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ARTIFICIAL INTELLIGENCE FOR RENEWABLE ENERGY SYSTEMS

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Artificial Intelligence for Renewable Energy Systems

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Contents

Utilizing artificial intelligence for environmental sustainability

13

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13.1 Introduction

The implementation of artificial intelligence (AI) and its extremely wide influence across various sectors necessitates an assessment of its implications on achieving the Sustainable Development Goals. The rapid progress of AI must be accompanied by the appropriate regulatory knowledge and supervision for AI-based technologies in enabling sustainable development. Failing to do so might lead to inconsistencies in terms of accountability, security, and ethical norms [1].

Unprecedented stresses on the environment are escalating by the second, leading to disastrous consequences. During the past industrial revolution, detrimental consequences were extensively imposed on our planet. Climate change, loss of biodiversity, disturbed biogeochemical cycles, and loss of land are the boundaries we have crossed in reaching the threshold limit of the earth system [2].

The triple bottom line [3] of 3Ps—people, planet, and profit [4,5]—shown in Fig. 13.1 comprises interconnected factors that are the building blocks of environmental sustainability. Social, economic, and environmental variables should be viable, equitable, and bearable to attain sustainability in a true sense [6].

The United Nations has established 17 Sustainable Development Goals (SDGs) “to achieve a better and more sustainable future,” some of which are discussed in this chapter. Considering SDG1, “no poverty,” COVID-19 has instigated a rise in poverty on a global level. In 2020, approximately 71 million people were strapped into life-threatening paucity. An economic loss of $23.6 billion due to natural disasters has exacerbated global poverty. Since the 19th century, the share of the population living under extreme poverty has been reduced from 33% to 9%, which is a notable decline. The healthcare facilities referred to in SDG3 have also improved during the 20th century; the maternal death rate has dropped by 37%, and the death rate of children below age 5 has decreased by 47%. Complying with SDG7 referring to global electricity accessibility, around 87% of the people around the globe use sustainable and cleaner energy in the 20th century. On the other hand, the world is subjected to 415-ppm carbon dioxide levels leading toward grave consequences of climate change, and

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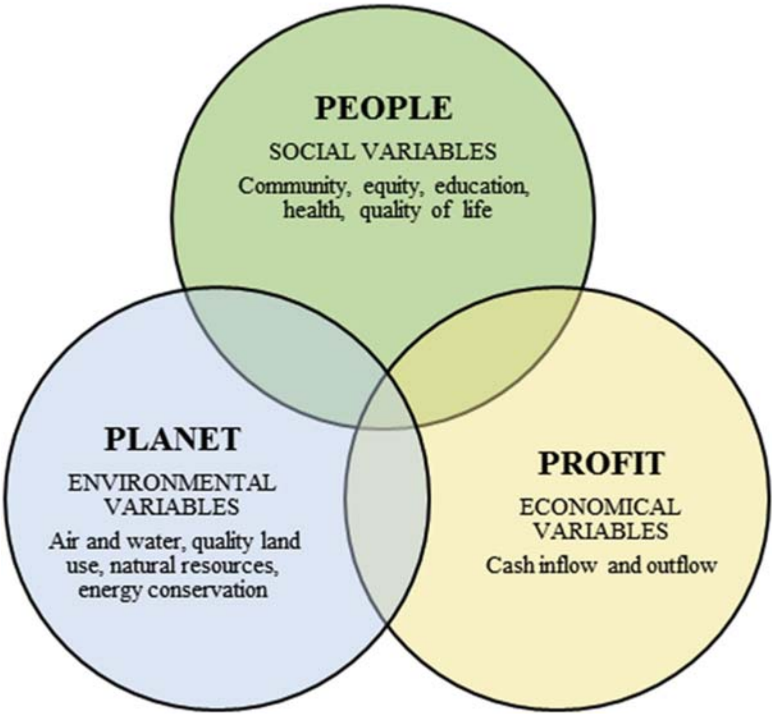

Figure 13.1 Components of environmental sustainability—triple bottom line approach.

according to United Nations; the persistence of such anthropogenic conditions will pose the threat of human extinction [7].

SDG6, SDG7, SDG13, SDG14, and SDG15, which address water security; clean air; climate change and weather and disaster resilience; healthy oceans; and biodiversity and conservation, respectively, are the prime environmental sectors of concern.

13.1.1 Sustainable development goal 6: "ensure access to water and sanitation for all"

Although momentous growth has intensified accessibility to pure drinking water and hygiene, billions of individuals, specifically in rural areas, still face a dearth of these vital and fundamental amenities [8]. Globally, one of every three individuals lacks access to pure drinking water [9], two of every five lack access to basic handwashing facilities with water and soap [10], and approximately 673 million people still defecate in open areas [11]. The COVID-19 pandemic has highlighted vital necessities related to health, hygiene, and accessibility to safe water in disease prevention and control [12]. Hand hygiene [13] can save a person's life. Handwashing is one of the most efficient methods to prevent disease and the spread of pathogens, including the COVID-19 virus [14]. Despite this, billions of people still lack access to clean drinking water, and financing is insufficient [15].

13.1.2 Sustainable development goal 7: "ensure access to affordable, reliable, sustainable and modern energy"

With hopeful indications that energy is being transformed into a more viable and largely accessible resource, the global population is progressing toward Goal 7 [16]. Access to electricity has begun to improve in undeveloped countries, energy productivity is growing, and renewable energy is making considerable headway in the electrical sector [17]. Nonetheless, increasing access to clean and safe cooking fuels and technologies for three billion people is a priority [18]. Meanwhile, escalating the use of inexhaustible energy sources from outside the electrical sector and expanding the electrical base in sub-Saharan Africa would require more concerted effort [19].

13.1.3 Sustainable development goal 13: "take urgent action to combat climate change and its impacts"

The year 2020 will go down in history as the second hottest on record [20]. Climate change has affected every single nation on each continent [21]. It is imposing havoc on national financial states and placing livelihoods in jeopardy [22]. The weather is changing, sea levels are rising, and extreme weather is becoming more frequent [23]. Because of travel restrictions and economic slowdowns arising from the COVID-19 pandemic [24], greenhouse gas emissions are expected to decline by roughly 6% in 2020 [25]. However, this improvement is only temporary. In the near future, there will be no reversal in the uptrend of climate change; as the global economy recovers from the epidemic, emissions are expected to rise again [26].

13.1.4 Sustainable development goal 14: "conserve and sustainably use the oceans, seas and marine resources"

The ocean is vital to the global processes that make our planet habitable. The ocean influences all our rain, drinking water, meteorological conditions, temperature, seashores, many of our foodstuffs, and even the oxygen we breathe. Vigilant supervision of this vital global resource is required for a sustainable future [27]. Coastal waters, on the other hand, are now deteriorating from pollution, and ocean acidification is severely affecting ecosystems and species. Small-scale fisheries are also suffering as a result [28].

13.1.5 Sustainable development goal 15: "sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss"

The survival of the human race is dependent on nature; the oxygen we breathe is provided by nature, and it regulates our weather patterns. It also plays a crucial role in pollinating our crops and provides us with fiber, food, and fodder. However, it is increasingly becoming stressed. Life on land is in danger.

Anthropogenic activities have changed over 75 percent of the world's area, constraining wildlife and the environment to an ever-smaller swath of earth [29]. According to the

Global Assessment Report on Biodiversity and Ecosystem Services (2019), approximately one million plant and animal species are threatened. The report recommends drastic environmental restoration and protection measures [30]. It has been revealed that the health of ecosystems on which humanity and all other species rely is deteriorating at an unprecedented rate. Globally, it influences the fundamentals of our livelihoods, food security, economies, quality of life, and health. Human-induced deforestation [31] and desertification, along with climate change, exemplify enormous impediments to sustainable development, affecting millions of lives and livings [32].

Forests are vital to the existence of life on Earth and crucial in the fight against climate change [33]. Land restoration is important for enhancing livelihoods, reducing vulnerability, and reducing economic hazards [34]. The state of our planet also affects the spread of zoonotic diseases that may be passed from animals to humans [35]. Infections in animals can transfer to livestock and humans as people continue to invade natural areas, increasing the risk of disease development and propagation [36].

The literature review was carried out by searching specific keywords such as environmental sustainability, artificial intelligence (AI), and sustainable development goals in Scopus. From the search, 1601 results were obtained for the last 10 years of data (2000–21). The publication statistics reveal that environmental sustainability and AI have been much-researched areas over the last 10 years. The bibliometric content analysis displaying network visualization was done using VOSviewer version 1.6.16, with the co-occurrence keyword threshold taken as 20. The network visualization is shown in Fig. 13.2.

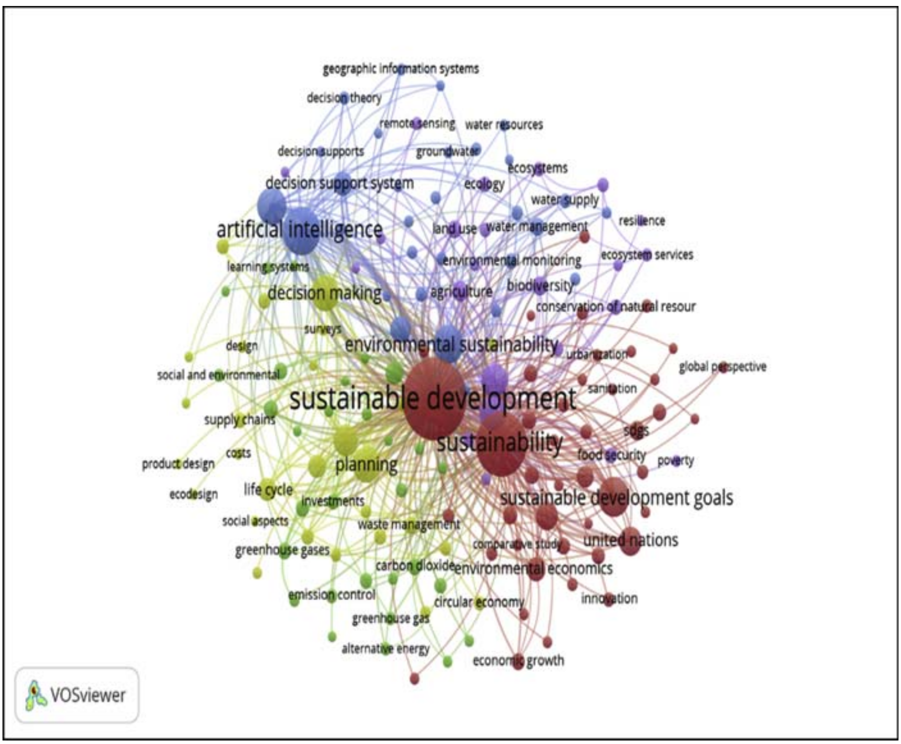

Figure 13.2 Bibliometric content analysis displaying network visualization.

Environmental uses of AI include agricultural yield predictions [37], wildfire management [38], analysis of poaching in protected areas [39], disaster occurrence, intensity, and impact predictions [40], bird migration forecasts [41], and as a tool to combat deforestation [42]. In the agricultural sector, AI is helping farmers monitor their crops [43] and diseases and predicting planting and harvesting dates to eventually increase their productivity [44] and decrease fertilizer use [45].

Indeed, AI is increasingly transforming industry domains, but it can also be used to harness our ability to monitor and manage our environment for more sustainable outcomes [46]. For instance, deep learning approaches have transformed our ability to leverage large amounts of satellite remote sensing data collected across the globe for more accurate land cover mapping [47]. Also, various multinationals like Microsoft AI for Earth [48], Facebook, Tesla, Google, Apple, PwC have been using the power of AI for better results [49].

Microsoft Zero Carbon Footprint by 2030 initiative is to become carbon-negative using AI-based Microsoft Azure, a cloud repository. Similarly, Google DeepMind is a specialized subdivision dedicated to AI interventions to cool the Google data centers accordingly [48,50].

13.2 Artificial intelligence—the game-changer

Since the inception of smart agriculture, weather forecasting, oceanic monitoring, decentralized trial energy, water grids, and trading in the early 1990s, AI has been an active Earth game-changer [51]. The accessibility of big data, open-source software, improved algorithms, accelerating returns, processing power has led to an efficiently connected globe [52]. The amalgamation of these elements has facilitated AI's transition from in-vitro to in-vivo contemporary applications [53]. The indicative timeline of AI as an Earth game-changer in Fig. 13.3 reveals the progression of an AI-enabled better world.

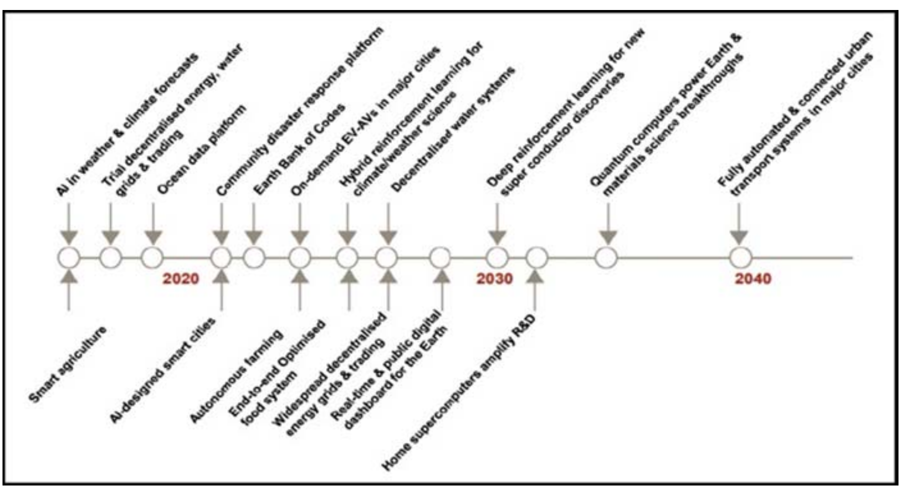

Figure 13.3 Chronology of artificial intelligence in environmental sustainability [51,54].

13.3 Artificial intelligence and nature: better together for enabling environmental sustainability

Environmental sustainability [55] requires a balance between its components such as water security, healthy oceans, clean air, climate change, biodiversity, weather prediction, and disaster resilience (Fig. 13.4). AI can accelerate global efforts to protect the environment and save resources by detecting energy emission reductions, assisting in CO_2 removal, aiding in the creation of greener transportation networks, monitoring deforestation, and forecasting extreme weather occurrences [57].

The application of AI can channel and tackle environmental issues. In the case of clean water and sanitation referring SGD six proper water-supply management and monitoring [58], water quality modeling and data alert [59], self-adaptive water filtration [60], assets maintenances on the water as well as wastewater expenses [61]; application of AI can act as a positive catalyst.

13.3.1 Climate change

Optimized energy system forecasting can be used for clean power generation to fight climate change [62]; this forecasting can also be considered for smart grids [63] for

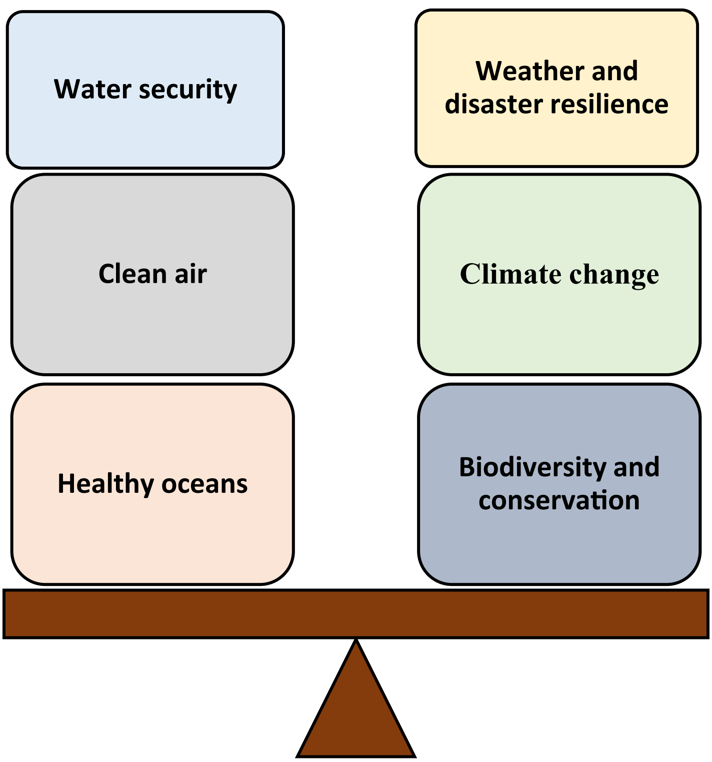

Figure 13.4 Equilibrium of environmental sustainability [56].

electricity use [64] and to predict solar flares for power grid protection [65]. Along with these, renewable energy plant assessments [66], optimized virtual power plants [67], and optimized decentralized and peer-to-peer renewable energy systems [68] can prove beneficial.

Considering the need for smart cities and homes, sustainable buildings, energy-efficient building management, intelligent transport systems, and proper urban planning play key roles. Smart traffic lights [69] and parking systems for urban mobility management [70], along with optimized sustainable building design [71−73], will lessen the burden of greenhouse gases.

Energy-efficient building management systems [74], auditory responsive lighting and heating [75], and optimized urban-level energy generation and use [76] including analytics and automation for smart urban planning [77] will also prove to be a smart decision to curtail the adverse impacts of climate change and global warming.

Implementing smart transport system AI-enabled electric cars [78] or autonomous vehicles used for efficient transport can reduce the carbon footprint [79,80]. Integrated cost-efficient transport systems, optimized traffic flows [81] along with on-demand shared transport mobility [82] can contribute to reducing emissions. AI and machine learning can reduce energy consumption and be important factors in infrastructure communication and the optimization of vehicles [83], including demand-response charging infrastructure in the transportation and planning systems [84].

For sustainable land use, machine learning can easily predict the early crop yield [85] involving artificial cognition to achieve precision agriculture and nutrition [86]. For crop management and crop issues [87] early detection can be achieved using deep learning, artificial neural networks (ANNs), recurrent neural networks, and autoencoders [88] to forecast hyperlocal weather [89].

Machine learning is applied in automated and enhanced land-use [90] change detection to avoid deforestation by ANNs, Bayesian networks, and generalized linear mixed models [91]. Big data, wearable sensors [92], and machine learning applications in monitoring the health of cattle are a recent revolution in livestock farming [93].

To control the excessive exploitation of resources contributing to climate change resilience, AI, Internet of Things, and blockchain technology are applied to affect supply chain monitoring and its transparency [94] and achieve sustainable production and consumption. In addition, the intervention of AI in the active optimization of industrial machinery and manufacturing [95] and the use of digital twins for life span performance optimization [96] are enhancing factors.

Smart fresh-food replacement [97] and smart recycling systems [98] are paving the way to more sustainable production and smarter consumption using AI-enabled environmental sustainability of products [46].

13.3.2 Biodiversity and conservation

Habitat protection and restoration by precision monitoring of ecosystems [99] using AI are gaining momentum. Bird habitat and migration pattern prediction [100], simulation of animal and habitat interaction [101], habitat loss detection and monitoring [102], microdrones for pollination [103], and optimized breeding of plants [104] can be used in biodiversity conservation through deep learning and AI intervention.

For pollution control, analysis of urban runoff quality issues by decision support and responsible AI is leading to multiobjective optimization [105]. Pollutant dispersal prediction and tracking [106] can be achieved through big data compilation and modeling.

Currently, machine-automated biodiversity analysis [107], smart mosquito traps [108], and vector-borne disease control [108] are done globally. Plant disease identification and detection using deep learning [109] and image computation [110] can be fruitful in detecting invasive species and disease control.

Sustainable trade is a key factor in sustainable development. The detection of unauthorized animal capture [111] and image-based detection of illegal wildlife trade [112] through AI have potential. Poacher route prediction [113] and high-risk animal tracking [93], food value chain optimization [114,115], supply chain monitoring [116] and origin tracking [117] can boost sustained trading and environmental resilience.

13.3.3 Healthy oceans

Disruptive technology applications using AI can create a balance among aquaculture, sustainable fishing, and trade [118]. Breakthrough technologies such as drones, deep data mining, machine learning, and AI can prevent plastic pollution and illegal dumping in seas and oceanic reservoirs [119]. Protecting habitats in marine ecosystems, especially in areas beyond national jurisdiction, facilitated by a data-driven AI approach will be less time-consuming and more hassle-free. Predictive marine habitat mapping can be used to protect the megabenthos [120]. Sea surface temperature modeling through soft computing [121], along with an estimation of the partial pressure of CO_2 remote sensing and machine learning, can curtail air−sea CO_2 flux. Thus, by involving an ensemble of machine learning and decision-making, marine acidification and coral bleaching can be reduced to a greater extent [122].

13.3.4 Water security

Machine learning systems [123] enable “responsible AI” in the water supply [124] and in achieving water efficiency and plays a critical role in water security [105]. The ANN can be deployed for catchment flow estimation and control [125]. SDG3, related to health and sanitation, can be reaffirmed with AI in underdeveloped countries, too [126]. The application of machine learning and simulation leads to the implementation of toilet alarms in informal settlements for better sanitation [127]. The tracking, forecasting, and planning of drought using extreme machine learning provide significant output [128].

13.3.5 Clean air

Application of ANN in estimating PM2.5 peak concentration value [129] can be beneficial inaccurate air pollution forecasting. The necessity of clean air in the COVID-19 pandemic resulted in Arduino's inbuilt air purification systems [130]. Monitoring and preventing air pollution [131] and accurate primary pollutant estimating are multifold through AI interpolation [132]. Early warning and monitoring systems [133] equipped with ensemble machine learning and AI have high-performance efficiency [134]. In terms of clean fuel generation, production of clean fuel, and optimization of an energy-exergy domain, the application of genetic algorithms, deep learning, and machine learning are promising. Real-time, integrated, adaptive urban management of air quality parameters [129] through ANN can be done in less time and smoothly [135].

13.3.6 Weather and disaster resilience

There has been an exponential increase in climate-induced disasters in the last decades. The advances in disaster prediction and weather forecasting using data analytics [136], drones [137], deep learning models [138] are abreast with AI. Using machine learning algorithms, rainfall forecasting [139], prediction of tornadoes [140], cyclones [141], and floods [142] are now easier tasks. The use of AI has become imperative during this pandemic situation too. The ongoing epidemic of COVID-19 is forecasted through adaptive machine learning and can reduce the disease burden in minimum dependencies in less time [143]. The hazard impact assessment and visualization can be effortlessly done by equipped decision support system [144]. In addition, the utilization of ANN [145] to obtain accurate and efficient forecast-based financing [146] will be a promising alternative for resilience planning [84].

13.4 Unintended consequences of artificial intelligence

The risks associated with general AI [147] can be segregated into control threats, financial threats, moral threats, performance threats, security threats, and social threats. The intimidations due to unintended impacts of AI concerning the control, economic, ethical, performance, safety, societal hazards are enumerated as follows in Table 13.1:

13.5 Challenges of using artificial intelligence in environmental sustainability

According to a comprehensive assessment of the literature, research into AI for sustainability is being hampered [55]by its too much dependency on previous data in the case of machine learning models [153]. Uncertainty in AI-enabled interventions

Table 13.1 Artificial intelligence (AI)-imposed risks and their salient features.

Hazards	Features	Investigators
Control related	– Lack of ability to manage malicious AI – Hazard of AI being "mischievous"	[148]
Financial aspect	– Accountability threat – "Clean sweep" concentration of authority threat – Job-displacement risks – Reputation risk	[149]
Moral risk	– Objective alignment threat – "Lack of values" threat – Value alignment risk	[150]
Performance threat	– Risk of favoritism – Risk of error – Risk of interpretability – "Black box" risk – Risk of stability of performance	[41]
Safety hazard	– Cyber invasion threat – Open-source software threat – Privacy threat	[151]
Public hazard	– Autonomous weapons proliferation threat – "Intelligence divide" threat	[152]

and decision-making [154] is observed during reinforced learning. In today's world, cybersecurity risks are also seen as a significant problem [155]. AI applications can have negative consequences, especially in the bioethical domain [156]. Measurement of the impact of intervention techniques is difficult in AI-enabled environmental sustainability interventions [157]. Researchers and AI experts must ensure that data procured from AI systems must be clear, ethical, and credible [158]. There is also an issue of delivering a "responsible AI" excluding biases [159]. Moreover, funding by multinational companies, higher education institutions, and governmental organizations for the research and innovation of such technologies is of major concern. Globally, appropriate standardizations for producing and applying AI interventions, as the demand for automation solutions requires higher precision data-study for environment-related aspects [160].

13.6 Conclusion

To achieve the SDGs, AI can cater to better decision-making, and environmental impacts can be channeled by incorporating multicriteria analysis in decision support systems. The AI-coupled decision support system will strengthen the sustainability indicators and enhance environmental protection and sustainable planning. While implementing AI to achieve the SDGs, the threats and unintended consequences should also be considered. In past decades, much research has been done focusing on deploying AI to achieve the SDGs. However, significant lab-based studies are required to assess the credibility of AI in a real-world situation without compromising the associated risks. Most applications concentrate only on using automated and aided intelligence to extract value from massive unstructured real-time sources. Future applications will very certainly include more systems empowered by autonomous decision-making, posing new opportunities and threats. Identifying and scaling these pioneering innovations is a challenge for inventors, researchers, stakeholders, and governments. It is also suggested that mainly AI is applied in financially strong and developed economies, but it will be a biased condition for underdeveloped and educationally backward countries to avail its benefits. Thus, awareness regarding AI can be created by introducing it into the education curricula of developing countries. The higher education institutes are the base for any country pledging to build an environmentally sustainable nation. Proper facilities and adequate funding should be provided for conducting unbiased research in the field of AI applications in achieving environmental aspects. If things get right at their respective places, surely a day will come for the AI-enabled sustainable environmental revolution, which will pave the way from crisis to sustainability.

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