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

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ABSTRCT

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 paper, 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 paper discusses the technology interventions & management of natural Environmental & Ecology and Identifies the role of ICCT underlying technologies in environmental & ecological management. The paper also discusses implementation strategies of use of ICCT underlying technologies in environmental & ecological management and analysis of the possible role of ICCT in ecological management using a qualitative ABCD analysis framework.

Paper Type: Conceptual Analysis
Keywords: Environmental management, Ecological management, ICCT underlying technologies, ICCT in environmental management, ABCD analysis for ICCT in Ecological management

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 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. The branch of environmental science which 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 wellbeing 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 paper, the effect and role of ICCT underlying technologies on Environmental management and ecology management are discussed and analyzed.

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 & Computation Technology (ICCT) and Nanotechnologies, which have capabilities to support intangible and tangible products and services in all industry sectors. Information Communication & Computation Technology (ICCT) is growing like an umbrella and contributing through many emerging new sub-technologies called ICCT underlying technologies [6]. Table 1 lists twelve ICCT underlying technologies along with their objectives and potentialities. In this paper, we made a detailed analysis of the role of ICCT underlying technologies in environmental and ecological management for maintaining sustainable living systems on earth.

Table 1 : Twelve ICCT underlying Technologies with their objectives and potentialities

S. No.	ICCT underlying Technology	Objectives	Potentialities
1	Artificial Intelligence & Robotics Technology	To create intelligent machines.	Machines can think and make decisions better than human beings.
2	Bigdata & Business Intelligence Technology	To analyze continuously generated data in business processes and find the pattern to predict the future.	Use of bigdata 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	Cyber Security 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 & Marketing Technology	Reaching every potential customer and providing information and awareness about products/services.	Ability to improve business models towards 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.
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 & 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 & 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.

In this paper, how ICCT underlying technologies are useful in Managing a sustainable environment and ecology are discussed and analyzed.

3. OBJECTIVES :

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

4. ROLE OF ICCT UNDERLYING TECHNOLOGIES IN ENVIRONMENTAL MANAGEMENT :

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

(i) Artificial intelligence technology helps environmental management especially planning, monitoring and controlling a sustainable environment. It includes analysing the current environment, forecasting future changes, monitoring, and controlling the environmental changes using various AI-supported monitoring and decision supporting systems [7].
(ii) AI & Robotics technology is also useful for modelling 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 modelling [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 modelling and simulation, integration of qualitative and quantitative knowledge, theoretical aspects of ecological modelling, 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 Bigdata & Analytics Technology in Environment and Ecology Management :
(i) Big data generally represents the mass volume of data generated using video detectors (CCD cameras) and continuously monitors the changes in any system and cannot be processed using ordinary data processing tools and practices. In environmental management systems, big data is 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-based monitoring 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 & 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 :
(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].
(vi) Cloud computing platform can be used to evaluate ecological environment quality in tourist areas of smart cities.
(vii) In modern forest fire management, green construction management, and power consumption management systems, cloud computing platforms can be extensively used for better cost and time management.

(5) Role of Cyber Security & Forensics in Environment and Ecology Management :

(i) Cyber security and forensics have applications in environmental data protection during such data transactions and storage.
(ii) Cyber security and forensics technology have advantages in protecting the data of primary industry sector including agriculture, forestry, fisheries, mining, etc.
(iii) Minimizing crimes in various industry sectors that affect the environment and natural ecology is possible using cyber security and forensics technology.
(iv) Cyber security technology supports protecting research data on environmental monitoring and natural ecology management on the earth's surface [27].

(6) Role of 3D Printing Technology in Environment and Ecology Management :

Three Dimensional (3D) Printing is an additive manufacturing process of physical objects layer by layer from a digital design. Ideal 3D printing should manufacture any physical object of any size using the combination of required input raw material made by any element and compounds. 3D printing technology is expected to play a special role in future environmental and ecological management :
(i) 3D printing process can use reusable/recycled materials thereby can contribute to control environmental degradation [28].
(ii) 3D printing technology supports effective waste management due to the fact that Product/object printing takes place in a location of demand and waste materials after recycling can be used as input [29-30].
(iii) 3D printing has many positive and negative implications on the environment and natural ecology. Managing them by proper planning and precautions [31].
(iv) The negative environmental impacts of manufacturing industries can be minimized using 3D printing technology due to its systematic layer by layer manufacturing process model [32].

(v) 3D printing enables improving the processes related to evolution and ecology in terms of better experimental techniques, greater flexibility, reduced cost, and ease of production [33].
(vi) 3D printing models provide an opportunity to conduct research using more life-like models with more appropriate responses from organisms involved without really affecting the living ecology of nature.
(vii) Raid and low-cost printing of various ecological models for museums to educate and create awareness of the environment and its effective management is possible using 3D printing technology.

(7) Role of Digital Business & marketing technology in Environment and Ecology Management:
Digital business models which are different versions of traditional brick and mortar models have changed the way of doing business and provided many advantages and benefits to both customers and business organizations. The digital business technology using the internet allows ubiquitous sales of both tangible and intangible commodities. E-Business in any form including mobile business (m-business) [34] allows to improve the business models to improve towards ideal business model [35]. Similarly, online marketing models using internet technology allow individuals and organizations to reach every potential customer across the world. Digital business and digital marketing technologies contribute substantially to environmental and ecological management by decreasing many physical business processes in almost all industries.
(i) Digital business and marketing models decreased environmental pollution due to ubiquitous online business opportunities.
(ii) Many business processes including transportation of human and other resources, both for tangible and intangible commodities.
(iii) This technology provided many features for effective business leading to customers satisfaction and delight.
(iv) E-business and e-marketing strategies allowed to plan the business processes in such a way to decrease various industrial waste, effective reuse, and hence decrease the cost of doing business [36].

(8) Role of Internet of Things (IoT) in Environment and Ecology Management :
Internet of things (IoT) describes a group of physical objects interconnected through the internet called Things, embedded with sensors, software, and other features for the exchange of data and instructions. IoT contains cyber-physical systems connected through the internet in such a way that the connected things can be controlled by each other without human intervention [37]. IoT has many potential applications in environmental and ecological management:
(i) IoT systems can be used to track the data of various detectors connected in an environmental monitoring system and analyse them to study the changes in environmental patterns.
(ii) IoT has the potential ability to be used in climate change and environmental monitoring and management. IoT supports functions like storing, organizing, processing, and sharing data and information and their applications in environmental monitoring and management [38].
(iii) IoT can be used effectively for automatic waste management through monitoring and controlling connected devices in Smart cities [39].
(iv) IoT has many technological advantages for ecological research and monitoring wild animals especially using its networked sensor technology to measure environmental parameters related to accurate, real time, and comprehensive data for monitoring conservation of wildlife and animal ecology [40].
(v) IoT has the potential ability to support forest eco management systems and stability. IoT can be used in the conservation of habitats and species, prevention of degradation of forest soil, forest fire prediction and control, timber production and management, etc. [41].

(9) Role Information Storage Technology in Environment and Ecology Management :
Information storage & management for long time information ecology so that information storage systems can be leveraged to achieve eco-efficiency, eco-equity, and eco-effectiveness [42].
(i) Information storage & management systems support such information storage that relates to the development of a sustained, robust, persistent infrastructure for data collection in environmental science research [43].

(ii) Information storage management technology helps to process huge wild-life location data, tracking systems that have large, continuous, and high frequency data sets of wildlife behaviour, to be processed using Global Positioning Systems (GPS), and other animal attached sensor devices [44].

(10) Role of Quantum Computing in Environment and Ecology Management :

Quantum computers and optical computers are high speed computers that use quantum optical principles for computation unlike electronic signals in currently used electronic computers. Most widely used model of quantum computer uses quantum circuits that function based on quantum bits or qubits. Qubits can be either 0 or 1, or both (i.e., in a superposition of 0 and 1). In quantum computing, the information is encoded in qubits. The speed of quantum computers are several million times of the speed of supercomputers (supercomputers operate at a speed of the order of several hundred petaflops). The role of quantum computers in Environmental and ecological management include:

(i) Quantum computers are potential machines for innovative climate change solutions through the simulation of quantum-level atomic interactions, could pave the way to discovering a new catalyst for carbon capture, heralding a new era of scrubbing carbon directly out of the air [45].

(ii) Quantum computing may help to optimize the design of carbon intensive materials to help to reduce carbon emissions from buildings, transportation, or any other heavy industry products [46].

(iii) Quantum computers have the potential to predict extreme weather situations based on numerical climate and weather prediction models.

(11) Role of Online Education Technology in Environment and Ecology Management :

Online education technologies are useful to educate people by providing environmental science education in online mode. This will create responsibility among the citizens to maintain a clean & green environment. Through online education technology, Governments and NGOs can create awareness among the public about water, air, and soil pollution and precautions to be taken to maintain a quality environment and ecosystem.

(12) Role of Virtual & Augmented Reality in Environment and Ecology Management :

Virtual reality is a technology used to mimic reality in a synthetic or virtual mode. Augmented reality enriches the real world by superimposing computer-generated effects on it.

(i) Virtual reality is used for environmental management training [47].

(ii) Virtual reality technology is used for visualizing ecological data [48].

(iii) Virtual reality technology is used in visualizing natural environments from data [49]

(iv) Virtual reality technology is used to visualize forests under climate change [50].

(v) Virtual reality technology is used to promote awareness creation on climate change [51].

(vi) Improving video games with players augmented reality.

(vii) Augmented reality technology has potentiality in providing impressive environmental education.

(viii) Effective teaching on climate change using augmented reality technology.

(ix) Use of mobile augmented technology for environmental monitoring [52].

6. IMPLEMENTATION STRATEGIES OF USE OF ICCT UNDERLYING TECHNOLOGIES IN ENVIRONMENTAL & ECOLOGICAL MANAGEMENT :

Any technology management framework involves six stages that include (i) identification, (ii) analysis, (iii) selection, (iv) acquisition, (v) exploitation, and (vi) protection of technology to be used to fulfil the individual or organizational objectives.

(i) Identification stage involves both identifications of need/want to change called problem and identification of possible technologies that drive the change.

(ii) Analysis of technologies in connection to the identified problem using a suitable analysis framework which may include SWOC analysis, ABCD analysis, PESTLE analysis, six thinking hats analysis, etc.,

(iii) Based on analysis find a suitable technology as optimum technology which provides incremental/ radical/ Architectural/ disruptive innovation and is depends on objective adopting technology.

(iv) The chosen technology should be adopted in the business processes, through systematic acquisition. This includes in-house development of solutions using chosen open-access technology,

(v) Exploitation of acquired technology by utilising other resources of the organization to increase the performance and to get maximum benefits is essential for getting benefits of new technology used.

Failure to recognize and manage new technologies by organizations results in inefficiencies and frustration.
(vi) Protection of technology copying by others, especially by competitors through certain strategies like having patent/ trademark/ copyright rights are essential and desirable.

ICCT underlying technologies have the capability to innovate and provide new solutions to existing problems in society and hence are having their applications in all industry sectors in one or the other way. These technologies can be potentially used for environmental protection. Due to liberalization and subsequent globalization, economic development without environmental considerations causes the environmental crisis. As a result, organizations are cautious about environmental degradation and hence call for diligent management of the environment which in turn is indispensable for sustainable development. ICCT underlying technologies are capable to solve many environmental and ecological problems and are considered as general-purpose technologies of the 21st century.

7. ANALYSIS OF POSSIBLE ROLE OF ICCT UNDERLYING TECHNOLOGIES IN ENVIRONMENTAL AND ECOLOGICAL MANAGEMENT USING QUALITATIVE ABCD ANALYSIS :

ABCD analysis framework developed by our group (Aithal P. S. (2016) [53]) has two models as simple ABCD listing or quantitative factor & elemental analysis. In this section the ABCD listing [54] of the use of ICCT underlying technologies in the environment and ecological management are considered:

Advantages :
(1) Effectiveness of managing the natural environment and its ecology
(2) Cost efficiency of managing the natural environment
(3) Saves time of intervention in managing the natural environment
(4) Better awareness creation among people to manage natural environment
(5) Systematic environmental monitoring to detect and manage changes.
(6) Visualizing natural environments from data
(7) Efficient waste management through recycling and pollution management

Benefits :
(1) Maintaining a sustainable natural environment and its ecology
(2) Low-cost players in managing sustainable natural environment and its ecology
(3) Corrective Action can be taken in time to manage the natural environment
(4) Awareness about the importance of a natural and sustainable environment leads to a involvement of everyone in minimizing environmental pollution.
(5) Systematic environmental monitoring using ICCT underlying technologies leads to proper planning to control and manage changes.
(6) Based on data analysis using virtual reality and simulation, corrective measures shall be taken if the deviation is found.
(7) Effective management of waste leads to balancing ecology on earth.

Constraints :
(1) Identification, procuring, and implementation challenges
(2) New technologies are prohibitively costly and complex
(3) Increased skill gaps between different tech-generations of people in society
(4) New technology based disruptive changes are difficult to accept by stakeholders
(5) Adequate training is required for existing employees to utilize the new technologies

Disadvantages :
(1) Job loss due to automation
(2) Risk of social isolation and addiction of technology
(3) Risks of failure of management of technology
(4) Ethical and legal concerns
(5) Extreme dependability

8. CONCLUSION :

ICCT underlying technologies, due to their general-purpose technology characteristics have potential applications to innovate efficient natural environmental management and natural ecological management in society. The role of ICCT underlying technologies in environmental & ecological management is identified and analyzed. Various implementation strategies of the use of ICCT underlying technologies in environmental & ecological management are discussed. Analysis of the use of ICCT underlying technologies in natural environment management and ecological management using qualitative ABCD framework is depicted. It is found that ICCT underlying technologies have potential advantages and benefits in managing the natural environment and ecology in order to sustain living beings for a longer period.

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