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Environmental Informatics

Challenges and Solutions

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Preface

Environment is the aspect for everyone and important part of the society. Environmental Informatics is simply the utilizations and applications of Information Technology in Environment and Ecological Management. Environment is the major concerns not only for the individual but also for the organizations, institutions, and enterprises. Advanced tools and technologies are considered important in different environmental activities including environmental pollution. Today we all are getting benefits and support of the emerging technologies, and in this context, ICT applications in environment and ecology are considered as worthy. Technologists and scientists are engaged in healthy design and development along with implementation of environmental-friendly system for sustainable society. Environmental Informatics is a subfield of informatics which is dedicated in manual and computational environmental information systems. Informatics is board and interdisciplinary in nature and may be concentrated in different domain-based and functional areas. Domain-based Informatics may be restricted in the areas of biological science, social science, and pure science. Energy consumption is an important concern of Environment Informatics; therefore, energy informatics or environmental computing is also considered as similar area. Furthermore, Environmental Informatics may also known as

- Environmental information management
- Environmental information systems
- Sustainable computing
- Energy informatics.

In many countries, Environmental Informatics becomes a subject of study, research, and training and known as environmental information science. The latest applications of the computing, technologies, IT, and informatics principles in environmental aspects enriching Environmental Informatics for the support of environmental management, environmental systems and engineering, sustainable computing practice, etc. Environmental Informatics as a branch Informatics evolved first, and gradually, it is also known as environmental information technology and environmental information systems. Ecological informatics, forest informatics, irrigation informatics, geo-informatics, biodiversity informatics, etc., are also considered as

valuable in healthy Environmental Informatics practice. Different sub-technologies of IT, viz. artificial intelligence, cloud computing, big data, Internet of things (IoT), edge and fog computing, robotics, and ML. Even some of the emerging information systems areas are also important in sophisticated environmental systems management. The effective and smarter ecological systems are worthy in advanced sustainable ecological practices using ICT. Speed, better monitoring, and management are considered as vital in promotion of the ICT in ecology and environmental practices. Governmental agencies, organizations, and scientific foundations are highly engaged in incorporation of environmental technological practices in recent past. This book is a comprehensive overview in environmental information science; therefore, it deals with the foundation topics, including basic and latest technologies applicable in environment and ecological systems. This research-based book, therefore, can be suitable for the readers interested in gathering knowledge of the following.

- Environmental Informatics with basics including applications using emerging technologies
- Role of ICCT underlying technologies in environmental and ecological management
- Green computing for business
- Green information centres and allied foundations
- Social and economic impact of artificial intelligence-based environmental
- E-waste in AI and digital healthcare context
- Smart energy conservation in irrigation management
- Artificial intelligence in agricultural system
- Advances and applications of bioremediation
- Internet of things (IoT) and drone applications in environmental systems
- Li-Fi-based energy-efficient traffic sensing and controlling system management
- Geospatial technologies and systems in water systems
- Automated geoprocessing model.

In summary, Environmental Informatics consists various technologies, tools, users, consumers, or data centre professionals. In better Environmental Informatics practice, some of the concerns may be important like cost effectiveness, energy and star rating, less power consumption and releases less carbon emission, less toxic material, and other harmful chemical, etc. Green informatics can also be suitable in general or manual documentation practice to current technology-based information systems management everywhere. Green information systems may be implemented. Environmental Informatics as a whole partially supported to the geo-informatics, forest management, and agriculture informatics to the enhanced, smarter, and sustainable ecological systems.

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Contents

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

P. K. Paul

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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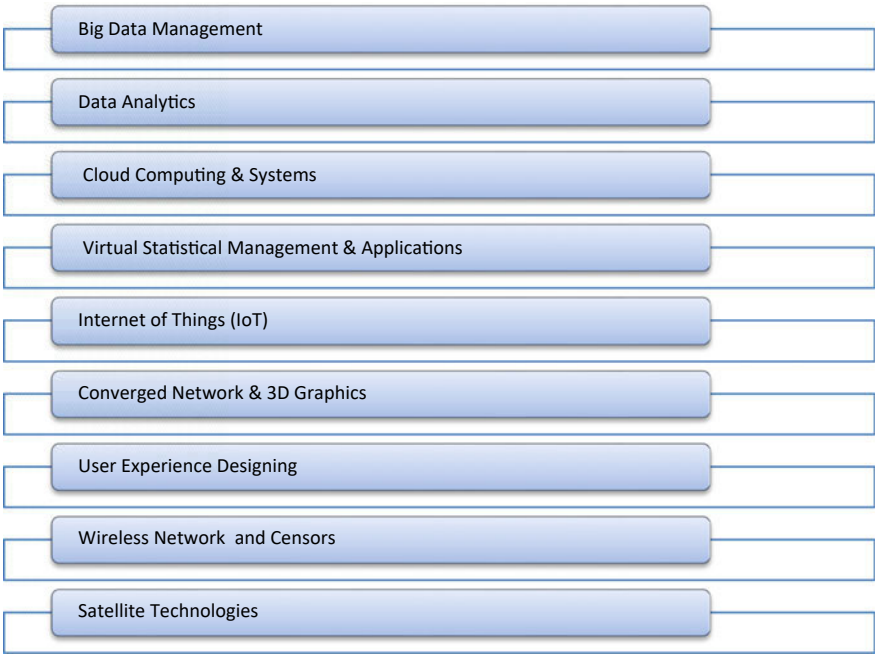

Fig. 1.1 Emerging IT components in Environmental Informatics required in environmental systems

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.

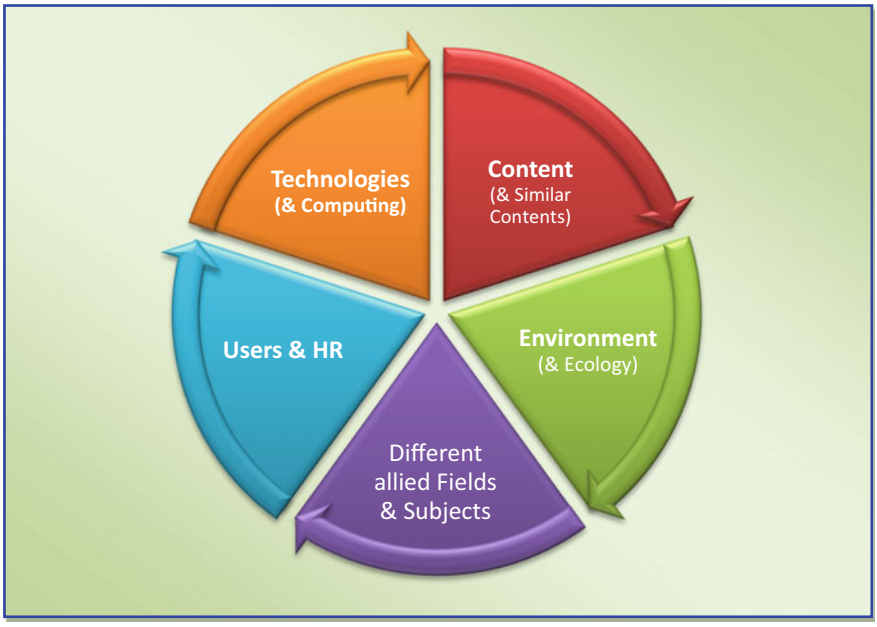

Fig. 1.2 Major stakeholders of developing Environmental Informatics

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.

References

1. Allen, T. F., Giampietro, M., & Little, A. M. (2003). Distinguishing ecological engineering from environmental engineering. *Ecological Engineering, 20*(5), 389–407.
2. Argent, R. M. (2004). An overview of model integration for environmental applications—Components, frameworks and semantics. *Environmental Modelling & Software, 19*(3), 219–234.
3. Borchardt, M., Wendt, M. H., Pereira, G. M., & Sellitto, M. A. (2011). Redesign of a component based on ecodesign practices: Environmental impact and cost reduction achievements. *Journal of Cleaner Production, 19*(1), 49–57.
4. Cruz, F. B. D. L., & Barlaz, M. A. (2010). Estimation of waste component-specific landfill decay rates using laboratory-scale decomposition data. *Environmental Science & Technology, 44*(12), 4722–4728.
5. Dmitrović, L. G., Dušak, V., & Milković, M. (2017). Involving environmental informatics in Croatian technical studies. *Technical Gazette, 24*(6), 1869–1875.
6. Frew, J. E., & Dozier, J. (2012). Environmental informatics. *Annual Review of Environment and Resources, 37*, 449–472.
7. Green, D. G., & Klomp, N. I. (1998). Environmental informatics-a new paradigm for coping with complexity in nature. *Complex Systems, 98*, 36–44.
8. Haupt, S. E., Pasini, A., & Marzban, C. (Eds.). (2008). *Artificial intelligence methods in the environmental sciences.* Springer Science & Business Media.
9. Hilty, L. M., Page, B., & Hřebíček, J. (2006). Environmental informatics. *Environmental Modelling & Software, 21*(11), 1517–1518.
10. Huang, G. H., & Chang, N. B. (2003). The perspectives of environmental informatics and systems analysis. *Journal of Environmental Informatics, 1*(1), 1–7.
11. Hunt, C. B., & Auster, E. R. (1990). Proactive environmental management: Avoiding the toxic trap. *MIT Sloan Management Review, 31*(2), 7–14.
12. Jones, D. A., Lelyveld, T. P., Mavrofidis, S. D., Kingman, S. W., & Miles, N. J. (2002). Microwave heating applications in environmental engineering—A review. *Resources, Conservation and Recycling, 34*(2), 75–90.
13. Laird, D. A., Yen, P. Y., Koskinen, W. C., Steinheimer, T. R., & Dowdy, R. H. (1994). Sorption of atrazine on soil clay components. *Environmental Science & Technology, 28*(6), 1054–1061.
14. Lu, J. W., Chang, N. B., & Liao, L. (2013). Environmental informatics for solid and hazardous waste management: Advances, challenges, and perspectives. *Critical Reviews in Environmental Science and Technology, 43*(15), 1557–1656.
15. Mayfield, C., Joliat, M., & Cowan, D. (2001). The roles of community networks in environmental monitoring and environmental informatics. *Advances in Environmental Research, 5*(4), 385–393.
16. Maxim, L., & van der Sluijs, J. P. (2011). Quality in environmental science for policy: Assessing uncertainty as a component of policy analysis. *Environmental Science & Policy, 14*(4), 482–492.

17. Mykrä, H., Heino, J., & Muotka, T. (2007). Scale-related patterns in the spatial and environmental components of stream macro invertebrate assemblage variation. *Global Ecology and Biogeography, 16*(2), 149–159.
18. Page, B. (1996). Environmental informatics towards a new discipline in applied computer science for environmental protection and research. *Environmental Software Systems*, 3–22.
19. Page, B., & Wohlgemuth, V. (2010). Advances in environmental informatics: Integration of discrete event simulation methodology with ecological material flow analysis for modelling eco-efficient systems. *Procedia Environmental Sciences, 2*, 696–705.
20. Paul, P. K. (2013). Environment and sustainable development with cloud based green computing: A case study. *Scholars Academic Journal of Biosciences (SAJB), 1*(6), 337–341.
21. Pau1, P. K., Ganguly, J., & Sinha, A. (2014). Environmental information processing for eco friendly social and business development—A short communicationin. In *National conference on corporate social responsibility: Expectations and challenges* (pp. 258–264).
22. Paul, P. K., Kumar, K., Das, P., Karn, B., & Poovammal, E. (2016). Environmental information systems: Tools, technologies and other facets better green world: A brief conceptual study. *International Journal of Recent Researches in Science, Engineering & Technology, 4*(05), 142–147.
23. Paul, P. K., Bhuimali, A., Ghose, M., & Chatterjee, D. (2016). Eco informatics and green IT as an interdisciplinary environmental-computing-management domain: With a case study of united kingdom programs. *Palgo Journal of Education Research, 4*(6), 225–229
24. Paul, P. K., Bhuimali, A., Ghose, M., Ganguly, J., & Ghosh, M. (2017). Information technology and green-eco environment: The aspects in interdisciplinary scenario. *International Journal of Scientific Research and Modern Education (IJSRME), 2*(2), 27–30.
25. Paul, P. K., Aithal, P. S., Bhuimali, A., & Kalishankar, T. (2020). Environmental informatics vis-à-vis big data analytics: The geo-spatial & sustainable solutions. *International Journal of Applied Engineering and Management Letters (IJAEML), 4*(2), 31–40.
26. Paul, P. K., Bhuimali, A., Aithal, P. S., & Kalishankar, T. (2020). Environmental informatics: Educational opportunities at bachelors level—International context and Indian potentialities. *International Journal of Applied Engineering and Management Letters (IJAEML), 4*(1), 243–256.
27. Paul, P. K., Aithal, P. S., & Bhuimali, A. (2020). Environmental informatics and educational opportunities in post graduate level—Indian potentialities based on international scenario. *IRA-International Journal of Management & Social Sciences, 16*(2), 45–58.
28. Paul, P. K., Saavedra, M. R., Aithal, P. S., Aremu, P. S. B., & Baby, P. (2020). Environmental informatics: Potentialities in iSchools and information science & technology programs—An analysis. *International Journal of Management, Technology, and Social Sciences (IJMTS), 5*(1), 238–251.
29. Paul, P. K., Bhuimali, A., & Aithal, P. S. (2020). Environmental informatics: The foundation, allied & related branches—Analytical study. *International Journal of Social Sciences, 9*(1), 01–07.
30. Sandler, S. I. (1996). Infinite dilution activity coefficients in chemical, environmental and biochemical engineering. *Fluid Phase Equilibria, 116*(1–2), 343–353.
31. Thompson, S., Treweek, J. R., & Thurling, D. (1997). The ecological component of environmental impact assessment: A critical review of British environmental statements. *Journal of environmental Planning and Management, 40*(2), 157–172.
32. Tochtermann, K., & Maurer, H. A. (2000). Knowledge management and environmental informatics. *Journal of Universal Computer Science, 6*(5), 517–536.
33. Yakhou, M., & Dorweiler, V. P. (2004). Environmental accounting: An essential component of business strategy. *Business Strategy and the Environment, 13*(2), 65–77.

Chapter 2
Exploring the Role of ICCT Underlying Technologies in Environmental and Ecological Management

P. S. Aithal and Shubhrajyotsna Aithal

Abstract Technology is an enabler of the implementation of various strategies in solving environmental problems. Information communication and computation technology (ICCT) and nanotechnology (NT) are two new emerging general-purpose technologies that have the capabilities to solve many problems of society in an innovative and effective manner. These technologies have potentiality to manage the natural environment and ecology of the earth to support sustainable living creatures. In this chapter, we made a detailed analysis of the role of ICCT underlying technologies in environmental and ecological management for maintaining sustainable living systems on earth. The chapter discusses the technology interventions and management of natural environmental and ecology and identifies the role of ICCT underlying technologies in environmental and ecological management. The chapter also discusses implementation strategies of use of ICCT underlying technologies in environmental and ecological management and analysis of the possible role of ICCT in ecological management using a qualitative ABCD analysis framework.

Keywords Environmental management · Ecological management · ICCT underlying technologies · ICCT in environmental management · ABCD analysis for ICCT in ecological management

2.1 Introduction

Managing the physical, social, and economical environment is an important and essential responsibility of everyone in society for sustainable living on the earth. The physical environment also called the natural environment comprises of everything within and around every living creature. In a literature sense, environment means

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everything surrounding an individual, object, element, or system and their relationship and interaction. For a sustainable environment, there should be a cordial and long-lasting interrelationship between individuals, objects, elements, or systems with their surroundings [1]. Though the concept of environment is complex in nature, they can be simplified using a system model that is based on the interaction between input, output, processes, and surroundings of a system. Systematic study of the relationship between the components of any system in terms of its physical, social, and economical concepts constitutes environmental science. It is the branch of environmental science that focuses on the interaction between various organisms and their environment. It is interesting and appropriate to know the possible impact of technology and its management for maintaining a sustainable environment and ecology of living and nonliving systems including individuals and organizations. Any system is stable if and only if its environment supports it, i.e., the characteristics, performance, and productivity of every system depend on its environment [2]. Management of the environment and ecology of the earth using innovative technologies for the sustainability of living beings is finding primary importance and should be given utmost preference for the survival of living beings. The current scenario of environmental degradation due to natural and man-made disasters is alarming and threatens the continuation of living beings on mother earth. Sustainable environment and ecology are important for human well-being and prosperity. Ecology enriches the interdependence of human beings and nature by maintaining clean air and water, nutritious food, and sustaining biodiversity in a changing climate. In this chapter, the effect and role of ICCT underlying technologies on environmental management and ecology management are discussed and analyzed.

2.2 ICCT Underlying Technologies

There are many debates on the interaction between technology and the environment [3]. Technology, being an application of science, is an enabler and driver of all industries to progress and prosper. Technology-based various industry generations are identified [4], and currently, industry 4.0 is active that is driven mainly by the Internet of Thigs (IoT) to ubiquitously connect various cyber-physical systems. Recently, two technologies are identified as universal technologies that have capabilities to solve many problems in all industry sectors including primary industry sector, secondary industry sector, tertiary industry sector, and quaternary industry sector [5]. These two universal technologies are information communication and computation technology (ICCT) and nanotechnologies, which have capabilities to support intangible and tangible products and services in all industry sectors. Information communication and computation technology (ICCT) is growing like an umbrella and contributing through many emerging new sub-technologies called ICCT underlying technologies [6]. Table 2.1 lists twelve ICCT underlying technologies along

Table 2.1 Twelve ICCT underlying technologies with their objectives and potentialities

S. No.	ICCT underlying technology	Objectives	Potentialities
1	Artificial intelligence and robotics technology	To create intelligent machines	Machines can think and make decisions better than human beings
2	Big data and business intelligence technology	To analyze continuously generated data in business processes and find the pattern to predict the future	Use of big data indications in the form of business intelligence for making current decisions based on future predictions
3	Blockchain technology	Connecting digital information in the form of digital ledger of transactions in such a way that it is vulnerable to change, hack, or cheat	To allow digital information to be recorded and distributed in such a way that it cannot be edited at any one point during transaction
4	Cloud computing technology	To access and use any third-party electronic device through Internet so that the concept of rental usage of third-party hardware and software resources instead of owning them	Organizations and individuals can use rented digital devices for processing and storage of information ubiquitously to reduce the expenditure and to optimally utilize available resources
5	Cybersecurity and forensic technology	To stop digital crimes by identifying and gathering proofs of crime in an exceedingly forensically sound manner with required evidence	Possibility of providing perfect security for digital information during processing, transmission, and storage by effectively handling the unauthorized intrusion and disclosing the crime
6	Digital business and marketing technology	Reaching every potential customer and providing information and awareness about products/services	Ability to improve business models toward ideal business model
7	3D-printing technology	Printing physical objects of any size layer by layer by mixing and processing required raw materials systematically	Ubiquitous printing of physical objects anytime, anywhere. This avoids logistics of physical products between countries
8	Internet of Things (IoT) technology	Connecting cyber-physical devices through Internet	Automated controlling of Internet-connected devices ubiquitously

(continued)

Table 2.1 (continued)

S. No.	ICCT underlying technology	Objectives	Potentialities
9	Information storage technology	To enhance digital information storage ability of devices along with decrease in their size and cost	Storing huge amount of data and digital information for future tech-world
10	Optical and quantum computer technology	Increasing the speed and capability of computers beyond electronic computers capability	High-speed computers which can cater the need of every one of this world through cloud computing platform
11	Online education technology	Education to every one through effective online ubiquitous models	Providing education to every one irrespective of their geographical and economic background, at any age and any time
12	Virtual and augmented reality technology	To provide real-world experiences through virtual environment, i.e., mimicking reality through virtual setup	Creating artificial environment with scenes and objects that mimics the reality

with their objectives and potentialities. In this chapter, we made a detailed analysis of the role of ICCT underlying technologies in environmental and ecological management for maintaining sustainable living systems on earth.

In this chapter, how ICCT underlying technologies are useful in managing a sustainable environment and ecology is discussed and analyzed.

2.3 Objectives

(1) To discuss the technology interventions and management of natural environmental and ecology.
(2) Identify and analyze the role of ICCT underlying technologies in environmental and ecological management.
(3) Implementation strategies of use of ICCT underlying technologies in environmental and ecological management.
(4) Analysis of the possible role of ICCT in ecological management using qualitative ABCD analysis framework.

2.4 Role of ICCT Underlying Technologies in Environmental Management

(1) **Role of Artificial Intelligence and Robotics in Environment and Ecology Management**

(i) Artificial intelligence technology helps environmental management, especially planning, monitoring, and controlling a sustainable environment. It includes analyzing the current environment, forecasting future changes, monitoring, and controlling the environmental changes using various AI-supported monitoring and decision supporting systems [7].

(ii) AI and robotics technology is also useful for modeling environmental systems using case-based reasoning, rule-based models, artificial neural networking, fuzzy logic models, multi-agent systems, genetic algorithms, machine learning models, cellular automata, swarm intelligent models, and hybrid modeling [8].

(iii) Predicting and managing environmental data in environmental management systems, sustainable green human resource management, and water resource management for sustainable environmental planning, atmospheric forecasting and management, and e-waste management for environmental planning, using the principles of artificial intelligence [9].

(iv) Artificial intelligence-based expert systems are helpful in sophisticated environmental management models of materials with reduce, reuse, recycle, and recover slogans [10].

(v) Artificial intelligent technology is used in ecological management based on modeling and simulation, integration of qualitative and quantitative knowledge, theoretical aspects of ecological modeling, and natural resource management and policy analysis, etc [11]. Artificial intelligence-based expert systems are expected to provide useful tools for ecological research and ecological knowledge management applications [12].

(vi) Robotics technology has attractive applications in environmental engineering, environmental monitoring, and environmental management of the planet and its environmental processes. Robots are used to explore deep oceans, track harmful algal blooms and to control the spread of pollution, and monitor remote volcanoes [13].

(vii) Areal robotics are used for forest management and seeding, Autonomous robotics are used in identification and management of invasive aquatic plant species, pest control in agriculture, ecological management of agricultural weed, plant eco-phenotyping, etc [14].

(2) **Role of Big Data and Analytics Technology in Environment and Ecology Management**

(i) Big data generally represent the mass volume of data generated using video detectors (CCD cameras) and continuously monitor the changes in any system and cannot be processed using ordinary data processing tools and practices. In environmental management systems, big data are used to monitor and control the continuously changing environment due to various environment degradation activities.

(ii) Big data-based analytics are used to describe a situation, predict a situation, and prescribe a solution to control a situation in environmental management.

(iii) Descriptive analytics of environmental information describes what is already happened based on analysis of environmental and ecological data.

(iv) Predictive analytics of environmental information predicts what could happen in the future based on analysis of environmental and ecological data [15].

(v) Prescriptive analytics of environmental information prescribes what should happen and how variations can be controlled based on analysis of environmental and ecological data.

(vi) Big data technology helps effective analysis of agricultural and rural ecological management systems [16].

(vii) Big data and analytics support societal development and environmental sustainability. It also supports urban ecological environmental management through the upgraded geographical management system.

(viii) Study of environmental impact on the earth surface, marine, and atmosphere using big data and analytics and intervention on disaster resilience through big data for environmental sustainability [17].

(3) **Role of Blockchain Technology in Environment and Ecology Management**

(i) Blockchain technology also called distributed ledger technology is helpful for maintaining undistracted environmental data for long period for continuous analysis.

(ii) Blockchain technology can be used for the management of effective treatment of industrial wastewater and safely discharge to water bodies [18].

(iii) Blockchain technology, with its decentralized property, has the capability to protect and sustain the global environment at various levels including life on earth, life below the earth's surface, and climate changes. Blockchain technology is used to monitor the climate

change, biodiversity, conservation of healthy water bodies to manage the ecological threats [19].

(iv) Blockchain technology is used in securing environmental data due to its unique property of non-modifying data feature at any one stage. Hence, it can be used in industrial pollution data security, weather monitoring and forecasting data security, marine data security, etc [20].

(v) Blockchain technology has potential applications in designing a smart environment and smart mobility by planning the use of renewable energy sources and creating awareness regarding environmental and energy sustainability [21].

(vi) Blockchain technology enables individuals and organizations to manage their carbon emission footprints, the social and environmental costs, and environment management policies and strategies [22].

(vii) Blockchain technology can be used to monitor and control unauthorized looting of natural resources including mines, forests, sand from mafias and hence protect natural resources for environmental and ecological sustainability.

(viii) Blockchain technology can be used effectively or to improve the efficiency of waste management including solid, liquid, and gases wastes from various economic activities in society to maintain a sustainable environment and ecosystem.

(ix) Blockchain supported e-agriculture and animal husbandry to include public participation and support for basic resources like water and feed management.

(4) **Role of Cloud Computing in Environment and Ecology Management**

Cloud computing technology allows individuals and organizations to use ubiquitous computing resources (both software and hardware) for digital information processing and storage. The major roles of cloud computing technology are as follows:

(i) Use of cloud computing platform to decrease the cost of using computing processes related to environmental planning, monitoring, and controlling.

(ii) Cloud computing platforms can be used for urban ecological environment investigation and management using computer neural network algorithm [23].

(iii) Cloud computing can be also used for reducing the operational cost of regional environmental monitoring and management systems and agencies in every country [24].

(iv) Cloud computing platforms can be also used to develop healthy and sustainable development environmental systems [25].

(v) A new model of cloud computing platform based on modern eco-agriculture is possible [26].