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Water Resources Management using Geographic Information Systems (G.I.S.): Case Study of the Nestos River Basin

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Abstract: Directive 2000/60/EC introduces a framework for water protection by assessing ecological quality through biological, physicochemical, and hydromorphological parameters at the river basin level. Member States are required to maintain registers of water bodies used for human consumption, in compliance with Community legislation. This study aims to develop an electronic database (EDB) to document water supply drillings in accordance with the Directive, using Geographic Information Systems (GIS) for a pilot implementation in the Nestos River Basin. The EDB enables real-time monitoring and prompt intervention by authorities to address water quality issues, such as nitrate pollution, thereby supporting sustainable water resource management and public health protection.

Keywords: *WFD 2000/60/EC, Geographic information systems, Nestos River, Electronic database, Groundwater, River basin management*

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1. Introduction

The purpose of the Water Framework Directive 2000/60/EC is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters, and groundwater (Directive 2000/60/EC, 2000). A revolutionary aspect of the WFD is that the quality of surface water is measured not only by chemical elements but also by ecological quality values. The directive aims for the protection of all surface and underground water supplies, with the critical objective of achieving "good" water status through the application of effective management plans at the river basin level, which must be updated every six years.

This "good" water status is established by representing hydro-morphological, physicochemical, and biological values. These characteristics are named descriptors and are differentiated according to the system applied (System A or B, WFD 2000/60). For each surface water category, the relevant surface water bodies within the River Basin district must be differentiated according to type, as defined using either system A or system B.

However, water management faces several significant challenges. These include scarcity and overuse, due to over-extraction of groundwater and climate change impacting precipitation patterns; pollution from industrial discharge, agricultural runoff, and improper waste disposal; aging infrastructure leading to inefficiencies; challenges in ensuring equitable access; complications from climate change; governance and policy fragmentation; economic factors limiting investment; and insufficient public awareness and engagement (Burrough, 1992; Burrough & McDonnell, 2000). Addressing these challenges requires a collaborative approach to implement sustainable and innovative solutions.

Geographic Information Systems (GIS) present a powerful tool for addressing these complex issues. A GIS is designed to capture, store, manipulate, analyse, manage, and present all types of geographical data, revealing relationships, patterns, and trends (Burrough, 1992; Burrough & McDonnell, 2000; Fytilis & Palatos, 2022). The benefits of GIS, which include cost savings, better decision-making, and improved record-keeping, are well-documented across various water management applications. For instance, GIS plays an essential role in mapping water resources (Clark, 1998; Tsihrintzis et al., 1996), flood prediction and risk management (Kourgialas & Karatzas, 2011; Qi & Altinakar, 2011), drought management, water quality monitoring (Dimitriou & Zacharias, 2010), infrastructure planning, and Integrated Water Resources Management (IWRM). It is a dynamic system that integrates diverse datasets to inform decision-making at every level.

This study aims to highlight the importance of Geographic Information Systems (GIS) in water resources management, with a specific focus on compliance with Directive 2000/60/EC. As a case study, this work analyses the usefulness of GIS for managing water supply drillings in the catchment area of the Nestos River. The primary objective is to create an electronic database (EDB) to monitor drilling parameters in real time. This system is designed to enable immediate intervention by stakeholders (e.g., Regional Unit or Municipality) to avoid adverse consequences. For example, if a sudden increase in nitrates is detected (possibly due to agricultural runoff), the competent authority can act immediately to mitigate potential problems for the general population, thereby enhancing public health protection and sustainable resource management.

2. Materials and methods

The study area focuses on the Nestos River Basin, an ecologically significant region in northeastern Greece that extends into southern Bulgaria. The Nestos River (known as the Mesta in Bulgaria) originates in the Rila Mountains and flows 243 km south into the Aegean Sea, with 103 km of its length located in Greece. The total river basin area is 5,479 km², of which 2,000 km² (approximately 36%) lies within Greece. The basin is characterized by rich biodiversity and its delta forms a unique protected wetland ecosystem. The pilot implementation was conducted within the Municipality of Abdera, in the Region of Eastern Macedonia and Thrace, which has a population of 17,137 people. This municipality relies on 35 water wells for its drinking water supply, three of which are located within the Nestos River catchment area (Fytilis, 2014; Fytilis & Voudouris, 2019).

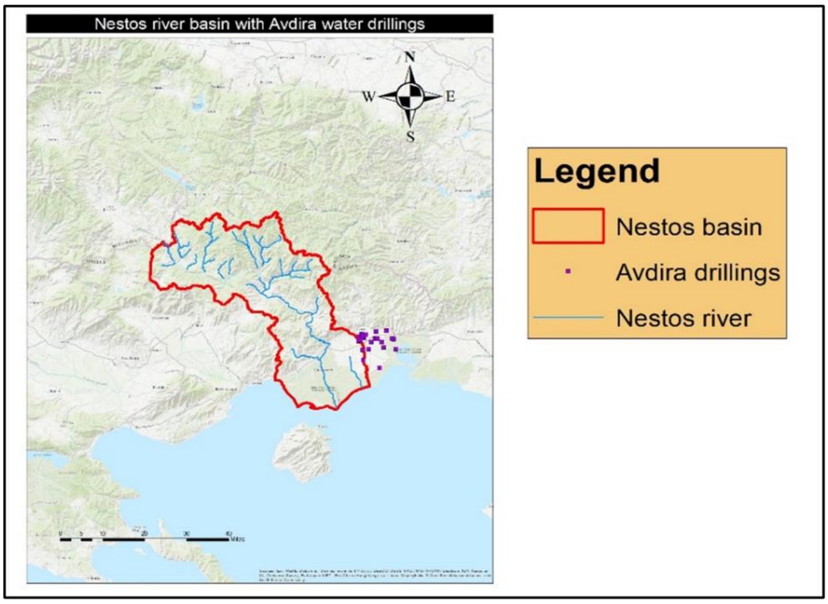

Figure 1: Nestos River Basin

For this case study, the ArcGIS 10.4 software was utilized to create an electronic database for recording water supply drillings, a recognized tool for water management applications. The methodological process involved several sequential steps. The process began by opening the ArcGIS program and loading the relevant shapefiles folder to open ArcMap. The shapefiles of the Nestos River basin were then uploaded using the "add data" button, followed by the addition of a base map for background context. The subsequent step involved uploading an Excel file provided by the Municipality of Abdera, which contained the data for the municipal water wells. This was achieved by using the "Add XY Data" function; the table named "Drill Abdera" was selected, with the X and Y fields designated for the respective coordinate data to geospatially plot the well locations onto the map. Upon completion of these steps, the electronic database was established and could be interrogated using the Identify command to access all available drilling data. This database integrates key chemical parameters—including pH, conductivity, dissolved oxygen, temperature, turbidity, and total organic carbon—provided by the Municipality of Abdera according to their standard monitoring protocols and measurements. The immediate availability of this data enables prompt intervention in the event of a parameter error, allowing stakeholders to avoid adverse consequences.

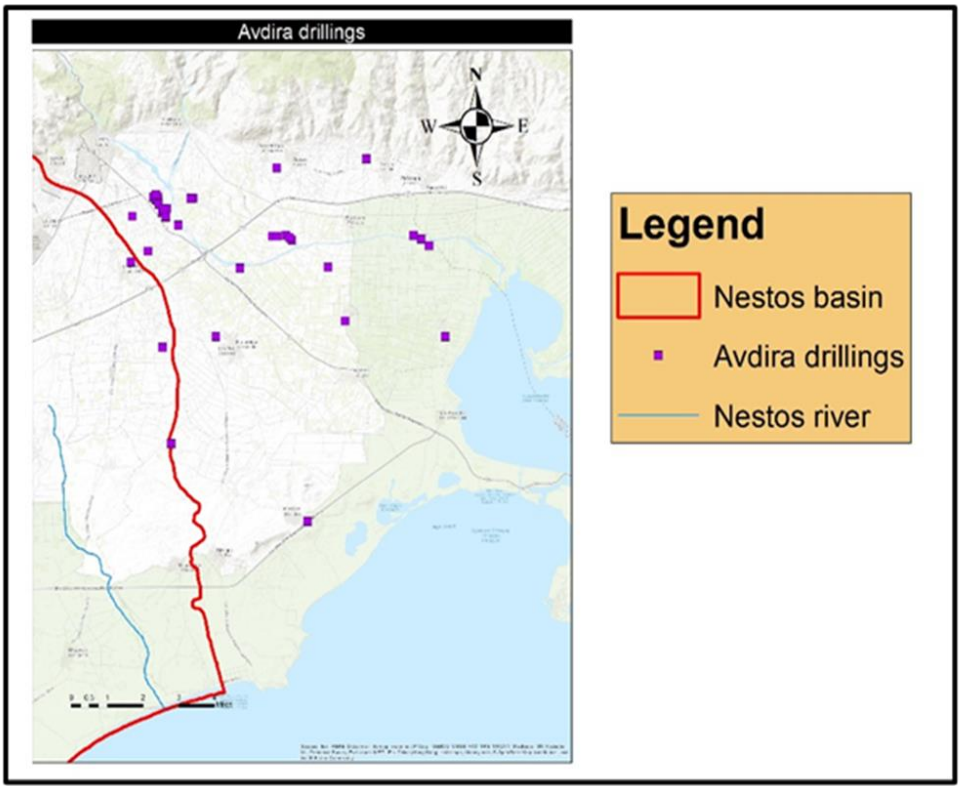

Figure 2: Drillings in Nestos River Basin

3. Results and discussion

The primary finding of this study is the successful development and implementation of a comprehensive Electronic Database (EDB) for water supply drillings in the Municipality of Abdera, within the Nestos River Basin, utilising ArcGIS 10.4 software. The database serves as a centralised repository, integrating both spatial data (the precise geographical coordinates of the 35 municipal water wells) and descriptive, attribute data comprising key water quality parameters. These parameters, which include pH, conductivity, dissolved oxygen, temperature, turbidity, and total organic carbon, were provided directly by the Municipality of Abdera based on their ongoing monitoring protocols.

The technical process of creating the EDB proved to be methodologically robust and efficient. By following a structured workflow—importing basin shapefiles, adding a base map for spatial context, and using the "Add XY Data" tool to plot the well locations from an Excel spreadsheet—the study successfully georeferenced all water points. The resulting interactive map allows for immediate visualisation and interrogation of the data. Using the 'Identify' command, stakeholders can instantly access the complete chemical profile of any selected drilling, fulfilling the core objective of creating a dynamic and accessible management tool.

The implementation of this EDB aligns directly with the requirements of the Water Framework Directive 2000/60/EC, particularly Article 6, which mandates Member States to create a register of protected areas, and Article 7, which requires the identification of all water bodies used for human consumption (Directive 2000/60/EC, 2000). This study demonstrates that GIS technology is an indispensable tool for achieving this regulatory compliance. By moving from paper-based or disparate digital records to a unified, spatially-referenced system, the EDB provides a "better record keeping" capability, one of the fundamental benefits of GIS as outlined by Burrough & McDonnell (2000).

The database significantly enhances "decision making" (Burrough, 1992; Fytilis & Palatos, 2022) by transforming raw data into actionable intelligence. For instance, the scenario described in the introduction—where a sudden increase in nitrates from agricultural runoff is detected—can be managed proactively. The EDB would allow authorities to immediately identify the affected drilling, its location, and the extent of the deviation, enabling swift corrective intervention to restore water quality and protect public health. This capability for real-time monitoring and response is a substantial improvement over traditional methods, mitigating potential adverse consequences before they escalate.

A critical strength of the implemented EDB is its adherence to international standards, notably the INSPIRE Directive, which supports "homogenization, usability, and reuse of the data" (Bartha & Kocsis, 2011; Mitchel, 2005). This standardisation is not merely a technical formality but a fundamental aspect of modern resource management that ensures data compatibility across different platforms and governmental bodies. The use of ESRI's GIS software offers significant advantages, including the ability to manage large data volumes, ensure interoperability, utilise data in web applications, maintain data security, and present information accurately across all scales (Boskidis et al., 2012). The system allows for efficient organisation of large quantities of data without repetition, provides greater accuracy in spatial calculations, and represents a cost-effective technology, making it accessible for municipal applications.

Furthermore, the architecture of the system allows for access from compatible applications on local computers and offers the potential for secure, confidential access via the internet using commercial or personalised software (Boskidis et al., 2012). This opens the door for future expansion into a web-based portal where multiple stakeholders could view relevant data in near real-time, significantly improving communication and coordinated management.

The findings of this pilot study have profound implications that extend beyond technical management into the realms of public health and environmental conservation. By ensuring continuous monitoring of water quality parameters, the EDB acts as an early warning system, directly contributing to the provision of safe drinking water and reducing the risk of waterborne diseases. This aligns with the WFD's ultimate goal of achieving "good" water status, which encompasses both human health and ecological integrity.

From an environmental perspective, the ability to track parameters like total organic carbon and turbidity aids in "pollution tracking" and "environmental impact assessments," which are established applications of GIS in water quality monitoring (as noted in the document). By promptly identifying and addressing pollution events, the EDB supports the "biodiversity conservation" goals of the WFD, helping to protect the rich biodiversity of the Nestos River Basin and its unique delta ecosystem. This approach facilitates "sustainable water management" by providing data-driven insights that help balance human water needs with the protection of aquatic habitats.

4. Conclusion

This study demonstrates the critical role of Geographic Information Systems (GIS) in modern water resources management, particularly in achieving compliance with the Water Framework Directive (2000/60/EC). The successful development of an Electronic Database (EDB) for the Municipality of Abdera's water supply drillings in the Nestos River Basin provides a powerful tool for proactive governance. The GIS-based system enables not only the centralised storage and spatial visualisation of key water quality parameters but also facilitates immediate intervention, thereby preventing public health risks and reducing potential maintenance costs associated with water well deterioration.

The implemented methodology offers a replicable framework for sustainable water management. To further enhance its capabilities, future work should focus on integrating telemetry systems with the water supply and irrigation networks. This advancement would enable genuine real-time data transmission, transforming the EDB into a dynamic decision-support system for watershed management. Such a system could significantly contribute to the national water management strategies devised by the Greek Ministry of Environment.

Moreover, the scalability of this approach allows for its adaptation to other regions with more complex datasets, promoting standardised water resource monitoring across different basins. In conclusion, the application of GIS in this context profoundly enhances data collection, monitoring efficiency, and informed decision-making processes. It represents a significant step toward fulfilling the objectives of the WFD, ultimately ensuring the sustainable management of water resources and the protection of aquatic ecosystems.

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References

Abd-el-Kader, M. M., El-Feky, A. M., Saber, M., AlHarbi, M. M., Alataway, A., & Alfaisal, F. M. (2023). Designating appropriate areas for flood mitigation and rainwater harvesting in arid region using a GIS-based multi-criteria decision analysis. *Water Resources Management, 37(*3), 1083-1108.

Bartha, G., & Kocsis, S. (2011). Standardization of geographic data: The european inspire directive. *European Journal of Geography, 2(*2), 79-89.

Boskidis, I., Gikas, G. D., Sylaios, G. K., & Tsihrintzis, V. A. (2012). Hydrologic and water quality modeling of lower Nestos River basin. *Water resources management, 26(*10), 3023-3051.

Burrough, P.A., 1992. *Principles of Geographical Information Systems for Land Resources assessment.* Clarendon Press. Oxford.

Burrough, P.A., McDonnell, A. (2000). *Principles of Geographical Information Systems*. Oxford University Press. New York. pp. 333

Clark, M. J. (1998). Putting water in its place: A perspective on GIS in hydrology and water management. *Hydrological Processes, 12(*6), 823-834.

Dimitriou, E., & Zacharias, I. (2010). Identifying microclimatic, hydrologic and land use impacts on a protected wetland area by using statistical models and GIS techniques. *Mathematical and Computer Modelling, 51(*3-4), 200-205.

Directive 2000/60/EC of the European parliament and of the council of 23 October 2000 establishing a framework for Community action in the field of water policy.of 23 October 2000 establishing a framework for Community action in the field of water policy.

Doorga, J. R., Magerl, L., Bunwaree, P., Zhao, J., Watkins, S., Staub, C. G., ... & Boojhawon, R. (2022). GIS-based multi-criteria modelling of flood risk susceptibility in Port Louis, Mauritius: Towards resilient flood management. *International Journal of Disaster Risk Reduction,* 67, 102683.

Fytilis, K. (2024). *Water management as an agricultural policy tool for crop restructuring/distribution*. Pilot application in a rural area of Pinios River basin (Master thesis). Aristotle University of Thessaloniki (AUTH). Faculty of Agriculture (in Greek). DOI:10.26262/heal.auth.ir.355927

Fytilis, K., & Palatos, E. (2022). Study of Ichthyofauna: Fishes in the Enipeas River's Catchment Area, Central Macedonia, Greece. *Journal of Sustainability and Environmental Management, 1(*2), 73-76. https://doi.org/10.3126/josem.v1i2.45335

Fytilis, K., & Semos, A. (2022). Crop management by linear programming. A literature review. *International Journal of Innovation Scientific Research and Review (IJISRR), 4(*2), 2364-2366. DOI: 10.6084/m9.figshare.20466030

Fytilis, K., & Voudouris, K. (2019). *Creation of an Electronic Database of water drillings using GIS software. Pilot application at the Nestos River basin*. The announcement in conference proceedings: 3rd Conference on Geographic Information Systems in Agriculture and the Environment (December 11 to 13, 2019). In Conference proceedings (pp. 114-115). DOI: 10.13140/RG.2.2.20257.68961

Fytilis, K., Kontogeorgos, A., Michailidis, A., & Semos, A. (2022). Crop structure optimisation for maximising yield within environmental constraints in a rural area. *International Journal of Sustainable Agricultural Management and Informatics, 8(*2), 200-217. DOI: 10.1504/IJSAMI.2022.10047564

Fytilis,K. (2022a). *Optimizing crop distribution under environmental constraints in the Spercheios River basin* (Doctoral dissertation), Aristotle University of Thessaloniki (AUTH). Faculty of Agriculture (in Greek). DOI: 10.12681/eadd/52534

Ghosh, P., & Kumpatla, S. P. (2022). *GIS applications in agriculture. In Geographic Information Systems and Applications in Coastal Studies*. IntechOpen.

Kamal, R. M., & Amin, M. S. M. (2010). GIS-based irrigation water management for precision farming of rice. International *Journal of Agricultural and Biological Engineering, 3(*3), 27-35.

Konstantinos, F. S. (2022). Linear Programming In Agriculture Using The Solver Tool Of Excel. *International Journal of Scientific and Technology Research, 11(*1), 73-76.

Kourgialas, N. N., & Karatzas, G. P. (2011). Flood management and a GIS modelling method to assess flood-hazard areas—a case study. *Hydrological Sciences Journal–Journal des Sciences Hydrologiques, 56(*2), 212-225.

Mitchel, A. (2005). *The ESRI Guide to GIS analysis, Volume 2*: Spartial measurements and statistics. ESRI Guide to GIS analysis.

Qi, H., & Altinakar, M. S. (2011). A GIS-based decision support system for integrated flood management under uncertainty with two dimensional numerical simulations. *Environmental Modelling & Software, 26(*6), 817-821.

Raihan, A. (2024). A systematic review of geographic information systems (GIS) in agriculture for evidence-based decision making and sustainability. *Global Sustainability Research, 3(*1), 1-24.

Tsihrintzis, V. A., Hamid, R., & Fuentes, H. R. (1996). Use of geographic information systems (GIS) in water resources: a review. *Water resources management,* 10, 251-277.

Wang, X., & Xie, H. (2018). A review on applications of remote sensing and geographic information systems (GIS) in water resources and flood risk management. *Water, 10(*5), 608.