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MACROECONOMIC EFFICIENCY OF LAKE RECLAMATION

1. Introduction

Lakes in Poland are undergoing a process of accelerated eutrophication. The causes lie in the excessive, compared to the natural inflow, discharges of nutrients from various anthropogenic sources. These discharges are from both point (e.g. communal or industrial sewage outlets) and non-point (e.g. surface runoff from fertilized fields or aquaculture) sources.

Eutrophication leads to an excessive concentration of nitrogen and phosphorus in surface waters and, subsequently, an excessive growth of aquatic plants. While decaying they decrease the oxygen content in lake waters, which may lead to the extinction of some fish species, changes in water plankton, the creation of a sulphurized hydrogen layer close to the floor of the lake and, in consequence, unpleasant visual and odorous sensations, as well as allergic reactions when bathing. In particular, it precipitates the overgrowth of vegetation, shallowing of lakes and their inevitable atrophy.

Generally the cleanness of Polish lakes is assessed as being poor and it is gradually deteriorating [Pyłka-Gutowska, 2001]. In order to counteract the lake degradation, various methods have been tried all over the world, including Poland, generally known as lake reclamation [Kajak, 1990].

Methods of reclamation have been categorized by Chełmicki [2001]. They include:

- flushing (letting in fresh water with minimal nutrient content),
- aeration (pumping air into lake waters),
- removal of sediments (dredging the floor, in order to remove sediments rich in nitrogen and phosphorus),

- controlling the population of littoral plants and increasing fish catches (removal of organisms rich in phosphorus),
- seston catches (usually by filtering off suspended organisms),
- biomanipulation (intervention in the trophic chain resulting in the elimination or limitation of selected species, mainly phytoplankton organisms).

Lake reclamation is usually expensive and presents difficulties. Polish reclamations have not always ended in a success [*Rekultywacja...*, 2005; Jańczak, 2002].

The lakeside town of Ełk in northern Poland ordered a study entitled 'A Programme of Action for Environmental Protection as Applied to Improving the Cleanness of Lake Ełk and the River Ełk' [*Program...*, 1995] within the framework of the 'National Programme of Action for Environmental Protection'. In accordance with this programme, the reclamation of the northern basin of Lake Ełk started in 1999. It was accompanied in the following years by diversified actions aimed at eliminating or significantly limiting the inflow of pollutants into the lake from various sources and also clearing some parts of the lake and the inflowing river of the rubbish accumulated there, thanks to the voluntary work of scuba divers from Ełk.

Besides cutting off the inflow of nutrients, the lake waters were for several years mechanically aerated and treated with the coagulant PIX, in order to precipitate phosphoric compounds. Also, the lakeside part of the town was developed and turned into a recreational area.

The reclamation ended in 2005 as a complete success [*Ocena...*, 2004]. A macroeconomic appraisal of this endeavour may well be of interest to specialists in water management, since it is likely that similar projects will be undertaken in other locations in the future.

2. Reclamation costs

Since the reclamation activities extended over 7 years, the expenditure may be classified as either initial investment or operational. All financial expenditure in this study has been converted to 2005 price level using the construction price index [*Wskaźniki...*, 2006]. The core part of the investment was financed by a consortium of several agents, as shown in Table 1. The building of such a multilateral financing system may be partially acknowledged as a particular success of the Ełk municipal office and in part as a lucky strike for the town, since a pilot project was needed anyway to start the 'National Programme of Action for Environmental Protection'. The total value of investment expenditure amounted to 2859.5 thousand PLN. The main component of the reclamation installations were two Stratiflox aerators served by a compressor station [*Północne...*, 1998]. Additionally, a Bio-hydro grid was installed in the channel

between lake Sunowo and lake Elk. This plays the role of a bio-filter limiting the influx of nutrients from lake Sunowo, where intensive aquaculture operations take place.

Table 1. Structure of investment expenditure at 2005 price level (thousand PLN)

Financing institution	Expenditure	Share, %	Total share, %
Aerating installations and biological filters			
EAPSP ^a (USAID), grant for studies and design	73.4	6.1	2.6
Ekofundusz ^b , grant for construction	574.1	47.9	20.1
Suwałki governor, grant for construction	206.7	17.2	7.2
Suwałki Provincial Fund for Environmental Protection and Water Management, loan for construction	198.7	16.6	6.9
Elk municipal budget	145.7	12.2	5.1
Total	1198.7	100	41.9
Accompanying investments			
Elk municipal budget, waterfront area development,	1131.6	100	39.6
Elk municipal budget, separators	529.2	100	18.5
Grand total	2859.5		100

Notes:

^a EAPSP stands for Environmental Action Program Support Project. This was a support programme maintained by USAID (US Agency for International Development) and USEPA (US Environmental Protection Agency), aimed at supporting ecological projects by providing technical aid. EAPSP financed a Local Environmental Action Program (LEAP, its official name was National Environmental Action Program Pilot Project), which mainly comprised construction of programs for certain environmental protection activities in the towns of Warsaw, Radom and Elk. The Elk local authority chose lake reclamation and the reduction of air pollution from low-emission sources as the main environmental problems in the town [Polish..., 1997].

^b Ekofundusz was established in 1992 with the aim of managing the capital accumulated from the so called eco-conversion of part of the Polish government's foreign debt into financing environmental protection. Agreements on such partial eco-conversion were signed with the governments of the US, France, Switzerland, Sweden, Norway and Finland. The means obtained in this way are utilized by Ekofundusz in the form of grants to selected environmental protection projects.

Source: Authors' own research.

Re-development of the waterfront area accompanied the direct investments in reclamation. Also, six oil and suspended solid separators were installed in the outlets of storm drains into the lake.

Operational expenditures were entirely financed by Elk's Communal Fund for Environmental Protection and Water Management. Their composition is presented in Table 2.

It can be seen that energy costs dominated other operational costs.

Table 2. Operational costs of the reclamation project, at 2005 price level (thousand PLN)

Cost item	Year							Average	Share, %
	1999 (VIII–XII)	2000	2001	2002	2003	2004	2005		
Electricity	17.3	38.3	75.7	111.9	105.4	99.4	95.7	77.7	45.8
Monitoring ^a	17.2	34.0	46.7	20.5	12.0	11.9	12.5	22.1	13.0
Maintenance ^b	20.0	43.2	76.3	77.9	62.3	54.3	43.0	53.9	31.8
Materials ^c	24.5	15.5	21.4	15.4	10.5	13.3	10.4	15.9	9.4
Total	79.1	131.0	220.1	225.6	190.2	179	161.7	169.5	100.0

Notes:

^a Monitoring of water quality in the lake by the Hydrobiological Station in Mikołajki, Polish Academy of Sciences [Ocena..., 2004].

^b Several engineering firms were successively hired for inspecting, maintaining and operating the equipment.

^c The material costs included purchase of the coagulant PIX, its transportation from the PIX factory in Police to Elk, purchase of spare parts for the pumps, compressors and aerators, the material costs of rethe surroundings of the compressor station.

Source: Authors' own research.

3. Benefits of reclamation

Reclamation has definitely enhanced the recreational value of the lake. Both the permanent inhabitants and tourists frequenting the region have felt the beneficial effects from cleaning the lake waters (generally speaking from below third class to second class purity) and the new layout of the lakeside area. The economic value of this positive change was estimated as split into two components: amenity value to the inhabitants defined as the increased utility represented by their willingness to pay and its attractiveness to tourists represented by the increase in net cashflow from services provided to tourists in three waterfront hotels.

The positive effects of reclamation should, in the opinion of the environmental protection inspectorate in the Elk municipality, extend over about 50 years, thanks to the now decidedly diminished inflow of pollutants into the lake. After that time reclamation will probably have to be repeated.

The contingent valuation method was applied to estimate the value to inhabitants. The increase in the net cashflow in hotels was estimated from the hotel accounts for recent years. The survey among the inhabitants was conducted in the spring of 2006. 100 fully answered questionnaires were collected by the stratified random sampling of interviewees. The social structure of the sample according to employment and sex reflects the social structure of the population of Elk. This structure was taken from municipality files. 68% of respondents declared willingness to pay for lake reclamation. The

distribution of positive and negative answers among various social groups is shown in Table 3.

Table 3. Declaration of the willingness to pay by various social groups

Classification criterion	Re-sponse	Interval					
		age, years	25 and below	26 to 35	36 to 45	45 to 60	above 60
	yes, %	62	49	54	35	43	
	no, %	38	51	46	65	57	
education	primary	vocational	secondary	incomplete university	university		
	yes, %	72	36	69	80	73	
	no, %	28	64	31	20	27	
employment	pupil/student	employed	self employed	entrepreneur	unemployed	pensioner	
	yes, %	75	83	83	80	26	64
	no, %	25	17	17	20	74	36
family income, PLN/month/person	below 300	300-700	700-1000	1000-1200	1200-1500	above 1500	
	yes, %	20	53	89	80	100	100
	no, %	80	47	11	20	0	0
sex	female	male					
	yes, %	70	65				
	no, %	30	35				

Source: Authors' own research.

The answers regarding willingness to pay might have fallen into one of the four following categories: none (0), between 0 and 1 PLN monthly, between 1 and 2 PLN, between 2 and 5 PLN. No one declared willingness to pay above 5 PLN per month. Table 4 illustrates the distribution of willingness to pay in particular social groups. The mid values of these intervals were used.

Assuming the survey results are representative of the whole population of Elk they may be generalised as follows: approximately 35% of inhabitants are willing to pay on average 0.5 PLN/month, 28% of them 1.5 PLN/month and 5% of them 3.5 PLN/month. The average monthly values that various categories of inhabitants are willing to pay are given in Table 5.

Table 4. Distribution of the willingness to pay in various social groups by value, %

Classification criterion	Payment PLN/month	Interval					
		25 and below	26 to 35	36 to 45	45 to 60	above 60	
age, years	0-1	47	47	57	64	55	
	1-2	41	47	43	29	45	
	2-5	13	5	0	7	0	
education	primary		voca-tional	second-ary	incom-plete uni-versity	univer-sity	
	0-1	46	80	56	64	46	
	1-2	38	20	41	36	46	
	2-5	15	0	3	0	8	
employment	pupil/student	em-ployed	self em-ployed	entrepre-neur	unem-ployed	pen-sioner	
	0-1	44	60	60	0	100	57
	1-2	39	40	40	75	0	43
	2-5	17	0	0	25	0	0
family income, PLN/month/person	below 300	300-700	700-1000	1000-1200	1200-1500	above 1500	
	0-1	100	76	47	27	20	0
	1-2	0	21	47	64	80	50
	2-5	0	3	6	9	0	50
sex	female	male					
	0-1	45	58				
	1-2	45	36				
	2-5	9	7				

Source: Authors' own research.

In order to estimate the total annual willingness to pay, the unit values for the employment groups were used, because the social structure of the interviewed sample exactly followed the social structure of the town's population as recorded in municipal files.

The total estimated willingness to pay in 2005 equalled 516016 PLN/year. This year was assumed to be the first in which this social benefit occurred, because reclamation activities ended then and the target state was reached.

It was assumed that the individual average annual willingness to pay would stay constant in the following years, hence estimated total willingness to pay

Table 5. Unit average willingness to pay in various social groups, PLN/month

Classification criterion	Payment PLN/month	Interval					
		age, years	25 and below	26 to 35	36 to 45	45 to 60	above 60
average		1.32	1.19	0.94	1.10	0.93	
education	primary	vocational	secondary	incomplete university	university		
average		1.39	0.75	1.05	0.88	1.15	
employment	pupil/student	employed	self employed	entrepreneur	unemployed	pensioner	
average		1.39	0.90	0.90	2.00	0.50	0.93
family income, PLN/month/person	below 300	300–700	700–1000	1000–1200	1200–1500	above 1500	
average		0.50	0.85	1.16	1.50	1.25	2.50
hsex	female	male					
average		1.23	1.06				

Source: Authors' own research.

is proportional to the predicted population. The rate of growth in the future was assumed to be equal to the average rate observed in the years 1999–2005, *i.e.* 4.73 % per year.

The increase in the net benefits to the hotelbusiness from cleaning up the lake waters was estimated as the difference between the average annual net cashflow from tourist services in the years 2000–2004 and this cashflow in 2005. In 2000–2004 the lake was held in good repute because of the reclamation activity being carried out. This reputation was almost completely lost in 2005, due to false information in a Pascal tourist guide [Tomczyk, 2005] about the allegedly disastrous state of the lake. This caused the turnover and net cashflow from tourist services to drop significantly.

Besides this, one of the three hotels situated at the waterfront and profiting from its lakeside location underwent a temporary financial breakdown in 2002 and 2003 because of disputes between the owners and inefficient management [Kubicki, 2003]. Therefore, this hotel in these years was excluded from the calculation.

The increase in the net cashflow from hotel and restaurant services provided to local people was not taken into account, since it probably resulted in an equivalent loss from analogous services rendered by other hotels and restau-

rants in the town and in this way did not add to total social benefit. The sum of the increases in the net annual benefit from tourist services calculated as above amounted to 20 814 PLN.

4. Economic efficiency

Standard efficiency indicators were calculated, *i.e.* Net Present Value, its Equal Annual Equivalent, Internal Rate of Return, Benefit/Cost Ratio and Break Even Point.

The value of the discount rate was needed for the calculation of some of them. For valuations of consumer goods this rate is usually set to be equal to the bank deposit rate, reflecting the opportunity cost of consumer capital. Another method of valuing this capital may envisage, still available to a consumer, a more advanced investment in treasury bonds. In this case the indicator of opportunity cost becomes equal to the interest rate on such bonds.¹ Alternatively, a discount rate of 4%, suggested by Martin Weitzman at an environmental economists' congress in Venice in 1998 as the average result from a world wide survey among environmental economists could be used, particularly in the case of environmental goods.²

Since the calculations used constant prices, the real, and not nominal, values of these rates should be used. Therefore, the nominal values for 2005 were transformed using the standard formula

$$R_{\text{real}} = \frac{1 + R_{\text{nom}}}{1 + R_{\text{infl}}} - 1$$

where:

R_{real} – real rate of interest

R_{nom} – nominal rate of interest

R_{infl} – inflation rate, in this case equal to the consumer price index (CPI)–1.

The average interest rate on bank deposits in 2005 was 2.95% [*Średnie...*, 2005] and the most frequent rate on treasury bonds was 4.5% [*Obligacje...*, 2006]. The CPI index equalled 1.021 [*Roczne...*, 2006]. Hence, the real rates emerged as 0.83% and 2.35% respectively.

The results of the sensitivity analysis described above are presented in Table 6.

¹ A question arises as to whether the income tax imposed on interest should be deducted. The income tax decreases private income from interest on capital, but not social income and therefore was not deducted in this case.

² Professor Tomasz Żylicz, personal communication.

Table 6. Economic efficiency indicators for the lake reclamation

Indicator	Discount rate, %		
	0.83	2.35	4.0
Net present value (NPV), thousand PLN	21 192	13 453	8 194
Equal annual equivalent, thousand PLN/year	461.8	427.2	365.3
Internal rate of return, %	9.43	9.43	9.43
Benefit/cost ratio (calculated using present values)	6.29	4.51	3.32
Break even point, setting 1999	14	16	17

Source: Authors' own research.

5. Discussion

From a social (macroeconomic) perspective the venture has proved highly efficient, independently of the discount rate adopted. The main benefit appears to be an increase in the general utility of the lake for the inhabitants, represented by their willingness to pay. This accounted for 96.1% of the total benefit, while the remaining 3.9% represented the increased net cashflow from hotel services for tourists.

Pupils and students were the social group most interested in the cleanness of the lake, as shown by Table 5 and their valuation was a large proportion of the total valuation as shown in Table 7. But even excluding their willingness, on the ground that they do not represent effective, but only potential demand for waterfront amenities, would not change the positive economic assessment of the reclamation. For example, when discounting at 0.83% annually, the net present value (NPV) becomes 13 222 thousand PLN instead of 21 192 thousand PLN, with a discount rate of 2.35% this becomes 7807 thousand PLN instead of 13 453, with a discount rate of 4% it becomes 4705 thousand PLN instead of 8194. Despite a significant decrease in the NPV, the positive assessment is far from being nullified.

In fact it is this potential, rather than effective, demand that is a better measure of the social value of environmental improvement.

In the case of Elk, the older members of the population were familiar with the voluntary funding of public ventures, since in the mid-nineties a municipal indoor swimming pool was built thanks to a voluntary subscription of 1 PLN per month from the working adults in the town.

The unit value of investment expenditure, including separators and waterfront re-development, per hectare of the surface of the lake's northern basin amounted to 35.6 thousand PLN. The investment per inhabitant was 51.2 PLN and per professionally active person it was 111.3 PLN. The number of inhabitants in December 2005 was used for these calculations.

Table 7. Share of particular employment groups in the total annual willingness to pay for lake reclamation, %

Share	Employment					
	pupil/student	employed	self-employed	entrepreneur	unemployed	pensioner
Share in total willingness	32	23	12	21	3	8

Source: Authors' own research.

The operational and maintenance costs over the 7 years of operation calculated at 2005 price levels amounted to 1186.5 thousand PLN. These costs were attached only to the aeration activities. The maintenance of the waterfront area was excluded, as the costs were probably similar to the costs born before. From this perspective, the ratio of the operational and maintenance costs to the value of the investment can be calculated to be 0.415.

The younger and more educated members of local society appear to be more sensitive to the cleanness of the lake. Also, women were willing to sacrifice 16% more money than men to ensure that the lake waters are in a good state.

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