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ECONOMIC ASPECTS OF IMPLEMENTATION OF ENVIRONMENTAL FLOWS

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ABSTRACT: Sustainable management of water resources requires leaving in the rivers a flow that ensures biological life. Since 2014, water authorities have been seeking to develop a methodology for determining environmental flows that are to reflect the inherently time-changing environmental water needs. The paper presents economic aspects of the implementation of environmental flows that will bring environmental benefits from providing the necessary amount of water for aquatic ecosystems as well as for water dependent ecosystems. However, on the other hand, they can cause significant costs for existing water users and limitations in economic use of water resources in the future. The cost-benefit approach is developed to estimate costs and benefits from introducing environmental flows in river basins. As the result the unit costs and benefits indicators for different water users are estimated and applied for the economic analysis in six study areas. The outcomes provide new information and methodological approach for decision-making about implementation of environmental flows.

KEY WORDS: environmental flows, cost-benefit analysis

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Introduction

Environmental flows have aroused much controversy because for many rivers in Poland, they proved to be much higher than the currently used instream flows, and thus were seen as a threat limit the existing water abstractions. Ensuring enough water for fulfilling the needs of various actors in a catchment can be a difficult task under certain circumstances, in particular when the cumulative demand for water abstraction exceeds the available resources. Water is needed for domestic uses, various economic sectors (e.g. agriculture, aquaculture, fisheries, industries, energy, etc.) as well as to sustain ecosystems life in the rivers and catchments. In order to fulfil the last requirements environmental flows need to be established to allow the ecosystems to stay in a good condition. Healthy ecosystems can bring benefits for humans and economy. However, in the water scarce catchments the trade-offs between the various water uses are inevitable. Therefore a methodology for determining environmental flows that are to reflect the inherently time-changing environmental water needs, is sought by the water authorities. The environmental flows calculation methods are compared in the next chapter providing a background for the economic analysis. This issue is important as adequate calculation of environmental flows lead to fair distribution of water resources between the ecosystems and other water uses. Thus, there would be enough water for ecosystems preferable without undermining the other needs. However, if environmental flows were establish at significantly higher level than the previously used instream flows, it would result in limited disposable resources in rivers, which might translated into limitation of existing water permits for water abstraction. Therefore, the decisions about the water resources allocation for the various actors needs are not easy to make and thus the objective methods for decision-making are sought. One of possible methods is Cost-Benefit Analysis that compares the benefits and the costs resulting from different scenarios of water allocation in a catchment.

The paper aims to present economic aspects of the implementation of environmental flows. The hypothesis is that environmental flows bring environmental benefits from providing the necessary amount of water for aquatic ecosystems as well as for water dependent ecosystems, but also they can cause costs for existing water users and limitations in economic use of water resources in the future.

Case studies of several catchments in Poland served for exemplification of the costs and benefits of various water users as well as the methods to estimate the economic values. In the following chapters the environmental flows calculation methods are shortly presented together with the method of

analysis. The Cost-Benefit Analysis was tailored for the assessment of costs and benefits from changes in environmental flows for stakeholders, such as households, various economic sectors and ecosystems.

An overview of literature

The idea of environmental flows (eflows) was introduced as a response to the degradation of aquatic ecosystems caused by overuse of water. An environmental flow can be defined as water regime provided within a water body (river, wetland or coastal zone) to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated (Dyson et al., 2003). An environmental flow encompasses a biological flow, which is the minimum boundary flow of water in rivers that cannot be reduced as a result of business operations. The properly established environmental flow will take into account, not exclusively, hydro-biological conditions ensuring good status and preservation of fauna and flora in the rivers and river dependant ecosystems as well as protection requirements of legally protected natural sites. The aspirations to maintain the environmental flow should not be identified back to its natural regime, but the process should take into account a wider set of criteria and values than is the case for the needs arising from the economic use of watercourses (water supply, hydropower, shipping) as well as protection against flood and recreation. In contrast to the inviolable flow, medium and high flows are also taken into account in its determination. A flow is inviolable in a given section of the watercourse and for a given period of the year, it is contractual, appropriate for the established ecological state of the watercourse, the volume and quality of which, due to the preservation of this state, can not be, and due to the institution of universal use of water, they should not be reduced by human activities except during periods of emergency. For a part of the inviolable flow associated with the need to preserve the assumed ecological condition of the watercourse, the hydrobiological flow was adopted. The idea of hydrobiological flow is closer to environmental flows.

In the scientific literature, case studies of the concept of integrated assessments, so-called holistic methodologies for assessing environmental flows (Gopal, 2016; Akter et al., 2014) that take into account physical, biological, water quality and socio-cultural aspects of river ecosystems. As the trade-offs between human and environmental water needs are increasing in frequency and amplitude on the increase, the environmental flows concept has continued to evolve in response to these challenges (Pahl-Wostl et al., 2013) and studies on conceptual frameworks for eflows governance as well

as hydro-economic models and most frequently case study analyses of particular water bodies have been developed. The tradeoffs among water policy choices were addressed by implementing hydro-economic model in the study of Kahil et al. (2016). This study confirmed the importance of adequate policies protecting water resources and natural ecosystems, as in their absence water users will deplete reservoirs, aquifers and river flows for short-term adaptation to climate change, disregarding the impacts on the environment and future human activities (Kahil et al., 2016).

In the work of Acreman and Dunbar (2004) one can find a series of types of methods for determining environmental flows in terms of costs. Based on this review the following classification of these methods from the cheapest to the most expensive in implementation can be presented:

- look-up tables analysis – it is the most frequently used method, based on expert indicators to determine target flows,
- analysis of existing materials – it is a desk analysis based on collected data and analysis of results of modeling outcomes,
- functional analysis – it integrates hydrological, hydraulic and biological analyzes of the watercourses with the expert analyses,
- hydro-biological – habitat and hydraulic modeling based on methods requiring field testing, taking into account the conditions necessary for functioning for species and habitats in determining the desired flows.

Acreman and Dunbar (2004) state that the available in the literature and applied methods for the determination of environmental flows differ in usability depending on the conditions in which they are to be applied, such as: the degree of complexity and the amount of implementation costs. Relatively cheap and simple methods are less accurate and better for cross-section analysis with a high degree of generality. While more complex methods with higher implementation costs, like the hydraulic habitat modelling, give more accurate results in specific assessment cases. This leads to the conclusion that the choice of the method to be used should be primarily dependent on its purpose, e.g. regional cross-cutting and comparative studies, planning for the needs of management in catchments and river basin areas, environmental impact assessment and restoration of rivers.

The implementation of environmental flows may result in limiting the current use (consumption) in order to leave the flow to the environment – ensuring conditions for the proper functioning of water ecosystems. Social and economic impacts may be significant, but they will be diversified, and the overall assessment of the effects will depend on whether and to what extent the benefits generated by the introduction of environmental flows exceed economic losses caused by limiting the current use of river water resources. Therefore, an important element of the implementation of environmental

flows is the identification of costs and benefits that may arise from their introduction (Dyson et al., 2003).

Research methods

The proposed analytical approach is based on Cost-Benefit Analysis (European Commission, 2014), implemented here to analyze the potential socio-economic and environmental consequences of changing the required level of environmental flows at the catchment scale. The index method approach was used.

In the calculations of costs and benefits for various kinds of water users (the exemplary calculation presented in table 2) available data from water--economic balances were used to determine impacts of changes in environmental requirements on reducing users' water consumption as well as unit costs and benefits indicators presented in table 1. The unit costs were estimated as potential loss of benefits/revenues for the users from restraining to use water and the unit indicators of water productivity estimated with the use of input-output data of economic sectors (GUS, 2014; Godyń, 2012).

Benefits are related to improvement of ecosystems conditions and hence the improvement of their functions, and services they provide, due to higher water availability (Grygoruk et al., 2013; Panasiuk, 2014; Hackbart et al., 2017). In the benefits calculation the value estimates obtained from ACA (2008) study were used. The study reviewed estimates of Willingness to Pay (WTP) of various case studies worldwide and provided the value estimate for WTP per year per capita for the protection of minimum instream flows. The value was adjusted to polish conditions taking into account GDP per capita and inflation rates.

Results of the research

The highest water abstraction is realized by the conventional energy sector (GUS, 2017), which uses the water for cooling purposes and the intakes, are located on big rivers (area >5000 km^2). In such cases, when the maximum permitted intake does not exceed 3 m^3/s the minimum (environmental) flow does not need to be measured (IMGW-PIB, 2016) as it is assumed that there will be enough water for the users. In other cases the trade-offs needs to be examined.

The unit costs and benefits indicators obtained in the analysis for various kinds of users are presented in table 1.

Table 1. Unit costs and benefits indicators

Users	Costs	Unit indicators
Municipal water supply network	development of new intakes	65 million PLN/m^3/s
	loss of revenue*	10 PLN/m^3
Industry sector	loss of revenue*	142 PLN/m^3/year
Carp ponds	loss of revenue*	458,30 PLN/dm^3/s
	drought compensations*	44,61 PLN/dm^3/s 300 PLN/ha
Salmon ponds	loss of revenue*	1772 PLN/dm^3/s
Irrigation	drought compensations*	1200 PLN/dm^3/s 1000 PLN/ha
Hydropower	loss of revenue*	21000 PLN/m^3/s/1m of slope/year
Nature and ecosystems	ensuring minimum biological flows	11,34-81,99 PLN/year/household

* due to the temporary lack of water withdrawal possibility

Source: author's own work based on MGGP, 2018.

Comments on estimated indicators: for the industry sectors the indicators were estimated based on the added value of this sectors in the Polish economy as a whole. The indicator for carp ponds was estimated based on revenues of a small number of ponds, it can be updated on a specific case (applied water management solutions on ponds – time and quantity distribution of abstractions, other species of fish). For salmon ponds indicator was estimated with the assumption of productivity of 1 t/1 dm^3/s and profitability of 1772 PLN/t. For irrigation the indicator was calculated for a small number of water intakes, so in every case it needs to be adjusted taking into account type of crop, type of irrigation, harvesting volume. The basic assumptions for hydropower included: efficiency 90%, working time 8000 h/year, electricity price 170 PLN/MWh and external benefits from clean energy 100 PLN/MWh.

Example estimates for two river catchments are presented in table 2. These are two surface water bodies – Mroga from Mrożyca to estuary and Radomka to Domaniów reservoir, where the existing use is abstractions for fishponds. In these catchments, the estimated environmental flows are higher than the existing inviolable flows, which may cause a withdrawal limitation for existing fishponds. In addition, in the case of Mroga, there are also available disposable resources for future users, which are "lost" (traded to the environment) after the introduction of environmental flows.

Table 2. Estimates of costs and benefits in study areas

Catchment	User	Costs or Benefits carrier	Costs or Benefits [thousand PLN/year]
Mroga from Mrożyca to estuary	Carp ponds	withdrawal limitation	8-16
	Carp ponds	loss of disposable resource (for future uses)	13
	Nature and ecosystems	WTP (5500 households)	63-452
	Net Benefits		**41-423**
Radomka to Domaniów reservoir	Carp ponds	withdrawal limitation	714
	Nature and ecosystems	WTP (2600 households)	30-212
	Net Benefits		**29-211**

Source: author's own work.

The estimated costs are not high due to the type of water users in these catchments – fishponds, and this kind of economic activity is characterized by low economic efficiency. Sample estimates made for other types of users – municipal water abstraction or industry, show that with the adopted unit cost indicators, even a small change in the time guarantee and deficit in consumption may cause high costs.

Discussion

It should be noted that direct up-scaling of the results obtained for the analysed catchments would not provide a reliable outcomes because of the variability of conditions between the catchments. The uniqueness of conditions of flow regimes could be exemplified by a case study of the Upper Noce River in northern Italy, in which the river regulated by hydropower is showing the seasonality of ecosystem services and their internal non-linearity (Carolli et al., 2017).

Not ensuring an adequate environmental flow leads to limitations in the provision of services by ecosystems, which results in: loss of income (e.g. lower crop yields), costs related to the repair of negative effects and loss of the ability to use ecosystems. (SWH, 2009) The estimation of these vales in particular case requires time-consuming and expensive process of: mapping of ecosystems services and their characteristic *in-situ*, identification of the ecosystems services and their valuation. Therefore, for more holistic studies transfer methods can be used. Richardson et al. (2015) provided guidance for application benefits transfer methods to estimate monetary values of ecosys-

tem services. Nevertheless, it should be taken into account that economic valuation with the use of transfer methods is not precise due to the fact that the conditions for which the values are calculated are not the same as well as the assumptions between the case studies may vary. Also, values estimated with the use of contingent valuation methods are the elicited hypothetical values, which do not necessarily reflect the real-life choices.

The valuation of ecosystem services is possible in relation to ecosystems as a whole, because they provide many services at the same time, whose availability depends on the functioning of the ecosystem as a whole consisting of many components dependent on each other (Kronenberg, 2012). Therefore the benefits in the presented study were assessed with the use of outcomes of WTP studies. At the same time, it should be taken into account that economic values assigned to resources in the valuation process do not constitute the full economic value of these resources.

Willis and Garrod (1998) studied benefits to anglers and general public from increasing river flows from low flows level caused by over-abstraction to an environmentally satisfying level, using the contingent valuation and stated preference methods. They compare it to the costs to water companies caused by the need of replacing the water from elsewhere, and concluded that the costs should be the decisive variable in decisions about low flows alleviation in any low flow river. Also, the results of the study conducted on the Lower Ebro river (Gómez et al., 2014) shows that the lost revenues from reduced energy production resulting from the occurrence of floods are lower than the observed tendency to pay for river restoration programs.

Conclusions

The hypothesis that environmental flows bring environmental benefits from providing the necessary amount of water for aquatic ecosystems as well as for water dependent ecosystems, but also they can cause costs for existing water users and limitations in economic use of water resources in the future, was confirmed.

The estimates of costs and benefits for various water users in the analysed catchments confirm observations from the literature studies that the benefits from existence of natural ecosystems (secured by environmental flows or by rivers and floodplains reclamation) obtained through the WTP elicitation or WTP transfer are much greater than the costs. Taking into account the features of the revealed preference methods the benefits values constitute rough estimates that could bring monetised revenues in the future.

As there is a high variation in the unit costs indicators between the water users the costs of environmental flows can significantly vary between the catchments depending on the size of water demand expressed by the various types of water users.

The contribution of the authors

Anna Dubel – 50% (conception, development, literature review, acquisition of data, analysis and interpretation of data).

Izabela Godyń – 50% (conception, development, literature review, acquisition of data, analysis and interpretation of data).

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