and concentrated within such a short period of time.

For forest management districts, opportunity costs varied from 1640 to 1743 PLN per hectare of nature reserve annually depending on the calculation method used. Calculated per hectare of forest area, opportunity costs of nature protection were 13–101 PLN per hectare depending on forest district and calculation method used, with averages being 56 PLN/ha or 60 PLN/ha. The results of this study are comparable with other publications of different authors. Fonder and Serafin (2010) estimated that opportunity costs of timber harvesting cessation on protected areas of Mińsk Forest District were about 375 thousand PLN in 2009, which was about 42 PLN per 1 hectare of forest area in that district.

Significantly lower values of opportunity costs were estimated in the research of Janusz (2010). Her study described opportunity costs related to cessation of timber harvest in nature reserves located in forest districts within the Krakow Regional Directorate of State Forests in 2005–2009. The average opportunity cost was estimated to be 7.50 PLN/ha/year, which is significantly lower than the results presented in the above article.

The sum of annual opportunity costs related to discontinuation of timber harvesting in nature reserves calculated by the method II varied from 140.6 thousand PLN in the Płońsk Forest District to 1612.0 thousand PLN in the Grójec Forest District. These values were equal to 2.0% and 12.3% of the net profits from sales of products, goods and materials in these districts in 2011. In the Celestynów Forest District, this share was 4.4% and in Zwoleń Forest District 6.9%, while when calculated for all the four studied forest districts it was 7.4%. Such results are significantly lower than the results presented in the study of Fonder and Serafin (2010) for Mińsk Forest District, where opportunity costs were equal to 28.3% of forest district profits related to its basic and secondary activities. However, the above results show that opportunity costs estimated in the studied forest districts are significant and discontinuation of timber harvesting in natures reserves could have serious consequences for the financial situation of these districts. Such evidence should be considered in the context of preservation of financial self-sufficiency of the State Forests and also in the situation when large forest areas are planned to be contained by protective limitations, such as establishment of Natura 2000 areas.

Cessation of timber harvesting due to establishment of nature reserves also carries social costs. Decreased timber harvesting in four studied forest districts resulted in loss of about 22 workplaces. If average loss in workplaces is estimated to be 0.44 positions per 1000 hectares of forest, then potential employment within the borders

of the Warsaw and Radom Regional Directorates of the State Forests where the studied forest districts are located would decrease by about 220 positions annually (with the total area of forest in these Directorates being 501.7 thousand hectares). The calculations, however, did not include many forest activities, such as forest regeneration, tending and protection of plantations and, therefore, real social costs could be higher.

The last part of this research concerned opportunity costs of municipalities due to lower forest taxes in forests located within the borders of nature reserves. The total amount of forest tax concessions in all the studied forest districts was about 18.1 thousand PLN in 2011 and varied from about 1.0 thousand PLN in the Płońsk Forest District to more than 10.2 thousand PLN in the Grójec Forest District. These values are not highly significant; however, it should be remembered that proceeds from forest taxes in Poland comprise the own profits of municipalities and losses resulting from lower forest taxes are not repaid to local authorities from the state budget. In 2011, the share of forest tax in own and general revenues of municipalities was 0.54% and 0.25% respectively (GUS 2012). Establishment of new protected areas or increase in area of already existing protected areas with simultaneous lack of compensations from the central budget could result in a situation of conflict between supporters of nature protection of forests and local authorities as well as representatives of local communities. Such a dilemma is not just theoretical due to other responsibilities related to establishment of protected areas, which also affect financial situation in forest districts and situation at the local labour market. While benefits from protection of valuable natural areas are felt by the whole society, economic and social costs of protective activities concentrate on the areas where they originate and, therefore, these costs are mostly endured by forest owners and local communities. The solution to this problem requires active intervention of the state and also development of forest and nature protection policy, which considers the interests of all parties involved.

The research conducted and the results obtained by this study allow formulating the following conclusions:

1. Exclusion of forest stands from timber harvesting in the studied forest districts resulted in an average loss of 56–60 PLN per 1 hectare of forest area annually. Estimated opportunity costs constitute about 7.4% of net profits from the sales of products, goods and materials in these districts in 2011.

2. Social costs of nature reserve establishment, as calculated by the research method used, can be expressed by the loss of about 22 workplaces annually. The losses by municipalities related to lower proceeds from forest taxes were estimated to be more than 18 thousand PLN in 2011.

3. Economic and social costs related to protective activities, unlike benefits from protection of biological diversity, concentrate on the place of their origin and mostly affect forest owners and local communities. It is therefore recommended to establish and introduce instruments that allow mitigating negative consequences related to limitation in forest use. This could be achieved by development of forest and nature protection policies that take into account interests of all parties involved.

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Contributions

AK – study conception and design, acquisition of data, analysis and interpretation of data, drafting of manuscript; WM – study conception and design, acquisition of data, analysis and interpretation of data, critical revision of the manuscript.

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