RUDN Journal of Ecology and Life Safety
Вестник РУДН. Серия: Экология и безопасность жизнедеятельности
ISSN 2313-2310 (Print); ISSN 2408-8919 (Online)
2021 Vol. 29 No. 4 341–354
http://journals.rudn.ru/ecology

ЭКОНОМИКА ПРИРОДОПОЛЬЗОВАНИЯ
ENVIRONMENTAL ECONOMICS

DOI 10.22363/2313-2310-2021-29-4-341-354
UDC 502.3:504.03

Research article / Научная статья

Evaluation and use of existing economic valuation methodologies in the management of Lake Victoria's water resources

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Abstract. Lake Victoria is the second-largest freshwater lake in the world, with an ecosystem critical to 25–30 million inhabitants of Kenya, Uganda, Tanzania, Rwanda, and Burundi who live in the lake basin. The lake provides several ecosystem services from inland waterway transport, fisheries to hydropower and supports many different industries such as tourism, trade, and wildlife. However, Lake Victoria's ecosystem management has been highly extractive; hence its water resources are either inefficiently or overused. This is because the value of this resource is either unknown or underestimated. The main purpose of the research was to contribute to Lake Victoria's conservation efforts by providing the best techniques that can be used to assess the value of this resource and develop appropriate policies for the sustainable management of the lake. The study reviewed relevant literature on the economic assessment methods of environmental resources in the context of water management. Search engines such as Google Scholar, Web of Science, and ScienceDirect were used for it. The study suggests methods for economic valuation of Lake Victoria water ecosystem for each service. The proposed techniques can be used for assessing the value and benefits of conservation and restoration of Lake Victoria ecosystem.

Keywords: water ecosystem services valuation, water resources management, Wetland's valuation

Acknowledgements and Funding. This article acknowledges the organizers of the *GEC 2021: International Research Conference on Global Environmental Change: Ecosystems, Climate, Natural Resources, Humans* for publishing (on 30th March 2022) this abstract in their conference proceedings. The conference was held online on 14th of September 2021.

Article history: received 15.06.2021; revised 25.12.2021.

For citation: Mamboleo M. Evaluation and use of existing economic valuation methodologies in the management of Lake Victoria's water resources. *RUDN Journal of Ecology and Life Safety.* 2021;29(4):341–354. http://doi.org/10.22363/2313-2310-2021-29-4-341-354

Использование экономических методологий оценки при управлении водными ресурсами озера Виктория

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Аннотация. Озеро Виктория – второе по величине пресноводное озеро в мире, экосистема которого критически важна для 25–30 млн жителей Кении, Уганды, Танзании, Руанды и Бурунди, проживающих в бассейне озера. Озеро обеспечивает несколько экосистемных услуг: от внутреннего водного транспорта, рыболовства до гидроэнергетики и поддерживает множество различных отраслей, таких как туризм, торговля и дикая природа. Однако управление экосистемой озера Виктория не было ресурсосберегающим; следовательно, его водные ресурсы используются либо неэффективно, либо чрезмерно. Это связано с тем, что ценность данного ресурса неизвестна или недооценена. Основная цель исследования – внести вклад в усилия по сохранению озера Виктория, предоставив лучшие методы, которые можно использовать для оценки ценности этого ресурса и разработки соответствующей политики для устойчивого управления озером. Проведен обзор соответствующей литературы по методам экономической оценки ресурсов окружающей среды в контексте управления водными ресурсами. В исследовании использовались поисковые системы Google Scholar, Web of Science и ScienceDirect. Предложены методы экономической оценки водной экосистемы озера Виктория для каждой услуги, которые могут применяться для оценки ценности и преимуществ сохранения и восстановления экосистемы озера.

Ключевые слова: оценка услуг водных экосистем, управление водными ресурсами, оценка водно-болотных угодий

Благодарности и финансирование. Выражается благодарность организаторам «GEC 2021: международная научно-исследовательская конференция по глобальным изменениям окружающей среды: экосистемы, климат, природные ресурсы, человек» за публикацию (30 марта 2022 г.) этого реферата в материалах конференции. Конференция прошла в онлайн-режиме 14 сентября 2021 г.

История статьи: поступила в редакцию 15.06.2021; принята к публикации 25.12.2021.

Для цитирования: *Mamboleo M.* Evaluation and use of existing economic valuation methodologies in the management of Lake Victoria's water resources // Вестник Российского университета дружбы народов. Серия: Экология и безопасность жизнедеятельности. 2021. Т. 29. № 4. С. 341–354. http://doi.org/10.22363/2313-2310-2021-29-4-341-354

Introduction

Water resources include surface water, groundwater, inland, rivers, lakes, transitional, coastal, and aquifers [1]. Together, these water resources are critical to human health and the environment and vital to the East African economy. However, over time, water resources have degraded and depleted. These adverse impacts on water result from increased water demand from agriculture, industry, hydropower generation, and ongoing pollution. From an economic point of view, the water resources of Lake Victoria are overused and inefficiently used. The effect is exacerbated by population growth, rapid urbanization, and climate change [2].

Lake Victoria, the second-largest freshwater lake globally, is located in the upper reaches of the African Nile River system. The Lake Victoria basin's ecosystem is critical to the 25–30 million inhabitants of Kenya, Uganda, Tanzania, Rwanda, and Burundi who live in the lake basin [3]. The population is mainly dependent on extensive rainfed agriculture for domestic and commercial purposes. The lake also provides inland waterway transport and hydropower and supports many different industries such as tourism, trade, wildlife, and fishing. Ecosystem management in the Lake Victoria Basin has been highly extractive for much of the past 70 years, with declining food production, economic downturn, rising poverty, rising floods, and increasing burden of human disease, especially malaria and HIV/AIDS [3; 4]. Lake Victoria has become eutrophic due to the deposition of high levels of phosphorus and nitrogen in the lake from the atmosphere, the surrounding catchment area, and municipal centers [2]. Severe erosion in some parts of the catchment area has increased sediment deposition in streams and the lake. Infestation of water hyacinths was particularly severe in the late 1990s, affecting fisheries, urban water systems, and transport.

The term economic valuation refers to the process of determining the monetary value of goods and services provided by environmental and natural resources, whether market prices are available or not [5; 6]. In turn, this can be measured in terms of the minimum amount that a person is willing to give up consuming goods and service so receive some other goods and services [7]. The rational use of natural and environmental resources depends on the value it has, and the value can be measured through the process of economic valuation. The value of water resources can be determined based on the value of the products or processes they contribute to. Several initiatives can be taken to ensure sustainable management and conservation of this valuable resource by recognizing the deterioration in the products and processes and the quantity and quality of water. The first objective of this study was to explain and critically assess the suitability of various economic valuation methods for the economic analysis of Lake Victoria's water resources. The second goal was to demonstrate how these methods can be used in the development of appropriate policies for the sustainable management of Lake Victoria's water resources. This study aims to contribute to conservation of Lake Victoria by providing best techniques for assessing the quantity and quality of the environment.

Materials and methods

The primary purpose of this study was to explain and evaluate the suitability of various economic valuation methods and demonstrate how these methods can be used in developing appropriate policies for the sustainable management of Lake Victoria's water resources. To achieve these goals, this research systematized a review of the literature on the economic assessment methods of environmental resources and how they can be applied in managing water resources. The analysis was based on a review of the literature and secondary data. Scientific search engines such as Google Scholar, ScienceDirect, Web of Science, and PubMed were used to systematically review the literature on various wetland assessment methods. Key searches included methods for natural resource valuation, wetland assessment, and wetland management. Secondary searches included experimental designs, willingness to pay, Lake Victoria, and qualitative methods. The study analyzed definitions and methods for assessing and valuing ecosystem services to summarize current knowledge and propose a practical and flexible approach that is relevant to Lake Victoria's water resources management.

Results

Economic assessment of Lake Victoria freshwater resources

Ecosystem services are the benefits that people receive from ecosystems [8]. These services enhance people's well-being and are often critical to life. Most of the liquid surface fresh water on which humanity depends is located in several lake basins [9]. Wetlands are among the most valuable ecosystems because they provide clean water, minimize natural risks (e.g. water retention and coastal protection), and act as CO_2 sinks (e.g. swamps and marshes). Freshwater tropical lakes in Africa are among the most biologically productive lakes globally [9]. Equatorial Lake Victoria is the second-largest freshwater lake globally by surface area and the largest freshwater lake in Africa, with a surface area of 69,000 km^2 [10] and a catchment area of 284,000 km^2 [11]. Lake Victoria is large enough to create its weather system and influence regional climate [10; 12]. In addition, Lake Victoria supports Africa's largest inland fishing grounds [13] and shares its border with Uganda (43%), Tanzania (51%), and Kenya (6%). The ecosystem services offered by the Lake Victoria Basin include fishing, water supply, wildlife conservation, navigation, tourism, and power generation.

Freshwater ecosystem services, type of value and applied valuation methods developed by [14; 15]

Category	Ecosystem service	Valuation method
Provisioning	Fisheries and aquaculture	RC, MP
	Transport and navigation	MP
	Industrial and domestic water supply	NFI, RC, PF, MP
	Agriculture	NFI, RC, PF, MP
	Recreation/amenity	TC, CEM, CVM, HPM
	Energy (fuelwood and hydropower)	MP
	Conservation of wildlife	MP
	Raw material (biotic)	RC, MP
Supporting and regulating	Bequest, existence and altruistic values	CEM, CVM
	Biodiversity	CVM, CEM
	Storm protection and flood control	CVM, RC, PF
	Nutrient retention	COI, RC
	Soil erosion prevention	PF, RC
	Water purification	CVM, RC
	Maintaining habitats and populations	RC
	Pollution reduction	COI, RC
	Microclimate stabilization	PF
Cultural	Spiritual and symbolic appreciation	CVM, TC
	Intellectual and aesthetic appreciation	CVM

Note: PF – production function; NFI – net factor income; RC – replacement cost; MP – market prices; COI – cost-of-illness; TCM – travel cost method; HPM – hedonic pricing method; CVM – contingent valuation method; TC – travel costs; CEM – choice experiment method.

This study found that several methods can be used to estimate the economic value of freshwater ecosystem services in Lake Victoria. These methods can be roughly divided into two approaches: stated preference approaches and revealed preference approaches. Stated preference approaches refer to structured survey methods to determine people's preferences for non-market environmental goods. Revealed preference approaches refer to techniques that use evidence of individual preference for commodity products, including environmental performance. For an economic valuation of Lake Victoria's water resources, the first step is to identify the benefits of ecosystem services that need to be assessed. In [16; 17] authors have argued that this is the easiest way to conduct an assessment and avoid double counting. The choice of the initial assessment method depends on the ecosystem service being assessed and the beneficiary population. Table shows the various valuation techniques for each ecosystem service.

Techniques for assessing and evaluating Lake Victoria aquatic ecosystem services

Revealed preference (RP) methods, also known as indirect valuation methods, look for related or surrogate markets in which ecological goods are implicitly sold, i.e., they are one of the many components of a product that the consumer is buying [18]. Revealed preference surveys are about human choices. The strength of this type of survey is that it provides us with real choices made by users in a specific context of constraints. These methods are suitable for assessing those water resources sold indirectly and therefore can only assess their use (direct and indirect). Revealed preference studies use behavioral evidence to determine the value of environmental assets. These methods attempt to separate the value of ecological goods from the total value of goods sold [19]. These methods are discussed below.

Travel cost method (TCM) is a method that has been developed to assess the value of recreational uses of non-market goods, usually open natural areas, but applicable to any recreational use [20]. This method infers the value of a set of attributes from cost (time and money spent on travel) for outdoor recreation or wildlife visits. For example, the willingness to pay (WTP) of people visiting Lake Victoria can be estimated based on the number of trips they make with different travel costs. This is analogous to estimating the WTP of people per item sold based on the quantity demanded at different prices. TCM includes various models, from simple site-specific TCMs to regional and generic models that include quality metrics and are site replaceable [21]. TCM was first proposed by [22] and later developed by [23]. Such models have been used to measure the welfare effects of changes in recreational water quality (e.g., [24; 25]). However, TCM has several limitations: very few non-entertainment applications; processing a large amount of data; what value should be given to travel time; statistical problems.

Hedonic pricing method (HPM) estimates the value of a non-market good by observing the behavior of the corresponding good in the market [26]. The HPM was developed by [27] to assess the value of quality change in consumer products. If environmental resources are not traded in any market because it is a public good, there will be no market price to determine the WTP. A resource can be defined in terms of the services it provides or the "attribute" that it embodies. This attribute can be embodied in other goods or assets that are sold at observable prices. By using these prices, the East African countries can reap economic benefits from Lake Victoria. The limitation of HPM is that it only measures the direct use cost of water perceived by consumers of the product they are implicitly trading. This method measures only a subset of the consumer values for which people are WTPs in the relevant market. If consumers are not fully informed about the qualities of the attributes being assessed, hedonic price estimates are of little value. Services such as flood control, water quality improvement, species habitat, and groundwater recharge can provide far more benefits to humans than benefits that HPM cannot understand [28].

Replacement cost (RC) method. The cost of replacing natural and ecological resources, in this case, water, is a valuable way of assessing the value of a resource in a given context. This method assumes that the damage is measurable and that the value of the environmental asset does not exceed its replacement value. It also does not imply additional benefits associated with environmental costs. This approach identifies damage to water assets mainly due to the cost of restoring, repairing, or replacing the resource or services of the water resource without compromising the level of resource stocks or the flow of services. Such costs may be related to the purification of the water source or the cost of introducing new aquatic animals into the water source.

The replacement cost method is relatively simple when the water resource is not unique, and its substitutes are readily available. The researcher moves forward by collecting a sample of indirect values from a primary or secondary source of information. Based on this sample of cost information, the analyst prepares an estimate of the most likely range of expected costs to replace a significant water resource or service. This process can be much more challenging to implement when water resources have unique characteristics. The replacement cost method is considered an arbitrary valuation of natural resources that may have little to do with real public value. The resource replacement method requires data on the cost of restoring, rehabilitating, or replacing damaged or lost resources and resources. This method is especially applicable where a standard must be met, such as a certain level of water quality [29].

Cost of illness (COI) technique aim to identify and measure all costs associated with disease [30]. The method describes and assess the economic burden of a particular disease on society and, therefore, the savings that could be obtained if the disease were eradicated [31]. Here, the benefits of reducing pollution are measured by assessing the potential savings in direct personal costs of illness (e.g., drugs, doctors, and hospital bills) and opportunity costs (e.g., lost benefit from illness). To conduct a COI study, it is necessary to define the disease, the epidemiological approach, the type of cost, and the study's prospect. Subsequently, resource consumption and unit cost data can be collected, and the results presented and methodically discussed along with a sensitivity analysis to verify their reliability. Two limitations of this approach are that it does not account for the actual uselessness of patients and does not account for the costs of protection or prevention that people could take to protect themselves [21].

Aversive expenditures method. Information is needed on the household cost of water treatment and socio-economic details so as to estimate the averting expenditure as a measure of households' willingness to pay [32]. This method is based on the theory of consumer behavior of the production function of households. In the context of water resources, households can respond to the increasing degradation of these resources in various ways, commonly referred to as preventative or protective behavior, to avoid adverse effects of water pollutants. This includes the purchase of non-durables (such as bottled water), the cost of liming to reduce acidification of the water, and behavioral changes to avoid exposure to the contaminant (such as boiling water for cooking and drinking or reducing the frequency or duration of showers if volatile organic chemicals are present). However, this method has its limitations. People may use more than one preventative behavior in response to environmental change, and prevention behavior may have other positive effects that are not explicitly considered. For example, buying bottled water to avoid the risk of consuming contaminated stocks may also provide additional benefits flavoring advantages. In addition, prevention behavior is often not a permanent solution but discrete; for example, a water filter is either purchased or not. Typically, prevention costs do not measure all of the pollution costs that affect household utilities and therefore can only provide a lower bound on the true cost of increasing pollution.

Net factor income method estimates the change in producer surplus (i.e., in monetary terms, the net benefit to the firm producing the product) by subtracting the cost of other inputs from total revenues and treating the remaining surplus as an environmental cost [15]. The factor income method is used as a valuation tool in applications where natural resources are used as resources for other goods and services. Accordingly, the associated economic costs of production are an essential source of information when applying the factor income approach. There are several resource types for which the factor-based approach is potentially well suited, including surface and groundwater resources, forests, and commercial fisheries. Surface and groundwater resources can be resources for irrigated agriculture, manufacturing, or private, municipal water supply systems. The products in these cases (cereals, logs, manufactured goods, and municipal water) may have market prices. Likewise, commercial fish stocks (populations or fish stocks) are the starting material for commercial fisheries. The economic benefits of improved water quality can be measured by increasing income from increased agricultural productivity while improving water quality. Alternatively, water quality affects the cost of treating drinking water from urban sources, so the economic benefits can be measured by reducing the cost of providing clean drinking water.

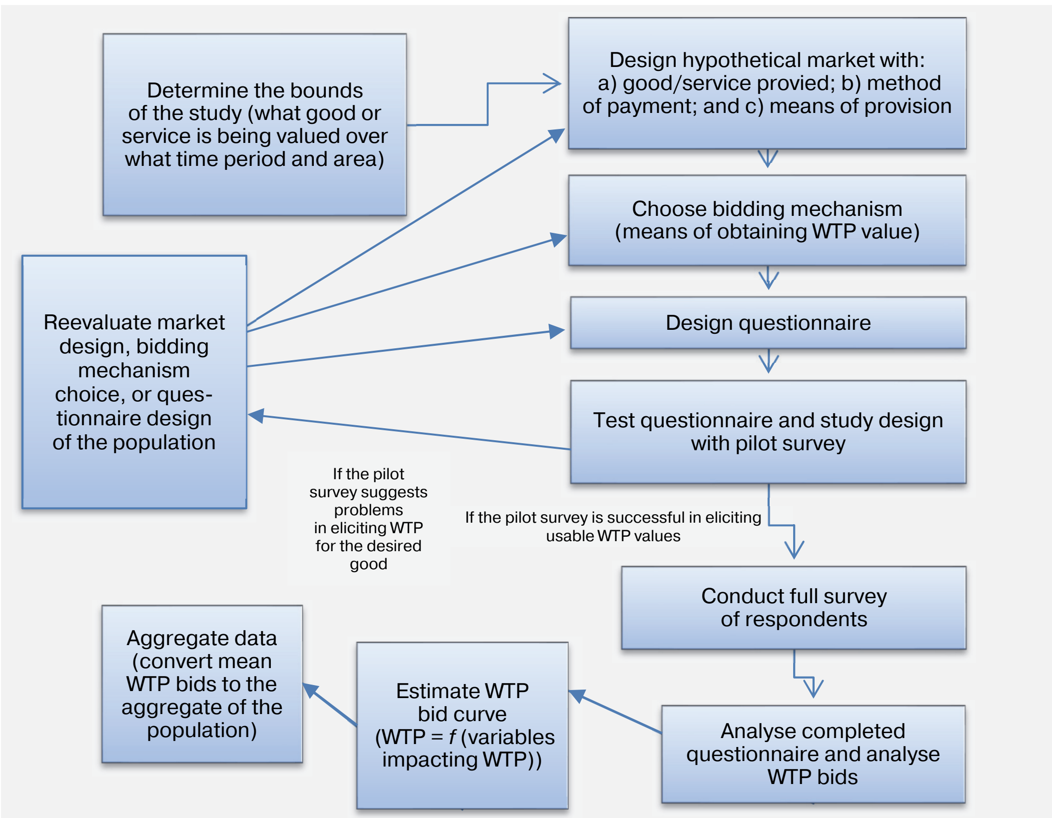
Production function approach can be used to value non-tradable goods and services that serve as raw materials to produce tradable goods. This approach links the release of specific tradable goods or services (e.g. agricultural products, timber, catches) to the costs required to produce them. The implicit cost of water can also be calculated by measuring the contribution of water to profit in cases where water is an essential component of the production process, and the cost structure of the producer is known. If the water supply is unlimited, the producer will continue to use units of water to such an extent that the last unit's contribution to profit is simply equal to its cost to the firm. Even if the water is "free," the producer bears the cost of using the water (including pumping and transport costs). If the water supply is limited (for example, by quotas or water rights), producers can stop using water until equity is achieved. The producer's water use rate at various costs determines the coefficient of "derived" demand since the water demand is determined by the demand for the producer's product (e.g., agricultural goods).

Market prices are the current prices at which an asset or service can be bought or sold. The demand for natural resources is measured on the assumption that many factors that can influence demand, such as prices for ancillary goods and services, personal income, individual tastes, and recommendations, remain unchanged over the study period. The market price occurs where the forces of supply and demand meet. Hence, market pricing is a useful approach to water resource valuation. For water resources, the market price estimate is an estimate of the income from the sales value of the water resource. A standard method for measuring the use-value of inputs traded in the market is to estimate the surplus of producers and consumers using market price and quantity data [33]. Net prices can also be used in assessing water resources. It is calculated as the actual market price minus the actual operating costs of utilities, including the normal return on investment. The net price method can be applied to the benefits of recycled water in the market. This method considers only economically available stocks of utilities with a positive net price. If the use of the benefits from the use of water resources is not related to market transactions, direct or indirect non-market valuation should be applied.

Stated preference (SP) methods collect responses to hypothetical situations presented to users, in this case, about public transport. This type of survey attempts to overcome some of the limitations of the revealed preference survey. One limitation of RP surveys was that many scenarios provide insufficient variability in observations. Hence, observed behaviors can be difficult to correlate with certain qualitative variables (such as comfort) and the inability to measure choices between alternatives that do not yet exist [34]. Nonetheless, preference surveys allow users to quasi-experiment with the choices that users make when presenting hypothetical situations. Such as having a new alternative type of public transport or a new version of existing public transport service, using variables that can be qualitative or quantitative or both. The main disadvantage of stated preference surveys is that they are based on the hypothesis that the user will make the same choice in the scenarios presented to him as in reality, which is not always the case [34].

Contingent valuation method (CVM) is a non-market valuation method that requires individuals to indicate the maximum amount they are willing to pay (WTP) and can pay for a given quantity or quality of an environmental good [35; 36]. The person may be asked directly how much they are willing to pay for a certain amount of a product from Lake Victoria or asked if they are (and can) pay a certain amount. Once individual ratings or proposals have been obtained, they can be averaged and aggregated to obtain the total value of the item in question.

To conduct a Lake Victoria CVM, a researcher must pay special attention to the design and conduct of the survey. Focus groups, consultation with relevant experts, and pre-testing of the survey are important prerequisites. A decision must be made on how to conduct the interview (in person, by mail, or over the phone); which payment method is most appropriate (e.g. annual tax increase, lump sum, environmental fund contribution, among others [37]; as well as the WTP extraction format [38]. Ultimately, the sample mean WTP can then be extrapolated to the population to obtain the aggregate WTP or ecological resource value [39]. While a researcher can use conditional-graded surveys to grade a virtually unlimited number of items in a variety of contexts, conditional-graded surveys are conducted in a relatively sequential process. The steps in the basic contingent valuation process are shown in Figure.



The process of conditional valuation of ecosystem services [7; 35; 39]

For water-related applications, CVM is useful for exploring the value of direct uses, such as recreational fishing and hunting, and the value of indirect uses, such as improving water quality. Unlike preference-revealing methods, CVM can also measure the cost of biodiversity-related alternative water use, as well as the cost of non-use. However, despite the strengths of CVM in terms of its ability to assess untapped values and assess irreversible changes, the method has been criticized for its lack of validity and reliability [40]. This is due to potential issues including information bias, design bias (origin bias and vehicle bias), hypothetical bias, yes bias, strategic bias (free rides), site replacement, and embedding effects.

Choice experiment method (CEM) is a highly 'structured method of data generation [41] based on carefully designed problems or "experiments" to identify factors that influence choice. An ecological resource is defined in terms of its attributes and the levels that these attributes assume with and without sustainable resource management. Choice experiments (CE) have long been used to assess consumer preferences and predict consumer behavior in the marketplace [34] and non-market valuation studies [41]. Choice experiment is a survey approach designed to determine consumer preferences based on hypothetical markets. Respondents must choose between several public or private goods. Like CVM, CEM can estimate the economic value of any ecological resource and can be used to estimate unused and use-value. However, CEM makes it possible to estimate not only the value of an ecological resource as a whole but also the implicit value of its attributes, their assumed ranking, and the value of simultaneously changing more than one attribute [38; 41].

Discussion

The total economic value of Lake Victoria should recognize two distinctions between the value that people get from using this ecological resource, that is, the use-value, and the value that people get from this ecological resource, even if they do not use it themselves, that is, unused values. Use value can be divided into three broad categories: direct use value, indirect use-value, and option value. The cost of direct use of Lake Victoria's water resources includes drinking water, irrigation, or industrial resources. Their direct use almost entirely determines the value of most private (ordinary) goods. However, Lake Victoria has several functions that indirectly benefit people: the value of indirect water use includes benefits such as flood control, nutrient retention, and protection from storms. Finally, the option value considers that people who are not currently using the resource may still appreciate being able to use it in the future. Thus, the opportunity cost of Lake Victoria water resources represents their potential to provide economic benefits to human society in the future. Quantifying the benefits of ecosystem services Lake Victoria provides to humans will help justify investments in conserving and restoring this aquatic ecosystem. Benefits from Lake Victoria ecosystem services can also be included in a cost-benefit analysis to implement the principle of cost recovery in the water supply system. While Lake Victoria water resources are vital to the functioning of the East African economies, they continue to be depleted and degraded at an unsustainable rate. Therefore, it is necessary to determine Lake Victoria's total economic value (TEV) and integrate it into the private and public sector decision-making processes to implement the most effective social and economic policies that prevent excessive degradation and depletion of this resource. Awareness programs about water pollution and its consequences and the advantages of quality water, and improved education may increase the willingness to pay for quality water.

The methods evaluated in this study have been used worldwide to value and, in turn, to manage water resources. In [42] TCM is used in China to assess the significance of water quality improvements in the East Lake in Wuhan. The results from this study indicate that lake users have significant water reserves for the use of the lake and its structures, offsetting some of the costs of maintaining recreational water quality. Another example in developing countries is applying the avertive expenditures method by [43]. They evaluated the non-marginal benefits of improving drinking water quality using protective factors in Guarapari, Grande Vitoria, Espiritu State, Brazil. Market prices and prices for substitute products have been used in Nigeria by [44] to analyze domestic groundwater demand in Northern Nigeria to assess the recharge function of groundwater wetlands. They found that the study area population would be severely affected if the wetlands no longer provide their current daily groundwater recharge. The contingent assessment method is widely used to assess water resources in developing countries. In [45] authors compared CVM and TCM results to assess surface water quality improvement in rivers and seawater near a community in Davao, Philippines. The results of their CV show that household WTPs have low environmental benefits such as improved water quality. The loss of economic benefits from reduced water quality has also been estimated in Vietnam by [46]. Authors of [47] showed that improved income increases the households' willingness to pay for improved water services. Researchers of [48] included fertilizer and pesticide contamination of groundwater as an attribute in a study of willingness to pay for agricultural sustainability among residents of Milan, Italy. They found that the public derives significant economic benefits from the reduction of groundwater pollution. In [49] CEM was used to assess the benefits of soil conservation measures in the Alto Genil and Guadajoz watersheds in southern Spain. The surface and groundwater quality were included as important attributes of soil conservation measures. Scientists concluded that water quality is of the highest economic importance among all the characteristics of soil conservation measures included in the study. Finally, [50] applied this method to assess the significance of water quality improvements in Cairo, Egypt. They investigated the welfare effects of improved health status through improved water quality. They concluded that the estimated WTP is relatively low compared to the cost of a program that could achieve these improvements. These methods have been used before and successfully helped develop policies used to manage these resources, hence their practicability to Lake Victoria.

Conclusion

This study aimed to explain and evaluate the suitability of various economic valuation methods and demonstrate how these methods can be used to develop appropriate policies for the sustainable management of Lake Victoria's water resources. The study presents economic valuation methods that can be used to determine the total economic value of changes in the quantity and quality of water resources in Lake Victoria. The value of ecological resources such as water is difficult to assess due to their social utility. Therefore, Lake Victoria TEV accounting is integral to developing economic incentives and institutional arrangements to ensure sustainable, efficient, and equitable water distribution in the Lake Victoria basin. The methods proposed in this document for assessing and valuing aquatic ecosystem services in Lake Victoria provide a knowledge base for improving water resources management. From this perspective, cost-effective and remediation measures can be improved to include all latent benefits and beneficiaries of aquatic ecosystem services. To effectively manage the ecosystem services of Lake Victoria, it is necessary to identify the services of interest and determine the main consequences of many factors and pressures on the ecological state of the lake. Assessment of Lake Victoria aquatic ecosystem services can reveal hidden benefits to society and raise awareness among users and stakeholders. In general, the proposed assessment methods can be used to assess the benefits of the conservation and restoration of aquatic ecosystems in implementing the Lake Victoria water resource management program.

References

[1] Chave P. *The EU water framework directive*. IWA Publishing; 2001.

[2] Scheren PA, Zanting HA, Lemmens AM. Estimation of water pollution sources in Lake Victoria, East Africa: application and elaboration of the rapid assessment methodology. *Journal of Environmental Management.* 2000;58(4):235–248.

[3] Swallow BM, Sang JK, Nyabenge M, Bundotich DK, Duraiappah AK, Yatich TB. Tradeoffs, synergies and traps among ecosystem services in the Lake Victoria basin of East Africa. *Environmental Science & Policy*. 2009;12(4):504–519. http://doi.org/10.1016/j.envsci.2008.11.003

[4] Verschuren D, Johnson TC, Kling HJ, Edgington DN, Leavitt PR, Brown ET, Hecky RE. History and timing of human impact on Lake Victoria, East Africa. *Proceedings of the Royal Society of London. Series B: Biological Sciences.* 2002;269:289–294. http://doi.org/10.1098/rspb.2001.1850

[5] Dosi C. *Environmental value, valuation methods, and natural disaster damage assessment.* CEPAL; 2001.

[6] Barbier EB, Acreman M& Knowler D. *Economic valuation of wetlands: a guide for policy makers and planners*. Gland: Ramsar Convention Bureau; 1997. Available from https://www.iucn.org/backup_iucn/cmsdata.iucn.org/downloads/03e_economic_valuation_of_wetlands.pdf (accessed: 02.08.2021).

[7] Arrow K, Solow R, Portney PR, Leamer EE, Radner R, Schuman H. Report of the NOAA panel on contingent valuation. *Federal Register*. 1993;58:10.

[8] Sarukhán J, Whyte A. (eds.) *Ecosystems and human well-being: wetlands and water.* Washington: World Resources Institute; 2005.

[9] Herdendorf CE. Distribution of the world's large lakes. In: Tilzer MM, Serruya C. (eds.) *Large Lakes.* Berlin, Heidelberg: Springer; 1990. p. 3–38.

[10] Crul R. *Limnology and hydrology of Lake Victoria*. UNESCO; 1995.

[11] Ntiba MJ, Kudoja WM, Mukasa CT. Management issues in the Lake Victoria watershed. *Lakes & Reservoirs: Research & Management*. 2001;6(3):211–216. http://doi.org/10.1046/j.1440-1770.2001.00149.x

[12] Stager JC, Johnson TC. The late Pleistocene desiccation of Lake Victoria and the origin of its endemic biota. *Hydrobiologia.* 2008;596(1):5–16. http://doi.org/10.1007/s10750-007-9158-2

[13] Geheb K, Medard M, Kyangwa M, Lwenya, C. The future of change: roles, dynamics and functions for fishing communities in the management of Lake Victoria's fisheries. *Aquatic Ecosystem Health & Management.* 2007;10(4):467–480. http://doi.org/10.1080/14634980701704098

[14] Reynaud A, Lanzanova D. A global meta-analysis of ecosystem services values provided by lakes presented at the in Toulou. *2nd Annual Conference of the French Association of Environmental and Resource Economists.* Toulouse; 2015.

[15] Brander LM, Florax RJ, Vermaat JE. The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. *Environmental and Resource Economics.* 2006;33(2):223–250. http://doi.org/10.1007/s10640-005-3104-4

[16] Fisher B, Turner RK. Ecosystem services: classification for valuation. *Biological Conservation.* 2008;141(5):1167–1169. http://doi.org/10.1016/j.biocon.2008.02.019

[17] Fisher B, Turner RK, Morling P. Defining and classifying ecosystem services for decision making. *Ecological Economics.* 2009;68(3):643–653. http://doi.org/10.1016/j.ecolecon.2008.09.014

[18] Lancaster KJ. A new approach to consumer theory. *Journal of Political Economy.* 1966; 74(2):132–157. Available from: https://www.journals.uchicago.edu/doi/pdf/10.1086/259131 (accessed: 20.08.2021).

[19] Clinch JP. Cost-benefit analysis applied to energy. In: Cleveland C. (ed.) *Encyclopedia of Energy.* Oxford, St. Louis: Elsevier; 2004. http://doi.org/10.1016/B0-12-176480-X/00237-0

[20] Loomis J, Bockstael N, McConnell K. Environmental and resource valuation with revealed preferences: a theoretical guide to empirical models. *Environ. Resource Econ.* 2009;42:133–135. https://doi.org/10.1007/s10640-008-9240-x

[21] National Research Council. *Valuing ground water: economic concepts and approaches*. National Academies Press; 1997.
[22] Hotelling H. The economics of exhaustible resources. *Journal of Political Economy*. 1931;39(2):137–175.
[23] Clawson MA, Knetsch JL. Economics of oufdoor recreation. *Natural Resources Journal*. 1966;8(13):738.
[24] Caulkins PP, Bishop RC, Bouwes NW. The travel cost model for lake recreation: a comparison of two methods for incorporating site quality and substitution effects. *American Journal of Agricultural Economics*. 1986;68(2):291–297.
[25] Bockstael NE, Hanemann WM, Kling CL. Estimating the value of water quality improvements in a recreational demand framework. *Water Resources Research*. 1987; 23(5):951–960. http://doi.org/10.1029/WR023i005p00951
[26] Rosen S. Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy*. 1974.82(1):34–55.
[27] Griliches Z. *Price indexes and quality change: studies in new methods of measurement.* Harvard University Press; 1971.
[28] Boyer T, Polasky S. Valuing urban wetlands: a review of non-market valuation studies. *Wetlands*. 2004;24(4):744–755. http://doi.org/10.1672/0277-5212(2004)024[0744:VUWARO]2.0.CO;2
[29] Markandya A, Harou P, Bellu LG, Cistulli V. *Environmental economics for sustainable growth: a handbook for practitioners.* Edward Elgar Publishing Ltd.; 2002.
[30] Byford S, Torgerson DJ, Raftery J. Cost of illness studies. *BMJ*. 2000;320(7245):1335. http://doi.org/10.1136/bmj.320.7245.1335
[31] Koopmanschap MA. Cost-of-illness studies. *Pharmacoeconomics.* 1998;14(2):143–148.
[32] Gertrude MN. Averting expenditure-measure of willingness to pay. *Journal of Environment and Earth Science*. 2014. p. 28–32.
[33] Lipton DW, Wellman K, Sheifer I, Weiher R. Economic valuation of natural resources: a handbook for coastal resource policymakers. *NOAA Coastal Ocean Program Decision Analysis Series 5.* Silver Spring, MD; 1995.
[34] Louviere JJ, Hensher DA, Swait JD. *Stated choice methods: analysis and applications.* Cambridge University Press; 2000. http://doi.org/10.1017/CBO9780511753831
[35] Carson RT. Contingent valuation: a practical alternative when prices aren't available. *Journal of Economic Perspectives*. 2012;26(4):27–42. http://doi.org/10.1257/jep.26.4.27
[36] Ardila S, Quiroga R, Vaughan WJ. *A review of the use of contingent valuation methods in project analysis at the Inter-American Development Bank*. Washington, D.C.: Inter-American Development Bank, Sustainable Development Department, Environment Division; 1998.
[37] Champ PA, Flores NE, Brown TC, Chivers J. Contingent valuation, and incentives. *Land Economics.* 2002;78(4):591–604. Available from: http://le.uwpress.org/content/78/4/591.full.pdf+html (accessed: 25.08.2021).
[38] Bateman IJ, Carson RT, Day BH, Hanley N, Hett T, Swanson S. *Guidelines for the use of stated preference techniques for the valuation of preferences for non-market goods.* Cheltenham: Edward Elgar; 2003.
[39] Mitchell RC, Carson RT. *Using surveys to value public goods: the contingent valuation method.* RFF Press; 2013.
[40] Kahneman D, Knetsch JL. Valuing public goods: the purchase of moral satisfaction. *Journal of Environmental Economics and Management.* 1992;22(1):57–70. http://doi.org/10.1016/0095-0696(92)90019-S
[41] Hanley N, Wright RE, Adamowicz V. Using choice experiments to value the environment. *Environmental and Resource Economics*. 1998;11(3):413–428.
[42] Yapping D. The value of improved water quality: an application of contingent valuation and travel cost methods to East Lake in Wuhan, China. *EEPSEA Research Reports.* 1998.

[43] McConnell KE, Rosado MA. Valuing discrete improvements in drinking water quality through revealed preferences. *Water Resources Research.* 2000;36(6):1575–1582.
[44] Acharya G, Barbier E. Using domestic water analysis to value groundwater recharge in the Hadejia'Jama'are Floodplain, Northern Nigeria. *American Journal of Agricultural Economics*. 2002;84(2):415–426.
[45] Choe K, Whittington D, Lauria DT. The economic benefits of surface water quality improvements in developing countries: a case study of Davao, Philippines. *Land Economics.* 1996;72(4):519–537. http://doi.org/10.2307/3146913
[46] Phuong DM, Gopalakrishnan C. An application of the contingent valuation method to estimate the loss of value of water resources due to pesticide contamination: the case of the Mekong Delta, Vietnam. *Water Resources Development.* 2003;19(4):617–633.
[47] Adepoju AA, Omonona BT. Determinants of willingness to pay for improved water supply in Osogbo Metropolis, Osun State, Nigeria. *Res. J. Soc. Sci.* 2009;4:1–6.
[48] Travisi CM, Nijkamp P. *Willingness to pay for agricultural environmental safety: evidence from a survey of Milan, Italy, residents*. Working Paper no. 100-2004.
[49] Colombo S, Hanley N, Calatrava-Requena J. Designing policy for reducing the off-farm effects of soil erosion using choice experiments. *Journal of Agricultural Economics.* 2005;56(1):81–95.
[50] Abou-Ali H, Carlsson F. Evaluating the welfare effects of improved water quality using the choice experiment method. *Working Papers in Economics.* 2004;131.

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