Opportunity Costs of Forest Set-asides in Poland:
A case study of Sulechow Forest District

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Front cover:

Oak trees in The Sulechow Forest District (Photo: Piotr Łysiak)

ABSTRACT

Due to the world's increasing scarcity of different dimensions of biodiversity there is a constant need for finding the right balance between economical concerns and nature conservation in forestry. The management of natural resources requires a good assessment of the productive stand value as well as costs of forgone opportunity. Such costs appear when setting the areas aside for nature conservation purposes. In this thesis calculations of opportunity costs of set-asides were based on differences in the holding value among three management scenarios with increasing level of restrictions:

I. Faustmann model scenario - forest management without restrictions concerning set-asides and applying optimal rotation age according to the financial maturity.
II. Higher rotation age scenario - forest management without restrictions concerning set-asides but with higher rotation ages, determined with respect to ecological and social values (rotations presently used in Poland).
III. Set-aside scenario - management where 26,4% of the forest area is excluded from production as set-asides and applying higher rotation ages on the rest of the area, determined with respect to ecological and social values (rotations currently used in Poland).

The data used for the analysis were collected from The Sulechow Forest District for the year 2007. Pine and Oak, species dominating in the area, on three representative site quality classes, were taken into account for the calculations. All together 417,5 ha of forest in 126 stands were examined.

The opportunity cost of the examined set-asides was expressed in terms of the present value difference compared to stands calculated according to scenario I, which was the reference one, and the set-aside scenario (III). The present value was calculated pursuant to the holding value equation, with 2% discount rate. The difference between I and III scenario was 12,03 millions PLN (3,45 millions €) for the whole area, which gives 28,8 thousand PLN/ha (8,26 thousand €/ha). The value of all the stands calculated according to the scenario III was 29,5% lower than for the Faustmann model scenario (I). The conclusion is that the non-timber value of a set-aside area should be at least as high as this opportunity cost of this area to outweigh the loss in timber production value, and thereby motivate the set aside economically.

The comparison made between the first and the second scenario shows how much the stand value is affected by the rotation age. The value of the second scenario, where rotation age was determined by the traditional Polish method, was 10,5% lower than the value of reference scenario where the soil expectation value maximization was used to determine the optimal rotation.

Key words: set-aside, opportunity cost, nature conservation, holding value, soil expectation value.

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1. INTRODUCTION

1.1 Background

Development brings a lot of benefits as well as many threats, and this trend does not exclude the forest sector. However the problem of overexploitation of the forest resources has been recognized and a lot of effort has been made to reduce this trend. The nature conservation and environmental preservation issues have become important topics in practical forestry today. The United Nations Conference on Environment and Development, which was held in Rio de Janeiro in June 1992, proved to be a milestone in shaping the current way of nature conservation. During this conference the foundation of the forest certification idea was born.

One of the most important aspects of current forestry practices is to keep the balance between the social, economical and environmental goals, which seems to be the base of sustainable development. This term, first used in 1987 by the United Nations, was defined as development that "*meets the needs of the present without compromising the ability of future generations to meet their own needs*" (United Nations, 1987).

To reach the right balance of biodiversity and timber production, the sustainable forest management has to provide a number of measures that would ensure the sustainability of the ecosystem. One such measure is setting areas aside, which creates good conditions for the nature conservation and preservation of rare species. Set-aside strategies do not always mean that the area is left unmanaged. In many cases it can be an active preservation, which is focused on ensuring that the area will serve the specific preservation function.

In Poland there are many set-aside strategies, because it is impossible to fit all preservation aspects in one pattern and not all dimensions of nature conservation require strict protection. The balance of all three constituent parts, social, economical and environmental, has to be kept.

1.2 Set-aside strategies in Poland

The whole area of Poland is 31,27 millions ha. The set-aside strategies applied on a national level (not only forests but all landscape formations) are presented in the following.

a. National parks

The area of a national park in Poland is more than 1000 ha and has to contain special natural, scientific, social, cultural and educational values. The preservation of such an area includes both nature and landscape characteristics. The overall purpose of creating a national park is preservation of biodiversity, natural resources, formation and components of inanimate nature and landscape characteristics as well as restoration of disturbed or extinct elements of a native nature (Act on Nature Conservation, 2004). There are currently 23 national parks in Poland with a total area of 317,3 thousand ha, which take up 1% of the total area of the country (Central Statistic Office, 2008).

b. Nature reserves

This type of set-aside is an area that consists of natural or practically undisturbed ecosystems as well as habitats of plants, animals or fungi and formations or components of inanimate nature, which contains specific natural, scientific, social, cultural and educational values (Act on Nature Conservation, 2004). The main difference, compared to a national park, is the minimum area of the reserve, which is not defined by the act, so that even a small area can be a nature reserve. An entire reserve or one of its parts can be under strict, active or, so-called, landscape preservation. The strict preservation is based on free ecosystem development. In the active one, preservation activities are allowed, for instance, to remove the trees that shadow the habitat of the protected plant species. Landscape preservation is fulfilled by performing agricultural, forestry or fishing activities in a way that takes into consideration the particular preservation purpose of the reserve. Nature reserves in Poland account for 0,54% of the total country area (Central Statistic Office, 2008).

c. Landscape parks

A landscape park is a type of protected area where, in comparison with a national park, less stringent restrictions on development and economic use are applied.

Legally, it is defined as "*an area protected because of its natural, historical, cultural and scientific values, for the purpose of conserving and popularizing those values in conditions of balanced development*" (Act on Nature Conservation, 2004).

There are 120 landscape parks in Poland which cover 8% of the total country area.

d. Others

There are more ways of protecting the natural resources:

- protected landscape areas
- geological "documentary sites"
- "ecological sites"
- "nature and landscape complexes"
- natural monuments (mainly single trees, but also some caves etc.).

These are not less important than the ones presented above (a, b and c), but the regulations regarding protection of the area are not so strict.

1.3 Nature conservation in the State Forests National Forest Holding

In Poland 78,1% of total forest area is managed by a self-sufficient governmental organization called the State Forests National Forest Holding (SF NFH) or just the National Forest Holding (NFH). Among all the set-aside strategies mentioned above only national parks are not located on the area managed by the NFH. National parks are directly financed by the government.

In the forests managed by the NFH every stand serves some kind of a function. It can be either economical (commercial) or protective of different kinds. From the total forest area managed by NFH, 46,4% performs some kind of protective function. All functions (economical and protective) and their shares of the forest area are shown in **Figure 1**.

In a few years it is expected that the share of protective functions will be even bigger because of Natura 2000 sites, which were not taken into account in **Figure 1**(The State Forests National Forest Holding, 2007a).

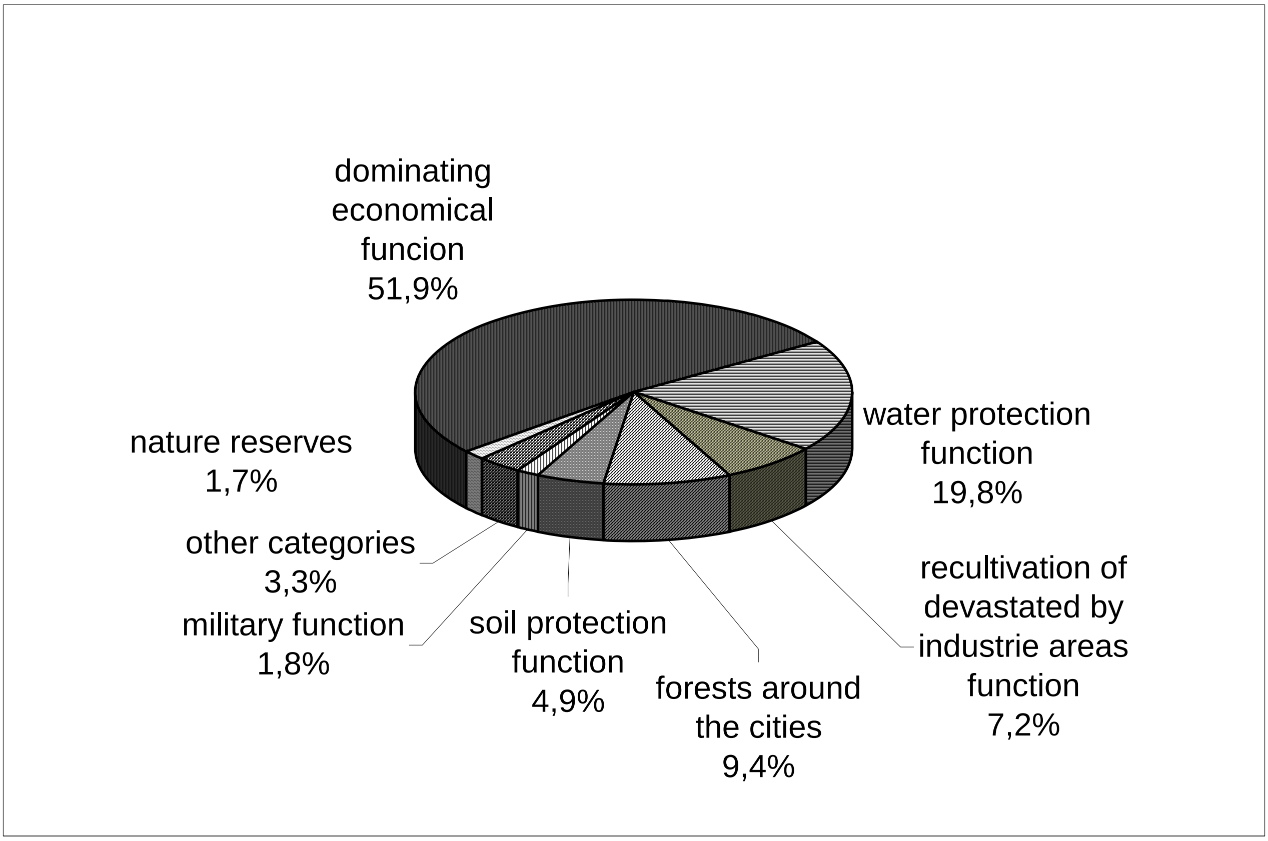

Figure 1. Acreage share of forest functions in the National Forest Holding, Poland (Adapted from The State Forests National Forest Holding, 2007a)

1.4 Trade-offs between timber and biodiversity

The forest is a multifunctional natural resource and provides a multitude of goods and services such as timber, game, berries and recreation. It also sequesters carbon, prevents wind erosion and it is a shelter for flora and fauna (Kindstrand, 2008). In Poland the demand for timber is increasing year by year (Matysiak, 2007). The amount of timber harvested in the SF NFH has risen by 4% annually in the last few years (more than 950 thousand m^3) and in 2007 it was 30 million m^3. However, demand for timber was on the level of 35 million m^3. The private forest owners provided 3 million m^3, resulting in a 2 million m^3 timber deficit on the national level (Matysiak, 2007).).The deficit in timber on the market is caused mainly by pressure from nature conservation and biodiversity, and this situation has initiated an intensive debate in Poland between environmentalists and the timber industry on trade-offs between the harvesting level and biodiversity.

There is therefore pressure from the timber industry to increase the harvesting level (Szkopiński, 2008). Some scientists claim that the timber harvest in Poland could be increased (Szkopiński, 2008), however, the authorities postulate that existing regulations prevent from overexploitation and help to achieve a sustainable level of biodiversity (Szweda-Lewandowski, 2007.

However, there may be conflicts in setting priorities between timber production and nature conservation (Bobiec, 2006). NFH, as a self-sufficient organization, needs to bring about profits in order to exist and nature conservation is mostly financed by the timber production. There are therefore more and more questions about the real costs of so-called forgone opportunity, which appear when the areas are set-aside for nature conservation purposes.

1.5 Polish forestry background

To better understand the way in which forests in Poland are managed it is necessary to have knowledge about the facts and figures as well as the social and environmental conditions.

According to the data obtained from the Central Statistic Office (CSO) in 2007 forests cover 28,9% of the area of Poland (Central Statistic Office, 2007). It is important to emphasize that 82,1% of the forests are publicly owned and 78,1% of the total forest area is under the management of NFH (**Figure 2).** State ownership represents one centralized management policy and a representative view of the whole country can be obtained by investigating just one forestry district, because they are working according to the same regulations and forest management is performed in similar ways (Bis, 2008). It is therefore relatively easy to apply a nature preservation regime and control, if it is carried out in the way that it should be.

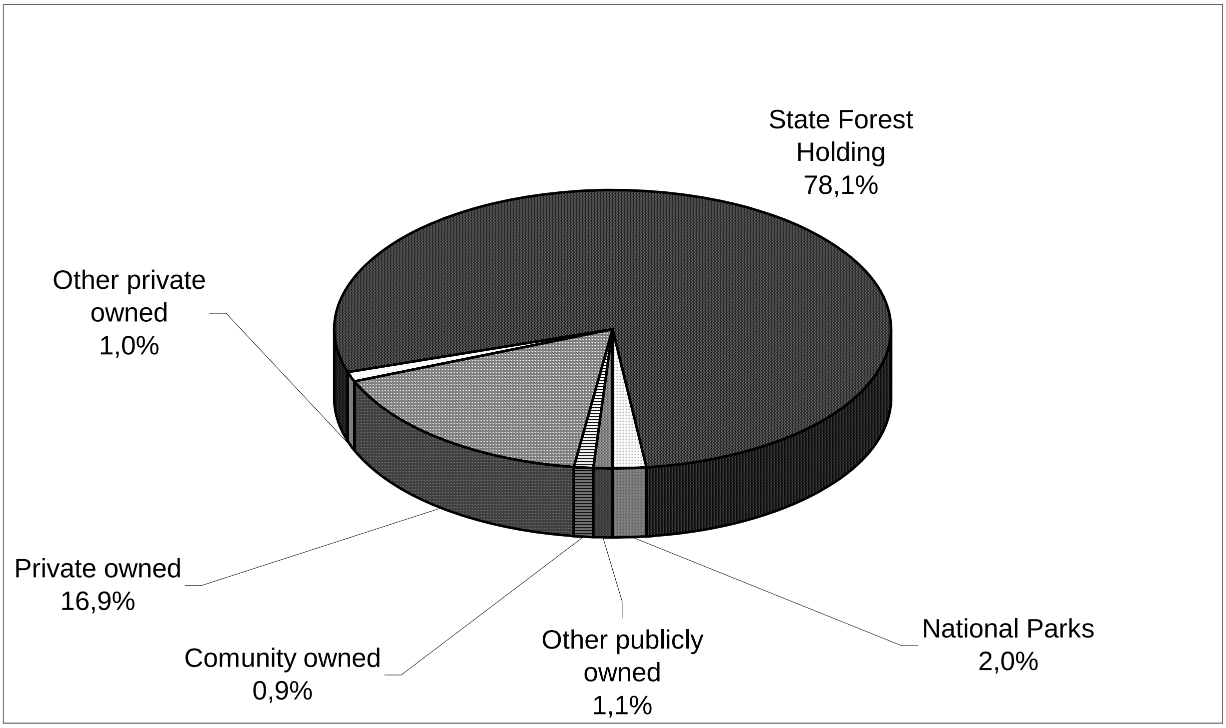

Figure 2. Ownership structure of the total forest area in Poland (Adapted from Central Statistic Office, 2008).

There are 1,5 million hectares of forest in private hands, but the average size of a holding is about 1 ha, and thus the fragmentation of private forests is significant. There are no strong organizations gathering private forest owners and therefore the forest holders do not take part in the discussion during the process of policy making.

The potential forest habitat structure in Poland is dominated by coniferous habitats with 55,1% of the total forest area, and the remaining 44,9% are broadleaved habitats. It means that potentially the coniferous – broadleaved species composition could be more or less even, because of the habitat properties that would allow it. But the actual species composition is dominated by coniferous species with a share of 75,6% (**Figure 3**). So some coniferous stands are growing on sites that are more suited for broadleaved forests. Nevertheless the share of broadleaves has increased between 1945 and 2007 from 13% to over 24% and it is still increasing, but it is still much lower than the potential habitat share (The State Forests National Forest Holding, 2007b).

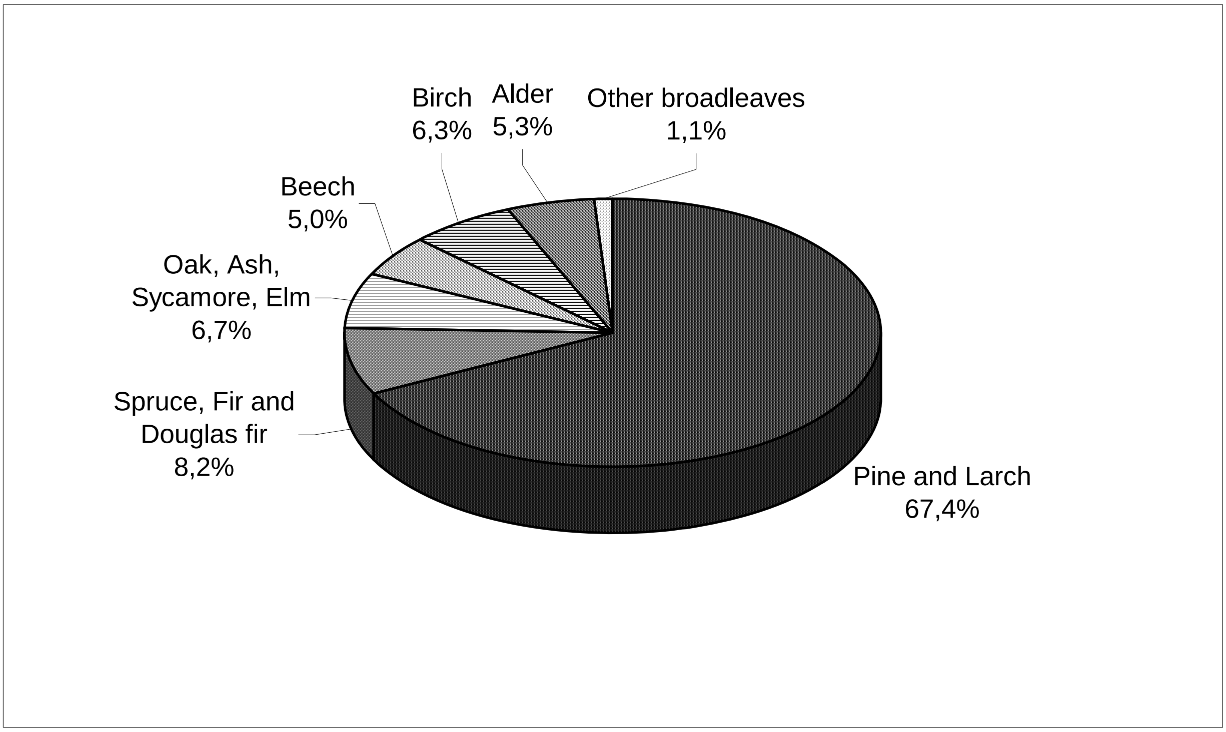

Figure 3. Share of the forest area by different tree species (Adapted from Central Statistic Office, 2008).

The pine domination has its origin in the after-war period. Pine is very productive and was therefore planted wherever it was possible using a clear cutting system and artificial regeneration. As a result only 49,5% of the pine forests are typical pine sites and the rest is mixed coniferous- broadleaved and broadleaved sites. This has created huge even-aged pine stands where pest control is very difficult (Tomanek, 1997).

2. AIMS OF THE STUDY

The aim of the thesis is to estimate the opportunity costs of set-asides in one Forest District of NFH located in the western part of Poland. The opportunity costs are in this case the timber production value foregone when making set-asides (Klemperer, 1996). The calculated opportunity cost can therefore answer the question of how high the nature protection value (and other non-timber values) of an area at least should be, to be worthwhile setting aside.

The holding value of selected stands was calculated. The estimations focused on the two most important species in the district, Pine and Oak. The calculations considered three management scenarios:

I. Faustmann model scenario - forest management without restrictions concerning set-asides and applying optimal rotation age according to the financial maturity.

II. Higher rotation age scenario - forest management without restrictions concerning set-asides but with higher rotation ages, determined with respect to ecological and social values (rotations used today in Poland).

III. Set-aside scenario - management where 26,4% of the forest area is excluded from production as set-asides and on rest of the area applying higher rotation ages, determined with respect to ecological and social values (rotations used today in Poland).

The roman numerals represent increasing restriction levels, so the economical perspective (I) is compared to management that is carried out according to guidelines and restrictions existing in Polish forest and nature conservation legislations (II), (III). The percentage of set-asides was calculated as the summed shares of nature reserves and areas with water and soil protection functions, located in all forests under the administration of NFH **(Figure 1)**. However, not all stands treated as set-asides in the calculations are such areas in reality. The assumption was made to keep the percentage level of protected areas in the district the same as in Poland at large. This assumption was motivated because only a few of the analyzed stands were serving some kind of protective function. The empirical data was based on one forest district but the model of assessing the opportunity cost can be adjusted for all such areas across Poland. Therefore, it was necessary to apply the percentage of set-asides existing at the national level. Some of the examined stands were thus hypothetically considered as set-asides.

The value difference between stands with rotation age set by soil expectation value (SEV) maximization and the traditional Polish method (section **3.2.2**), was analyzed by comparing the reference Faustmann model scenario (I) with the second one (II) with higher rotation age.

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3. THEORY

3.1 Economical efficiency and stand value calculation

Economic efficiency occurs when the net value (total value-total cost) is maximized, and the output can therefore not be changed without reducing net value (Field, 1994; Moffat, 2009; Heyne, 1991).

The analysis of stand value in this thesis will be carried out mainly with methods based on economic theory, which is not commonly used in Polish forestry. The reason for this is that in the Polish NFH, which is managing most of the Polish state forests, only the cash flow is used as an indicator of economic performance (Bis, 2008). It means that the discount rate is not taken into consideration when making investments in new and existing stands as well as in rotation age determination. The NFH is a self-sufficient organization, which means that it has to earn money to fulfill its needs. According to Zylicz (2004) , Polish forests could be managed in a more economically efficient way. Applying the Faustmann model could increase the rate of return. This would decrease the costs or increase the benefits of timber production (or both) and therefore increase the profit. The original Faustmann model from 1849 does not include the social and ecological value of old forests. According to the Faustmann model the simple methods used in NFH, if they are not accounted explicitly for ecological and social values, are not good ways to achieve the efficiency because they are not maximizing the net value of timber production and they are not providing the optimal rotation age. The investments in forestry should work similar to other investments like bank accounts, bonds, certificate of deposit or the rate used in discounting future values to arrive at present values (Klemperer, 1996), but also account explicitly for ecological and social values. Therefore different calculation methods of assessing the stand value will be presented.

3.1.1 Net present value

Net present value (NPV) is the present value of revenues minus the present value of costs. This method refers to one rotation only (Klemperer, 1996). It is the value of bare forest land.

$$\text{NPV}=\sum_{t=0}^{T}\frac{R_t-C_t}{(1+r)^t}; \qquad (1)$$

Where:

R - Revenues in year *t;*

C - Costs in year *t*;

T - Rotation age;

r – Interest rate

In equation (**1**) all revenues (R) , like profit from thinnings and final felling, and all costs (C) connected with establishing and tending the stand, are considered for the production period . NPV is useful in comparing net values of alternative investment options (Bis, 2008).

3.1.2 Forest rent

Forest rent (FR) accounts for all revenues minus all costs divided by rotation age.

$$\text{FR}=\sum_{t=1}^{T}\frac{R_t-C_t}{T} \qquad \textbf{(2)}$$

This indicator includes timber prices and all the costs. This model assumes (since a zero interest rate is applied), that the forest owner does not care about the realization of costs and benefits in time. It therefore does not account for the rate of return on alternative investments (Bis, 2008). The usage of this method in assessing the economical outcome can potentially lead to large economic losses (Hyytiäinen and Tahvonen 2003).

3.1.3 Perpetual analysis

For a correct economic solution to the rotation problem, it was assumed that a forest will be regenerated and new stands will be established and harvested an infinite number of times into the future. Thus it requires a different way of analysis.

3.1.3.1 Soil expectation value

Soil expectation value (SEV) is also called land expectation value or willingness to pay for land. It is the present value of all future costs and revenues of the productive asset. SEV is the net present value (NPV) for an infinite time horizon (Klemperer, 1996). This value corresponds to bare forest land.

$$SEV=\frac{\sum_{y=0}^{T} R_t(1+r)^{(T-t)}-\sum_{y=0}^{T} C_t(1+r)^{(T-t)}}{(1+r)^T-1}+\frac{a-c}{r} \qquad \textbf{(3)}$$

Where:

a- Annual revenues;

c- Annual costs.

In equation (**3**), (a) could be, for example, revenues from hunting or fishing rent on the area, while (c) could be the administration costs.

The FR solution **(2)** corresponds to the SEV solution **(1),** if the interest rate is zero (Bentley and Fight, 1966).

3.1.3.2 Holding value

The data from existing stands of different ages will be used in the analysis, but the value calculated by the SEV or NPV methods assumes that the stand is in year “0”. To calculate the present value of a forest of age “y”, instead of bare land (age 0), it is therefore necessary to convert the SEV formula **(3).** To assess the present value of already existing stands (in the year “*y*”) it is necessary to discount all future income after year *y*, for example, thinnings (occurring in year “*d*”, “*e*”, etc.) and of course the revenue from final harvest (in year “*T*”). The land will be used in perpetuity and so discounted SEV of all future forest generations must be added. This method of assessing the forest value is also called the holding value (HV) method (Klemperer, 1996).

$$HV_y=\frac{R_d-C_d}{(1+r)^{(d-y)}}+\frac{R_e-C_e}{(1+r)^{(e-y)}}+\ldots+\frac{R_T-C_T}{(1+r)^{(T-y)}}+\frac{SEV}{(1+r)^{(T-y)}} \qquad \textbf{(4)}$$

Where:

R- Revenues in year *d*, *e*, *T*;

C- Costs in year *d*, *e*, *T*;

T- Rotation age;

r – Interest rate;

y-Year of value calculation ($y < d, e, T$).

3.2 Rotation age

Determination of the optimal rotation age is among the oldest problems and one of the most important in forestry (Pearse, 1967). This is the age at which a stand is considered economically mature and ready for harvesting (Bozic, 2001). However, economically optimal rotation age, which maximizes SEV, does not necessarily imply that the forest is mature in a silvicultural sense. Rotation age is affected by many factors including site quality, desired product, stocking, and intensity of forest management activity as well as timber price and interest rates. Despite the fact that the correct answer to the problem of optimal rotation was first proposed by Faustmann (1849) 160 years ago, and a considerable amount of data have been gathered over the years, there remains persistent confusion of the correct rotation criterion and the economic meaning of reaching the optimal rotation (Chang, 1984).

3.2.1 Determination of optimal rotation age

There are various ways of determining the optimal rotation age based on maximization of some objective function. The most important of them are presented here, the objective functions were described in the previous section.

- Maximizing NPV of one rotation (Fisher, 1930).

When the interest rate equals the value increment of the stand it means that according to this model it should be harvested (Chang, 1984), also called "the guiding rate of return". When comparing the SEV model and the NPV model the latter does not consider all the future rotations' income and cost. The opportunity cost of using the land in a perpetual manner is not taken into account in the NPV model (Chang, 1984). When the rotation age is high the estimations provided by maximizing NPV and maximizing SEV are so close to each other that for practical purpose they can be seen as almost identical. This simplification should not be made while making calculations for fast growing species like poplars. In this case the difference in rotation age determination can be significant (Chang, 1984).

- Maximizing FR, the mean annual net revenue (Chapman, 1931; Markus, 1967).

This is a simple cash-flow measure. This method, expressed with equation **(2)** represents a *limited case of the SEV,* i.e. when the interest rate equals zero (Bentley and Fight, 1966).

- Maximizing SEV (Faustmann, 1849).

To determine the optimal rotation age according to this method it is necessary to maximize the present value of all future costs and revenues of the productive asset **(3)**. The stand should be harvested when the interest rate equals the value increment of the stand plus the value increment on the land. It is important to stress that this assessment includes an infinite time horizon.

- Maximizing the mean annual increment of the stand (Chang, 1984).

The relationship between this non-economic model and SEV model can be seen when a stumpage price for all age classes is constant, regeneration costs equal zero and the interest rate equals zero as well. In this case the non-economic model becomes the appropriate model of determining the optimal rotation age (Chang, 1984).

3.2.2 Determination of the rotation age in Poland compared with an economic approach

According to the Polish guidebook of forest management (Wazynski et al., 2005), the rotation ages are not set for a certain forest or estate, but for all species which by the time they reach this age are considered to reach the demanded maturity. In principle the rotation age should be determined by the mean age when the species reach the forest production goal, with respect to ecological and social needs.

The rotation ages for the five main Polish forest species (Pine, Spruce, Fir, Oak and Beech) were set almost 30 years ago, based on a list approved by the Minister of Forestry and Timber Industry. It does not take into consideration the site quality and the functions, which certain stands are serving, like economic, water and soil protection, etc. (**Figure 1**).

It is worth emphasizing that the above mentioned rotation age list approved by the Minister in Poland is used only to calculate the annual harvest level. This list is in practice used only as a reference point and are treated as the mean values. The ecological and biodiversity needs are also taken into account, because the rotation age should not be determined only by the technical and assortment demand criteria,. In other words the rotation age should meet the different demands of the multifunctional forest management (Wazynski et al., 2005). Those needs are analyzed once a year in each of the Regional Forest Directories on the meetings of forest authorities (Technical-Economy Commission). On these meetings the rotation ages of different species are determined for each of 17 Regional Directorys.

The standardized setting of rotation ages in Poland differs from a more economically oriented approach where rotation ages are determined at stand level. Therefore the age when the stand will generate the maximal revenue or economic yield is calculated. Economically established interest rate is determined by the species, site quality, market situation and personal preferences of the investor.

The economically optimal rotation is shorter for higher interest rate and whilst political uncertainties and bigger risk occur, the harvest age is even shorter (Zhang, 2000).

Table 1. The usual range of rotation age for the 5 main forest species in Poland (Wazynski et al., 2005).

Species	Rotation age range
Pine	100-120
Spruce	80-100
Fir	100-120
Oak	120-160
Beech	100-120

4. MATERIALS AND METHODS

4.1 Data source

The data for the analysis were collected in The Sulechow Forest District. The district is located in the western part of Poland in the Regional Directorate of State Forests in Zielona Gora (**Figure 4**). The district area is 25 352 ha and 44% of this area consists of forests. Pine forests covers 84,9% of the forest land (Regional Directorate of State Forests in Zielona Gora, 2008).

Figure 4. The location of The Sulechow Forest District in Poland (black dot).

The sampled stands are located in Klenica Forest Division, a part of The Sulechow Forest District. The Klenica Division has an area of 1550 ha and it is located on the eastern bank of the Odra river (Regional Directorate of State Forests in Zielona Gora, 2000). Nearness to the river results in nutrient rich soils, thus yielding a slightly different conifer-deciduous composition compared with the rest of district. Monoculture pine stands make up 48,1% of the forest area (Regional Directorate of State Forests in Zielona Gora, 2000). Due to the chosen species, Pine and Oak, it was relevant to do the calculations on a district that contains stands with both species in significant quantities.

4.2 Type of data

The data taken from The Sulechow Forest District administration contain quantities and types of assortments (**Table 2),** which were produced and sold in 2007. The residual assortment (diameter lower than 7cm) was not included in the analysis due to small quantities and low price. The prices of assortments as well as costs of logging and establishing new stands were taken from The Sulechow Forest District.

All pine and oak stands that contain more than 50% volume of one of the species were included. Pine accounts for 39,9% while oak accounts for 42,9% of the total timber volume in the division (Regional Directorate of State Forests in Zielona Gora, 2000). Nevertheless, there are more pine stands with more than 50% of the volume share of pine, even though the total volume of oak is higher.

From all six quality (site index) classes for pine stands, three (considered as the representative) were chosen for the analysis; I, III and V. For oak stands from four quality classes the I, II and III site index were chosen because there were very few stands growing on the poorest IV site. The Polish system of assessing the fertility of a site is shown in **Table 3**, in which quality classes used in research have been converted into a site index system where the fertility is distinguished as the mean height of the stand when it reaches 100 years.

In total 82 pine stands were chosen with an area of 202,62 ha and 44 oak stands with 214,91 ha. The total volume of all examined stands was 33946m^3 and 57,7% of the total volume was composed of pine stands whilst the rest were oak stands.

All calculations were provided in Polish currency (PLN), based on costs and revenues data are from the year 2007. The exchange rate to Euro and Swedish Crowns (SEK) was, respectively:

1PLN =0,287 € or 2,60SEK (December 2007)

Table 2. Types and prices of pine and oak assortments (class A – the best quality, class D – the worst quality).

Pine

Assortment		Diameter range	Price [PLN/m^3]
Saw logs	Class A	>35cm	318
		25-34cm	286
	Class B	>35cm	270
		25-34cm	239
		17-24cm	228
	Class C	>35cm	239
		25-34cm	217
		17-24cm	196
	Class D	>35cm	159
		25-34cm	149
		17-24cm	122
	Veneer	>35cm	819
		25-34cm	744
	Plywood	>35cm	416
		25-34cm	328
		17-24cm	246
Pulp wood	Class A	12-24cm	159
	Class B	5-24cm	149
Fuel wood		>5cm	65
Sticks		7-14cm	116

Oak

Assortment		Diameter range	Price [PLN/m^3]
Saw logs	Class A	>35cm	1160
		25-34cm	882
	Class B	>35cm	907
		25-34cm	643
		17-24cm	441
	Class C	>35cm	615
		25-34cm	445
		17-24cm	285
	Class D	>35cm	365
		25-34cm	277
		17-24cm	175
	Veneer	>35cm	1489
		25-34cm	1323
Pulp wood	Class A	12-24cm	169
	Class B	5-24cm	149
Fuel wood		>5cm	81,5

Table 3. Mean height of the stands at 100 years of age for quality classes and species used in the analysis.

Species	Quality class/Site Index		
Pine	I / 28	III / 20,3	V / 12,5
Oak	I / 30,9	II / 26,9	III / 22,8

4.3 Calculations

To calculate the value of a specific stand it is necessary to take into account the assortments that can be produced and their prices.

To simplify the process of the stand value calculation a model price curve for a spectrum of diameters was created. To estimate the price curve it was necessary to collect data of the assortment shares of different diameter classes. There was no such information for Polish conditions, so Lithuanian tables were used (Kuliesis et. al., 1997).

The percentage share of each assortment, for each diameter class was multiplied by the net price of this assortment (**Table 4a and b**) to get a weighted average net price for each diameter class. Price curves were estimated for final felling and thinning separately because the costs of harvesting and logging are higher for the thinning process. It resulted in differences in net prices of the same assortment (**Figure 5a and b**). To estimate the relationship between the price and diameter data from **Table 4a and b**, different functional forms were tested for both species. For pine a logarithmic relationship was used. The regression line for clear felling was expressed with the function: $y = 56{,}713Ln(x) - 21{,}503$ and for thinning: $y = 56{,}713Ln(x) - 37{,}503$, where y is the net price and x is the diameter. The correlation with the data in both cases was the same: $R^2 = 0{,}9965$.

Because of more rapid price growth with diameter for oak, a quadratic relationship was used for price curve estimation. For clear felling the regression function is: $y = -0{,}2416x^2 + 21{,}404x - 147$, and $R^2 = 0{,}9937$. For thinning correspondingly: $y = -0{,}2403x^2 + 21{,}295x - 160{,}81$ and $R^2 = 0{,}995$.

Table 4a. The percentage share of assortments in diameter class for pine and weighted average of the net price and percentage share.

		Assortment						Weighted average of the net price and percentage share in diameter classes	
		Saw logs with diameter: >35cm	25-34	17-24	Pulpwood	Sticks	Fuel wood	Clear felling	Thinning
Net Price of assortments [PLN/m³]	Clear felling	216,89	189,19	166,11	120,66	85,00	34,00		
	Thinning	200,89	173,19	150,11	104,66	69,00	18,00		
Percentage share of assortment in diameter class	8cm	0	0	0	60,5	24,5	15	98,93	82,93
	12cm	1,6	1,6	19,9	54,1	8,4	14,4	116,87	100,87
	16cm	7,1	11,4	28	33,6	6,8	13,1	134,25	118,25
	20cm	13,9	19,9	27,9	20,3	5,2	12,8	147,41	131,41
	24cm	23,9	24,6	23,1	11,5	4,6	12,3	158,72	142,72
	28cm	37,5	23,4	17,3	6,7	3,3	11,8	169,24	153,24
	32cm	50,5	19,3	11,7	4,4	2,7	11,4	176,96	160,96
	36cm	60	15,4	8,2	3	2,4	11	182,29	166,29
	40cm	67	12	6	2,1	2,2	10,7	186,03	170,03

Table 4b. The percentage share of assortments in diameter class for oak and weighted average of the net price and percentage share.

		Assortment					Weighted average of the net price and percentage share in diameter classes	
		Saw logs with diameter:			Pulpwood	Fuel wood		
		>35cm	25-34	17-24				
Net Price of assortments [PLN/m^3]	Clear felling	450,17	333,21	206,86	135,38	50,54		
	Thinning	434,17	317,21	190,86	119,38	34,54	Clear felling	Thinning
Percentage share of assortment in diameter class	12cm	0	0	5,1	31,1	63,8	84,9	68,9
	16cm	6,3	6,3	9,5	20,4	40	116,84	103,64
	20cm	12,3	16,4	23,1	7,3	40,9	188,35	172,35
	24cm	34,1	19,2	18,6	3,4	36	227,3	211,3
	28cm	34,1	19,2	14,2	1,7	30,8	264,73	284,37
	32cm	46,5	15	9	0,8	28,7	293,52	277,52
	36cm	55,8	10,2	5,5	0,4	28,1	311,3	295,3
	40cm	62,1	6,2	3,1	0,1	28,5	321,17	305,17
	44cm	65,2	4,2	2	0	28,6	326,1	310,1

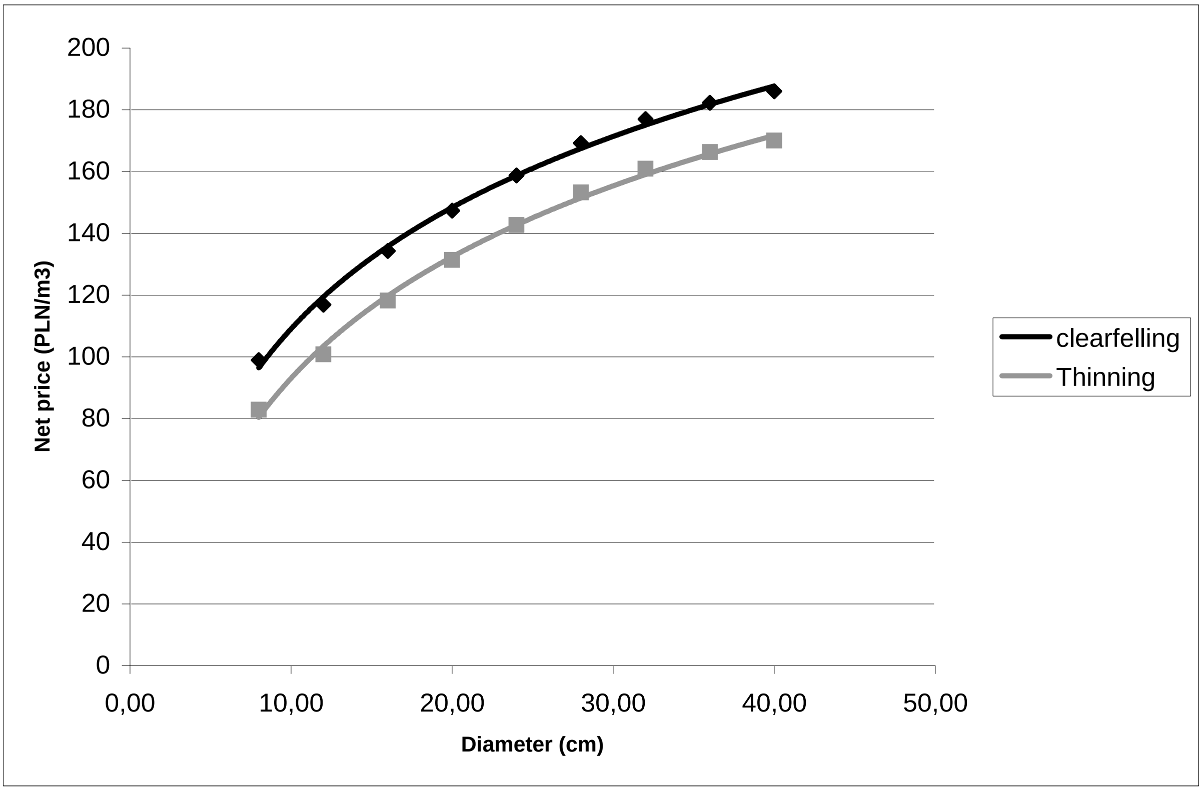

Figure 5a. Net price curve for pine.

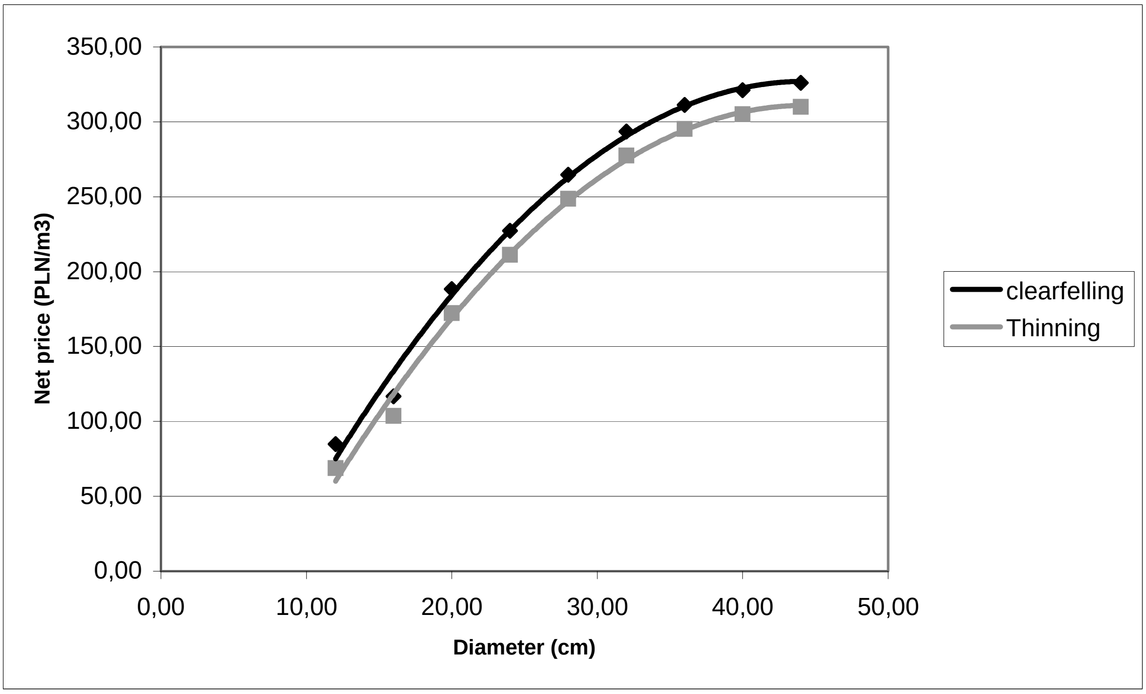

Figure 5b. Net price curve for oak.

The calculations were made using Polish yield tables. The tables were created by M. Czuraj in 1990, based on German work; Schwappach for pine stands and Wimmenauer for oak stands (Czuraj M. 1990).

Based on the yield tables the following data were used: height, diameter and current growing stock at a certain age as well as thinning volume in 10 year periods.

The next step in the calculations was to estimate the net price at the roadside. To do this, the mean diameter of trees in different age classes, taken from the yield tables, was inserted into the price curve regression function.

The net price of each assortment at the roadside multiplied by the corresponding volumes of the stand at thinning and clear felling gave the net income from the one hectare of examined forest for one rotation.

Subtracting costs of establishing and tending the stand (**Table 5a and b**) from the net income year by year resulted in a cash flow for whole rotation age. The costs of thinning and final harvesting were subtracted during the process of calculating the net price at roadside. Administration charges were not included.

The table presented in **Appendix 1** was the base to provide the calculations for determining the optimal rotation age based on soil expectation value (**3**). For the calculation, 2% interest rate was used. The motivation for this is that the mean annual timber growth of forests in Poland is approximately 2% (calculated from the current timber stock, 1500 million m^3, and its annual increment, 30 millions m^3) (CSO, 2004). The classic Clark (1976) model assumes that the rate of return from permanent forest exploitation can not exceed the natural forest growth level (Clark, 1976). According to this, a 2% discount rate was used. In the analysis only pine and oak were taken into consideration and the mean annual growth for those species can be higher than 2% annually. Nevertheless, 2% is a lower bound according to mean annual increment on a national level. The SEV estimation was carried out in 10 years interval starting from age 30. SEV was calculated for every possible rotation age in 10 years interval and in this way the rotation length with maximum SEV was chosen as optimal.

One purpose of the thesis is to compare the value of a forest with the rotation age set in accordance with Polish rules (II) to an economic approach by calculating the HV of the same forest but with rotation age determined by maximizing the SEV (III). A rotation age defined with the SEV method should not be considered in this research as economically optimal because the silvicultural program does not provide measures that can be considered as optimal from a strictly economic point of view. It is so, because of the schematic silvicultural program usage. It results from the yield tables construction (Czuraj, 1990), which assume the same schematic, 10 years interval thinning regime, both for Pine and Oak. For the calculations where maximization of SEV was used, the silvicultural program, compared to other calculations, was different in shorter rotations and smaller number of thinnings but with the same interval of 10 years.

To estimate the stand holding value (HV), equation (**4**) was used. The data for the calculations were taken both from yield tables and from real stands. Tree diameter and timber volume for calculating the final felling net revenue were taken from the actual stands. The volume and cutting diameter in all thinning processes were taken from the model yield tables.

It is worth to explain that SEV was only used to determine the optimal rotation age in scenario (I). The data to calculate this age was taken only from the yield tables and not from the stands used in the research. The HV was calculated for all examined stands for all three scenarios (**Appendix 2**). Real data from the existing stands was used for HV calculation.

Table 5a. Costs of establishing and tending 1ha of pine stand. PCT – Pre-commercial thinning.

Year	treatment	cost/ha [PLN]
0	Slash removal	210,00
	Soil scarification	310,00
	planting	1750,00
	plants	1123,00
1 to 10	Supplementary Planting	2900,00
	weeding x2	1020,00
	PCT(early) x2	600,00
11 to 20	PCT(late) x2	800,00

Table 5b. Costs of establishing and tending 1ha of oak stand. PCT – Pre-commercial thinning.

Year	treatment	cost/ha
0	Slash removal	210,00
	scarification	310,00
	planting	2000,00
	plants	2200,00
	fencing	1400,00
	fencing material	1906,00
1 to 10	Supplementary Planting.	2900,00
	weeding x2	1020,00
	PCT(early) x2	600,00
11 to 20	PCT (late) x2	800,00

4.4 Choosing the set-aside areas

In selecting the stands that should be set aside, it was difficult to distinguish what should be the "right" percentage of areas to set aside or in other words which set-aside strategies should be taken into consideration.

Because all the data were taken from the National Forest Holding only preservation strategies provided in the holding were taken into account **(Figure 1)**. From those strategies only the percentage share of water and soil protective forests as well as nature reserves under NFH administration were chosen as a reference for the percentage share of set-asides in examined stands.

Thus 26,4% of analyzed area was considered as the real amount of set-asides that should be taken into account in calculations.

To get a lower bound of the estimations, the choice of set-asides in the examined area only included the stands with the lowest site index. It does not mean that in reality the forests with some kind of protective function are growing only on the poorest sites, but the resulting economic estimates should be a conservative assessment of the opportunity cost of set asides.

5. RESULTS

5.1 Holding value of chosen stands

The same stands were analyzed using the three scenarios (I, II, and III). Results from the HV calculation of the stands differ among all scenarios, exhibiting the expected trend. The stands had the highest HV in scenario (I) where the optimal rotation age was estimated with SEV maximization method, equation **(3)**.

The difference in value comparing reference Faustmann model scenario (I) to the set-aside scenario (III), is 12,03 millions PLN, or 28,8 thousand PLN per hectare (total area 417,5 ha). The value of all stands in the higher rotation age scenario (II) was 10,5% lower and in the set-aside scenario (III) 29,4% lower than the reference Faustmann model scenario (**Figure 6**; **Table 6**).

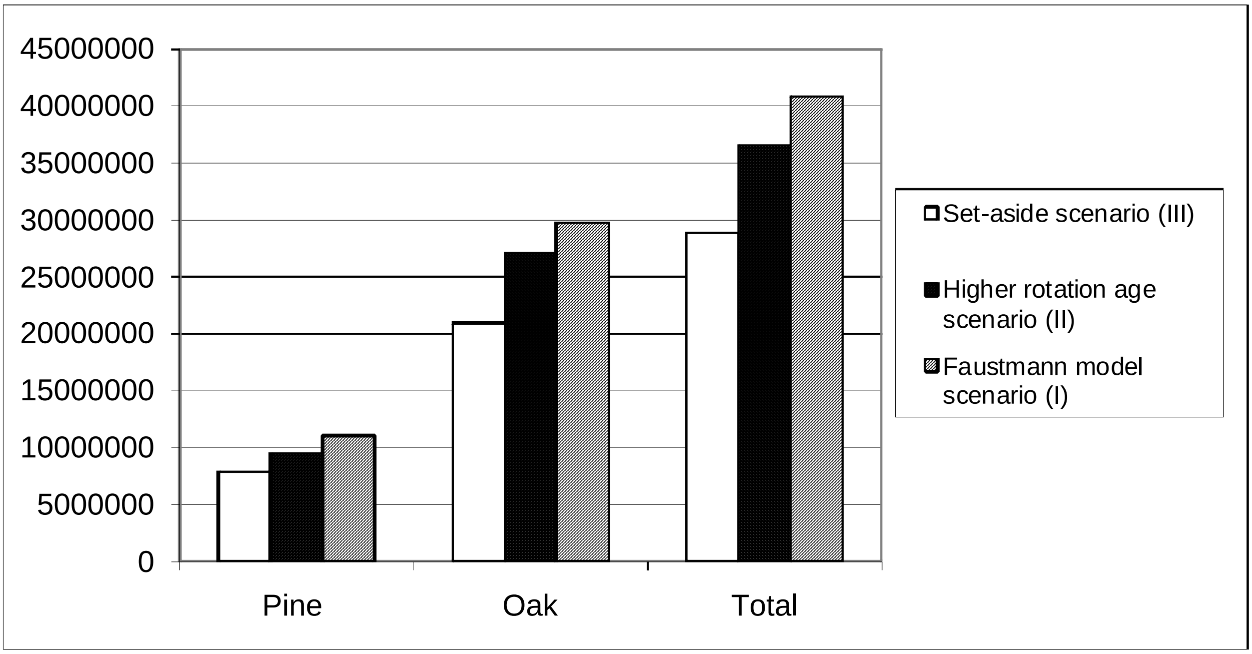

Figure 6. Holding value (PLN) of all stands in three scenarios.

The growing trend of weighted-average HV per hectare was exactly the same as in the former situation (**Figure 7, Table 6**).

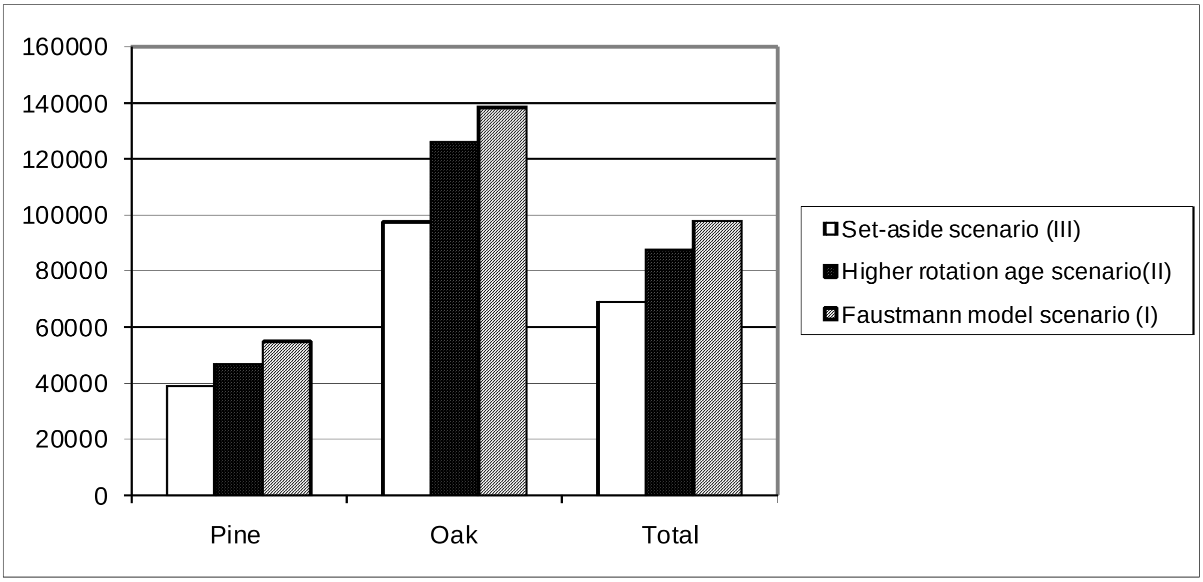

Figure 7. Holding value of stands per hectare (PLN).

Table 6. Holding value of all the stands and percentage loss in value in three scenarios.

Stand calculation scenario	Total value [PLN]	Value/ha [PLN]	Loss in value % in total	% per ha
I. Faustmann model				
Pine	11082478	54696	Reference scenario	
Oak	29775005	138546		
SUM	40857483	97862		
II. Higher rotation age				
Pine	9492759	46850	14,34	14,34
Oak	27087576	126041	9,03	9,03
SUM	36580336	87617	10,47	10,53
III. Set-asides				
Pine	7874003,5	38861	28,95	28,95
Oak	20956348	97512	29,62	29,62
SUM	28830352	69055	29,44	29,43

Holding values of all stands are shown in **Appendix 2**.

5.2 Rotation age set by maximizing the soil expectation value

To exhibit the difference in stand value, when the rotation age is decreased, scenario (I) assumes that the harvest age should be set with usage of the SEV method. To reach this goal the method of maximizing the soil expectation value, shown in theory equation **(3)**, was used.

As expected, the resulting rotation ages were much shorter as compared to those normally used in Poland. The differences were also apparent between the highest and lowest site index, which was a result of slower growth and therefore a longer time needed to reach the production goal on the poorest sites (**Table 7**). It resulted in the same harvest age for medium and the lowest site index for oak. (**Appendix 1**). There were small differences in SEV for lower site indexes for ages close to optimal

Table 7. Rotation ages in two scenarios and three site indexes used in the analysis.

Species	Site index class		
Pine	I	III	V
"Polish" way	100	100	100
Set with NPV	60	70	70
Oak	I	II	III
"Polish" way	140	140	140
Set with NPV	80	90	90

6. DISCUSSION

The difference in value comparing the reference (I) scenario to the (III) scenario is 12,03 million PLN or 28,8 thousand PLN per hectare. This is due to the longer rotation age and the over 26% of forest area set aside in scenario III. Thus the calculated value difference is the opportunity cost of applying those two nature conservation measures simultaneously. The conclusion is that the non-timber values of such areas should be at least as high as the opportunity cost to outweigh the loss in timber production value.

The second aim of the thesis was to compare the traditional Polish way of setting the rotation age to that set by the soil expectation value (SEV) method. The results follow expectations, where the rotation age set with an economic approach is much shorter comparing to the traditional way used in Polish forestry (**Table 7**). In Poland the harvest age is not correlated with site index. Therefore, when determining this age using economical tools, there are some differences in rotation ages among site qualities. Obviously, the reason for this is slower growth of the trees on the lowest quality sites.

The holding value of all stands with rotation age set with the traditional method used in Poland (higher rotation scenario) is 10,5% lower than set with the SEV maximization method (scenario I). It is likely that the difference in the holding value would be even bigger if for the Faustmann scenario applied an economically optimal silvicultural programme.

Future analysis of this topic could assume one more calculation scenario. It could be Faustmann model scenario, where the rotation age is determined by the financial maturity and set aside areas for nature conservation purpose are excluded. The result of such research could give some arguments in the discussion on the strategy of nature conservation that assumes differentiation on areas dedicated for a timber production and areas with a nature conservation purpose, respectively, without combining those two functions.

The analysis was based on some important assumptions. The Lithuanian tables were used when creating price curves to set the percentage usage of timber assortments (**Table 4a and b**). There are no such tables made for Polish conditions. Nevertheless, the types of assortments are similar to those that are produced by NFH in Poland. The price curves were estimated based on only nine observations for each of the tree species. It is not enough from a statistical point of view, however, the shapes of both curves are reasonable and each of the nine points actually represent a much bigger material since they are averages from a large number of observations.

Some may consider the 2% discount rate too low. The reason for this is biological and is motivated by forest sustainability. The analysis could be repeated using higher discount rates. This will lead to shorter rotation ages and probably to higher opportunity costs.

The current way of managing the forests in Poland gives great opportunities for forest protection. The biodiversity in Poland appears to be on a high level as there exist many nature conservation strategies and huge amount of areas are protected. However, it is most likely that there will be more discussions regarding the values of nature conservation. A lower bound for the biodiversity values of set-asides can be given by calculating the opportunity costs.

Forest managers and policy makers in Poland could, for financial reasons, be forced to take into consideration more economic principles of managing the forest within the costs of nature protection. The opportunity costs could give guidance if it is worthwhile to set some area aside. A more economic approach would also involve changing the way of value calculation from simple cash flow methods to those based on a discounting rate.

A natural next step in the research would be to estimate the non-timber values in economic terms and too see if the benefits of the set asides exceed the alternative costs as estimated in this thesis. This could be done with stated preference methods like, for example, the contingent valuation method. For a review, see e.g. Mitchell and Carson, 1989 or Bateman et al., 2002. If the non-timber values turn out to be at least as high as the opportunity cost, the forest policy should be beneficial to society.

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APPENDICES

APPENDIX 1. Tables for determining the optimal rotation age, with usage of SEV maximization method.

1. Oak
    - Quality class I

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0					-8026,00	
1-9					-4520,00	
10					0,00	
11-20					-800,00	
20	39	6,5		0	0,00	
21-30	7	8,7	6,27	43,88	43,88	
30	126	11	59,21	7460,51	7460,51	-19129,90
31-40	20	13,2	78,41	1568,28	1568,28	
40	216	15,5	126,72	27371,00	27371,00	900,51
41-50	27	18	144,64	3905,36	3905,36	
50	294	20,5	190,25	55933,38	55933,38	16674,39
51-60	31	22,8	199,80	6193,75	6193,75	
60	363	25	237,10	86067,30	86067,30	25912,15
61-70	33	27,1	239,81	7913,59	7913,59	
70	422	29	270,53	114163,83	114163,83	30016,39
71-80	34	30,8	267,12	9082,01	9082,01	
80	**474**	**32,5**	**293,44**	**139090,56**	**139090,56**	**30888,38**
81-90	35	34,2	286,41	10024,51	10024,51	
90	523	36	310,43	162355,10	162355,10	30303,32
91-100	35	37,8	300,79	10527,68	10527,68	
100	563	39,5	321,50	181005,40	181005,40	26533,56
101-110	34	41,2	308,65	10494,07	10494,07	
110	599	43	326,65	195665,51	195665,51	22601,87
111-120	33	44,8	310,91	10260,17	10260,17	
120	634	46,5	325,89	206611,98	206611,98	23203,05
130	668	50	319,20	213225,60	213225,60	19597,03
140	700	53,3	307,47	215231,92	215231,92	16330,89

- Quality class II

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0					-8026,00	
1-9					-4520,00	
10					0,00	
11-20					-800,00	
20	14	5,2		0	0,00	
21-30	0	7,2	-19,94	0,00	0,00	
30	75	9,2	29,47	2210,08	2210,08	-25660,74
31-40	11	11,2	47,55	523,06	523,06	
40	154	13,3	94,94	14620,23	14620,23	-10658,57
41-50	18	15,4	110,14	1982,58	1982,58	
50	224	17,5	153,58	34401,92	34401,92	1816,71
51-60	23	19,4	161,87	3723,09	3723,09	
60	281	21,2	198,18	55688,61	55688,61	9473,60
61-70	25	23	201,86	5046,41	5046,41	
70	332	24,8	235,23	78094,88	78094,88	14043,52
71-80	26	26,6	235,61	6125,87	6125,87	
80	379	28,3	265,24	100525,27	100525,27	16369,98
81-90	27	30	261,77	7067,79	7067,79	
90	**425**	**31,7**	**288,73**	**122708,28**	**122708,28**	**17257,48**
91-100	28	33,4	282,37	7906,47	7906,47	
100	467	35	306,18	142986,06	142986,06	15596,23
101-110	28	36,7	297,06	8317,65	8317,65	
110	504	38,3	318,37	160459,78	160459,78	13392,87
111-120	28	40	306,51	8582,28	8582,28	
120	539	41,6	325,30	175338,37	175338,37	14462,71
130	572	44,6	327,04	187065,36	187065,36	12001,34
140	602	47,5	324,58	195397,16	195397,16	9649,94

- Quality class III

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0					-8026,00	
1-9					-4520,00	
10					0,00	
11-20					-800,00	
20	0	3,7		0	0,00	
21-30	0	5,2	-56,57	0,00	0,00	
30	32	6,3	-21,74	-695,80	-695,80	-29242,24
31-40	2	8,3	-0,62	-1,23	-1,23	
40	83	10	42,88	3559,04	3559,04	-20294,06
41-50	10	11,8	57,01	570,12	570,12	
50	144	13,8	102,36	14740,55	14740,55	-11145,36
51-60	15	15,6	112,91	1693,69	1693,69	
60	195	17,2	149,67	29186,40	29186,40	-4337,69
61-70	19	18,8	154,60	2937,48	2937,48	
70	243	20,4	189,10	45950,65	45950,65	518,27
71-80	20	22	191,37	3827,50	3827,50	
80	288	23,6	223,57	64388,98	64388,98	3740,55
81-90	21	25,2	223,22	4687,70	4687,70	
90	**329**	**26,7**	**252,25**	**82991,10**	**82991,10**	**5532,48**
91-100	22	28,2	248,61	5469,48	5469,48	
100	366	29,7	275,59	100864,42	100864,42	5290,22
101-110	22	31,2	269,68	5932,88	5932,88	
110	402	32,7	294,57	118417,28	118417,28	4563,07
111-120	22	34,2	286,41	6301,12	6301,12	
120	436	35,6	308,79	134631,67	134631,67	5914,55
130	470	38,5	318,94	149902,93	149902,93	4635,33
140	500	41,3	324,89	162445,25	162445,25	3214,95

2. Pine

- Quality class I

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0					-3393,00	
1-9					-4520,00	
10					0,00	
11-20					-800,00	
20	63	6,5		0,00	0,00	
21-30	16	8,7	85,19	1362,97	1362,97	
30	165	11,1	115,00	18975,34	18975,34	7200,23
31-40	43	13,5	110,10	4734,44	4734,44	
40	250	15,9	135,38	33845,81	33845,81	19091,70
41-50	48	18,2	127,05	6098,18	6098,18	
50	306	20,3	149,24	45666,93	45666,93	23206,76
51-60	50	22,1	138,06	6902,82	6902,82	
60	**353**	**23,8**	**158,26**	**55865,56**	**55865,56**	**24406,63**
61-70	50	25,4	145,95	7297,47	7297,47	
70	388	27	165,41	64180,55	64180,55	24004,18
71-80	50	28,5	152,48	7624,01	7624,01	
80	416	29,9	171,20	71219,10	71219,10	23009,22
81-90	48	31,3	157,79	7574,16	7574,16	
90	437	32,7	176,28	77032,83	77032,83	20010,77
91-100	48	34,1	162,65			
100	453	35,4	180,78	81891,50	81891,50	17385,59
101-110	48	36,7	166,82			
110	465	37,9	184,65	85860,38	85860,38	15116,17
111-120	45	39	170,27			
120	474	40	187,70	88971,90	88971,90	13170,29
130	41	41,6	189,93			
140	474	43,1	191,94	90978,46	90978,46	9994,27

- Quality class III

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0						
1-9						
10						
11-20						
20	3,4	0	3,40		0,00	
21-30	5,4	5	5,40	58,14	290,69	
30	7,4	70	7,40	92,01	6440,49	-9708,07
31-40	9	23	9,00	87,11	2003,49	
40	10,5	139	10,50	111,85	15547,23	253,80
41-50	12	31	12,00	103,42	3206,13	
50	13,4	191	13,40	125,68	24005,20	5300,81
51-60	14,8	34	14,80	115,32	3920,79	
60	16,2	225	16,20	136,44	30699,75	7319,89
61-70	17,6	36	17,60	125,14	4505,19	
70	**19**	**258**	**19,00**	**145,48**	**37535,12**	**8481,18**
71-80	20,4	36	20,40	133,52	4806,61	
80	21,8	275	21,80	153,28	42152,37	8441,66
81-90	23,1	36	23,10	140,57	5060,39	
90	24,4	290	24,40	159,67	46304,70	7040,22
91-100	25,7	36	25,70	146,62		
100	26,9	301	26,90	165,20	49726,21	5717,37
101-110	28,1	36	28,10	151,68		
110	29,3	304	29,30	170,05	51695,24	4418,36
111-120	30,4	34	30,40	156,14		
120	31,4	305	31,40	173,98	53062,62	3299,98
130	33,1	31	33,10	176,97		
140	34	292	34,00	178,49	52118,35	1410,63

- Quality class V

Age	Volume of Thinnings and Clear Felling [m^3]	Diam. of cutt. [cm]	Net price at roadside [PLN/ha]	Gross income [PLN/ha]	Cash flow	SEV r=2%
0					-3393,00	
1-9					-4520,00	
10					0,00	
11-20					-800,00	
20	0	2		0,00	0,00	
21-30	2	3,1	26,66	53,32	53,32	
30	1	4,5	63,80	63,80	63,80	-17890,31
31-40	4	6,1	65,05	260,20	260,20	
40	28	7,4	92,01	2576,19	2576,19	-12341,17
41-50	11	8,4	83,20	915,15	915,15	
50	68	9,3	104,97	7137,81	7137,81	-7783,03
51-60	13	10,2	94,21	1224,69	1224,69	
60	102	11,1	115,00	11730,21	11730,21	-5115,00
61-70	16	12	103,42	1654,78	1654,78	
70	129	12,8	123,08	15877,80	15877,80	-3606,15
71-80	19	13,5	110,10	2091,96	2091,96	
80	**151**	**14,2**	**128,97**	**19474,52**	**19474,52**	**-2775,53**
81-90	21	14,8	115,32	2421,67	2421,67	
90	164	15,4	133,57	21905,67	21905,67	-3023,52
91-100	23	16	119,74			
100	175	16,6	137,83	24119,66	24119,66	-3331,16
101-110	24	17,2	123,84			
110	175	17,8	141,78	24812,37	24812,37	-3824,04
111-120	26	18,4	127,67			
120	172	19	145,48	25023,41	25023,41	-4273,12
130	10	19,6	147,25			
140	156	20,2	148,96	23237,49	23237,49	-5064,60

APPENDIX 2. List of all the examined stands with holding values.

1. Oak

Stand nr	Area	Quality class	Age	Diameter	Volume	HV
1	3,21	3	112	37	343	311894,2
2	0,76	3	137	45	354	125901,8
3	3,97	3	117	37	316	442593,7
4	0,85	2	117	38	351	117292,2
5	0,5	3	15	0	0	11835,03
6	0,51	3	42	8	73	17938,65
7	0,5	2	92	29	360	47376,57
8	3,23	3	112	35	333	313837,4
9	1,62	3	117	45	298	180605
10	2,72	3	112	36	346	264284,2
11	15,32	1	107	44	444	2100863
12	11,25	2	117	50	499	1552397
13	20,86	2	117	48	454	2878489
14	12,79	1	117	53	479	1993131
15	11,83	2	117	48	439	1632431
16	1,5	1	97	48	555	183001,3
17	2,5	3	117	60	301	278711,4
18	0,58	2	102	38	395	61929,02
19	3,88	1	17	0	0	167459,4
20	3,8	1	10	0	0	131789,2
21	4,08	1	11	0	0	141499,9
22	16,37	2	122	46	466	2258910
23	3,32	1	57	26	354	267402,9
24	2,91	2	127	56	512	489491,2
25	0,47	2	127	55	295	79058,72
26	2,34	2	92	42	393	221722,4
27	7,07	2	107	49	433	855284,6
28	6,39	2	127	62	598	1074862
29	1,82	3	102	35	191	154848
30	6,75	2	107	62	359	816573
31	2,34	2	107	53	414	283078,6
32	7,69	2	127	50	364	1293535
33	5,56	2	132	49	366	935247,8
34	1,53	2	87	36	279	144972,3
35	1,2	3	92	27	127	89700,25
36	0,41	1	16	0	0	17695,46
37	0,77	3	127	50	293	104642,3
38	1,09	2	92	30	349	103280,9
39	17,22	2	117	45	350	2376202
40	7,37	3	117	56	347	821641,3
41	6,06	3	117	51	286	675596,5
42	0,95	2	107	43	384	114925,1
43	1,98	3	102	37	428	168461
44	7,04	1	117	63	434	1097079

2. Pine

Stand nr	Area	Quality class	Age	Diameter	Volume	HV
1	1,41	1	37	14	193	73710,91
2	0,67	3	11	0	0	11552,07
3	3,26	3	11	0	0	56208,59
4	0,74	1	47	19	252,5	42174,66
5	2,95	1	42	14	236,5	154217,9
6	4,69	1	42	16	250,8	245180,2
7	1	1	47	16	257,4	56992,78
8	0,37	3	11	0	0	6379,503
9	0,21	1	52	19	249,7	11968,48
10	0,8	1	37	16	218,6	41821,79
11	1,68	3	107	35	262,2	88891,85
12	1,11	1	37	11	192,3	58027,73
13	2,68	1	40	15	257,7	140103
14	2,32	1	40	13	296,8	121283,2
15	0,53	1	67	23	245	32708,04
16	2,9	1	40	13	268,4	151604
17	0,48	1	42	15	187,6	25093,07
18	2,52	1	50	15	402,5	143621,8
19	1,8	1	92	35	446,5	146595,2
20	1,26	1	49	15	365,7	71810,91
21	4,43	3	40	9	157,3	132636,7
22	0,73	1	67	24	301,9	45050,7
23	0,72	1	67	24	292	44433,56
24	1,06	3	38	7	116,1	31737
25	7,23	1	45	12	309,9	412057,8
26	10,97	3	34	7	121,4	289348,1
27	1,24	1	52	16	274,9	70671,05
28	3,81	3	47	10	154,1	125568,3
29	3,04	3	112	26	273,7	153381
30	4	3	27	0	0	105505,2
31	7,44	3	21	0	0	162943,8
32	0,95	1	67	25	280	58627,62
33	0,97	1	67	23	279,9	59861,88
34	2,94	3	37	7	108,2	88025,25
35	1,12	1	77	25	405,4	82511,27
36	1,72	1	82	30	391,8	126713,7
37	1,55	1	57	20	291,1	95871,54
38	2,06	1	56	17	404,2	127416,4
39	8,54	1	72	23	412,2	527031,4
40	1,42	1	77	23	503,3	104612,5
41	0,81	1	52	18	301,5	46164,15
42	2,76	1	72	28	405,5	170328,7
43	4,14	3	44	9	163,9	123953,9
44	2,3	1	49	16	309,1	131083,4
45	1,6	3	42	9	146,1	47904,9
46	0,76	1	52	18	275,3	43314,52
47	2,03	1	16	0	19,6	81064,65
48	0,53	3	82	21	182,4	22204,5

49	1,91	3	44	9	163,2	57186,47
50	1,69	3	102	24	294,3	87703,21
51	4,48	3	107	25	337	268759,3
52	4,59	3	102	22	253,8	197714,9
53	2,04	3	36	7	130,1	61078,75
54	9,88	3	112	25	264	476555,2
55	3,85	3	112	32	320,2	237672,6
56	11,62	3	102	24	303	622283,2
57	2,46	1	67	24	418,2	151814,7
58	1,77	1	38	11	220,7	92530,71
59	1,3	3	87	22	214,5	59127,96
60	1,64	3	92	23	245,9	74592,2
61	1,72	3	87	24	245,1	78230,84
62	1,01	3	87	22	247,3	45937,88
63	0,44	3	87	21	291,5	20012,54
64	1,07	3	87	22	248,7	48666,86
65	0,88	1	37	11	193,9	46003,97
66	1,14	1	57	20	320,5	70511,97
67	0,39	1	42	13	225,2	20388,12
68	3,08	3	42	9	146,8	92216,93
69	0,88	1	38	11	245,7	46003,97
70	0,49	1	38	11	191,6	25615,85
71	1,17	3	47	10	206,7	38560,34
72	2,27	3	47	10	203,2	74813,65
73	1,8	1	67	24	312,7	111083,9
74	4,32	3	102	24	301	229756,9
75	1,45	1	52	16	336,5	82639,54
76	5,57	1	44	14	366,7	291184,2
77	5,44	1	52	14	303,2	310040,7
78	0,56	3	26	0	39,2	14770,73
79	0,73	3	36	7	72,7	21856,61
80	2,45	1	15	0	20,3	97836,65
81	2,26	3	72	18	209,4	79014,77
82	2,02	3	72	14	231,1	70623,82