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INTEGRATED ACCOUNTING OF WATER RESOURCES IN THE SYSTEM OF ENVIRONMENTAL AND ECONOMIC INTERRELATIONSHIPS: ANALYSIS OF THE SEEAW STANDARD

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ІНТЕГРОВАНИЙ ОБЛІК ВОДНИХ РЕСУРСІВ У СИСТЕМІ ВЗАЄМОЗВ'ЯЗКУ ДОВКІЛЛЯ ТА ЕКОНОМІКИ: АНАЛІЗ СТАНДАРТУ SEEAW

The purpose of the article is to reveal the essence and analytical potential of the System of Environmental-Economic Accounting for Water (SEEAW) as an international instrument for standardizing the statistical accounting of water resources, which ensures the transition from a fragmented to an integrated approach in reflecting the interconnections between the economy and the environment.

The hypothesis of the article is based on the assumption that the implementation of integrated environmental-economic accounting for water resources contributes to overcoming the fragmentation of statistical sources and creates a unified methodological basis for combining environmental and economic indicators within a single information system. It is assumed that the standardization of water resource statistics under the SEEAW methodology not only enables tracking physical water flows but also assessing their economic value, thus forming a tool for evaluating the efficiency of natural resource management and supporting sustainable development policy decisions.

The study provides a structural and analytical overview of SEEAW, defines its place within the broader System of Environmental-Economic Accounting (SEEA) developed under the auspices of the United Nations Statistical Commission, and outlines its connection with the System of National Accounts (SNA). The logical framework of SEEAW is analyzed, emphasizing its integration of physical, monetary, and hybrid supply and use tables, as well as asset and water quality accounts. The dual physical-monetary approach of SEEAW makes it possible to represent water resources as both a natural and an economic asset, thereby linking ecological processes with economic outcomes.

The functional roles of the system's components have been clarified: physical tables reflect water abstraction, use, treatment, and return flows; monetary tables capture economic transactions related to water services, investments, taxes, and subsidies; hybrid tables integrate both types of data to assess water-use efficiency. Asset and water quality accounts enable tracking changes in the quantity and condition of water resources. It has been proven that the combination of these components forms an integrated system of indicators suitable for monitoring, international comparison, and decision-making in the field of natural resource management.

As a result of the analysis, the understanding of SEEAW's role as an international standard of integrated natural resource statistics has been further developed, the concept of dual (physical and monetary) water flow accounting has been deepened, the functional structure of SEEAW tables and accounts has been clarified, the relationship between SEEAW and the System of National Accounts (SNA) has been demonstrated, and the practical significance of the system for sustainable development policy has been substantiated.

SEEAW is viewed as a practical implementation of the environmental-economic integration concept introduced by the SEEA. Its application creates a unified information framework for assessing the efficiency of water use, water productivity, water-use intensity, and the economic value of water. It has been established that SEEAW serves as an important tool for monitoring progress toward the United Nations Sustainable Development Goals (SDG 6 "Clean Water and Sanitation" and SDG 12 "Responsible Consumption and Production"), providing both quantitative and qualitative evaluation of transformations in the water sector.

The main conclusions indicate that SEEAW ensures methodological consistency between environmental and economic data, enhances the quality of national statistics, allows for international comparability of indicators, and provides an analytical basis for informed decision-making in natural resource management. The implementation of SEEAW lays the foundation for transitioning from fragmented reporting to standardized accounting, increases data transparency, and supports the development of an integrated policy for sustainable water resource management.

Мета статті полягає у розкритті сутності та аналітичному аналізі Системи екологічно-економічного обліку води (SEEAW) як міжнародного інструменту стандартизації статистичного обліку водних ресурсів, що забезпечує перехід від фрагментарного до інтегрованого підходу у відображенні взаємозв'язків економіки та довкілля. Гіпотеза статті грунтується на припущенні, що впровадження інтегрованого екологічно-економічного обліку водних ресурсів сприяє подоланню розрізненості статистичних джерел і створює цілісну методологічну основу для поєднання природничих та економічних показників у межах єдиної інформаційної системи. Передбачається, що стандартизація статистики водних ресурсів за методологією SEEAW дозволяє не лише відстежувати фізичні потоки води, а й оцінювати їх економічну вартість, формуючи інструмент для аналізу ефективності природокористування і підтримки рішень у сфері сталого розвитку.

У дослідженні здійснено структурно-аналітичний огляд системи SEEAW, визначено її місце в загальній Системі екологічно-економічного обліку (SEEA), розробленій під егідою Статистичної комісії ООН, та окреслено її зв'язок із Системою національних рахунків (SNA). Проаналізовано логіку побудови SEEAW, що поєднує фізичні, грошові та гібридні таблиці постачання й використання води, а також рахунки активів і якості води. Показано, що подвійний підхід SEEAW — у фізичному та грошовому вимірах — створює можливість відображати водні ресурси як природний і економічний актив одночасно, що забезпечує зв'язок між екологічними процесами та економічними результатами.

Уточнено функціональне призначення елементів системи: фізичні таблиці відображають обсяги забору, використання, очищення й повернення води; грошові таблиці фіксують економічні потоки, пов'язані з водними послугами, інвестиціями, податками та субсидіями; гібридні таблиці поєднують ці два виміри для оцінки ефективності водокористування. Рахунки активів і якості води дають змогу відстежувати зміни запасів водних ресурсів, їхній стан та екологічну якість. Доведено, що сукупність зазначених елементів формує інтегровану систему показників, придатну для моніторингу, міжнародних порівнянь та підтримки управлінських рішень.

У результаті проведеного аналізу дістало подальшого розвитку розуміння ролі SEEAW як міжнародного стандарту інтегрованої статистики природних ресурсів, поглиблено розуміння концепції подвійного — фізичного і грошового — виміру водних потоків, уточнено функціональ-

ну структуру таблиць і рахунків SEEAW, доведено її зв'язок із системою національних рахунків (SNA) та обгрунтовано практичне значення системи у реалізації політики сталого розвитку.

SEEAW розглядається як практична реалізація концепції екологічно-економічного інтегрування, започаткованої у SEEA. Її застосування дозволяє створити єдине інформаційне поле для оцінки ефективності використання водних ресурсів, водної продуктивності, водної інтенсивності виробництва та економічної вартості води. Встановлено, що система є важливим інструментом моніторингу прогресу у досягненні Цілей сталого розвитку ООН (SDG 6 "Чиста вода і санітарія" та SDG 12 "Відповідальне споживання і виробництво"), оскільки забезпечує кількісну та якісну оцінку змін у водному секторі.

Основні висновки полягають у тому, що SEEAW забезпечує методологічну узгодженість екологічних і економічних даних, сприяє підвищенню якості державної статистики, дозволяє здійснювати міжнародні порівняння показників і формує аналітичну основу для прийняття управлінських рішень у сфері природокористування. Впровадження системи створює підгрунтя для переходу від фрагментарної звітності до стандартизованого обліку, підвищує прозорість статистичних даних та сприяє формуванню цілісної політики сталого управління водними ресурсами.

Key words: Water resources, environmental-economic accounting, water statistics, System of Environmental-Economic Accounting for Water (SEEAW), integrated statistical framework, natural resource accounting, environmental indicators, statistical standardization, System of National Accounts (SNA), sustainable development statistics, data harmonization, SDGs.

Ключові слова: водні ресурси, екологічно-економічний облік, статистика водних ресурсів, Система екологічно-економічного обліку води (SEEAW), інтегрована статистична система, облік природних ресурсів, екологічні індикатори, стандартизація статистики, система національних рахунків (SNA), статистика сталого розвитку, гармонізація даних, ЦСР.

INTRODUCTION

Water is a crucial resource of nature, determining the limits of the social and economic development, social welfare, and the environmental resilience of natural systems. The latest decades saw the increasing awareness of the fact that water resource scarcity, degradation, and uneven allocation were becoming global constraints for economic growth. Yet, water is key to implementing many Sustainable Development Goals, e.g. food safety, energy efficiency, and economic balance. This gives evidence of the need for a comprehensive and integrated approach to measurement, assessment and management of water resources.

Conventional methods for statistical accounting of nature resources have long considered water as merely a physical quantity like water intake, use or discharge. However, the challenges of our time call for interpreting water as an economic asset associated with production, consumption, and financial flows. This makes integrated accounting of water resources within the "environment-economy" system a required condition for setting an effective water policy, reasonable nature use, and elaborating sustainability strategies.

The System of Environmental-Economic Accounting for Water (SEEAW) developed under the aegis of the United Nations Statistical Commission lays the methodological foundation for combining data on hydrology, economy, and management. Its conception based on SNA extension allows for aligning water balance indicators with economic flows showing production, consumption, investment, and value of water services. This structure enables for assessing the efficiency of water use, the water productivity, as well as the real value of water resources within the national economy system.

The integrated water accounting, apart from being a statistical tool, lays an information base for taking management decisions. It allows governments, businesses, and communities to see the full chain of interactions between water resources, economic processes, and environmental effects. These accounts can be used in constructing water policy models, predicting the environmental impact of economic reforms, determining optimal schemes for infrastructure financing, and assessing the performance of water-preservation actions.

Not less important component of the current approach is standardization of the methodology. A comparability of data across countries, regions or sectors cannot be achieved unless the notions, classifications and tables are unified. The elaboration of SEEAW is, therefore, of crucial importance. It provides for a single terminological and methodological framework for collection, analysis, and presentation of water statistics. Standardization makes it possible to confront economic indicators with environmental ones, determine trends in water use over time, with integrating these data in the UN global reporting system on the sustainable development.

For the countries striving to achieve the water safety, the integrated environmental-economic water accounting

offers a tool for strategic management. It allows them to harmonize the policies on water supply, energy supply, agriculture, industry, and environment on a single statistical base. This accounting system becomes even more relevant amidst climate change and increasing anthropogenic pressures on the nature resources, because it lays a scientifically sound base for forecasting and decision-making. This theme is relevant due to the need of implementing a single standardized system for integrated accounting of water resources, which enables for a comprehensive assessment of causal links between economic activities and the water basin condition, enhances the efficiency of nature resource management, and lays the foundation for the transition to the sustainable development.

THE LITERATURE REVIEW

The literature review combines international and national perspectives on the development of water statistics and its role in ensuring environmental and economic sustainability. The analysis considers global approaches to water accounting presented in recent scientific works. One of the most comprehensive studies provides a global review of water accounting practices and indicators of best performance for effective water governance [1]. This work highlights that reliable water statistics are fundamental to sustainable management and provides a methodological foundation for integrating physical and economic data into national accounts.

Another significant contribution presents an overview of the corporate dimension of water accounting, emphasizing the importance of accurate measurement and reporting within enterprises [2]. This study expands the discussion on how statistical water data can be embedded in corporate sustainability strategies, promoting transparency and accountability in resource use. Further empirical evidence is offered by a global review focusing on accountability and advocacy mechanisms in the water sector [3]. This research demonstrates that statistical data form the backbone of effective governance and public trust, linking social responsibility with evidence-based management.

The national dimension of water accounting is represented by the framework of the State Agency of Water Resources of Ukraine [4], which defines procedures for maintaining the national system of water use statistics. This official source reflects how data collection and reporting are organized within the Ukrainian institutional environment and identifies the methodological gaps that require harmonization with international standards. Ukrainian researchers also explore issues of environmental security, global economic transformations, and sustainable policy within the broader paradigm of economic resilience [5—12]. Their works demonstrate the need to integrate environmental and economic statistics into state policy and emphasize the role of harmonized data systems in shaping sustainable governance mechanisms.

Theoretical support for this approach is provided by studies that link environmental and economic processes through the concept of sustainable development [13—14]. These works substantiate the idea that environmental statistics, when incorporated into economic analysis, enhance the understanding of natural capital and support evidence-based decision-making.

At the same time, it is essential to rely on the methodological foundations developed under the auspices of the United Nations. The System of Environmental-Economic Accounting for Water (SEEAW) [15], the System of Environmental-Economic Accounting — Central Framework (SEEA-CF) [16], and the Handbook of Integrated Environmental and Economic Accounting [17] jointly define international standards for combining environmental and economic data within a unified statistical system. Their conceptual framework is directly aligned with the System of National Accounts (SNA) [17] and the goals of the 2030 Agenda for Sustainable Development [18]. Complementary guidance from the European Commission, OECD, UN, and World Bank [19] emphasizes the importance of statistical standardization and data comparability in achieving effective natural resource governance. These international and national sources confirm the evolution of water statistics from a narrow hydrological focus to an integrated environmental-economic approach that supports policy coherence and sustainable development.

Despite the existing scientific literature, we have grounds to argue that integrated water resource accounting based on the SEEAW methodology ensures a unified system of comparable environmental and economic indicators. This approach allows assessing the efficiency of water use, reflecting the interconnection between economic activity and the condition of water ecosystems, and forming an analytical foundation for improving natural resource management. The hypothesis of the study assumes that the implementation of standardized environmental-economic water accounts promotes the transition from fragmented statistics to a holistic analytical resource management system oriented toward sustainable development.

THE PURPOSE OF THE ARTICLE

The purpose of the article is to highlight the essence of SEEAW as an international tool for standardization of water resource accounting, enabling for the transition from a fragmentary approach to an integrated one in showing the causal links between economy and environment.

RESEARCH RESULTS

The System of Environmental-Economic Accounting for Water (SEEAW) is a specialized module of the System for Environmental-Economic Accounting (SEEA), developed under the auspices of United Nations to align environmental and economic data. SEEAW is designed to integrate physical and monetary indicators of intake, supply, use, discharge and regeneration of water resources with relevant accounts of the national economy.

The principal purpose of SEEAW is to create a harmonized structure of statistical tables, enabling to reflect causal links between economic activities and the condition of water resources. SEEAW allows to combine conventional water management balances with SNA accounts of production, consumption, and accumulation.

SEEAW is built on the principle of dual recording of water flows: in physical units (cubic meters) and in the monetary unit. This approach enables to track the

Table 1. The evolution of approaches to water resource accounting

Phase	Source / system	Main characteristic	Limitations / gaps	Innovations of SEEAW
1	Conventional hydrological statistics	Accounting of quantitative indicators (intake, discharge, stocks)	Lack of economic dimension	Water estimate introduced as an economic asset
2	System of National Accounts (SNA-1993)	Accounting of economic flows and assets	Nature resources not accounted	SNA extended by integrating environmental components
3	System of Environmental-Economic Accounts (SEEA-2003)	Conceptual integration of environmental and economy	Lack of operation tables for water	SEEAW creates standardized physical and monetary accounts
4	SEEAW (2007)	Integrated accounting of water in physical and monetary units	—	Complete standardization of data, link with SDG water resource management

Source: compiled by the authors by [9—15].

Table 2. A comparison of the conventional and integrated approaches to water resource accounting

Criterion	Conventional water balance	Integrated accounting by SEEAW
Purpose	Accounting of quantitative volumes of water	Estimates of causal links between economy and water resources
Measurement unit	Physical units (m^3)	Physical and monetary units
Data	Hydrological observations	Hydrological, economic, statistical data
Structure	Flows by source and consumer	"Supply-use" balance by economic sector
Applications	Technical planning of water economy	Economic analysis, sustainability policy
Alignment with SNA	None	Full methodological alignment

Source: compiled by the authors by [9—15].

movement of water resources from the natural environment to economic entities and back, thus providing for a comprehensive vision of quantitative and value dimensions of water use.

SEEAW has five principal components: (i) physical tables of water supply and use; (ii) monetary tables of water supply and use; (iii) hybrid tables combining the two approaches; (iv) accounts of assets (water stocks); (v) accounting of water quality. Monetary supply and use tables constitute a part of SEEAW system that shows economic flows associated with water, in monetary units. While physical tables show the movement of water in volumes (cubic meters), monetary tables show the value of these flows, i.e. the cost of intake, supply, cleaning, allocation, use of water across economic sectors.

These tables show: (i) the revenues of enterprises supplying water (e.g. water canals, utility services, industrial enterprises selling cleaned water), (ii) the expenses of water consuming sectors for purchase, water disposal, water cleaning, (iii) the subventions, taxes or subsidies related with water services, (iv) the capital investment in water infrastructures, and (iv) the economic value of regeneration or loss of water resources (in case of their depletion or pollution).

To have a better grasp of the SEEAW conceptual framework, we will proceed with examining the evolution of international approaches to integration of natural and economic indicators. The creation of the current system for environmental-economic accounting of water resulted from a prolonged development and gradual transition from a fragmentary hydrological observation to a coherent methodological approach combining natural and economic statistics. This evolution of measurement methods and systematization of data determined the status of SEEAW in the structure of international statistical standards.

SEEAW is a product of developments sprung from ideas laid in SEEA-2003 built on SNA-1993. These documents gradually extended the conventional economic indicators by introducing nature resources as a component of the national welfare (Table 1).

Over a long time, the water resource accounting was confined to hydrological statistics recording physical volumes, intakes, discharges, and stocks of water. But these data were incapable to estimate the economic significance of water in the national production, productivity of water use or financial consequences of its depletion and pollution. It was in 2007 that SEEAW was elaborated as the first international statistical standard combining physical and economic dimensions of water resource use.

SEEAW specifies the SEEA principles for the water sectors, creating a single methodological framework for collection, aligning, and presentation of data on water in physical and monetary units. Its central assumption is that water is not a mere resource of nature, but an economic asset possessing a value, bringing a revenue, demanding investment, and affecting the efficiency of production. The SEEAW development ushered in the transition from fragmentary statistics to the regular environmental-economic accounting aligning hydrological and economic indicators. It helped create a shared language for environmentalists, economists, managers, and statisticians.

To have a deeper grasp of the logic behind SEEAW structure, we need to explore the differences between the conventional water balance and the integrated approach of SEEAW.

The underlying concept of SEEAW is integration. It means that all the categories of water resources — surface, ground, artificially accumulated waters — should be regarded not separately, but within a single system of natural and economic flows. All the tables have "supply-use" structure, enabling to balance water intakes, consumption, losses, cleaning and return to the environment. The key concept of SEEAW is integration of physical and monetary tables "supply-use", hybrid accounts, and asset accounts. Hence, SEEAW enables for estimating the

quantity of water along with its economic value and the role in the sustainable development. A comparison of the conventional approach to estimating water balance with the integrated approach of SEEAW helps better understand the evolution of the accounting methodology (Table 2).

Hence, SEEAW extends the boundaries of the water resource accounting, with a narrow technical approach being replaced by a systemic environmental-economic analysis (Table 3).

The body of tables underlying the SEEAW structure (physical, hybrid, monetary), as well as asset and water quality accounts contain a comprehensive set of indicators applicable for monitoring, analytical assessment, and international comparisons in water use domain.

It needs to be born in mind that SEEAW does not replace conventional hydrological statistics, but serves as a bridge between them to economic accounts. Apart from estimating the quantity of water, it enables to determine its contribution in value added creation, water use efficiency, water productivity, and the impact of various economic sectors on the water environment. SEEAW has a module structure enabling its gradual implementation depending on the availability of data. This approach is especially important for the countries where national environmental-economic accounting systems are still in the process of creation.

Table 3. The structure of SEEAW tables and accounts

Type of table	Contents	Principal purpose
Physical tables of supply and use	Water intake, supply, consumption, return	Estimating the balance of water flows
Hybrid tables	Combination of physical and monetary data	Analysis of water use efficiency
Monetary tables	Value-based estimates of water flows and services	Estimating the economic value of water
Asset accounts	Water stocks, change in volume, natural repletion	Monitoring the status of resources
Water quality accouts	Indicators of pollution, chemical composition, environmental performance	Estimating the environmental quality from the ecological perspective

Source: compiled by the authors by [9—15].

Table 4. The alignment of SEEAW tables with SNA

SEEAW tables	Corresponding SNA	Analytical applications
Physical tables of water supply and use	Accounts of production, consumption of intermediate capital	Estimating the water use efficiency in economic sectors
Monetary tables	Accounts of revenues and expenses, accounts of sectors	Structural analysis of expenses for water supply, tariffs, and subsidies
Asset accounts	Accounts of capital and nature assets	Estimating the value of water stocks and their change over time
Hybrid tables	Comparison of physical and monetary indicators	Estimating the water productivity and water intensity of GDP
Water quality accounts	Environmental satellite accounts	Estimating the impact of economic activities on the status of water ecosystems

Source: compiled by the authors by [9—15].

Integration of SEEAW with SNA is key to creating a holistic analytical space where nature resources are considered as economic assets. SEEAW methodology interprets water as not only a component of the natural environment, but as a part of the national capital involved in value added creation and determining the long-term resilience of economic growth.

SEEAW has several levels of integration with national accounts: (i) aligning of physical flows of water with accounts of production and consumption; (ii) estimating the economic value of water resources and services in monetary units; (iii) accounting of change in the stocks of water in natural and value-based indicators; (iv) linking the results with accounts of capital, investment, and consumption of fixed assets (Table 4).

The alignment of SEEAW and SNA enables for constructing composite indicators for water resource management: (i) water productivity ratio (the relation of GDP to the scope of used water), (ii) water intensity of production by sector, (iii) capital investment per unit of water intake or cleaning, and (iv) water efficiency of the economy over time. These indicators can shape decision-making at macro-level, especially in policy setting on energy and water intensity, tariff regulation or environmental payments and subsidies. In this context, SEEAW constitutes not only a statistical standard, but an analytical tool for public administration, enabling to link nature use with macroeconomic strategies.

An important advantage of SEEAW is that it ensures international comparability of data. When a single methodology is used, the water efficiency can be estimated not only within a given country, but between regions and economic blocks. This enables for analyses of water footprint of the production sector, comparing the cost-efficiency of resources by sector, and for setting aligned policies within regional groups such as the European Union.

In the global dimension, SEEAW supports the implementation of UN Sustainable Development Goals, especially Goal 6 "Clean water and sanitation for all", and Goal 12 "Responsible consumption and production". SEEAW allows for estimating the progress by indicators of water use efficiency, scopes of water reuse, and investment in water infrastructures.

Hence, SEEAW lays the basis for the transition from fragmentary statistics of nature resources to a holistic analytics management system focused on estimating causal links between economic activities, the status of water ecosystems, and social consequences of water policies. Its implementation ensures standardization of data, enhances the transparence of management decisions, and helps construct single criteria for the efficiency assessment of the use of natural resources.

CONCLUSIONS

This study is based on the hypothesis that leads to a series of conclusions. The abovementioned evolution of approaches shows that the gradual extension of methodological boundaries of economic statistics has given rise to an integrated system capable to combine physical characteristics of natural resources with their economic estimates. SEEAW logically occurs as practical implementation of the environmental-economic integration concept initiated in SEEA and, at the same time, as a tool for standardization of statistical measurement of water

resources. Its structure, contents, and methodological principles reflect the transition from a descriptive accounting of natural phenomena to a systemic economic-analytical approach focused on management and planning of the sustainable development.

This study is a contribution to the understanding of SEEAW role as an international standard for integrated statistics of natural resources. It was demonstrated that SEEAW ensured the transition from fragmentary data collection to standardized environmental-economic analysis by combining hydrological observations with national economic accounts.

The study could deepen the conceptual understanding of the integrated accounting of water resources, wherein water is given dual interpretation as a natural and economic asset. It was demonstrated that the dual approach of SEEAW — physical and monetary — laid the analytical foundation for estimating causal links between economic activities, the status of water environment, and the resource management efficiency.

This study specified the functional purpose of physical, hybrid, and monetary tables, as well as accounts of water quality and assets in the SEEAW structure, thus enabling to show their role as interlinked components of a single set of indicators, applicable for monitoring, international comparisons, and setting integrated policies on nature use.

The study is a contribution in analyses of the alignment of SEEAW with SNA, which enabled to show a complementarity of economic and natural accounts in the measurement of the efficiency of use of water resources. It is stressed that integration of water indicators in the macroeconomic system lays grounds for estimating water productivity, water intensity of production, and regeneration of stocks of natural capital.

When solving the research objective, we specified the practical significance of SEEAW in the sustainable development, particularly its role in the monitoring of UN Sustainable Development Goals (SDG 6 і SDG 12). It was demonstrated that the implementation of SEEAW in national statistical practices would enhance the quality of management decisions, ensure international comparability of data, and create a single informational and analytical base for the integrated management of natural resources.

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