Deep Science Publishing
https://doi.org/10.70593/978-81-981271-8-1_4

Chapter 4

Advancing the Sustainable Development Goals (SDGs) through artificial intelligence, machine learning, and deep learning

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Abstract: The use of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) significantly has the touch of transformational potential towards bringing the Sustainable Development Goals (SDGs) to be addressed in various industries. This research investigates the new developments and applications of these technologies in advancing sustainability programs in industry-intensive domains. Industries are beginning to undergo a major change by making today with the help of AI, ML, and DL that resources can be optimized, energy efficiency can be improved, and environmental impacts can be mitigated. A number of other trends - including predictive analytics and intelligent automation, allow for smarter and more efficient production, waste minimization and circular economy practices. AI-powered solutions are also now being used in the energy sector to maximize the generation of renewable energy, optimize grid management, and aid in the transition to low carbon energy systems. This will enable industries achieve better environmental benefits and higher operational efficiencies through big data analytics and IoT. AI and ML are also crucial in smart cities, urban planning, public services that delivery efficiency and overall support the sustainability agenda. The results reinforce the importance of strong regulatory structures and interdisciplinary collaboration to optimally leverage AI, ML, and DL to the SDGs, which will be intrinsic to designing for resilience and sustainability.

Keywords: Sustainable development, Artificial intelligence, Machine learning, Deep learning, Internet of things, Society 5.0, Sustainability

Citation: Rane, N. L., Kaya, O., & Rane, J. (2024). Advancing the Sustainable Development Goals (SDGs) through artificial intelligence, machine learning, and deep learning. In *Artificial Intelligence, Machine Learning, and Deep Learning for Sustainable Industry 5.0* (pp. 73-93). Deep Science Publishing. https://doi.org/10.70593/978-81-981271-8-1_4

4.1 Introduction

Sustainable development goals (SDGs) should be everyone's business, with world leaders coming together to work on united goals to alleviate the global community from poverty, inequality, climate change, environmental degradation, peace, and justice - both for those of us alive today and for the generations to come (Mhlanga, 2022; Goralski, & Tan, 2020; Singh et al., 2024). While the world continues to struggle with various challenges, the incorporation of cutting-edge technologies, particularly artificial intelligence (AI), machine learning (ML), and deep learning (DL), has unfolded as a revolutionary phenomenon (Leal Filho et al., 2023; Mercier-Laurent, 2021; Rane et al., 2024a). These technologies provide novel competencies for data processing, predictive analytics, and automated decision-making, which can greatly amplify the pursuit of the SDGs. Despite its divisiveness, the term AI is broadly used to describe any machine capable of simulating intelligent human behaviour such as problem solving, learning and adaptation. ML is a type of AI in which an algorithm modifies its own behaviour and improves its own performance according to patterns in data (Liengpunsakul, 2021; Leal Filho et al., 2023). Expanded applications with deep learning deep learning, a subset of ML, uses neural networks with many layers to identify intricate patterns in massive pools of data. The combination of these technologies can trigger a wave of change in fields like health, education, energy, agriculture, etc, and fuelling development in sustainable ways. Using ML and DL for SDG is a good technological improvement; it represents a special brief for a more inclusive and equitable development (Mhlanga, 2022; Leal Filho et al., 2023; Rane et al., 2024b). These technologies have the potential to offer creative solutions to track and assess progress on the SDGs, to get the resource to where it is needed, and to optimise existing systems for better performance (Vinuesa et al., 2020; Truby, 2020; Paramesha et al., 2024a). AI-enabled models can predict changes in the environment and suggest how to deal with these changes, and ML algorithms can be used to maximize energy utilization in smart grids or optimize diagnostic rates and treatment outcomes in healthcare using DL methods. Through comprehensive literature review, keyword and co-occurrence analysis, and cluster analysis, the purpose of this research is to investigate the role of AI, ML, and DL in SDG intervention work. To this end, we summarize relevant studies, identify recent trends and gaps, and offer a survey of the landscape and future directions of this interdisciplinary field.

Table 4.1 Sustainable development goals: objectives and description

Goal No	Goal Name	Description
1	No Poverty	End poverty in all its forms everywhere.
2	Zero Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
3	Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages.
4	Quality Education	Ensure inclusive and quality education for all and promote lifelong learning.
5	Gender Equality	Achieve gender equality and empower all women and girls.
6	Clean Water and Sanitation	Ensure access to water and sanitation for all, and manage these in a sustainable manner.
7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.
8	Decent Work and Economic Growth	Promote continuous, comprehensive, and sustained economic growth; full and productive employment; and decent work for all.
9	Industry, Innovation, and Infrastructure	Build Resilient Infrastructure that Promotes Inclusive and Sustainable Industrialization, and Foster Innovation.
10	Reduced Inequalities	Reduce inequality within and among countries.
11	Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable.
12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns.
13	Climate Action	Take urgent action to combat climate change and its impacts.
14	Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
15	Life on Land	Protect, restore, and promote the sustainable use of terrestrial and other ecosystems, sustainably manage forests, combat desertification, and stop and reverse land degradation and biodiversity loss.
16	Peace, Justice and Strong Institutions	Ensure that development is peaceful and inclusive, provide access to justice for all, and build a society with effective, accountable, and inclusive institutions at every level.
17	Partnerships for the Goals	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

As manifested in Table 4.1, the United Nations adopted the Sustainable Development Goals (SDGs) as a semblance of interventions towards global problems and paths to sustainable development. There are 17 goals covering critically relevant areas from poverty reduction and eradication and hunger ending to ensuring quality education and gender equality. The goals also discuss clean water and sanitation, affordable and clean energy, and promoting sustained economic growth and decent work for all. Other focus areas under the SDGs are building resilient infrastructure and promotion of innovation in the same, reducing inequalities within and among countries, and making cities and human settlements inclusive, safe, resilient, and sustainable. This also puts a premium on responsible consumption and production, urgency regarding climate action, conservation of marine ecosystems, and terrestrial ecosystems. The goals also seek to promote peaceful and inclusive societies, access to justice, and strong institutions by Goal 16, while global partnerships to support the implementation shall be strengthened by Goal 17. The holistic approach underlines the complex interrelation of development challenges and calls for integrated solutions to be put in place toward a sustainable and equitable future for all.

Contributions of the research work:

1) Offers an extensive inventory of the current literature for applying AI, ML, and DL to realizing the SDGs, identifies main insights and delineates research needs.
2) Detects top keywords and their patterns of co-occurrence to surface the thematic trends and focus in the research area.
3) Executes cluster analysis in order to classify and visualize different research themes connections to provide an insight onto the interdisciplinary nature of the field.

4.2 Methodology

This research analyses the role of AI, ML and DL in the context of SDGs by systematically reviewing available literature. A comprehensive search of peer-reviewed articles, conference papers, and review articles was performed to identify relevant publications present in major scientific databases: Scopus, Web of Science, and Google Scholar. The search highlighted a string of keywords along with "artificial intelligence," "machine learning," and "deep learning" as well as specific SDGs like "sustainable development goals," "poverty alleviation," "quality education," "clean energy," among others. The literature that was collected was examined by co-occurrence analysis and cluster analysis with the keyword frequency in VOSviewer software. The extraction and visualisation of the top occurring terms and the relationships between them in the dataset allowed to spot the main themes and research clusters. The clustering method resulted in coherent clusters focusing on the key areas for which the application of AI, ML, and DL for the advancement of SDGs is identified. Such a methodological approach created a

scaffold for the systematic review and synthesis of what is already known, helping to identify trends, gaps, and future directions with regard to the integration of AI technologies within the context of sustainable development.

4.3 Results and discussions

Co-occurrence and cluster analysis of the keywords

The network diagram (Fig. 4.1) is a keywords analysis, exposes the co-occurrence and clusters of these terms. The network diagram representation of edges and nodes. The nodes are important terms with the size of a node indicating the amount of each term in the dataset. Edges indicate pathways that link terms, with thicker edges corresponding to stronger relationships. The different colours in the figure represent different clusters, i.e., they group together the terms that are often found together. Key things such as sustainable development, AI, ML, and sustainable development goals are brought to the forefront in the graphic. These are just the most common terms in the data and that they should be regarded as most influential ones. The focus made on Sustainable development is in respect of the final goal of minting the three i.e., AI, technology the ML, and the thirdly, DL to churn out the desired the benefits of Sustainable Development Goals-SDG. The positive and negative points also reflect the complex character of sustainable development in three dimension as green, economy and social.

It centres around "artificial intelligence," "machine learning" and "deep learning." This indicates that a large amount of work should be done in the implementation of these higher-end technologies which can be used for the same functionalities to do for sustainability problems. It features more attention to "prediction," "neural nets," "algorithms," and "learning systems." This is advanced technological practices apparently used in their research. The network is separated into distinct clusters, with a cluster comprising a set of terms. These clusters emphasize the specific themes of the general field of AI, ML, DL and sustainable development. Phrases coming from the red cluster largely talk about integration and mashups of technologies. Essential terms that are used in these terms are artificial intelligence, internet of things, big data, blockchain, digitalization and industry 4.0. This cluster is about using state-of-the-art technology to push sustainable development further. The groups' focus on ideas such as the 'circular economy' and 'sustainability' also demonstrates the potential for these technologies to support environmental industries and economies of the future.

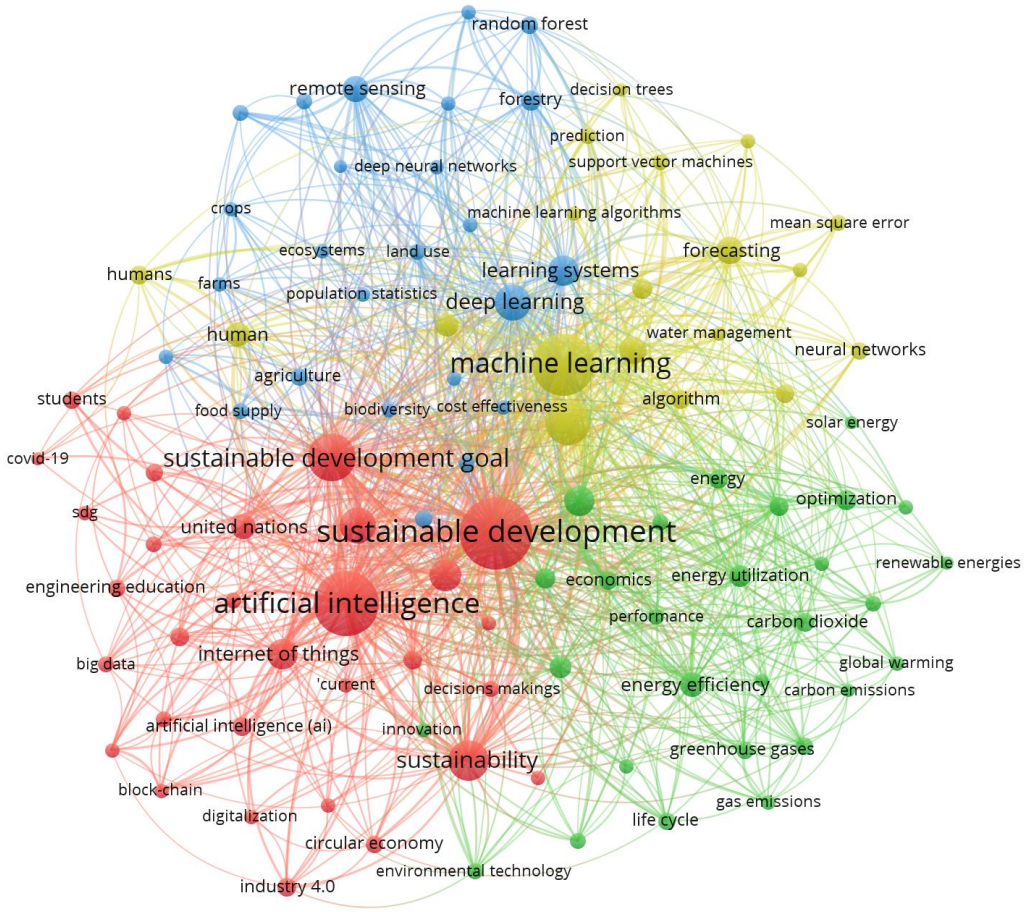

Fig. 4.1 Co-occurrence analysis of the keywords in literature

Green Cluster - Innovation in energy and environment sustainability purely from the scientific area of energy and environmental sustainability. Terms and set of words concomitant with scientific search and study are prevalent within this cluster. Subject matter goes from energy-to-energy efficiency, renewable energies, carbon dioxide, carbon emissions, greenhouse gases, global warming, etc. This research investigates the application of next-generation technological procedures, e.g., AI, ML, and DL, to improve the performance of the energy system, reduce emissions, as well as to encourage the use of renewable energy sources. This is reflected in the language used to describe these technologies - terms like "optimization" and "performance," which connotes the assumption that these technologies are employed to better the efficiency and effectiveness of environmental management techniques. The primrose cluster indicates agricultural and ecological management sentences. Consistent with this, there is a clear emphasis on using AI and ML techniques to help manage natural resources and agricultural systems, with

terms related to agriculture, crops, land use, ecosystems, biodiversity, water management, and forestry. Within this cluster we additionally identify terms such as random forest, support vector machines, and prediction, which are consecutive with the usage of generic ML techniques behind such situation.

Blue - Social Human-centered sustainable development. Similarly, including terms like human, student, education, and pandemic reflect the importance of adopting a Human-centered approach and develop greater awareness that social determinants are a key factor influencing long term outcomes. The term "engineering education" is used here to highlight the important role of education in educating the younger generation to deploy AI and ML optimally to engineer sustainable solutions. Analysis of the co-occurring terms provides us with interesting trends as to how broad the study is. This can be seen for example in the frequent pairing of the terms "sustainable development" with "artificial intelligence" and "machine learning," the implication being that these are considered important enabling tools for sustainability. The ties with other concepts like energy, optimization and renewable energies, and the like makes it evident that the innovation lies inherently in improving the Energy Systems via clever algorithms. Using the terminology often associated with sustainable development goals stresses the importance of a holistic effort required to attain these goals. The idea is for them to make progress that includes: advancements in technology, sustainable environmental practices, economic frameworks, and social factors. The terms, "sustainable development goal," "United Nations," and "SDG" have connections worldwide- between the concept and widespread, international frameworks, and policies coming out of them.

AI, ML, and DL Applications for Sustainable Development Goals (SDGs)

AI, ML and DL approaches have pushed the boundaries and in recent years have demonstrated to boost the progress of the United Nations' SDGs (Truby, 2020; Leal Filho et al., 2023). These sophisticated technologies provide powerful solutions to solve intricate global challenges, as they can make sustainable growth more inclusive to all international sectors (Mercier-Laurent, 2021; Liengpunsakul, 2021; Leal Filho et al., 2023). We can significantly improve efficiency, drive innovation, and deliver breakthrough results by folding AI, ML, and DL into SDG-specific solutions. Table 4.2 shows the AI, ML, and DL applications for SDGs.

AI, ML, and DL in agriculture is beneficial for SDG 2 (Ziesche et al., 2023). For example, smart drones and sensors are gathering real-time data on crop health, soil moisture, and weather conditions for precision agriculture (Ziesche et al., 2023; Pandey, & Pandey, 2023; Rane et al., 2024c). Through this data driven model farmers can make better decisions regards irrigating and fertilizing as well as control the spread of pests and

disease, resulting in higher yields and less waste. ML models take the prediction of these practices on to the next level, predicting how well a crop should perform, given the historic data and current conditions (Shankar et al., 2020; Pandey, & Pandey, 2023). For example, convolutional neural networks (CNNs) are used for disease detection in plants using image processing, hence acting as a predictive model for selective disease control to mitigate crop loss collectively with a strategy of early and rapid intervention. With technology, food production and distribution have become more efficient, and this is boosting food security around the world, thereby helping to eliminate hunger.

SDG 3 is good health and well-being, and AI, ML and DL are contributing to transforming the healthcare (Hameed et al., 2024). The most promising applications are of medical diagnostics. Using this technology, ML models have been trained to analyse enormous quantities of medical data - including X-ray, MRI, and CT scan images - to recognize diseases like cancer in their earliest forms (Fernandez, 2020; Hameed et al., 2024). Early detection is key for patient survival and treatment success. AI-enabled wearable devices also help to track the vital signs of patients and notify the healthcare workers before any possible health issue get downgraded to serious. Leveraging Natural Language Processing (NLP) technologies allows virtual health assistants that can provide healthcare advice, book patient appointments, and handle patient records, significantly increasing the accessibility and efficiency of healthcare services.

AI, ML, and DL are also converging rapidly to solve important sub-tasks in SDG 4, Quality Education, such as Educational Opportunities and Inequalities, Teaching, and Learning (Pedro et al., 2019; Zdravkova, 2023; Klašnja-Milićević, & Ivanović, 2021). The advent of adaptive learning software provides real-time technology analytics and personalizes learning to the student through the use of integrated data and learning analytics. Serving this universe of aspiring, learning minds, AI-driven platforms can determine individual students progress giving, and recommend further improvements to ensure everyone gets the required support they deserve. Additionally, these technologies enable distance learning, eliminating distance constraints and allowing quality education to reach students globally (Zdravkova, 2023; Klašnja-Milićević, & Ivanović, 2021). Interactive and engaging learnings experiences with intelligent tutoring systems powered by ML-Intelligent tutoring systems that leverage ML offer more interactive learning experiences, and in the long run, help students understand complex concepts better.

Improved water management and sanitation systems will aid AI, ML, and DL-based applications to also benefit SDG 6, Clean Water and Sanitation (Xu et al., 2020; Nti et al., 2023). Artificial intelligence-based software processes sensor data from water distribution networks in real-time to identify leaks, monitor consumption, and enable resource planning (Xu et al., 2020). This is the technologies also help to monitor water quality by

identifying contaminants and predict upcoming pollution events. The researchers believe that ML models can be used to help create efficient waste-treatment processes that have a smaller environmental footprint while shaping the best ways to use water in a sustainable manner. AI, ML, and DL help to improve the performance, effectiveness and reliability of water management systems thereby making a great contribution to effective access to clean water and sanitation at an affordable price for all.

Table 4.2 AI, ML, and DL applications for SDGs

References	SDG	Application	Description	Techniques
Mhlanga, (2021); Mhlanga, (2023)	No Poverty	Financial Inclusion	Using AI to provide financial services to underserved populations, enhancing economic opportunities.	Natural Language Processing (NLP), Credit Scoring Algorithms
Ziesche et al., (2023) Pandey, & Pandey, (2023)	Zero Hunger	Precision Agriculture	Utilizing ML algorithms for crop monitoring, yield prediction, and pest control to increase productivity.	Computer Vision, Remote Sensing, Predictive Analytics
Fernandez, (2020); Hameed et al., (2024)	Good Health and Well-being	Predictive Healthcare	Employing DL models to predict disease outbreaks and patient outcomes, improving healthcare delivery.	Neural Networks, Time Series Analysis, Electronic Health Records (EHR) Analysis
Pedro et al., (2019); Zdravkova, (2023) Klašnja-Milićević, & Ivanović, (2021)	Quality Education	Personalized Learning	Implementing AI-driven personalized learning platforms to cater to individual student needs.	Recommender Systems, Adaptive Learning Algorithms, Intelligent Tutoring Systems
Patón-Romero	Gender Equality	Bias Detection in Recruitment	Using AI to identify and	Fairness Algorithms, NLP

(2022); Lütz, (2023)			mitigate gender biases in hiring processes, promoting equal opportunities.	for Resume Screening, Bias Mitigation Techniques
Xu et al., (2020); Nti et al., (2023)	Clean Water and Sanitation	Water Quality Monitoring	Applying IoT and AI to monitor and ensure the quality of water sources.	IoT Sensors, Anomaly Detection, Real-Time Data Analytics
Ponnusamy et al., (2021); Jayachandran et al., (2022)	Affordable and Clean Energy	Smart Grid Management	Utilizing AI for optimizing energy distribution and integrating renewable energy sources.	Demand Forecasting, Energy Optimization Algorithms, Reinforcement Learning
Beltozar-Clemente et al., (2023); Leal Filho et al., (2021)	Decent Work and Economic Growth	Workforce Automation and Skill Development	Implementing AI to automate routine tasks and provide training for new job skills.	Robotic Process Automation (RPA), Skill Gap Analysis, e-Learning Platforms
Mhlanga, (2021); Regona et al., (2024)	Industry, Innovation, and Infrastructure	Predictive Maintenance for Infrastructure	Using ML algorithms to predict maintenance needs for infrastructure, reducing downtime and costs.	Predictive Analytics, IoT Data Streams, Fault Detection Algorithms
Bachmann et al., (2022); Goralski, & Tan, (2023)	Reduced Inequalities	Accessibility Tools	Creating AI-powered tools to assist individuals with disabilities, enhancing accessibility.	Speech Recognition, Text-to-Speech, Computer Vision for Sign Language Interpretation
Leal Filho et al., (2024); Ismagiloiva et al., (2019);	Sustainable Cities and Communities	Smart City Solutions	Applying AI for efficient urban planning, traffic management, and	Smart Sensors, Traffic Flow Optimization,

Schwarz-Herion, et al., (2019)			resource allocation.	Urban Planning Algorithms
Ivanov et al., (2024); Kulkov et al., (2023)	Responsible Consumption and Production	Waste Management Solutions	Using AI to optimize waste collection routes and recycling processes.	Route Optimization, Image Recognition for Waste Sorting, IoT for Waste Level Monitoring
Kumari, & Pandey, (2023); Sahil et al., (2023)	Climate Action	Climate Modeling and Prediction	Employing DL models to predict climate changes and assess environmental impact.	Climate Simulation Models, Neural Networks for Pattern Recognition, Big Data Analytics
Isabelle, & Westerlund, (2022); Ahmad, (2023)	Life Below Water	Marine Life Monitoring	Utilizing AI for monitoring marine biodiversity and health.	Underwater Drones, Image Recognition, Acoustic Signal Processing
Isabelle, & Westerlund, 2022); Kumari, & Pandey, (2023)	Life on Land	Wildlife Conservation	Applying ML for tracking and protecting endangered species.	GPS Tracking, Predictive Modeling, Computer Vision for Species Identification
Breczko et al., (2021); Tripathi, & Saxena, (2024); Mhlanga, (2022)	Peace, Justice, and Strong Institutions	Crime Prevention and Legal Analysis	Using AI to predict and prevent crime, and analyze legal documents for better judicial outcomes.	Predictive Policing, NLP for Legal Document Analysis, Anomaly Detection
Pigola et al., (2021); Singh et al., (2024)	Partnerships for the Goals	Global Collaboration Platforms	Leveraging AI to enhance global cooperation and data sharing for achieving SDGs.	Data Integration Platforms, Collaboration Tools, Blockchain for Secure Data Sharing

SDG 7-Affordable and Clean Energy in the optimization of energy production, distribution, and consumption. AI algorithms can be found in the field of renewable energy system, for instance, predicting energy generation from photovoltaics and wind, allowing for better integration of renewable power generation into the power grid and thus increasing the reliability of energy supply (Ponnusamy et al., 2021; Jayachandran et al., 2022; Paramesha et al., 2024b). Energy storage solutions can be optimized using ML models, guaranteeing a supply and demand free of renewable energy wasted (Singh et al., 2024; Hannanet al., 2021; Paramesha et al., 2024c). Furthermore, smart grids that are AI-driven also operate in real-time to control energy demand and supply bringing down a lot of energy waste along with the costs. As key enablers, these technologies are essential for the energy transition, and for contributing to a mitigation of climate change. AI, ML, and DL are contributing by improving city planning and development; thus, aiding SDG 11, Sustainable Cities and Communities (Leal Filho et al., 2024; Ismagiloiva et al., 2019; Schwarz-Herion, et al., 2019). AI-based technologies use all these different data sources - from satellite imagery to social media and sensor data - to build evidence and inform city planning and development. These technologies will help us design smart, resilient, and sustainable cities that can accommodate the growing numbers of men, women, and children who want to live in towns and cities. This could include AI algorithms that optimize public transportation systems so that they are less congested and everyone gets around more effortlessly. ML-based models are also being used to predict and reduce the occurrence of natural hazards, increasing self-sufficiency and greener communities.

Significant impacts from AI, ML, and DL for SDG 13 Climate Action, are achieved in environmental monitoring and climate modelling (Kumari, & Pandey, 2023; Sahil et al., 2023). The data gathered by satellites, scientists and AI-powered systems have the ability to predict weather patterns, measure and detect deforestation, and quantify the impact of climate change. It uses ML algorithms to design efficient carbon footprint reduction and resource conservation strategies. Which allows more concrete and timely responses to climate-induced problems, foots the bill for the global effort to mitigate climate change, and helps us with global climate adaptation. Governance and transparency can also we increase by AI, ML, DL so it also contributes to SDG 16, Peace, Justice, and Strong Institutions (Breczko et al., 2021; Mhlanga, 2022; Paramesha et al., 2024d). By analysing data (often in the form of Big Data) for corruption and detecting fraud patterns of abuse, AI enabled platforms have helped in reducing the opacity surrounding corruption processes placed undue pressure on the government, thereby increasing transparency and accountability into public agency operations. In crime prediction and resource distribution: ML models can predict what the next crime would be using data from various sources and enable rational resource allocation, supporting law enforcement agencies in the prevention and investigation of crimes. They also improve access to justice with the

legal assistance that AI-driven chatbots and virtual assistants can deliver, enabling people to manoeuvre legal systems more effectively.

Integrating AI, ML, and DL with Internet of Things (IoT) and Big Data for SDGs

IoT is the device connects to each other to transfer the data between them. For instance, these devices which include sensors spread across agricultural fields, smart meters in homes, collect huge amount of data which can be further totalled up for running meaningful insights into it. IoT allows for resource monitoring and management, enhances efficiency, and delivers real-time data for effective decision making (Goundar et al., 2022; Teh, & Rana, 2023). In the arena of sustainable development, the IoT has the ability to keep tabs on environmental conditions, monitor energy usage, and better organize waste management (Maksimovic, 2018; Rane, 2023). For instance, IoT sensors can monitor real-time water quantity and quality, which would enable efficient water management and also reduce the water scarcity. IoT devices can also be used to monitor soil conditions, climate changes and crop health, which could be a great help in agriculture which can make the operations more effective and can lead to a higher yield.

The term Big Data is the large data that is generated from every possible electronic device such as IoT devices, services like social media, and records created within enterprise systems as well. Decision making and sustainable development are effective through proper processing and analysis of this data (Allam, & Dhunny, 2019; AlZubi, & Galyna, 2023; Paramesha et al., 2024e). For policy makers, businesses, and for researchers Big Data analytics unlocks new patterns and trends that were previously undiscoverable. Big Data provides real-time monitoring and forecasting of environmental changes, as well as of progress relating to the SDGs, which it uses to distribute resources as efficiently as possible for sustainable development. For example, transforming data collected through varied sources can help in spotting the places at greatest risk due to climate change and in designing appropriate interventions. Big Data in healthcare can be used to track disease outbreaks and risk factors, so that targeted preventive and viable treatment strategies can be put in place.

Combining these technologies in the ecosystem not only aids in increasing the efficiency of each technology but drives the overall sustainable growth with AI, ML, DL, IoT, and Big Data integration (Goundar et al., 2022; Teh, & Rana, 2023; Januszewski, & Żółtowski, 2023). The integration allows to collect data in real-time, run advanced analytics and informed decision perspective leading to better and efficient solutions in achieving SDGs. In smart cities, for example, integration enables IoT devices to gather data on traffic, air quality, energy consumption and so on. This data is then analysed by

AI and ML algorithms to reduce traffic congestion, decrease pollution, and ensure energy efficiency. Apart from enriching residents' lives, it complements SDGs on affordable and clean energy, sustainable cities and communities, climate action.

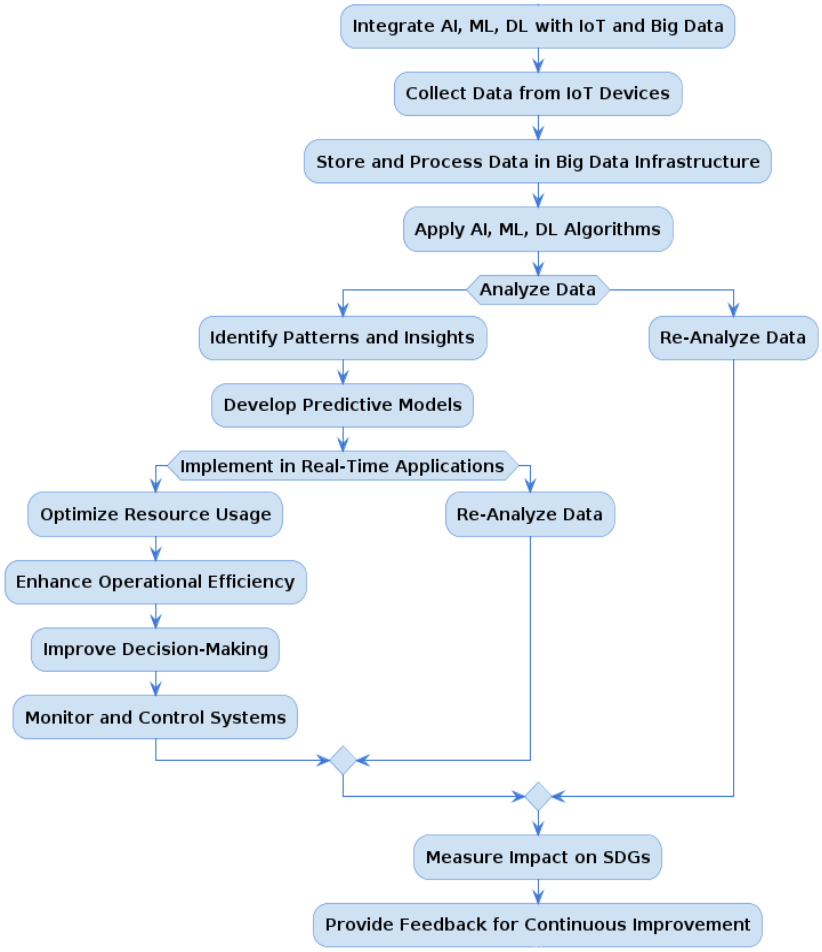

Fig. 4.2 A conceptual integration of AI, ML, and DL with the Internet of Things (IoT) and Big Data

Combining these technologies simultaneously in agriculture will lead to better farming practices and sustainability. Data from IoT sensors about the soil, weather information, crop health etc., then used by AI and ML algorithms that analyse this data and model it to provide real-time recommendations regarding irrigation, fertilization, and pest control which in turn can ensure that the resources are utilized effectively and also increase the crop yield. This aligns with SDGs such as: Zero Hunger, Clean Water and Sanitation, and Responsible Consumption and Production. Their integration can lead to better patient

outcomes for less cost in the healthcare sector. Through real-time monitoring of patients' vital signs by IoT devices, with AI and ML algorithms, health issues can be detected early and their future complications can be predicted. Which ultimately leads to treatment on time and personalization in treatment plans and becomes a significant contributor to SDGs of good health and well-being.

Fig. 4.2 shows a conceptual integration of AI, ML, and DL with the Internet of Things (IoT) and Big Data for better decision-making and performance efficiencies. It started with AI, ML, DL Integration with IoT, Big Data Technology. The data is collected by the first step which deals with many IoT devices constantly producing vast amounts of data. It is then stored and further processed in a Big Data infrastructure in order to be able to access and manage it. After that, the pre-processed data is used for AI, ML, and DL algorithms to get meaningful insights. Analysis is the most important stage of procedure. The system can recognize patterns and insights and then build predictive models, provided data analysis was successful. Such models are crucial to predict the future and take decisions. The subsequent step consists in the demonstration of the models in real-time applications. It also entails saving resources, working better, getting better information, and monitoring and controlling. Real-time implementations fail to achieve results, so the data is re-analysed and the model is re-learned, repeating the process till accuracy improves. If the interpretation of the data fails at first, a re-analysis step refines the process. The last steps of the process are accounting for impact on SDGs and feedback for constant improvement. This feedback loop is part of what ensures the system evolves and adapts over time and helps create better outcomes and more efficient systems.

The comparative bar chart depicts statistical summaries of the following six global regions: East and South Asia, Eastern Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, The OECD countries, and Sub-Saharan Africa. The dispersion diagram shows a side-by-side comparison for seven observed metrics for categories such as the mean, standard deviation, minimum 25th percentile, median or 50th percentile, 75th percentile, and maximum values. It is straightforward to notice from the graph that OECD countries always perform better than other regions in many metrics, mostly their mean values, which generally portray higher development and stability. Again, Sub-Saharan Africa has both the lowest mean and maximum values, indicating some difficulties in terms of developmental efforts. It had a relatively high standard deviation, thus demonstrating more excellent dispersion within the region. Eastern Europe and Central Asia, together with Latin America and the Caribbean, occupy intermediate levels of performance. Standard deviations for these latter two regions are lower—an indication of more homogeneous development. The Middle East and North Africa are better than Sub-Saharan Africa but worse than OECD countries-a clear case of divergence

in developmental outcomes. Whereas the dispersion of values within sub-Saharan Africa regarding indicators is relatively narrow, that for East and South Asia is more expansive because the region holds both the minimum and maximum values, which seem to point toward significant intra-regional discrepancies.

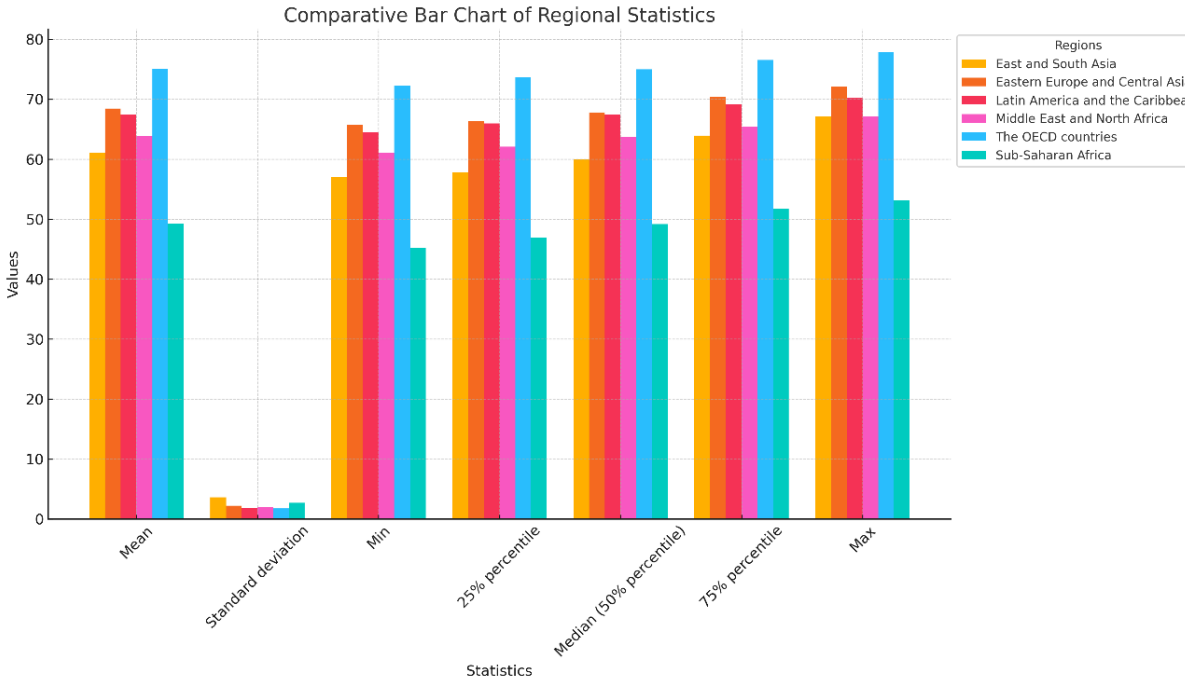

Fig. 4.3 Comparative analysis of regional development statistics

Another case of variability to take notice of would be within standard deviations across regions. It would again highlight sub-Saharan Africa, particularly alongside East and South Asia, as highly variable relative to the OECD countries that have performed much more stably. The Fig. 4.3 broadly underlines the vast disparities between development indicators across regions, showing that these gaps are one place where targeted efforts and international cooperation could be squarely placed.

4.4 Conclusions

The widespread implementation of AI, ML and DL technologies are essential to addressing the SDGs across multiple sectors. The promise of an advanced technology is transformation in end-to-end processes, efficiencies, and innovations it brings. On the backdrop of sustainable development, AI, ML, and DL provide wonderful solutions to imperative needs of the human kind including resource management, environmental

conservation and social equity. Industries leverage the power of AI and ML for energy efficiency, to cut waste, and to lower carbon footprints, thus playing a critical role in environmental sustainability (SDGs 7 and 13). Predictive analytics methods using ML algorithms have facilitated the optimization of energy consumption, and deep learning models have been used to manage renewable energy solar and wind power resources with a more accurate forecasting and maintenance scheduling. Importantly, AI-driven solutions contribute to advancing SDG 9 (Industry, Innovation, and Infrastructure) through the promotion of intelligent manufacturing processes. From automated quality control, predictive maintenance, and supply chain optimization, production can be made more productive and operational costs reduced across the board. These digital versions of systems, often referred to as AI-powered digital twins, provided simultaneously real-time operational monitoring and allowed for corresponding real-time operational decision-making, to maintain the industrial operation resiliently adaptive to changing circumstances. AI and ML are also changing the way agriculture is practiced, helping to meet the targets outlined in SDG 2 (Zero Hunger) by increasing productivity (better crop yields) and resource saving, as well as making farming greener. Thanks to AI-backed precision agriculture, farmers can use intelligent tools to have data-backed decisions to drive food security and sustainability. In health care, AI and DL applications achieve several goals of SDG 3 (Good Health and well-being) - such as early disease diagnosis, personalized treatment plans, and the effective robotic delivery of healthcare. It aids in creating new diagnostic tools and improves the provision of healthcare and quality services, especially in the remote areas. The strategic application of these technologies will be key to sustainable, equitable and fully engaged with global efforts for sustainable development.

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