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FROM PHYSICAL BALANCE TO STATISTIC REPORTING: METHODOLOGICAL FOUNDATIONS OF INTEGRATED INTERNATIONAL WATER ACCOUNTING

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ВІД ФІЗИЧНОГО БАЛАНСУ ДО СТАТИСТИЧНОЇ ЗВІТНОСТІ: МЕТОДОЛОГІЧНІ ОСНОВИ ІНТЕГРОВАНОГО МІЖНАРОДНОГО ВОДНОГО ОБЛІКУ

In the process of addressing the research task, which consisted in conducting a comprehensive comparative analysis of international water accounting systems in order to determine their methodological interrelations, practical applicability, and potential for integration into a unified framework model of water resources accounting, significant scientific results were obtained. The study encompassed four leading systems that represent different conceptual approaches to water accounting, namely the International Water Management Institute Water Accounting (IWMI WA), the Water Accounting Plus (WA Plus), the System of Environmental Economic Accounting for Water (SEEA Water), and the Australian Water Accounting Standard (AWAS).

The research has further developed the scientific understanding of the systemic nature of water accounting as a complex multilevel process that integrates physical, economic, ecological, and legal dimensions of water resources management. It has been established that none of the analyzed systems provides a complete integration of all these dimensions; however, their combination forms a conceptual foundation for developing a universal methodological platform for global water management.

The study advanced the theoretical and methodological foundations for classifying international water accounting systems according to their level of spatial detail, analytical depth, and requirements for data provision. This made it possible to specify the role of each system within the global structure of water statistics. IWMI WA and WA Plus have been identified as analytical systems for physical accounting; SEEA Water as an economic statistical platform; and AWAS as a legal and institutional basis for transparent management of water assets.

The research deepened the methodological understanding of the differences between physical, economic, and legal approaches to water accounting. It was found that IWMI WA and WA Plus provide the scientific basis for assessing water balance and water productivity, while SEEA Water integrates water indicators into national accounts, ensuring a link between physical data and macroeconomic statistics. AWAS, in turn, establishes legal legitimacy and accountability within the water accounting process, reinforcing institutional transparency and governance credibility.

The study demonstrated the scientific and practical significance of the comparative analysis of international water accounting systems for improving national water management practices. The findings indicate that IWMI WA and WA Plus are suitable for regional and basin level studies, especially in countries with limited data availability, where they can be applied to assess water balance and use efficiency. Conversely, SEEA Water and AWAS are most effective in countries with well developed institutional and statistical systems, where they support official reporting and regulatory frameworks within sustainable development policies.

Finally, the study substantiated the conceptual foundations of an integrated international water accounting framework that combines the strengths of all four systems and may serve as a methodological basis for developing unified international water reporting standards. The proposed model allows the integration of physical, economic, and legal data, increases the accuracy of water balance assessments, enhances data comparability across countries, and provides a methodological platform for monitoring the implementation of the United Nations Sustainable Development Goals, particularly Goal Six Clean Water and Sanitation.

The obtained results have important theoretical and practical implications. They expand the scientific basis of water management, promote the integration of cross sectoral data, and create a foundation for a global information and analytical system for water resources governance. Future research should focus on developing an indicator framework for assessing the level of integration between national water accounting models and international standards, as well as designing digital monitoring tools capable of supporting a unified global ecosystem for managing water assets.

У процесі вирішення дослідницької задачі, яка полягала у здійсненні комплексного порівняльного аналізу міжнародних систем водного обліку з метою визначення їхнього методологічного взаємозв'язку, практичної придатності й потенціалу інтеграції в єдину рамкову модель обліку водних ресурсів, було досягнуто значних наукових результатів. Дослідження охопило чотири провідні системи, що репрезентують різні концептуальні підходи до водного обліку, а саме: Міжнародну систему обліку водних ресурсів (International Water Management Institute Water Accounting, IWMI WA), Розширену систему обліку водних ресурсів (Water Accounting Plus, WA плюс), Систему екологічно економічного обліку води (System of Environmental Economic Accounting for Water, SEEA Water) та Австралійський стандарт водного обліку (Australian Water Accounting Standard, AWAS).

У ході дослідження набуло подальшого розвитку наукове уявлення про системність водного обліку як складного багаторівневого процесу, у межах якого фізичні, економічні, екологічні та правові складові поєднуються у цілісну структуру управління водними ресурсами. Підтверджено, що жодна з наявних систем не забезпечує одночасно повної інтеграції всіх зазначених вимірів, однак їх синтетичне поєднання відкриває можливість формування універсальної методологічної платформи для глобального водного менеджменту. Розвинуто теоретико методологічні положення щодо класифікації міжнародних систем водного обліку за критеріями просторової деталізації, глибини аналітичного охоплення та рівня вимог до інформаційного забезпечення. Це дало змогу виокремити функціональну специфіку кожної системи в глобальній архітектурі водної статистики: IWMI WA і WA плюс визначено як базові аналітичні системи фізичного обліку, SEEA Waterяк інтеграційну економіко статистичну платформу, а AWAS як нормативно правову основу прозорого управління водними активами.

Поглиблено наукове розуміння методичних відмінностей між фізичними, економічними та правовими підходами до обліку водних ресурсів. Установлено, що IWMI WA та WA плюс формують наукову базу для кількісного оцінювання водних балансів, ефективності водокористування та продуктивності води, тоді як SEEA Water забезпечує зв'язок між фізичними показниками та макроекономічною статистикою, дозволяючи інтегрувати водні ресурси у систему національних рахунків. AWAS, своєю чергою, створює механізм правової легітимності облікових процедур, забезпечує підзвітність і прозорість у розподілі водних прав, що підсилює довіру до сис-

теми управління водними активами. Доведено науково практичну цінність порівняльного аналізу міжнародних систем водного обліку для адаптації світових підходів у національні практики. Отримані результати свідчать, що системи IWMI WA і WA плюс придатні для регіональних і басейнових досліджень, особливо в країнах з обмеженою інформаційною базою, де необхідна оцінка балансових співвідношень і продуктивності води. Натомість SEEA Water і AWAS продемонстрували високу ефективність для держав із розвиненими інституційними структурами, оскільки дають змогу здійснювати офіційну звітність і нормативне регулювання на рівні політики сталого розвитку.

Обгрунтовано концептуальні засади інтегрованої рамкової моделі міжнародного водного обліку, що поєднує переваги всіх чотирьох систем і може слугувати методологічною базою для створення єдиних міжнародних стандартів водної звітності. Запропонована модель дозволяє поєднувати фізичні, економічні та правові дані, підвищує точність оцінювання водних балансів, забезпечує можливість транснаціонального порівняння показників і створює умови для гармонізації методів обліку в межах Цілей сталого розвитку Організації Об'єднаних Націй, зокрема Цілі шість Чиста вода та санітарія.

Отримані результати мають важливе теоретичне й практичне значення, оскільки поглиблюють наукові основи водного менеджменту, розширюють можливості інтеграції даних між різними обліковими системами та формують підгрунтя для створення глобальної інформаційно аналітичної бази управління водними ресурсами. Перспективним напрямом подальших досліджень є розроблення індикаторної системи для оцінки рівня інтегрованості національних моделей водного обліку з міжнародними стандартами, а також формування цифрових інструментів моніторингу, здатних забезпечити єдину глобальну екосистему управління водними активами.

Key words: Water accounting, Water statistics, Environmental economic accounting, Integrated water balance, Data comparability, Statistical methodology, Water productivity assessment, Hydrological data analysis, Economic valuation of water resources, Legal framework of water assets, National accounts integration, Water information systems, Sustainable water management, Data harmonization, International reporting standards.

Ключові слова: водний облік, водна статистика, екологічно економічний облік, інтегрований водний баланс, порівнянність даних, статистична методологія, оцінка продуктивності води, аналіз гідрологічних даних, економічна оцінка водних ресурсів, правове регулювання водних активів, інтеграція з національними рахунками, інформаційні системи водного обліку, сталий менеджмент водних ресурсів, гармонізація даних, міжнародні стандарти звітності.

INTRODUCTION

The problem of compatibility of international water accounting systems is closely related with issues of sustainable water resource management, assessment of ecosystem services, and setting the policy of adaptation to climate change. Amidst the increasing water scarcity and toughening cross-sector competition, governments and international organizations need aligned approaches to measurement, comparison, and management of water balances. The current water accounting systems — International Water Management Institute Water Accounting (IWMI WA), Water Accounting Plus (WA+), System of Environmental-Economic Accounting for Water (SEEA-Water), and Australian Water Accounting Standard (AWAS) — were built in distinct institutional and methodological contexts, with each reflecting the priorities of its time: from hydrological assessment of water productivity (IWMI WA) to normative-legal accounting of water assets (AWAS).

However, the lack of a single methodological framework limits the capabilities of cross-country comparisons, integration of data, and employment of obtained information in devising complex strategies of water safety. A comparative analysis of approaches involved in IWMI WA, WA+, SEEA-Water, and AWAS is a required step to reveal their crossing points and distinctions, determine their complementarity potentials, and elaborating recommendations on adaption of their components in national systems for water resource management.

The relevance of this study is determined by three interlinked aspects: the necessity of unification and comparability of data on water resources in the global system of natural accounts; the need for tools supporting integration of physical, economic, and institutional dimensions of the water cycle; the strategic significance of the choice of water accounting technique in implementing Sustainable Development Goals (SDGs) of the United Nations, specifically SDG 6 "Clean water and sanitation for all."

THE LITERATURE REVIEW

The reviewed body of literature demonstrates a systematic evolution of the conceptual and methodological frameworks for environmental and economic water

accounting, reflecting the growing recognition of water as both a natural and economic asset [1—3, 5, 10—12]. Foundational documents developed under the auspices of international organizations establish the theoretical and statistical basis for integrating environmental parameters into national accounts. The System of Environmental-Economic Accounting and its water-specific extensions provide a coherent structure for linking hydrological, physical, and economic information, enabling more comprehensive analysis of interactions between natural resource systems and economic performance [1—2].

International policy frameworks such as the 2030 Agenda for Sustainable Development emphasize water accounting as an essential instrument for achieving the Sustainable Development Goals, particularly through the development of consistent indicators of water use efficiency and sustainability [4—5]. Empirical and applied studies highlight the methodological advancements in compiling physical supply and use tables and asset accounts for water resources, illustrating the practical utility of harmonized statistical standards at the global and regional levels [6, 7].

The literature also examines the implications of environmental-economic accounting for governance and policy coherence. Studies confirm that incorporating SEEAW and SEEA-CF principles into national systems enhances data quality, supports evidence-based policymaking, and strengthens accountability mechanisms within the water sector [8, 9, 10, 12]. The emphasis on linking environmental data with economic indicators contributes to improved transparency, intersectoral coordination, and resource efficiency, serving as a foundation for integrated water management and sustainable development planning [9, 11].

At the corporate and regional scales, research explores how water accounting principles are applied beyond state-level reporting to support sustainability disclosure and resource optimization in private and institutional contexts [14, 16]. This approach aligns with broader theoretical developments in green economy and circular transition frameworks, which interpret environmental accounting as a key tool for monitoring ecological limits and guiding sustainable growth pathways [15, 21, 22].

A growing number of studies situate water accounting within interdisciplinary discussions of foresight, resilience, and economic transformation, underscoring its potential role in adaptive policy mechanisms and long-term sustainability governance [17—19]. This body of work establishes conceptual linkages between environmental-economic statistics and the strategic management of sustainability transitions, reinforcing the necessity of comprehensive data integration for assessing national and global progress toward resilience and equitable growth [18—20].

Recent contributions expand the analytical horizon of water accounting by connecting it with environmental markets, pollution regulation, and ecosystem service valuation [13, 24]. The focus on institutional mechanisms and regulatory coherence reflects an emerging consensus that effective water accounting requires both robust data frameworks and governance structures capable of translating statistical evidence into enforceable policy actions [20, 22—23].

Overall, the analyzed literature reveals a trajectory from methodological standardization toward functional integration of water accounting into the broader domain of environmental-economic statistics and sustainability governance. These insights form the theoretical and empirical basis for the comparative study presented in this article, aimed at assessing four major international systems-IWMI WA, WA Plus, SEEA Water, and AWAS-as complementary components of a unified architecture for global water resource accounting and management.

In spite of a large body of research devoted to selected aspects of water resource accounting by IWMI WA, WA+, SEEA-Water, and AWAS, a comprehensive comparative analysis that would highlight their methodological framework, structural distinctions, and integration potentials is still to be made.

We propose a systemic study aiming to explore and compare the four international approaches to water accounting embodied in IWMI WA, WA+, SEEA-Water, and AWAS, to reveal their common principles, distinct features and capabilities for elaborating a unified conceptual framework applicable in national and trans-border systems for water resource management.

THE PURPOSE OF THE ARTICLE

The purpose of the article is to highlight methodological links, practicability, and integration potentials of International Water Management Institute Water Accounting, Water Accounting Plus, System of Environmental-Economic Accounting for Water, and Australian Water Accounting Standard in a single framework model for water resource accounting.

This purpose involved the following tasks: highlighting theoretical and methodological principles of each accounting system, with outlining the logic behind their buildup and structural components; comparing the approaches to building up these systems by criteria of coverage, types of data, application level, and by ways of integrating physical, economic and legal dimensions of the water balance; revealing advantages and limitations of each system from the perspective of scientific analysis, management practice, and statistical accounting; assessing feasibilities for combining components of various systems, to create an adaptive model applicable in the national context.

RESEARCH RESULTS

International Water Management Institute Water Accounting (IWMI WA) is an early attempt to create an all-purpose technique for quantitative assessment of water balances within river basins. It is based on the concept of integrated management of water resources, assuming that the water use efficiency, apart from the water intake, depends on the useful water consumption and return to the natural environment. The IWMI WA methodology builds on the principle of water balance wherein all the water inflows to the system equal the sum of used, lost and stocked water. Hence, the system contains three groups of indicators (resources, uses and losses), showing natural and anthropogenic movements of water. This approach enables for estimating not only the scarcity or surplus of water resource, but the efficiency of water use by economic sector. An important point of IWMI WA is the concept of water productivity, i.e. the output of a useful

product, e.g. agricultural yield, produced per unit of used water. This concept is crucially important in water-scarce regions, where increases in water intake are prioritized in parallel with optimization of water use.

IWMI WA uses field hydrological observations and simulation data. Although this system is all-purpose, it does not include economic and legal components, which limits its applications in national sustainability strategies. However, it laid the foundation for more holistic approaches, e.g. Water Accounting Plus, (WA+).

WA+ was a follow up of the basic IWMI WA model, designed to overcome its limitations caused by insufficient spatial detailing and weak integration with environmental parameters. WA+ offers a multitier scheme wherein the water balance is presented by means of standardized tables covering principal components of the water balance: the base of resources, evaporations, and water intakes. WA+ has a specific feature of combining data from remote sensing with ground observations. This approach has analytical capacity even in the regions with a poorly development hydrological network. The assessment of evaporations, precipitations, and water use is made by satellite data, which notably increases the accuracy of spatial modelling. Methodologically, WA+ is designed for not only accounting of water scopes, but for showing links of water with types of land use. This enables for analyses of environmental effects from management decisions, e.g. changes in the water balance resulting from expansions of cultivated areas or urbanization. WA+ has high potential for integration with geo-information systems, and it is widely used in projects on efficiency assessment of water use in river basins.

The System of Environmental Economic Accounting for Water (SEEA Water) was developed under the aegis of the United Nations as part of the overall System for Environmental-Economic Accounting (SEEA). Its purpose is to align physical indicators of natural resource utilization with macroeconomic statistics. Unlike IWMI WA and WA+, SEEA Water is focused on the economic dimension of water use. It combines physical tables showing water stocks, supplies, consumption and return with monetary estimates. It enables to determine the economic value of water resources and record them in SNA. SEEA Water, used at country level, enables for international comparability of data. Its important function is laying the foundation for national policies on water resource management, and monitoring of SDGs, particularly SDG 6 "Clear water and sanitation for all". In spite of a high standardization level, SEEA Water has limitations when it comes to analyses of basin-related processes, because it deals mostly with aggregated indicators. Yet, SEEA Water creates a methodological link between environmental statistics and economic analysis.

The Australian Water Accounting Standard (AWAS) is the first normative worldwide document legalizing the principles of overall water accounting analogous to financial one. It was developed by the Australian Bureau of Meteorology to ensure transparence in water assets management. AWAS involves compilation of reports in the form of three principal documents: report on water assets and liabilities, report on changes in water assets and liabilities, and report on water flows. Hence, water resources are interpreted as assets, and rights for their use as liabilities subject to accounting and audit. Methodologically, AWAS is based on a combination of legal and hydrological principles, to ensure a legal authenticity of data. This approach fits for countries with developed systems of licensing of water rights, but it would be challenging when introduced wherever a digital monitoring is limited and institutional control is weak.

A comparison of the four international systems for water resource accounting enables to reveal both distinctions in methodologies and potentials for integration (see Tables 1—4). In spite of the common purpose of creating

Table 1. A comparison of purposes and applications of IWMI WA, WA+, SEEA-Water, and AWAS

System	Purpose	Application level	Orientation
IWMI WA	Quantitative analyses of water resource balances and water productivity	Basin, region	Physical accounting of water balance
WA+	Spatial analyses of the water cycle and relationship between water and land use	Basin, sub-basin	Hydrological and environmental approach
SEEA Water	Integrating environmental and economic indicators of water use	National	Economic-statistical approach
AWAS	Standardized legally-based accounting of water assets	National and regional	Legal and institutional approach

Source: developed by the authors.

Table 2. The principal structural components of IWMI WA, WA+, SEEA-Water, and AWAS

System	Principal components	Types of data	Sources of information
IWMI WA	Resources, uses, losses	Physical	Hydrological observations, modelling
WA плюс	Tables of resource base, evaporations, water intakes	Physical and spatial	Satellite images, field data
SEEA Water	Таблиці запасів, надходження, використання, активів	Physical and monetary	National statistics, departmental reports
AWAS	Звіт про водні активи, звіт про зміни активів, звіт про потоки	Physical, legal, financial	Registers of water rights, official databases

Source: developed by the authors.

Table 3. The integration between dimensions of water resource management

Система	Physical dimension	Economic dimension	Environmental dimension	Legal dimension
IWMI WA	High	Weak	Medium	None
WA+	High	Limited	High	None
SEEA Water	Medium	High	Medium	Limited
AWAS	High	High	Limited	High

Source: developed by the authors.

a sound information base for water resource management, each system was developed in various institutional, economic, and legal contexts.

The above comparison shows that IWMI WA, WA+, SEEA Water, and AWAS are complementary rather than contesting tools. Although they differ in detailing level, deepness of analytical coverage, and character of data, all of them are designed for one purpose, which is efficiency enhancement of water resource management. IWMI WA i WA systems are more flexible from the technical point, because they allow for estimating the water balance even with limited data. SEEA Water and AWAS, instead, require well-established statistical and legal infrastructures, but they ensure high reliability and international comparability of indicators. A comparison of structural characteristics showed that the difference between them arose not only from the data aggregation level, but from the principles of their validation, e.g. consistency check. This poses the issues of quality of data sources, accuracy of estimations, and compliance between physical and economic indicators, which necessitates a separate analysis of requirements to the information support of each system, and assessment of their accuracy and applicability in various socio-economic contexts. This aspect is summed up in Table 4.

The analysis of data accuracy and requirements shows that water accounting systems differ from methodological as well as organizational point. IWMI WA and WA+ are applicable even with a limited statistical base, because their technique builds on physical indicators that can be obtained from open sources and via satellite observations. It makes them especially useful for countries lacking comprehensive systems for environmental statistics.

SEEA Water, instead, involves high standardization and requires detailed official reporting; its efficiency, therefore, directly depends on the development of official statistics. The Australian standard AWAS builds on a totally difference logic, because it is based on legally fixed water rights and asset accounting, which requires institutional stability and digital infrastructure.

Hence, the essential difference between the systems stems from their applicability scales. While IWMI WA and WA+ are focused on analytical and research activities, SEEA Water and AWAS are designed for compiling official reporting and public administration.

For deeper understating of each system, we will proceed with examining their practical applications, integration potentials, and real examples of implementation. This aspect is summed up in Table 5.

The analysis of practical applications showed that each system had a target group of users and notable advantages in a certain type of administrative or research assignments. IWMI WA and WA+ are focused mostly on researchers, analysts, and specialists on water management dealing with hydrological models and efficiency assessment of water use. SEEA Water is used by official statistical offices and international institutions in setting policies for sustainable management of natural resources. The Australian standard AWAS was designed mainly for regulatory bodies charged with control of the rights for water use and assurance of transparency in resource allocation. It needs to be noted that the systems, in spite of different level of the institutional development, do not exclude one another. On the contrary, their integration opens up an opportunity for creating a multilevel system for water accounting, wherein physical indicators are supplemented by economic estimates, and legal mechanisms guarantee the soundness and accountability of the processes. Table 6 sums up the main advantages

Table 4. A comparison of accuracy and accessibility of data, and requirements to data collection in IWMI WA, WA+, SEEA-Water, and AWAS

System	Requirements to data	Sources of uncertainty	Accuracy level	Applicability for countries with limited data
IWMI WA	Basic hydrological observations	Incompleteness of data on underground waters	Medium	High
WA+	Satellite and surface data	Error of remote sensing	High	High
SEEA Water	Detailed national statistics	Delay of publications, aggregated data	High	Low
AWAS	Digital registers of water rights	Inconsistency of actual legal data	High	Low

Source: developed by the authors.

Table 5. The practical applicability and integration potentials of IWMI WA, WA+, SEEA-Water, and AWAS

System	Principal applications	Potential for integration with other systems	Examples of implementation
IWMI WA	Scientific research, assessment of water productivity	Compatible with WA+	Basins of Ganges, Nile, Limpopo
WA плюс	Management of water basins, environmental planning	Can be integrated with SEEA Water	Africa, Middle East, South Asia
SEEA Water	Official statistics, policy setting	Compatible with AWAS and WA+	EU, Canada, South Africa
AWAS	Water administration, audit, allocation of water rights	Partially compatible with SEEA Water	Australia, New Zealand

Source: developed by the authors.

Table 6. The main advantages and limitations of IWMI WA, WA+, SEEA-Water, and AWAS

System	Advantages	Limitations
IWMI WA	Structural simplicity, intelligible logic of water balance	Does not include economic dimensions
WA плюс	High detailing in space and time, integration of remote sensing	Requires elaborate technical support
SEEA Water	Integrity of environmental and economic data, alignment with international standards	Inadequately flexible for local studies
AWAS	Legal soundness, transparent administration	Challenging introduction in countries lacking water rights systems

Source: developed by the authors.

and limitations of each system, and reveals their potential combinations within the integrated approach to water resource management.

The comparative analysis demonstrated that each system had a specific function in the overall architecture of the international water accounting. IWMI WA and WA+ lay a physical and hydrological foundation for estimating water balances. SEEA Water provides for an economic dimension and allows to include water resources in SNA. AWAS creates a legal framework regulating property rights for water and responsibility for water asset management. Once these systems are integrated in a single methodological structure, it will enable to design a holistic model for water accounting, covering physical, economic, environmental, and legal dimensions of water management. This approach can lay the background for elaborating international standards adaptable in national systems of countries with various levels of institutional development.

CONCLUSIONS

A comprehensive comparative analysis of international water accounting systems, to determine their methodological links, practical applicability and potentials for integration in a single framework model of water resource accounting, contributed to scientific interpretation of the consistency of the water balance as a complex multilevel process combining physical, economic, environmental, and legal components of water resource management. It was shown that neither of these systems was capable to ensure full integration of all the dimensions, but, when combined, they would lay the basis for creating an all-purpose methodological platform of water management.

The analysis developed theoretical and methodological provisions on the classification of international water accounting systems by spatial detailing, deepness of analytical coverage, and requirements to information support. This enabled to pose each system within the global structure of water statistics, with defining IWMI WA and WA+ as analytical systems for physical accounts, SEEA Water as an economic-statistical platform, and AWAS as a legal framework for transparent management of water assets.

The scientific interpretation of technical differences between physical and economic approaches to water resource accounting was deepened. It was found that IWMI WA and WA+ laid a scientific groundwork for the assessment of water balance and water productivity, whereas SEEA Water offered a tool for integrating water indicators in SNA. AWAS provided for legal legitimacy of the accounting process and accountability of water use. This enabled to determine the potential of their integration in a single model incorporating natural, economic, and institutional factors.

The study demonstrated theoretical and practical significance of a comparative analysis of water accounting systems for improvements of national approaches to water resource management. Its results showed that IWMI WA and WA+ were applicable for regional studies in countries with limited information base, whereas SEEA Water and AWAS were more useful for countries with well-established institutional systems. This lays the background for adapting each system's components in national practices of water accounting.

The underlying principles of a framework model for international water accounting were conceptualized: it was demonstrated that the model combined the advantages of all the four systems and could lay the basis for a set of international standards for water reporting. The proposed approach ensures a compatibility of physical, economic, and legal data, enhances the accuracy of water balance estimates, and creates a methodological framework for monitoring of SDGs, especially SDG 6 "Clean water and sanitation for all".

Література:

1. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank. System of Environmental-Economic Accounting for Water (SEEAW). New York: United Nations, 2012. 154 p.

2. United Nations Statistical Division. System of Environmental-Economic Accounting 2012 — Central Framework (SEEA-CF). New York: United Nations, 2014. 378 p.

3. United Nations, European Commission, Organisation for Economic Co-operation and Development, International Monetary Fund, World Bank. Integrated Environmental and Economic Accounting: Handbook of National Accounting. New York: United Nations, 2003. 616 p.

4. United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. New York: United Nations, 2015. 41 p.

5. European Commission, OECD, United Nations, World Bank. Environmental and Economic Accounting and Indicators for Sustainable Development. Luxembourg: Publications Office of the European Union, 2020. 112 p.

6. Van Berkel, J., (2022), "Compilation of Physical Supply and Use Tables, Asset Accounts and Policy Indicators for Water 2018—2020", Eurostat grant report.

7. Vardon M. J., Le T. H. L., Martinez-Lagunes R., Pule O. B., Schenau S., May S., Grafton R. Q. Accounting for water: A global review and indicators of best practice for improved water governance. Ecological Economics. 2025. № 227. 108396. https://doi.org/10.1016/j.ecolecon.2024.108396

8. Smith R. Users and uses of environmental accounts: a review of select developed countries. Washington, DC: World Bank, 2020. URL: https://openknowledge.worldbank.org/handle/10986/33316 (дата звернення: 18.01.2026).

9. Souliotis I., Voulvoulis N. Natural capital accounting informing water management policies in Europe. Sustainability. 2021. Vol. 13, № 20. Article 11205. DOI: https://doi.org/10.3390/su132011205

10. Vardon M., Castaneda J. P., Nagy M., Schenau S. How the system of environmental-economic accounting can improve environmental information systems and data quality for decision making // Environmental Science & Policy. 2018. Vol. 89. P. 83—92. DOI: https://doi.org/10.1016/j.envsci.2018.07.007

11. Vardon M., Castaneda J. P., Nagy M., Schenau S. How the system of environmental-economic accounting can improve environmental information systems and data

quality for decision making. Environmental Science & Policy. 2018. Vol. 89. P. 83—92. DOI: https://doi.org/10.1016/j.envsci.2018.07.007

12. Vardon M., Martinez-Lagunes R., Gan X., Nagy M. The system of environmental-economic accounting for water: development, implementation and use // Water Accounting: International Approaches to Policy and Decision Making. Cheltenham, UK: Edward Elgar Publishing, 2012. P. 32—57. DOI: https://doi.org/10.4337/9781849807494.00010

13. Vardon M., Keith H., Lindenmayer D. Accounting and valuing the ecosystem services related to water supply in the Central Highlands of Victoria, Australia. Ecosystem Services. 2019. Vol. 39. Article 101004. DOI: https://doi.org/10.1016/j.ecoser.2019.101004

14. Meurer S., Van Bellen H. M. Water accounting: an overview of the corporate scenario. Revista Catarinense da Ciencia Contabil. 2024. № 23. e3469. https://revista.crcsc.org.br/index.php/CRCSC/article/view/3469/2638

15. Melnyk T., Reznikova N., Ivashchenko O. Problems of statistical study of "green economics" and green growth potentials in the sustainable development context. Baltic Journal of Economic Studies. 2020. Vol. 6, № 3. P. 87—98. DOI: https://doi.org/10.30525/2256-0742/2020-6-3-87-98

16. Hepworth N. D., Brewer T., Brown B. D., Atela M., Katomero J., Kones J., Gashaw M. Accountability and advocacy interventions in the water sector: a global evidence review. H2Open Journal. 2022. Т. 5, № 2. С. 307. https://doi.org/10.2166/h2oj.2022.062

17. Панченко В., Резнікова Н. Міжнародні стратегії економічного розвитку: навчальний посібник. Київ: АграрМедіа, 2025. 471 с.

18. Панченко В., Резнікова Н., Іващенко О. Стратегічний форсайт як інструмент протидії сучасним глобальним викликам економічній безпеці і нерівності: досвід ЄС для України у сприянні стійкості та сталості. Вісник Хмельницького національного університету. Серія: економічні науки. 2023. № 4 (320). С. 31—39. https://doi.org/10.31891/2307-5740-2023-320-4-5

19. Панченко В.Г., Резнікова Н.В., Іващенко О.А. Форсайт як інструмент відповідального державного управління і стратегування міжнародної економічної політики в умовах загострення глобальних проблем розвитку. Вісник Хмельницького національного університету. Серія: Економічні науки. 2024. № 326 (1). С. 350—358. https://doi.org/10.31891/2307-5740-2024-326-55

20. Резнікова Н. В. Глобальні і регіональні екологічні проблеми. Київ: Вістка, 2016

21. Reznikova N., Grod M. Macroeconomic impacts of the circular transition: the green swans of decarbonization on the path to sustainability. Aktualni problemy mizhnarodnykh vidnosyn. 2024. Vol. 1, № 160. P. 110—120. DOI: https://doi.org/10.17721/apmv.2024.160.1.110-120

22. Цибуляк А. (2025). Екологічний імператив парадигми сталості VS право на розвиток: у пошуках інституційних механізмів досягнення системного компромісу. Ефективна економіка. (квітень). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5231630

23. Цибуляк А. Еволюція теорій екологічної модернізації як прояв зростання ризиків міжнародної економіки: актуалізація сталих бізнес-практик в умовах цифрового переходу. Економічний простір: Збірник наукових праць. 2025. № 201 (травень). С. 370—377. https://economic-prostir.com.ua/wp-content/uploads/2025/06/201-370-377-czybulyak.pdf

24. Цибуляк А. International water markets in the context of the green transition: regulatory mechanisms for managing water pollution. Європейський науковий журнал Економічних та фінансових інновацій. 2025. С. 171—79. Том 3. № 17. https://economic-prostir.com.ua/wp-content/uploads/2025/06/201-370-377-czybulyak.pdf

References:

1. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank (2012), System of Environmental-Economic Accounting for Water (SEEAW), United Nations, New York, USA.

2. United Nations Statistical Division (2014), System of Environmental-Economic Accounting 2012 — Central Framework (SEEA-CF), United Nations, New York, USA.

3. United Nations, European Commission, Organisation for Economic Co-operation and Development, International Monetary Fund, World Bank (2003), Integrated Environmental and Economic Accounting: Handbook of National Accounting, United Nations, New York, USA.

4. United Nations (2015), Transforming our world: the 2030 Agenda for Sustainable Development, United Nations, New York, USA.

5. European Commission, OECD, United Nations, World Bank (2020), "Environmental and Economic Accounting and Indicators for Sustainable Development", Publications Office of the European Union, Luxembourg.

6. Van Berkel, J., (2022), "Compilation of Physical Supply and Use Tables, Asset Accounts and Policy Indicators for Water 2018—2020", Eurostat grant report.

7. Vardon, M. J., Le, T. H. L., Martinez-Lagunes, R., Pule, O. B., Schenau, S., May, S. and Grafton, R. Q. (2025), "Accounting for water: A global review and indicators of best practice for improved water governance", Ecological Economics, vol. 227, 108396. https://doi.org/10.1016/j.ecolecon.2024.108396

8. Smith, R. (2020), "Users and Uses of Environmental Accounts: A Review of Select Developed Countries", World Bank, Washington, DC, available at: https://openknowledge.worldbank.org/ handle/10986/33316 (Accessed 18 January 2026).

9. Souliotis, I. and Voulvoulis, N. (2021), "Natural capital accounting informing water management policies in Europe", Sustainability, vol. 13 (20), 11205, https://doi.org/10.3390/ su132011205

10. Vardon, M., Castaneda, J. P., Nagy, M. and Schenau, S. (2018), "How the system of environmental-economic accounting can improve environmental information systems and data quality for decision making", Environmental Science & Policy, vol. 89, pp. 83—92. https://doi.org/10.1016/j.envsci.2018.07.007

11. Vardon, M., Burnett, P. and Dovers, S. (2016), "The accounting push and the policy pull: balancing environment

and economic decisions", Ecological Economics, vol. 124, pp. 145—52. https://doi.org/10.1016/j.ecolecon.2016.01.021

12. Vardon, M., Martinez-Lagunes, R., Gan, X. and Nagy, M. (2012), "The System of Environmental-Economic Accounting for Water: development, implementation and use", Water Accounting, International Approaches to Policy and Decision Making, pp. 32—57, Edward Elgar Publishing, UK. https://doi.org/10.4337/9781849807494.00010

13. Vardon, M., Keith, H. and Lindenmayer, D. (2019a), "Accounting and valuing the ecosystem services related to water supply in the Central Highlands of Victoria, Australia", Ecosystem Services, vol. 39, 101004. https://doi.org/10.1016/j.ecoser.2019.101004

14. Meurer, S. and Van Bellen, H. M. (2024), "Water accounting: an overview of the corporate scenario", Revista Catarinense da Ciencia Contabil, vol. 23, e3469. https://doi.org/10.16930/2237-7662202434691

15. Melnyk, T., Reznikova, N. and Ivashchenko, O. (2020), "Problems of statistical study of 'green economics' and green growth potentials in the sustainable development context", Baltic Journal of Economic Studies, vol. 6 (3), pp. 87—98. https://doi.org/10.30525/2256-0742/2020-6-3-87-98

16. Hepworth, N. D., Brewer, T., Brown, B. D., Atela, M., Katomero, J., Kones, J. and Gashaw, M. (2022), "Accountability and advocacy interventions in the water sector: a global evidence review", H2Open Journal, vol. 5 (2), p. 307—322. https://doi.org/10.2166/h2oj.2022.062

17. Panchenko, V. and Reznikova, N. (2025), Mizhnarodni stratehii ekonomichnogo rozvytku [International strategies of economic development], AgraMedia, Kyiv. Ukraine.

18. Panchenko, V., Reznikova, N. and Ivashchenko, O. (2023), "Strategic foresight as a tool for countering modern global challenges to economic security and inequality: EU experience for Ukraine in promoting resilience and sustainability", Visnyk Khmelnytskoho natsionalnoho universytetu. Seriia: ekonomichni nauky, vol. 4 (320), pp. 31—39. https://doi.org/10.31891/2307-5740-2023-320-4-5

19. Panchenko, V., Reznikova, N. and Ivashchenko, O. (2024), "Foresight as a tool for responsible public management and adjustment of international economic policy in the focus of global development problems", Visnyk Khmelnytskoho natsionalnoho universytetu. Seriia: ekonomichni nauky, vol. 326 (1), pp. 350—358. https://doi.org/10.31891/2307-5740-2024-326-55

20. Reznikova, N. V. (2016), Hlobalni i rehionalni ekolohichni problemy [Global and regional environmental problems], Kyiv: Vistka.

21. Reznikova, N. and Grod, M. (2024), "Macroeconomic impacts of the circular transition: the green swans of decarbonization on the path to sustainability", Aktualni problemy mizhnarodnykh vidnosyn, vol. 1 (160), pp. 110—120. https://doi.org/10.17721/apmv.2024.160.1.110-120

22. Tsybuliak, A. (2025). "The ecological imperative of the sustainability paradigm vs the right to development: in search of institutional mechanisms for achieving a systemic compromise", Efektyvna ekonomika, vol. 4, available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5231630 (Accessed 15 Feb 2026). http://dx.doi.org/10.2139/ssrn.5231630

23. Tsybuliak, A. (2025), "Evolution of theories of ecological modernization as a manifestation of the increasing risk of the international economy: actualization of sustainable business practices in the conditions of digital transition", Ekonomichnyi prostir: Zbirnyk naukovykh prats, vol. 201, pp. 370—377. https://doi.org/10.30838/EP.201.370-377

24. Tsybuliak, A. (2025), "International water markets in the context of the green transition: regulatory mechanisms for managing water pollution", Yevropeiskyi naukovyi zhurnal ekonomichnykh ta finansovykh innovatsii, vol. 3 (17), pp. 171—179. https://doi.org/10.32750/2025-0315

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