Chapter 1
Environmental Informatics: Basics, Nature, and Applications Using Emerging Technologies with Reference to Issues and Potentialities

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Abstract Environmental Informatics is one of the emerging interdisciplinary knowledge domains which is also considered as a practicing field. This is the merger of domain Environmental Science with Information Science. Environmental Informatics is dedicated in information technology and computing applications in wide areas of Environment, Ecology, and Biodiversity Management. The role of Information Technology is emerging day by day and its results enhancement in Environment indirectly worthy for some of the other subjects such as Geology, Geography, Climatology, Oceanography, Agriculture, Forestry. According to the experts, the stakeholders of Environmental Informatics are IT, computing, and similar technologies from the technology side dedicated in effective environmental systems organization, management, and development. Environmental Informatics is associated with the management aspects and thus also worthy in environmental management. This chapter is conceptual in nature with the basics, features, and nature of the Environmental Informatics with the role in sustainable development practice. This chapter also illustrated the technologies involved for real practice with potential academic degrees and programs in this field.

Keywords Environmental Informatics · Computing · Environmental Information Science · Disaster management · Ecological development

1.1 Introduction

There are many subjects which are closely associated with the environmental-related subjects, like environment science, environment studies, environment engineering, environment management, etc., and therefore Environmental Informatics applicable on all these subjects using various Information Technology components like Software Technology, Web Technology, Database Technology, Networking Technology, and so on [1, 8]. IT is useful in several environment, ecological issues, and concerns and

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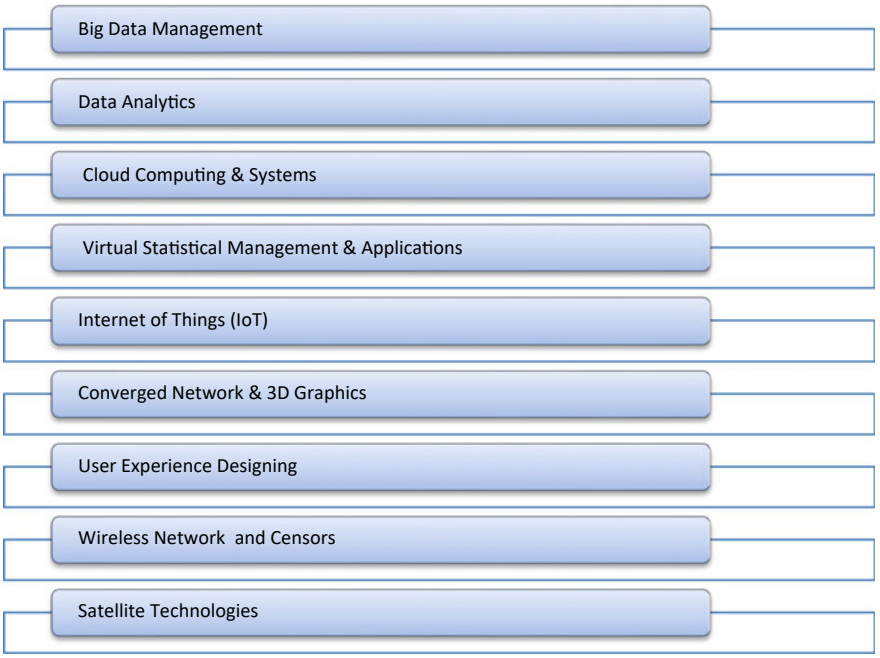

Fig. 1.1 Emerging IT components in Environmental Informatics required in environmental systems

right solution for solving the environmental aspects. Environmental Informatics in emerging scenario uses the sub-technologies like data analytics, cloud and virtualization computing, IoT systems, converged systems and network, usability systems and engineering, etc. [3, 20]. However, details of some other technologies are mentioned in Fig. 1.1.

Environmental Informatics in other words is also known as Environmental Information Science dedicated in ensuring eco-friendly information systems using state-of-the-art technologies. The society and community are modernizing and developing, at the same time, it is destroying the natural environment systems, and here use of Environmental Informatics-based systems would be suitable for improving the environment [7, 8, 28]. Several issues, challenges, and concerns of IT in environmental applications are emerging.

1.2 Objective

The chapter entitled 'Environmental Informatics: Basics, Nature and Applications using Emerging Technologies with reference to Issues and Potentialities' is conceptual and theoretical in nature and associated with deals with the following.

- To have an idea and concept of the subject Environmental Informatics including its evolution.
- To know about the characteristics, features, and nature (including components) of the Environmental Informatics.
- To get a picture of potential uses of the Environmental Informatics role and importance in developing environmental systems and development.
- To find out the core tools and technologies including environmental-related emerging technologies needed in environmental system management.
- To learn about the educational programs, potential programs in the areas Environmental Informatics and allied areas.

1.3 Methods

This chapter is theoretical in nature and conceptual too. The chapter is a review and having nature of environmental-related aspects lies on secondary and primary sources. To gather various attributes of Environmental Informatics like features and functions review of literature plays a leading role. Further, websites and web portals on environment and ecology are analyzed and mapped to get the current applications of IT in the environment and ecologies. In addition to this, various academic departmental websites reviewed and analyzed are associated with the Environmental Informatics education, training, and programs.

1.4 Environmental Informatics: Features, Role, and Stakeholders

The two main areas of Environmental Informatics are 'Environment' and 'Informatics'. Though *environment* does not mean it is only with the environmental science, it is also with other related areas such as environmental studies, ecology, agriculture, horticulture, and disaster management. *Informatics* includes the areas of IT, computing, as well as other similar technologies. The term Informatics was initially considered as practicing field, but gradually it has become a field of study and research [5, 30, 31]. Furthermore internationally in many universities, research centers Informatics as a branch widely started and practiced. The technologies of computing, technologies, and informatics are considered as worthy and increasing in almost all the sector due to its role in almost all the sectors. Environmental management today, in many ways supported by the sustainable computing, may sometimes also called as Environmental Informatics. Due to the interdisciplinary nature of the Environmental Informatics, the following features and characteristics may be considered as important.

- Applications and utilizations of the information technology and computing in environmental systems such as management and monitoring are possible with Environmental Informatics [2, 11].
- Environmental Informatics is supported by the environmental principles useful in information technology practice and development.
- The merging or integration of 'environment' and 'information technology'.

Environmental Informatics is purely interdisciplinary in nature and dedicated in modernizing environment and ecological information systems. It is required for various environment, disaster management, ecology, and waste management-related aspects.

- In the planning of energy, environmental systems tools and technologies supported by the IT and computing are considered as worthy. Environmental information technology therefore started in academics and in 'practice'.
- Regarding the simulation, optimization of environmental systems and monitoring Environmental Informatics is required [12, 22].
- In several areas and sectors, the increasing applications of GIS, remote sensing, and spatial IT are worthy and rising rapidly, and such technologies are part of Environmental Informatics.
- In the practice of environmental chemistry, biochemistry and allied activities also Environmental Informatics are valuable.
- As far as environmental management and monitoring are concerned, IT and computing systems are useful.
- In many environmental-related aspects, viz. atomic, molecular, and macromolecular scales, Environmental Informatics practice is emerging and urgent.
- In designing, developing, and modeling of biological environment-related processes, Environmental Informatics-based tools are highly required and supported.
- In the websites related to the environment and ecology role of Environmental Informatics practice is considered important in order to develop healthy Environmental Information Systems.
- In the modeling of biotechnological systems including pollution mitigation too, practice of Environmental Informatics is considered as worthy.
- In the managerial activities such as environmental statistics and environmental risk analysis including climate modeling and downscaling, the field Environmental Informatics is worthy [29].
- Regarding the impact and assessment of the adaptation planning, biological and disaster management systems promotion and development of Environmental Informatics can be considered as worthy and applicable [6, 13].

The applications of the animation and graphics include various visualization tools required in environmental decision support systems development; in this context, various emerging technologies may be considered as cloud computing, artificial intelligence, machine learning, deep learning, and so on are impacting. Initially,

Environmental Informatics nomenclature did not exist, but gradually due to its practice, it has become a field of study as well as research. Before the improvement of the Environmental Informatics, some of the domain-centric informatics include health informatics, geo-informatics, bio-informatics, medical informatics, and so on [9, 15]. Internationally in many universities and higher educational institutions educational, research and training programs have started in Environmental Informatics and allied areas. Many of them are offered as major degrees as Bachelors, Masters, and PhDs in Environmental Informatics and allied areas. There are some other nomenclatures too which are being used in different contexts such as

- Ecological informatics.
- Environmental computing.
- Ecological information science.
- Environmental information systems.
- Environmental information technology [8, 18, 24].

Environmental Informatics today has been evolved as an emerging interdisciplinary subject which comprises various environment and ecology-related subjects and also IT and computational sciences [19, 27]. Based on the analysis of the nature of Environmental Informatics, it may be considered as **stakeholders** comprising environment, content, and information, technologies, and people (i.e., User and HR). ***Environment*** is obviously an important component of environmental systems; as most of the living and non-living facets of the nature are part of environment. Owing the importance of ecology and environment, the field *Environmental Informatics* is treated as important for the real-time solutions. Because environment is a broad and interdisciplinary science, it has applications in diverse areas and allied area management like agriculture, forest management, oceanography, etc. Environmental Informatics dedicated in animals, forests, etc., [24, 25] and therefore in all the ecological and environmental-related aspects too is worthy and required. Environmental Informatics is indirectly applicable in various areas like

- Climatology sciences
- Oceanography systems
- Geological systems
- Geography and allied areas
- Agricultural systems
- Forestry, disaster management, etc.

All these stakeholders not only help in Environmental Informatics but also in allied areas, viz. agricultural informatics, forestry informatics, irrigation informatics, etc.

Content is treated as important stakeholder in Environmental Informatics subject and practice due to the role of information in developing environmental information systems and some other allied activities such as ecological information repositories, ecological and environmental database, and disaster environmental modeling [10, 14]. Environmental Informatics is purely based on content and similar contents [23,

26]. ***Technologies*** are another stakeholder in healthy Environmental Informatics practice, and it has uses in various basic information technology components, viz.

- Web technology.
- Networking technology.
- Database technology.
- Software technology.
- Multimedia technology, etc. [16, 17, 32].

In sophisticated Information Technology practice in environment and ecological systems, various subfields and parts of IT are important. Some of the subfields and emerging technologies are already mentioned in this work (Refer Fig. 1.2).

Users are obviously considered as important stakeholder in all type of informatics and engineering systems or computational systems. As far as Environmental Informatics is concerned, the users are importantly distributed in different areas, and apart from the basic users, the Human Resources are also considered as worthy in Environmental Informatics practice. Various types of Human Resources and skilled manpower are considered as crucial in such development.

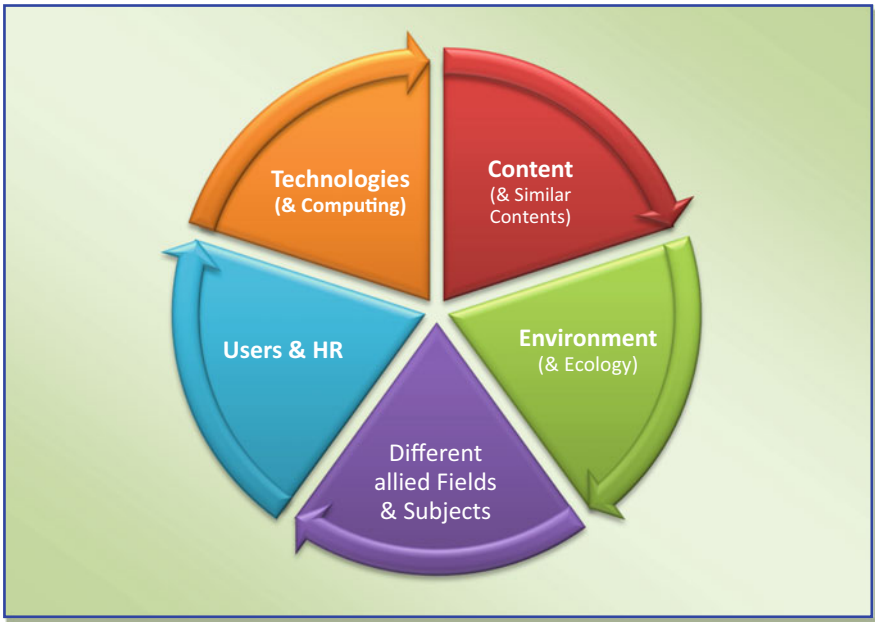

Fig. 1.2 Major stakeholders of developing Environmental Informatics

1.5 Issues and Challenges Concerning with the Environmental Informatics Practice

Environmental information science or Environmental Informatics practice is emerging rapidly throughout the world, particularly in developed countries. Though the analysis of current uses and concern of Environmental Informatics leads to various issues and challenges in the developing countries, some of them are as follows:

Technological Implementation—It is essential that proper, sufficient, and adequate technological implementation should be provided in order to avail proper benefits from the Environmental Informatics [17, 30].

Proper Awareness—The awareness of Environmental Informatics and its practice is need to care of urgently, including training and educational programs. Professionals and government personnel should take proper steps in environment and ecological systems development and monitoring [4].

Financing and Funding—Proper funding is important in developing Environmental Informatics practice. Financial arrangement is essential in order to take purchasing technology including implementation and development of the systems. Various environmental organizations, ministries, and departmental funding opportunities should be provided.

Management and Governance—Managing different technologies is an important issue in regard to environmental-related technologies. Here proper management and governance steps are essential to follow up.

Manpower and HR Development—It is a fact that there are many organizations, institutes, and higher educational institutions offering educational and training programs in this field and related areas; but there is a shortage of skilled manpower in designing and developing Environmental Informatics.

Interdisciplinary and Broad Cluster—Environmental Informatics is purely interdisciplinary and getting more broader day by day. Its requirement increasing gradually in all the areas of environment, agriculture, forestry, ecology, and other technological areas; therefore, the skill and knowledge development is a big and emerging concern [33].

1.6 Emerging Technologies, Environmental Informatics, and Environmental Management

Latest and emerging technologies of IT and computing dedicated in various activities and affairs of environment and ecological systems and among them important are big data management, cloud computing, robotics and artificial intelligence, Internet of things (IoT), usability engineering, and HCI, etc.

1.6.1 Big Data

Big data is an emerging component of information technology which is required in managing large number and complex data. The big data and analytics applications in the environment lead to several management problems such as global warming, climate change, satellite earth observation, and numerous data collection and its management. In forestry and forest management, in deforestation by counting trees too Environmental Informatics is applicable, in the creation of sustainable smart cities, in urbanization, in GPS sensors management too Environmental Informatics is important and required. Big data is useful in managing large amount of data management and therefore in pollution control in the cities, traffic flows, etc., and in all these allied areas, big data and analytics are effectively useful. As far as renewal energy management is concerned, big data and analytics tools are useful. In other power management-related aspects such as in wind and power management, big data is effectively useful by collecting the data and their proper analysis. Regarding hydroelectric power, in smart meters also big data analytics is being used. As far as geographic data management is concerned such as space, geospatial data management, cartographic naval navigation, regarding disaster, and emergency management also data analytics are useful and important. Satellite data is collected using GPS, remote sensing, and GIS; and in this context, big data management is worthy and important.

1.6.2 Cloud Computing

Cloud computing is the way and the platform of virtualization of different information technology systems. It helps in remote access of IT support from different place, and in this regard, it helps in environment-related aspects. The big data helps in generating and managing the data, and the same data is stored by cloud computing models and other cloud supported systems. In ecological monitoring, disaster management, forest management, wildlife management, and some other areas applications and utilizations of cloud computing are being used.

1.6.3 Robotics and Artificial Intelligence

Robotics and artificial intelligence are another two related aspects and sub-technology in the field of information technology and having impact in environment, ecology, and disaster management systems. Artificial intelligence is responsible in developing intelligent systems including the products and services. Therefore, it is required in the purpose of modeling and governance of environmental systems with intelligent mechanism. In identification of the tropical cyclone, weather forecasting

also artificial intelligence and robotics are considered as worthy and important. In the natural disaster management, trees and forests are basically affected, and with the artificial intelligence and robotics supported systems, it is possible to identify the affected trees and forests. As far as intelligent environmental power management system is concerned, it is empowered with the robotics and artificial intelligence.

1.6.4 Internet of Things (IoT)

Internet of things (IoT) is the latest emerging technology in IT and computing and dedicated in the collecting data using Internet. Internet of things is helpful in managing different kind of modern services and products associated with the Internet. IoT sensors are dedicated in collecting data from different nodes and points and which are being used in environmental and ecological concerns. The sensors are dedicated in collecting the data and ultimately help in environmental decision making, ecological monitoring, forest management, agricultural management, and so on [5, 31].

In addition, the abovementioned emerging technologies in the environmental practice lead to the development of some other activities as mentioned (in Fig. 1.3) [9, 21, 26].

1.7 Educational Programs and Potentialities in Promoting Environmental Informatics

In addition to these, some of the universities have started offering joint or integrated or dual degree programs such as University of North Carolina at Chapel Hill, US offers BS-Environmental Science and MS-Information Science Dual Degree, and this is offered by College of Environment, Ecology and Energy with School of Information and Library Science. However, BSc Environmental Informatics and Business Information Systems (Dual Degree) is offered by The University of Applied Sciences, Germany.

Environmental Informatics has started popularity in some of the universities, and therefore, it has started as major program at Bachelor's Degree in some of the universities such as at Auburn University, Alabama, USA, Wuhan University, China, Northern Arizona University, USA, Virginia Polytechnic Institute and State University, USA, etc.

There are potentiality to offer the program of Environmental Informatics with some other allied nomenclature such as ecological informatics, disaster informatics, and natural and eco-informatics. The program can be offered in other allied branches as specialization such as computing, information technology, information science as proposed in Table 1.1.

Fig. 1.3 Different emerging technological applications in ecological informatics (top) and few tools live examples (below)

Table 1.1 Potential Environmental Informatics major in IT and computing-related programs

Environmental Informatics potentiality as a major of IT and computing-related subjects
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Information Technology (Environmental Informatics)
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Computing (Eco and Disaster Informatics)
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Computing (Ecological and Forest Informatics)

Table 1.2 Potential Environmental Informatics major in biological-related programs

Environmental Informatics potentiality as a major in biological and related subjects
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Biological Science (Environmental Informatics)
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Forest and Disaster Management (Environmental Informatics)
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Botany (Eco and Disaster Informatics)
Bachelor of Science/Master of Science (BS/MS/BSc/MSc) Environmental Science (Ecological and Forest Informatics)

Similar to IT and computing program Environmental Informatics can be offered in biological sciences as a major or specialization, as depicted in Table 1.2.

However, Environmental Informatics or allied programs may be offered at Master of Computer Application (MCA) or Bachelor of Computer Application (BCA) degrees as a specializations. The allied areas and nomenclature of Environmental Informatics may be offered such as agricultural informatics, ecological informatics, forest informatics, and disaster informatics. Furthermore, the branch Environmental Informatics may be offered as by research mode. And in this context, degrees may be all what proposed and depicted in Tables 1.1 and 1.2 may be offered like MS (by research) in information technology (Environmental Informatics), etc.

1.8 Conclusion

Environmental Informatics is scientifically and academically developed in the atmosphere of information technology for different ecological and environmental purposes including modeling, simulation, designing, development, and data analysis of environmental systems. In addition to the basic technologies such as geographical information systems (GIS), remote sensing, and GPS, various spatial technologies are being used in this context. The technological development in Environmental Informatics is noticeable and changing day by day. Government ministries, bodies and departments, scientific houses, and environmental organizations are engaged in

diverse applications in Environmental Informatics and allied technologies. Different higher educational institutions and universities already started educational programs in developing proper manpower in this field. Though there is an urgent need of preparing skilled manpower, and thus short-term programs, certifications in the areas are highly important for complete sustainable development. Policymakers and the government bodies required proper steps in developing proper and effective Environmental Informatics practice. Robust benefits and complete solutions toward environment become possible from the field and for its final completion and further development.

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