ФУНДАМЕНТАЛЬНІ ЕКОЛОГІЧНІ ДОСЛІДЖЕННЯ

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FROM ENVIROMATICS TO SUSTAINABLE INFORMATICS: BEYOND THE DEFINITION AND CONCEPTUAL DELIMITATIONS

Environmental Informatics – as an integrated domain of interest– becomes the only real perspective of the scientific explanation of the environment, and the unique “way of thinking substantially different, so that mankind can survive.” Environmental Information Systems and Environmental Informatics play an important role in decision-making in the field, being closely linked with environmental requirements in decades and with environmental research methodologies, as part of the sustainable development management. The discussion on sustainability, as particular environmental research methodologies, aims to identify characteristic attributes that allowed passage of environmental data to environmental information and environmental knowledge; from Environmental Information System and Environmental Informatics to Sustainable Informatics, starts to interest more and more actors and activists focused on environmental protection – according to the definition spectrum found on internet exhaustive search.

To improve the management capabilities and environmental assessments, specialists should be able to manage and implement the concepts for the effective and efficient environment that can be achieved through information software environment. They should also have a simple and efficient access to knowledge and current information enabling them to take the best decisions both for sustainable development and for the development of economies.

The authors analyze few Romanian contributions in the domain of Sustainable Informatics, which try to incorporate with the main problems at the international level. The authors propose an integrative view on the subject under discussion as a dynamic open-access system, able to perform multiple functions, in particular, to meet the environmental protection goals and for users involved in specific environmental activities. Sustainable Informatics helps scientists define the information processing requirements, analyze real problems, and solve those problems using informatics.

Keywords: Environmental Information Systems (EISs), Environmental Informatics (EI), Sustainable Informatics (SI).

Problem statement. A lot has been written about environmental sciences and much more will be written in the future. In a certain sense, this kind of science is the one underlying everything that mankind has consciously accomplished. Today's civilization would probably have had another appearance without the considerable contribution of scientific work for more than 2,000 years. The scientific knowledge of our world has gradually developed through small steps. Over the course of time, there have been numerous scientific discoveries that have contributed to the cultural dowry and the progress of society (fig. 1) [2–5].

Most of the scientific elements are routine observations and records, contained in research reports, administrative and financial communications, each having its own importance within the intimate mechanism of the information act. The importance of a discovery (as can be considered Environmental Informatics) is weighed by its impact on the economic state of society or the benefit it brings to a large number of people (fig. 2a). It is the case of remote information transmission, modern transport, electricity, and much more, as "mature fruits" of purely scientific epochal discovery (fig. 2b) [4, 5].

An important benefit is, of course, the cultural one. Mankind raises the level of environmental understanding on the environment it belongs to, and, knowing it better, learns to value it more and improve its attitude towards it. The Knowledge Society, according to the multidisciplinary nature of Environmental Science (see fig. 3), cannot be sustained over time by the means at its disposal. This is

mainly because it is based on the exhaustible reserves of fossil fuels, where the progress of society necessarily imposes further reserves in the future. In addition, the human species risk self-destruction, just as a microbe is self-destructing after destroying the entire organism that has maintained it [4, 5].

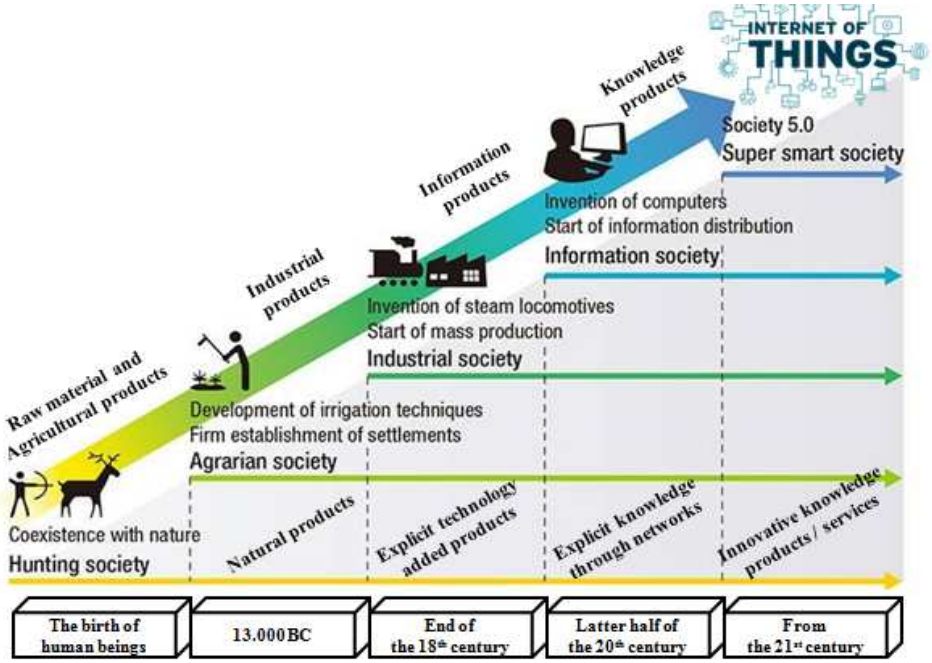
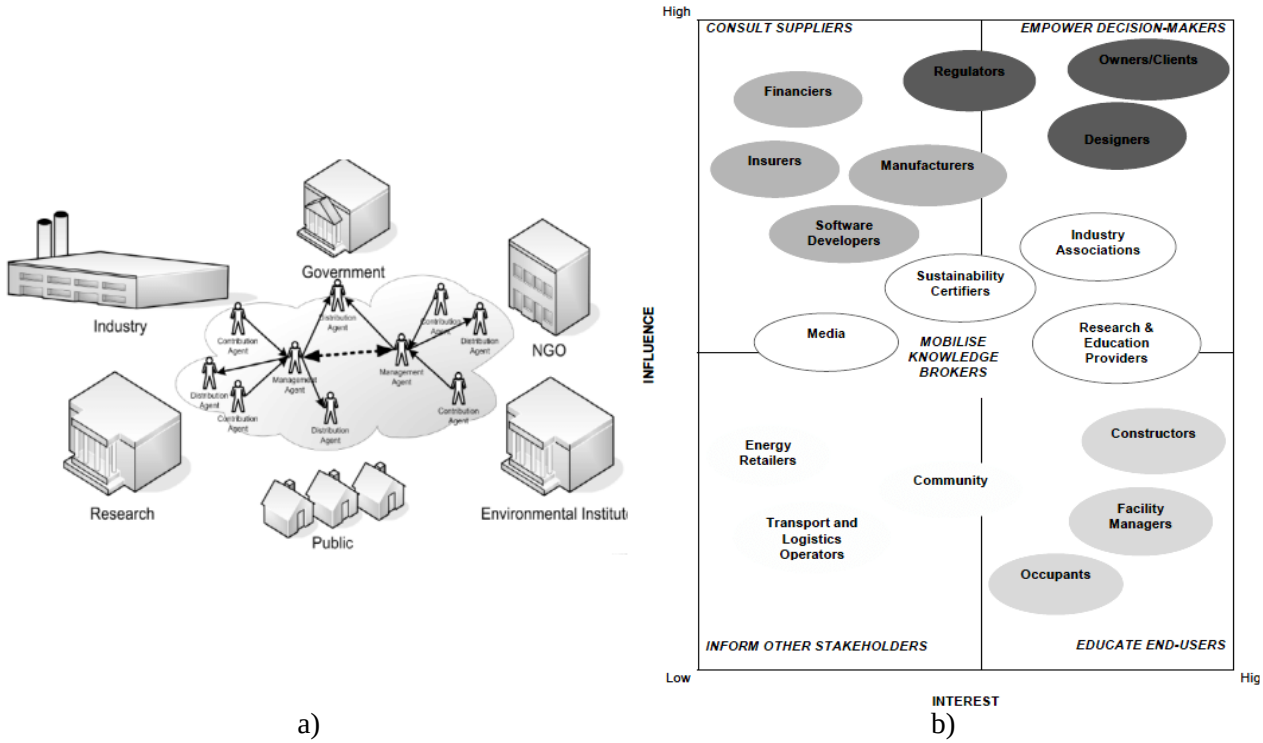


Fig. 1. Evolution of societies from the Hunting Society to Super Smart Society [9]



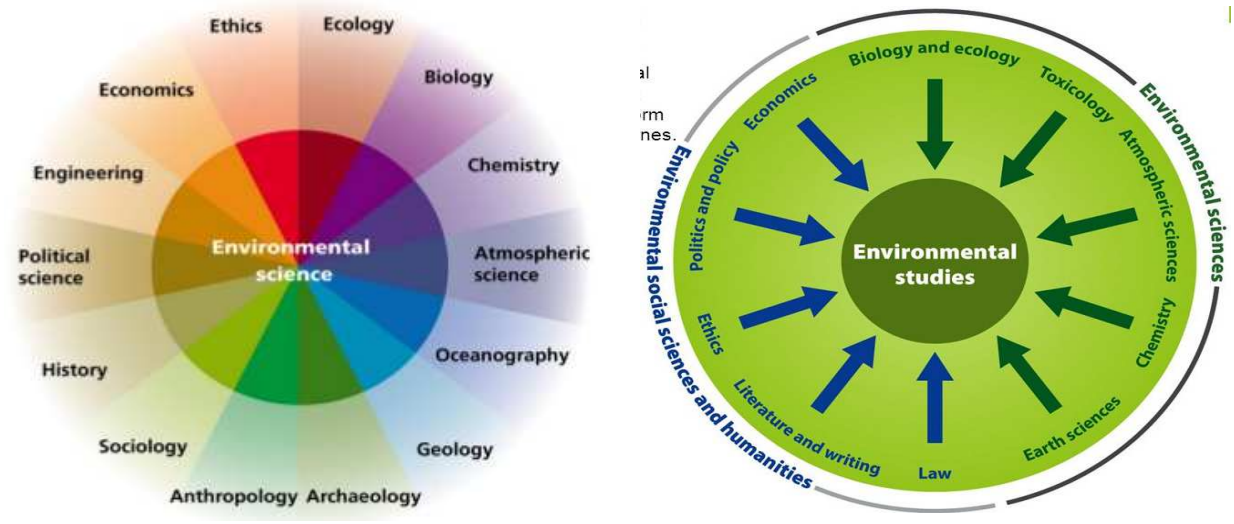
a) b)

Fig. 2. The main actors interested in Environmental Informatics [3, 6, 9, 40] **are:**
a) mixture of industry, government, research and the rest of community; b) influence-interest bridge

The reality approach, consisting of an infinity of elements in a particularly complex interconnection, by sectors and subsectors, as branches and sub-branches of reality, was the fruit of the first contact and the first perceptions of man about the environment. Subsequently, from the keen need of knowledge, the scientific branches were dismantled in ever more elementary pieces, the thin slices of reality being ever deeper [5].

But as many elements have become wholly unfathomable in one area or another of science, belonging to practically "frontier science", man has decided to start a more complex and appropriate

approach to reality simultaneously in two or more fields. For example: astrophysics, biochemistry, biophysics, biomathematics, biochemistry etc., and also for disciplines which are part of the environmental science area. So, Environmental Science is a field of interest that studies environmental systems. It is inherently interdisciplinary, drawing from fields such as chemistry, evolutionary biology, ecology, physics, mathematics, oceanography, geology, earth science, and more.



a) b)

Fig. 3. The multidisciplinary nature of Environmental Science (a) **and Environmental Studies** (b) [46, 54]

The obvious tendency toward an era of synthetic approach (global reality) at the expense of the analytical approach is, in the sense mentioned above, specific to Environmental Sciences. The latter address the environmental aspects of what is common to several domains (as presented in fig. 4) and not what is specific to them.

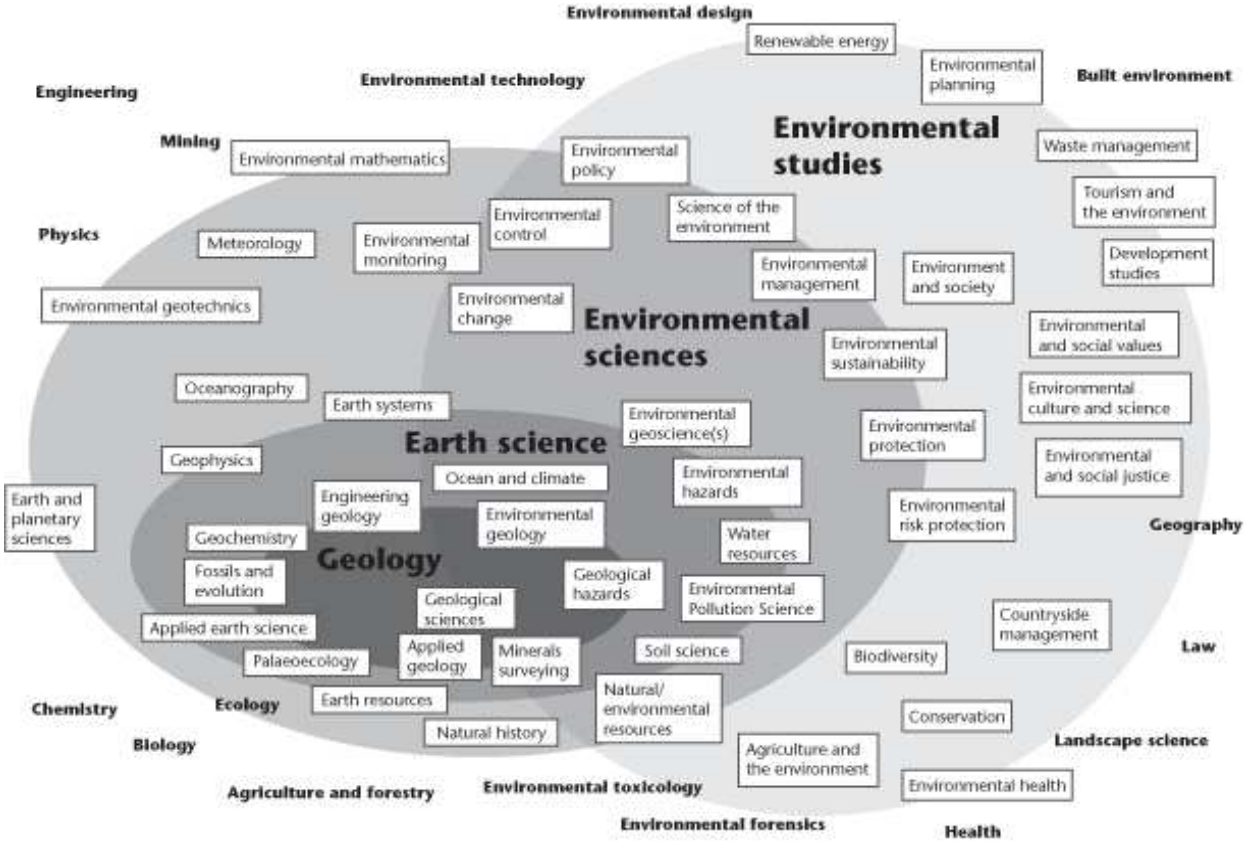
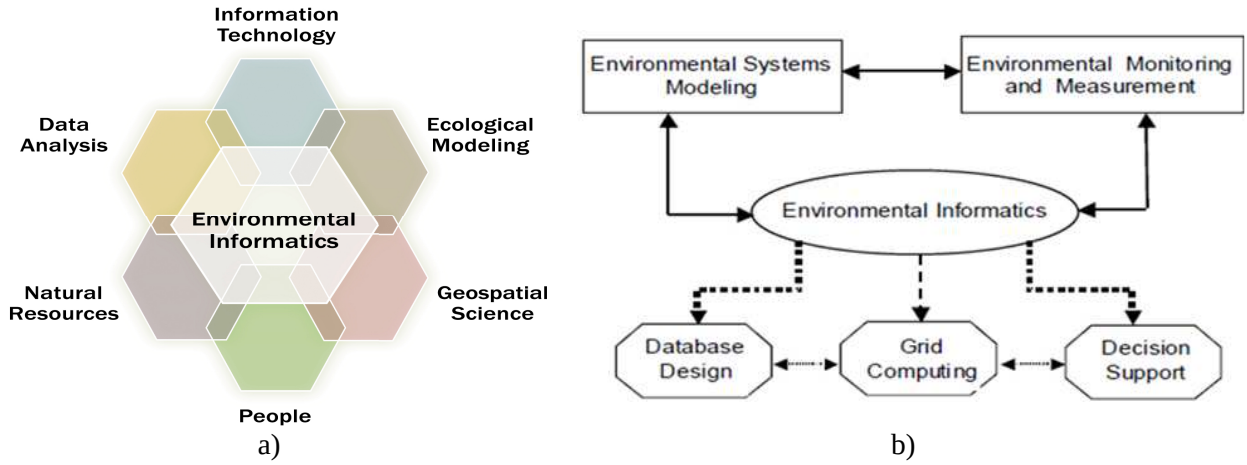


Fig. 4. Environmental Sciences as an intersection point of Earth science and Environmental studies [54]

Environmental Informatics – as an integrator domain of interest [1, 13] (fig. 5a and fig. 5b) – becomes the only real perspective of the scientific explanation of the environment, and the unique "way of thinking substantially different, so that mankind can survive."



a) b)

Fig. 5. Different perspectives for Environmental Informatics [40] **that:**
a) brings together science, technology and resources; b) integrates various environmental systems

As we know, EISs and EI are a new subdomain of Applied Informatics (design as in fig. 6); which comes with specific methods and tools for obtaining procedures that help to investigate, avoid and/or minimize burdens and environmental damage [1, 2–5, 13–15].

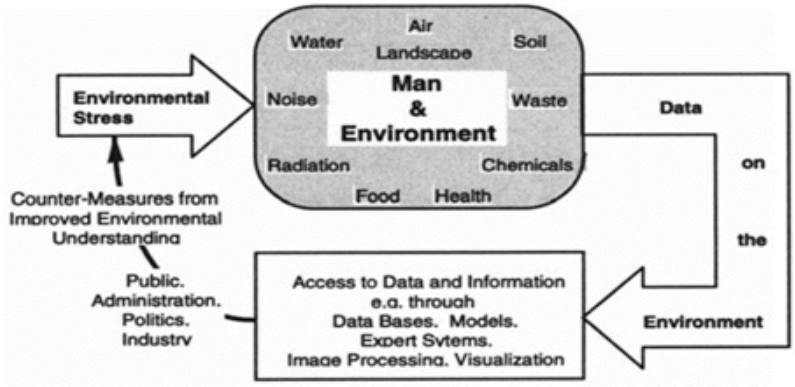
From EISs and Environmental Informatics to Sustainability Informatics: conceptual delimitations beyond the definition spectrum. Starting with the United Nations Conference on the Human Environment (also known as the Stockholm Conference), which set up the United Nations Environment Program (UNEP), it became increasingly evident that the collection and analysis of environmental data are of vital importance for humanity:

> "*Science and technology, as part of their contribution to economic and social development, must be applied to the identification, avoidance and control of environmental risks and the solution of environmental problems and for the common good of mankind.*
> *Education in environmental matters (...) is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension.*
> *Scientific research and development in the context of environmental problems (...) must be promoted in all countries, especially the developing countries. In this connection, the free flow of up-to-date scientific information and transfer of experience must be supported and assisted, to facilitate the solution of environmental problems; environmental technologies should be made available to developing countries on terms which would encourage their wide dissemination without constituting an economic burden on the developing countries."*
>
> (Principle 18-20 from Stockholm Declaration – www.unep.org)

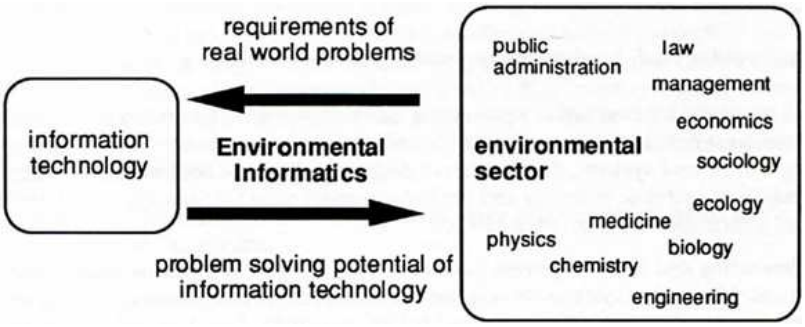
Recently, as a result of the spectacular development of IT and environmental sciences, a new science has emerged – generically named Environmental Informatics. It has taken on unimaginable impulses that have opened the way to unpredictable prospects, raising and bringing back to the present, on a higher plane and through a more comprehensive vision, environmental issues that need present day solutions [7, 8]. The enthusiasm of researchers and the dynamics of ecological manifestations have created a climate favorable to science-oriented research and applications, coagulated in fig. 7.

Classifications and definitions are objective requirements of any science, which must often be reviewed and periodically updated. Classification and definition of EISs and EI concepts have been made since the beginning of the environmental systems study, reflecting in general the level of integrated knowledge about the topic approached at one time and the aim pursued during the research, as presented in fig. 8.

In this respect, the first classifications were based on criteria regarding the structure and role of different categories of EISs or how the environmental information could be framed and supported by different environmental research sectors.



a)



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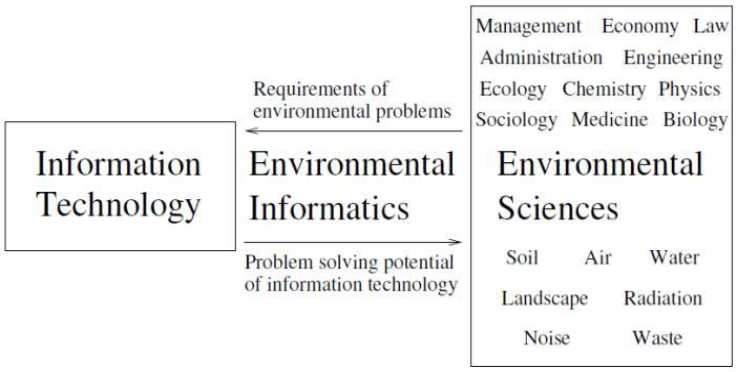

c)

Fig. 6. Different perspectives for Environmental Informatics [3, 4, 6, 9] **that brings together Information Technology and Environmental Sciences**

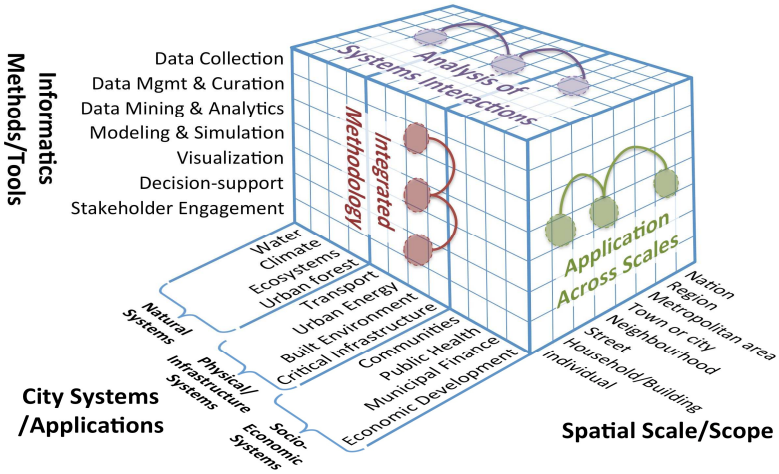

Fig. 7. From EISs and EI to Sustainable Informatics: methodology and specific applications [48]

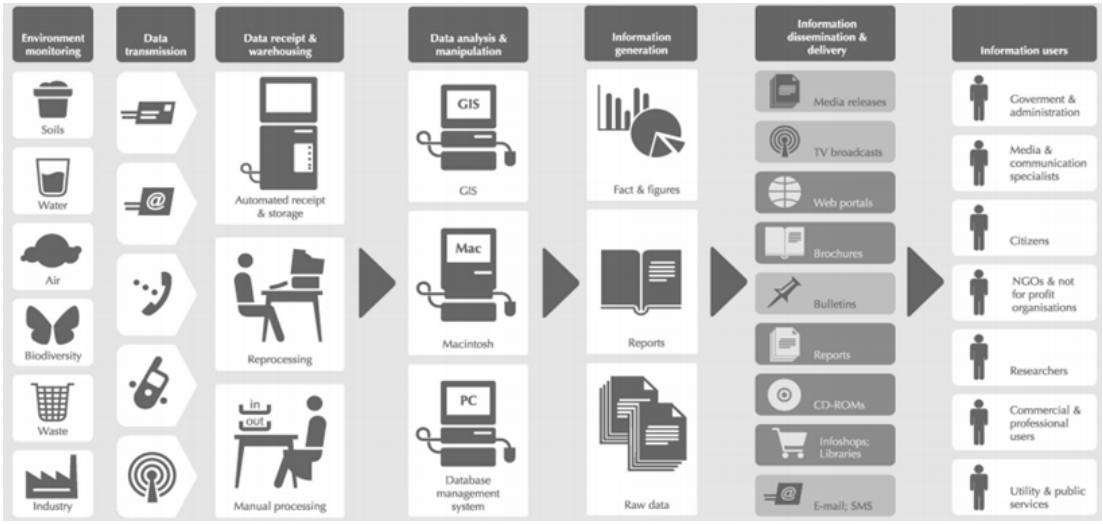

Fig. 8. Sustainable Informatics – example of integrated environmental computing systems [2, 3, 9]

Some of the cascading abbreviated definitions of the EISs are presented below, while also exposing their source, to complement the examination and the exhaustive exploration of the subject:

"EISs is the umbrella term for those systems used for: monitoring, data storage and access, disaster description and response, environmental impact reporting, state of the environment reporting, planning, simulation modelling and decision making; (...) are an important factor in environmental research, decision support, management and policy; EISs implementations have a number of requirements which are hard to satisfy, even with the information technology of today; the subject is still growing, in a multidisciplinary work environment which changes quickly, both in the IT and the environmental sector."

(International Symposium on Environmental Software Systems – www.isess.net)

"Environmental Information Systems are computer systems that use a variety of tools and technologies to facilitate the management and use of environmentally-related data and information."

(ESSA Technologies, Canada – essa.com)

"EISs are concerned with the management of soil, water, air and species in the world around us. This textbook describes a framework for systems based on four phases of data processing: data capture, aggregation, storage and analysis. The first part of the text concerns the collection of environmental raw data. The second part explains how this raw data is condensed and enriched to extract semantically meaningful entities. How aggregated data is then stored in a file or database is described in the third part of the text. In the final section the available information is prepared for decision support purposes."

(www.ucl.ac.uk/.../paper7.pdf)

It can be noticed, from the above definitions, that there is a complex spectrum of EISs that can be differentiated on the basis of the nature of the processed information [1, 4–6, 11–13]:

– control and monitoring systems – which interact closely with environmental processes and serve to perform automated and control measurements on water, air and soil quality, such as noise and exposure to radiation, while system control targets to directly involve at industrial level the supervision of working conditions and evolution of technological parameters;

– conventional information systems – which are of interest for introducing, storing, structuring, integrating, saving and presenting different types of environmental information in the form of formal, semi-formal and informal documents, such as environmental regulations and reference literature;

– information analysis and evaluation systems – supports the processing of environmental data collection using complex mathematical-statistical analysis methods and specific modeling techniques;

– decision support and planning support systems – directly supports decisions taken by 3rd parties by providing criteria for assessing alternatives or justifying the viability of decisions, including audit and eco-management schemes;

– integrated environmental computing systems – cannot be uniquely associated with a single class of simple systems, proving an affinity for multidisciplinarity, integrating an impressive variety of specific concepts and components; this category serves as distributed environmental computer systems.

EISs emerged roughly around the late 1980s in Central Europe. For example, in 1986 Germany's Gesellschaft für Informatik (Society for Computer Science) created the technical committee Informatik im Umweltschutz (Computer Science in Environmental Protection) dedicated to "the whole spectrum of subjects related to informatics in environmental protection" [41].

Since Informatik im Umweltschutz's inception, other groups, both there and in other regions of the world, were created, including The International Environmetrics Society (TIES, founded in 1989) [51] and the International Environmental Modelling and Software Society (iEMSs, founded in 2000) [53], as well as conferences like the International Symposium on Environmental Software Systems (ISESS, founded in 1995) [55]. Nowadays, EI is a developing field of science that applies information processing, management, and sharing strategies to the interdisciplinary field of environmental science. Applications include the integration of information and knowledge, the application of computational intelligence to environmental data and the identification of the environmental impacts [11, 13–15].

As a normal scientific process, several definitions have been offered for Environmental Informatics, especially by universities, as follows:

"(...) an emerging field centering around the development of standards and protocols, both technical and institutional, for sharing and integrating environmental data."

(University of California-Berkeley, USA – www.berkeley.edu)

"(...) a new and growing area in the modern environmental sciences; it is based on applying information technology to environmental issues. The size and complexity of environmental related data lead to a need for an advanced computational approach which helps to integrate information from various sources. With environmental informatics, new solutions to environmental problems can be found more effectively, and end users can be offered a higher level of information."

(University of Eastern Finland – www.uef.fi/.../envi/home)

"(...) a relatively young discipline, that uses environmental data to reveal, quantify and validate scientific hypotheses, with a panoply of tools from the Statistics, Mathematics, Computing, and Visualisation disciplines."

(University of Wollongong, Australia – niasra.uow.edu.au)

"(...) an integrator of science, methods and techniques and not just the creation of a new 'knowledge-paradigm' or the result of using information and software technology methods and tools for serving environmental engineering needs."

(Aristotle University of Thessaloniki, Greece – www.auth.gr)

"(...) an innovative use of IT to develop a framework for information sharing among research collaborations, and for information and knowledge access for all stakeholders for environmental and sustainable development tasks."

(University of Stanford, USA – web.stanford.edu/group/ei/index.html)

"(...) apply numerical and analytical techniques from mathematics and the geosciences to model and simulate environmental phenomena; (...) the use of mathematics and computer modeling to analyze and represent the Earth's environment; put simply, it can be considered to be the science and art of turning environmental data into information and understanding; (...) the use and understanding of quantitative and analytical techniques founded in mathematics and the geosciences to describe and predict the environmental phenomena on planet Earth that continue to challenge human society."

(University of Waterloo, Canada – uwaterloo.ca/.../earth-environmental-sciences.pdf)

"(...) with major topics such as modelling and simulation, data analysis, geographical information systems (GIS) and software development – applies computer science methods to environmental issues."

(University of Kassel, Germany – www.uni-kassel.de)

"(...) an integrated subject of bio-, eco- and geoinformatics in addition to computing."

(University of Göttingen, Germany – www.uni-goettingen.de)

"(...) a new interdisciplinary research field that can facilitate decisions regarding social, economic, ecological, and environmental goals based on a variety of IT measures."

(Technical University of Wien, Austria – ei.infosys.tuwien.ac.at)

"(...) the study of information and development of information processing tools for the understanding and sustainable management of human impacts on the environment, and for addressing environmental challenges with engineering."

(Technical University, Denmark – www.enviro5tech.org/.../env-informatics)

"(...) a mediating discipline that has developed over time in the context of changing technologies and environmental challenges."

(University of Zurich, Switzerland – www.zora.uzh.ch)

"(...) a part of Applied Informatics that supports methods and procedures of IT which contribute to environmental data analysis and environmental protection."

"(...) it is also a connection link between nature and engineering – applying data sampling and data analysis methods, statistics, simulation models and decision support systems on environmental problems and tasks one gets simulation results and prognoses to explain and to solve environmental problems. Methods of EI form a basis of decision making processes for environmental problems using state-of-the-art computer technology."

(Brandenburg University of Technology at Cottbus, Macedonia – www.tfb.edu.mk/.../EI2007.pdf)

"(...) studies how information can be acquired, processed, modelled and communicated for environmental sciences and management; it is also an important multidisciplinary research field covering several national research priorities."

(Griffith University, Australia – www.griffith.edu.au/.../environmental-informatics)

"(...) applies information science to the management of natural resources. It includes aspects of geographic information, mathematical and statistical modeling, remote sensing, database management, knowledge integration, and decision making."

(Virginia Polytechnic Institute and State University, USA – www.undergradcatalog.edu)

"(...) a broad range of collaborative research projects with academic, governmental, and nonprofit partners that integrate cutting-edge informatics tools with knowledge, theory, and data from ecology, climate science, and other environmental disciplines."

(Northern Arizona University, USA – nau.edu/informatics-computing-and-cyber-systems)

"(...) the knowledge, skills and tools which enable information to be collected, managed and disseminated to support research in environmental science and to promote sustainability."

(Dalhousie University, Canada – cdn.dal.ca/content/.../environmental-science-program)

"(...) the science of information in ecology and environmental science."

(Columbia University, USA – traitnet.ecoinformatics.org/ecoinformatics)

"(...) an interdisciplinary field of study that prepares industry leaders to develop and use analytical and computer-based methods to assess and protect the Earth's natural resources; students learn to apply these principles across fields as diverse as social sciences, policy analysis, and terrestrial and aquatic ecosystem management."

(University of Michigan, USA – seas.umich.edu/academics/ms/ei)

Following the same idea, other definitions have been offered, by different institutions and organizations with implications in environmental protection and environmental data management:

"(...) science and techniques of data elaboration and of computer processing of information concerning ecosystems and ecology."

(European Environment Information and Observation Network – www.eionet.europa.eu)

"(...) the application of research and system development focusing on the environmental sciences relating to the creation, collection, storage, processing, modelling, interpretation, display and dissemination of data and information."

(The UK Natural Environment Research Council – nerc.ukri.org)

"(...) an emerging discipline applying information science, ecology, and biodiversity to the understanding and solution of environmental problems."

(Korea Long-Term Ecological Reserch Network – www.klter.org)

"(...) a trans-disciplinary subject that integrates Ecology, Computational Science, Informatics and Social Sciences, in order to improve our understanding of ecological processes and expand socio-ecological theory to integrate the Earth's natural systems,human values, human health and well-being."

(Indian Institute of IT and Management – www.iiitmk.ac.in)

"(...) applies data systems and analytical tools to extract insights and understanding from large volumes of environmental data; (...) combines extensive environmental science experience with world-class data analytics to convert environmental data into usable information, reliable predictions and defensible decisions."

(Battelle NeuroLife™ Technology – www.battelle.org/.../environmental-informatics)

"(...) the process that transfers data and information from source to user in any field of knowledge of activity applicable to environmental problem solving; (...) the combination of software and environmental engineering methods and tools for the creation of a new "knowledge-paradigm" towards supporting environmental well-being at an international, national, regional, community or personal level."

(Siberian Center for Environmental Research and Training – www.scert.ru)

In addition to the above definitions, the defining attempts identified in various specialized publications also have an important role, as follows:

"(...) a field of applied computer science that develops and uses the techniques of information processing for environmental protection, research and engineering."

(Avouris N. & Page B., 1995)

"(...) the field that deals with the development, management and research on EISs."

(Haklay M., 1999)

"(...) may be viewed as a merging of biodiversity and ecological informatics with geographic information systems (GIS) and other environmental data."

(Lane M., Edwards J. & Nielsen E., 2000)

"(...) an emerging discipline defined as the design and application of computational techniques for ecological analysis, synthesis, forecasting and management."

(Recknagel F., 2003)

"(...) an interdisciplinary framework for the management, analysis and synthesis of ecological data by advanced computational technology."

(Recknagel F. 2009)

"(...) the application of data science that uses large multidimensional, complex datasets to study environmental problems, which can be discrete and continuous in space-time."

(Frew J. & Dozier J., 2012)

"(...) a new term in the science of information that describes the utilization of informatics in the interest of the natural environment (...) regarding sustainable development."

(Zacharoula S.A., 2012)

"(...) has the potential to be much broader than classical environmental statistics."

(Cressie N., 2014)

Conclusions. The specialists that work in the environmental protection or other connected domains need more and more information and knowledge at every level of environmental processes management and evaluation. At the same time, in order to elaborate and develop a project, they need to know and to understand the environmental phenomena and also the conditions. The analysis used must be based on the best available techniques, methods and data, and the knowledge get from self-experience or from another specialist.

Traditionally, this information and knowledge are obtained, in accordance with the temporary requirements, by directly accessing databases, reports and documents, by transferring/sharing information and knowledge with specialists or by the contacts established at the workshops, conferences and symposiums. To improve the management capabilities and environmental assessments, it is necessary for specialists to be able to manage and implement concepts for effective and efficient environment that can be achieved through information software environment. They must also have a simple and efficient access to knowledge and current information enabling them to take the best decisions for sustainable development for both developed economies.

The current approach starts from the few Romanian contributions in SI domain, trying to rally to the main concerns of the international level. We propose an integrative vision on the subject of discussion as a dynamic open-access system, able to perform multiple functions, particularly to meet the environmental protection goals of users involved in specific environmental activities. Sustainable Informatics (SI) helps scientists define information processing requirements, analyze real-world problems, and solve those problems using informatics.

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ВІД ЕКОЛОГІЧНОЇ ІНФОРМАТИКИ ДО СТАЛОГО РОЗВИТКУ: ЗА МЕЖАМИ ВИЗНАЧЕННЯ І КОНЦЕПТУАЛЬНИХ ОБМЕЖЕНЬ

Екологічна інформатика – як комплексна сфера інтересів – стає єдиною реальною перспективою наукового пояснення довкілля і унікальним «способом радикально іншого мислення, щоб людство могло вижити». Екологічні інформаційні системи та екологічна інформатика відіграють важливу роль у прийнятті рішень, оскільки вони тісно пов'язані з екологічними вимогами протягом десятиліть і з методологіями екологічних досліджень і є складовою управління сталим розвитком. Обговорення питання сталого розвитку і раціонального природокористування, як особливих методологій екологічних досліджень, спрямоване на виявлення характерних ознак, які дозволили перейти від екологічних даних до екологічної інформації та екологічних знань; від екологічної інформаційної системи та екологічної інформатики до інформатики сталого розвитку, яка починає цікавити все більше суб'єктів і активістів, орієнтованих на охорону навколишнього середовища – відповідно до спектру визначення, знайденого у процесі вичерпного пошуку в мережі Інтернет.

Для покращення можливостей управління та екологічних оцінок фахівці повинні мати змогу управляти та впроваджувати концепції для продуктивного і ефективного довкілля, що можна отримати за допомогою інформаційного програмного середовища. Вони також повинні мати простий і ефективний доступ до знань і поточної інформації, що дозволяє їм приймати кращі рішення як для сталого розвитку, так і для розвитку економіки.

У статті розглядається невелика кількість румунських внесків у сферу інформатики малого розвитку, які намагаються об'єднатися з основними проблемами міжнародного рівня. Ми пропонуємо інтегративне бачення на предмет обговорення як динамічної системи відкритого доступу, здатної виконувати кілька функцій, зокрема, для досягнення цілей охорони довкілля та для користувачів, залучених до конкретних екологічних заходів. Інформатика сталого розвитку допомагає вченим визначити вимоги до обробки інформації, аналізувати реальні проблеми та вирішувати ці проблеми за допомогою інформатики.

Ключові слова: екологічні інформаційні системи навколишнього середовища (EIC), екологічна інформатика (EI), інформатика сталого розвитку (ICP).

References

1 Avouris N., Page B., (1995) Environmental Informatics – Methodology and Applications of Environmental Information Processing. Dordrecht: Kluwer Academic Publishers.

2 Cioruţa A., Cioruţa B., (2016) Regarding the population dynamics investigation using Environmental Information Systems, International Conference "Scientific Research and Education in the Air Force" (AFASES®), 26–28 mai 2016, Braşov, pg. 411–416.

3 Cioruţa B., Cioruţa A., Coman M., (2012) Pledoarie pentru necesitatea formării unei culturi informaţionale environmentale, Journal of Environmental Research and Protection (Ecoterra®), Universitatea Babeş-Bolyai Cluj-Napoca, nr. 30, pg. 31–39.

4 Cioruţa B., Coman M., (2011) Evoluţia, definiţia şi rolul Sistemelor Informatice de Mediu în dezvoltarea strategiilor pentru protecţia mediului, Journal of Environmental Research and Protection (Ecoterra®), Universitatea Babeş-Bolyai Cluj-Napoca, nr. 27, pg. 11–14.

5 Cioruţa B., Coman M., (2011) Incursiune în cercetarea ştiinţifică modernă a mediului înconjurător. De la Sistemele Informatice de Mediu la Informatica Mediului, Journal of Environmental Research and Protection (Ecoterra®), Universitatea Babeş-Bolyai Cluj-Napoca, nr. 29, pg. 17–20.

6 Cioruța B., Coman M., (2012) Environmental Informatics – solutions and emerging challenges in environmental protection, Studia Universitatis Babeș-Bolyai AMBIENTUM, vol. 57, nr. 2, pg. 17–30, International Conference „Environmental Legislation, Safety Engineering and Disaster Management" (ELSEDIMA®), 25–27 octombrie 2012, Cluj-Napoca.

7 Cioruța B., Coman M., (2013) Studying Environmental Problematics and Hazards by Interactive Applications (SEPHIA), Studia Universitatis Babeș-Bolyai AMBIENTUM, vol. 58, nr. 1, pg. 39–46, International Conference „Environmental Legislation, Safety Engineering and Disaster Management" (ELSEDIMA®), 25–27 octombrie 2012, Cluj-Napoca.

8 Cioruța B., Coman M., Cioruța A., (2014) Studying Environmental Problematics and Hazards with help of Informatics Applications, International Conference "Scientific Research and Education in the Air Force" (AFASES®), 22–24 mai 2014, Braşov, pg. 289–292.

9 Cioruța B., Coman M., Cioruța A., Lauran A., (2018) From Human-Environment Interaction to Environmental Informatics (I): Theoretical and Practical Implications of Knowledge-based Computing, Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (Hidraulica®), 1 (2018):71–82.

10 Cioruța B., Coman M., Lauran A., (2018) From Human-Environment Interaction to Environmental Informatics (II): the sustainability evolution as requirement of Knowledge-based Society, Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics, 2 (2018):33–42.

11 Cioruţa B., Coman M., Mateşan V., (2013) Environmental Information Systems: solutions and emerging challenges for modern strategic development of Romanian local communities, International Conference "Scientific Research and Education in the Air Force" (AFASES®), 23–25 mai 2013, Braşov, pg. 372–375.

12 Coman M., Cioruţa B., (2013) Environmental Information Systems as a possible solution for strategic development of local and regional communities, Conferinţa Internaţională „Aerul şi Apa – componente ale mediului", 22–23 martie 2013, Cluj-Napoca, vol. 2013, pg. 516–523.

13 Günther, O. (1998) Environmental Information Systems. Berlin Heidelberg: Springer

14 Page, B., Voigt, K. (2003) Recent history and development of environmental information systems and databases in Germany. Online Information Review, 27 (1), 37–50.

15 Radermacher F., Riekert W., Page B., Hilty L., (1994) Trends in Environmental Information Processing. IFIP Transactions A: Computer Science and Technology (A-52) 1994, 597–604.

16 Aristotle University of Thessaloniki, Greece - www.auth.gr.

17 Battelle NeuroLife™ Technology - www.battelle.org/.../environmental-informatics

18 Brandenburg University of Technology at Cottbus, Macedonia - www.tfb.edu.mk/.../EI2007.pdf.

19 Columbia University, USA – traitnet.ecoinformatics.org/ecoinformatics.

20 Dalhousie University, Canada – cdn.dal.ca/content/.../science/environmental-science-program.

21 European Environment Information and Observation Network – www.eionet.europa.eu.

22 Griffith University, Australia – www.griffith.edu.au/.../environmental-informatics.

23 Indian Institute of Information Technology and Management – www.iiitmk.ac.in.

24 Korea Long-Term Ecological Reserch (KLTER®) Network – www.klter.org.

25 Northern Arizona University, USA – nau.edu/school-of-informatics-computing-and-cyber-systems.

26 Siberian Center for Environmental Research and Training – www.scert.ru.

27 Technical University of Wien, Austria – ei.infosys.tuwien.ac.at.

28 Technical University, Denmark – www.enviro5tech.org/.../env-informatics.

29 The UK Natural Environment Research Council – nerc.ukri.org.

30 University of California-Berkeley, USA – www.berkeley.edu.

31 University of Eastern Finland – www.uef.fi/.../envi/home.

32 University of Göttingen, Germany – www.uni-goettingen.de.

33 University of Kassel, Germany – www.uni-kassel.de.

34 University of Michigan, USA – seas.umich.edu/academics/ms/ei.

35 University of Stanford, USA – web.stanford.edu/group/ei/index.html.

36 University of Waterloo, Canada – uwaterloo.ca/.../earth-environmental-sciences.pdf.

37 University of Wollongong, Australia – niasra.uow.edu.au.

38 University of Zurich, Switzerland – www.zora.uzh.ch

39 Virginia Polytechnic Institute and State University, USA – www.undergradcatalog.registrar.vt.edu.

40 www.imagenesmy.com/find/environmental-informatics-imagenes-a7.html.

41 en.wikipedia.org/wiki/Gesellschaft_für_Informatik.

42 enviroinfo.eu.

43 github.com/CSIRO-enviro-informatics.

44 socratic.org/questions/what-is-environmental-science.

45 sustainabledevelopment.un.org/milestones/humanenvironment.

46 science.utep.edu/geology/index.php/esci-program.
47 vtnews.vt.edu/articles/2013/07/072413-cnre-environmentalinformatics.html.
48 web.cs.toronto.edu/research/areas/si.htm.
49 whatis.techtarget.com/definition/enviromatics-environmental-informatics.
50 www.biotecharticles.com/.../Environmental-Informatics-and-its-Applications-3381.html.
51 www.environmetrics.org.
52 www.frontiersin.org/.../sections/environmental-informatics.
53 www.iemss.org.
54 www.imagenesmy.com/imagenes/environmental-science-diagram-17.html.
55 www.isess.net.
56 www.limswiki.org/index.php/Environmental_informatics.

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