

Artificial Intelligence Strategies in Confronting Climate Change

استراتيجيات الذكاء الاصطناعي في مواجهة تغيرات المناخ

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Abstract:

Climate changes occurring in the layers of the atmosphere represent one of the greatest environmental challenges facing humanity today, due to their negative impacts on environmental, economic, and social levels. Therefore, countries are increasingly cooperating and coordinating their efforts to confront these challenges, overcome them, and mitigate the negative effects resulting from them.

Most countries have sought to adopt new policies, particularly the use of artificial intelligence within economic policies. This approach represents a strategic step toward employing advanced technologies effectively in order to reduce the impacts of climate change and contribute to achieving sustainable environmental development.

Keywords: Climate Change, Environmental Sustainability, Natural Resources, Artificial Intelligence.

الملخص:

تعتبر التغيرات المناخية التي تحدث في طبقات الغلاف الجوي من أكبر التحديات البيئية التي تواجه البشرية في هذه الآونة، لما لها من انعكاسات سلبية على المستوى البيئي والاقتصادي والاجتماعي، ولذلك فإن الدول تتكاتف فيما بينها وتتعاقد من أجل مجابهة تلك التحديات والتغلب عليها والتخفيف من حدة الآثار السلبية الناتجة عنها.

فقد سعت معظم الدول الى انتاج سياسة جديدة كالذكاء الاصطناعي في السياسات الاقتصادية فهي تعد خطوة استراتيجية نحو توظيفها بفعالية للتقليل أثار تغيرات المناخ والمساهمة تحقيق تنمية بيئية مستدامة.

الكلمات المفتاحية: تغيير المناخ، الاستدامة البيئية، الموارد الطبيعية، الذكاء الاصطناعي.

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Introduction:

Climate change issues—as the fundamental and common framework for successive human generations—have become some of the most concerning and preoccupying topics for states both internationally and nationally. This follows the unprecedented deterioration and decline witnessed by vital systems and elements across various regions of the world. In the face of this grave environmental situation, multifaceted debates and questions have intensified regarding the causes and drivers of this phenomenon, as well as the extent of modern man's ability to confront it and control its impacts. These phenomena have accelerated in terms of time and space, with complex causes and intertwined effects.

Despite the magnitude of the problem, technology offers new solutions and hope. Chief among these solutions is Artificial Intelligence (AI), which emerges as a powerful tool for understanding climate change and working toward mitigating its effects and adapting to them.

The power of AI lies in its ability to process vast amounts of data, discover patterns, and make predictions across various fields—such as industry, medicine, energy, and agriculture—and has now reached the environmental sector, performing faster than humans ever could. It has also been employed to enhance sustainable development efforts, monitor environmental risks, and guide climate policies.

The importance of this study stems from the fact that it addresses a dual-natured topic: the environmental field, characterized by its vital and strategic nature, and the field of Artificial Intelligence, as an advanced technical tool. This is driven by the urgent need to find scientific solutions capable of effectively dealing with the phenomenon of climate change, especially in light of growing global environmental challenges.

In this context, this research aims to shed light on the relationship between Artificial Intelligence and climate change. It seeks to bridge theoretical and practical dimensions and analyze how this modern technology can be utilized in air quality monitoring and emission prediction to ensure a better life.

In light of the above, we can pose the following problem: **To what extent is the employment of Artificial Intelligence strategies effective in confronting climate change?**

This problem will be addressed through the following two chapters:

- **Chapter One:** Basic Concepts of Climate Change and Artificial Intelligence.
- **Chapter Two:** Artificial Intelligence in Confronting Environmental Problems and Climate Change.

Chapter One: Basic Concepts of Climate Change and Artificial Intelligence

Climate change is one of the most prominent challenges facing humanity in the 21st century, due to the serious repercussions it leaves on environmental, economic, and social levels—particularly regarding natural resources and the stability of ecosystems.

Conversely, Artificial Intelligence represents one of the most prominent modern scientific innovations, with its immense capacity to process Big Data and provide solutions to complex challenges, such as climate change. This is achieved through the development of prediction and planning tools to establish effective strategies for adaptation and mitigation of damage.

Accordingly, we will attempt through this chapter to address the concept of climate change and its causes (**Section One**) and the essence of Artificial Intelligence (**Section Two**).

Section One: The Concept of Climate Change

The issue of climate change is considered one of the most prominent topics on the international stage, posing a challenge to all of humanity. This phenomenon is no longer confined to the biological and ecological scientific spheres; rather, it has become comprehensive, affecting all vital sectors in both developed and developing countries due to its various dimensions and impacts on diverse fields¹. Interest in monitoring the phenomenon of climate change began at the end of the 19th century, after climate scientists noticed a continuous shift in the climate that would negatively impact the planet and human lifestyles².

We will address the concept of climate change (**Subsection One**), followed by the causes of climate change (**Subsection Two**).

Subsection One: Definition of Climate Change

In this subsection, we will define climate change, while the factors contributing to it will be clarified in the second subsection.

¹ Fathi Maifi, The Impact of Climate Change on Food Security in Sub-Saharan Africa, Scientific Horizons Journal, Vol. 11, No. 4, 2019, p. 371.

² Abidi Mohamed, Effects of Climate Change on Human Security and Human Rights, Journal of Law and Human Sciences, Vol. 9, No. 1, 2015, p. 196.

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First: Defining Climate Change Within this subsection, we will define climate change, but first, we will clarify what climate is and the difference between climate and weather.

A: Definition of Climate There are numerous definitions of climate that differ in structure but generally agree in meaning. In its narrow sense, climate refers to the description of the atmospheric state over a long period of time¹. In its broad sense, it encompasses the general state of the atmosphere in a specific region for a long period, which may exceed a month or a single season, or the permanent state of the atmosphere².

The broad definition includes many details within the climate, as it is the average distribution of climatic elements: solar radiation, temperature, pressure, wind, precipitation, humidity, and air masses. It even adds certain climatic phenomena such as cloudiness and dust storms. Furthermore, climate relies on range and variance to demonstrate the nature of the climatic element³.

As for the climate system, the 1992 United Nations Framework Convention on Climate Change (UNFCCC) defined it as: "the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions"⁴.

Climatology, meanwhile, is the science that studies, describes, analyzes, and correlates the aforementioned climatic elements over periods that may be long or short⁵.

B: Distinction Between Climate and Weather The terms "weather" and "climate" are overlapping geographical terms linked by close relationships, sharing the basic elements from which they are composed (solar radiation, temperature, atmospheric pressure, wind, humidity, and forms of condensation). They also share the accompanying weather and climatic phenomena that form in the atmosphere, and both rely on recordings available at local and international meteorological stations.

Due to this connection and overlap in the elements they both address within the atmosphere, it is imperative for a student of climate and weather geography to understand the difference between them¹.

¹ Abidi Mohamed, Previous Reference, p. 195.

² Bahaa Ahmed Al-Abd, Scientific Foundations in the Study of Weather and Climate, 1st Edition, Janadriya for Publishing and Distribution, 2016, p. 9.

³ Qusay Abdul Majeed Al-Samarrai, Climate and Climatic Regions, Dar Al-Yazouri for Publishing and Distribution, 2020, p. 12.

⁴ Amari Houria, The Impact of Climate Change Threats on Environmental Security, PhD Thesis, Faculty of Law and Political Science, Ibn Khaldun University, Tiaret, 2019/2020, p. 30.

⁵ Qusay Abdul Majeed Al-Samarrai, Previous Reference, p. 13.

Weather is the state of the atmosphere in a particular place during a short period, which may be within a single day or for several days, including the prediction of its state². Climate, on the other hand, examines the "personality" of the weather or its general behavior that prevails in each month of the year throughout the years of observation³.

Thus, weather is the instantaneous state of the atmosphere, while climate is the average frequency of phenomena and their geographical distribution. Climatology is the means by which these phenomena are studied and analyzed—that is, it attempts to find a scientific explanation for their variations⁴.

In legal and academic scholarship, climate change is defined as: "A change occurring in average temperatures, wind patterns, and rainfall rates over time, whether resulting from natural fluctuations or human activities"⁵.

The United Nations Framework Convention on Climate Change (UNFCCC), in Article 1, Paragraph 2, defined it as: "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"⁶.

The Intergovernmental Panel on Climate Change (IPCC) defined it as: "All forms of changes that can be expressed by a statistical description, which can persist for successive decades, resulting from human activity or from internal interactions of the climate system components"⁷.

Second: Causes of Climate Change

A scientific consensus regarding the cause of climate change was not reached immediately, as scientific opinions split into two groups: the first attributes the causes of climate change to human activity, while the second considers it a natural phenomenon⁸.

¹ Kayed Khalid Abdul Salam, *Climate Change in the World*, 1st Edition, Janadriya for Publishing and Distribution, 2015, p. 15.

² Bahaa Ahmed Al-Abd, Previous Reference, p. 8.

³ Ibid., p. 9.

⁴ Qusay Abdul Majeed Al-Samarrai, *Principles of Weather and Climate*, Dar Al-Yazouri Scientific for Publishing and Distribution, 2020, p. 13.

⁵ Ben Ayad Jalila, Habbani Kamal, *The Impact of Climate Change on Environmental Security*, Journal of Scientific Research in Environmental Legislation, Vol. 12, No. 1, 2022, p. 45.

⁶ Ben Mahra Nassima, Laaroussi Ahmed, *Combating Climate Change in Algerian Environmental Legislation*, Journal of Research in Law and Political Science, Vol. 9, No. 1, 2023, p. 86.

⁷ Amira Abdel Azim Adani, *Climate Change and Sustainable Development in Light of Public International Law*, 1st Edition, Dar Al-Nahda Al-Arabia for Publishing and Distribution, Cairo, 2022, pp. 10-11.

⁸ Amari Houria, Previous Reference, p. 45.

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A: Arguments of those attributing climate change to human activity

This school attributes the causes of climate change to unprecedented human activity, which is considered the primary culprit for environmental pollution. Their theory relies on scientific analysis to prove the impact of carbon dioxide¹.

Proponents of this view believe that the Industrial Revolution—and the resulting increased dependence on chlorofluorocarbons (CFCs) and the use of fossil fuels (coal, oil, and natural gas)—caused an increase in the volume of gaseous emissions in the atmosphere, particularly: methane, nitrous oxide, and carbon dioxide (\$CO_2\$). The latter is considered the primary driver of the greenhouse effect, as its concentration in the atmosphere has risen above natural levels². Scientists have agreed that carbon dioxide levels remained somewhat stable at approximately 280 parts per million (ppm) for a thousand years before 1800. Since then, with industrial development and the use of fossil fuels, the ratios began to rise, reaching 370 ppm³.

B: Arguments of those attributing climate change to natural factors

Supporters of the "Natural School" consider the phenomenon of climate change to be nothing more than a cosmic phenomenon, noting that the climate has experienced changes over varying periods of time⁴. Proponents of this direction argue that the global warming phenomenon is due to natural factors, though they differ in the scientific explanation. They justify this view with the fact that during times when greenhouse gases were not present, temperatures witnessed a rise, particularly between the years 900 and 1100 AD. Furthermore, temperatures rose in the early 19th century until the mid-1940s, and quickly declined in the early 1970s, despite the rise in gaseous emissions⁵.

Section Two: The Concept of Artificial Intelligence

Artificial Intelligence (AI) is considered one of the most prominent technical achievements witnessed by the world during the last decade. It has transitioned from the realm of theoretical and laboratory research to practical application fields, encompassing various sectors such as industry, education, and transport, as well as environmental development policies.

¹ Abidi Mohamed, Previous Reference, p. 197. (Note: This refers to the historical temperature fluctuations mentioned in the text).

² Ibid., same page.

³ Abidi Mohamed, Previous Reference, p. 197.

⁴ Habib Maalouf, The Issue of Global Climate Change between Kyoto Failures and Paris Expectations, 1st Edition, Dar Al-Farabi, Beirut, 2016, pp. 13-14.

⁵ Amira Abdel Azim Adani, Climate Change and Sustainable Development in Light of Public International Law, Dar Al-Nahda Al-Arabia, Cairo, 2023, p. 116.

To understand this technology more accurately, we must examine and identify it by defining Artificial Intelligence (**Subsection One**) and then outlining the types of Artificial Intelligence (**Subsection Two**).

Subsection One: Definition of Artificial Intelligence

To understand the developmental role that AI has come to play in our current era, we must first determine its precise meaning. Definitions have varied according to the perspective from which it is viewed:

- Some view it as: "A branch of computer science that aims to design systems capable of performing tasks that usually require a degree of human intelligence, such as understanding, learning, and logical reasoning."
- Others consider it a simulation of human behavior through the development of algorithms and machine models capable of decision-making and problem-solving in a manner distinct from human performance¹.

Academic definitions of AI have differed depending on the angle of approach. Researcher John McCarthy, one of the pioneers of the field, defined it as: "The science and engineering of making intelligent machines." This definition focuses on the engineering and programming dimensions.

Meanwhile, the European Commission defined it as: "Systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals"².

From a procedural perspective, it can be said that: "Artificial Intelligence is an integrated system of mathematical methods and advanced algorithms that produce and process vast amounts of data with high efficiency, extracting patterns and hidden relationships that humans might not easily discover. This system is based on several fundamental pillars, most notably:

- Analyzing Big Data to extract accurate indicators for decision-making.
- Self-learning through gradual performance improvement based on experience and practice without direct human intervention.
- Dynamic interaction with the environment in a way that allows for the development of harmonious responses"³.

¹ John McCarthy, What is Artificial Intelligence?, Stanford University, 2007.

² European Commission, Ethics Guidelines for Trustworthy AI, Brussels, 2019, p. 5.

³ Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, Translated by the Center for Studies, Cairo, 2020, p. 112.

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Today, Artificial Intelligence has become an integral part of the global technological environment, as its use has expanded across several sectors, most notably:

1. **In Medicine:** Through early diagnosis of diseases by analyzing X-rays and MRI scans, and suggesting individual treatment protocols tailored to the patient's condition.
2. **In Education:** Developing smart educational systems that personalize content according to each learner and adopting automated assessment based on individual performance analysis.
3. **In Security:** Facial recognition systems, real-time analysis of massive video data, and the detection of crimes and financial fraud.
4. **In the Environment:** Monitoring air and water pollution levels, predicting natural disasters such as floods and fires, and supporting sustainable development projects¹.

Subsection Two: Classifications of Artificial Intelligence

Classifications of Artificial Intelligence vary according to the criteria adopted, highlighting its varying levels from simplicity to technical complexity. These classifications can be confined to two main paths: the first is based on cognitive capabilities and the extent to which the human mind is simulated in learning and decision-making, while the second focuses on functional scope and practical applications such as language processing and data analysis. Accordingly, this subsection will be addressed through: Classification by General Capabilities (**First**) and Classification by Functions and Technical Characteristics (**Second**).

First: Classification Based on General Capabilities

Classification based on general capabilities represents a fundamental pillar in Artificial Intelligence literature. It is based on measuring the developmental level of technical systems and comparing them to human intelligence in functions of learning, inference, and decision-making. This taxonomic perspective crystallizes through three essential levels:

A - Narrow AI: This type represents the most dominant technical model currently. These are specialized systems designed to perform exclusive and specific tasks; they lack self-awareness and remain restricted by the limits of

¹Wafaa Fawwaz Al-Maliki, Applications of Artificial Intelligence in Enhancing Educational Strategies in Higher Education (Literature Review), Journal of Educational and Technical Sciences, Arab Foundation for Science and Research Publishing, Vol. 7, No. 2, 2023, p. 39.

their programming and data scope, making them unable to adapt to contexts outside their specialization¹.

A-1 Strategic Value and Applications: Its importance lies in surpassing human capabilities in terms of speed, accuracy, and cost reduction. Its applications are evident in:

- **Digital Assistants:** Such as (Siri) and (Alexa), which rely on Natural Language Processing (NLP)².
- **Machine Translation:** Like the (Google Translate) model, which relies on Deep Learning for self-improvement³.
- **Computer Vision:** Used in security systems, precise medical diagnosis, and digital content organization⁴.

B - General AI: General AI, or "Strong AI," is the ultimate ambition for computer scientists. It aims to create systems possessing comprehensive cognitive capabilities that rival the human mind in critical thinking, creativity, and emotional intelligence. While it currently remains in the theoretical and research phase, institutions like MIT and Stanford are working on developing its first foundations⁵. This type is expected to represent a radical shift in the course of humanity through:

- **Medical Field:** Creating precise treatment protocols for incurable diseases by analyzing genetic maps.
- **Educational System:** Establishing the pillars of "Adaptive Learning," which tailors cognitive content according to a student's readiness⁶.
- **Environmental Issues:** Building superior predictive models to confront climate change. This development raises legal and ethical questions regarding "decision responsibility," necessitating the formulation of international regulatory frameworks to ensure its outputs align with human values and rights⁷.

¹ James Manyika et al., "AI in Health Care: The Hope, the Hype, the Promise, the Peril," McKinsey Global Institute Report, 2020, p. 17.

² Tahani Al-Sulami, "Artificial Intelligence and its Impact on E-commerce in the Kingdom of Saudi Arabia," Arab Journal of Administration, Vol. 45, No. 3, 2025, p. 67.

³ Nguyen, Tu, "Recommender Systems in E-Commerce: Applications and Trends," International Journal of Computer Science, Vol. 15, No. 3, 2020, p. 44.

⁴ Abd al-Salam Muhammad, Artificial Intelligence and its Applications, International for Scientific Books, Cairo, Egypt, 2018, p. 112.

⁵ Brynjolfsson, Erik, & McAfee, Andrew. The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. New York: W. W. Norton & Company, 2014, p. 68.

⁶ Tegmark, Max. Life 3.0: Being Human in the Age of Artificial Intelligence. New York: Alfred A. Knopf, 2017, p. 103.

⁷ World Economic Forum. (2023). Global Risks Report. Geneva: WEF.

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C - Super AI: Superintelligence represents the pinnacle of technical evolution and the most controversial, as it surpasses human capabilities in innovation, complex inference, and future prediction. It is unique in its ability to develop its own algorithms independently of direct human intervention¹. This stage raises fundamental fears regarding the loss of human control, as well as warnings of radical economic shifts that may eliminate traditional labor, and security risks including digital wars and autonomous weapons².

Second: Classification Based on Functions and Technical Characteristics

This classification depends on the nature of the tasks the intelligent system is programmed to perform and its ability to interact with the surrounding environment. It is one of the most common classifications in modern studies on Artificial Intelligence. It is divided into the following levels:

A: Reactive Machines: Reactive machines are the simplest models of AI. Their operation relies on immediate responses to current inputs without the ability to form a memory or benefit from past experiences. IBM's (Deep Blue) computer stands out as the most famous historical model of this type, as it succeeded in defeating the chess champion "Garry Kasparov" in 1997 by analyzing the possibilities of the moment with extreme precision, despite its complete lack of the property of learning from the past³.

B: Limited Memory AI: Limited Memory AI is characterized by the ability to link momentary data with stored experiences to enhance decision-making efficiency. This is evident in self-driving cars that predict hazards by retrieving nearby observational data, and in financial analysis and medical diagnosis that rely on analyzing historical patterns of records to ensure the accuracy of results⁴.

Third: Theory of Mind:

Theory of Mind represents a future goal that aspires to innovate systems that perceive human emotions and intentions, ensuring a smoother interaction between humans and machines. This stage requires a deep integration between cognitive psychology and natural language processing

¹ Bostrom, N. (2014). *Superintelligence: Paths, Dangers, Strategies*. Oxford University Press.

² Russell, S., & Norvig, P. (2016). *Artificial Intelligence: A Modern Approach*. Pearson.

³ Lakhel Mohamed, "Economy, Health, and Agriculture in the Shadows of Artificial Intelligence," *Journal of the Institute of Economic Sciences: Journal of Economic, Management and Trade Sciences*, Vol. 26, No. 2, 2023, p. 21.

⁴ Scherer, M. (2016). 'Regulating Artificial Intelligence Systems.' *Harvard Journal of Law & Technology*.

to understand social contexts. Its early signs are currently appearing in prototypes such as social and educational robots, and elderly care systems designed to simulate emotional responses¹.

Fourth: Self-Aware AI:

This level represents the pinnacle of technical development and the most complex, where machines are supposed to reach the stage of "self-awareness" and possess an independent consciousness of their feelings and existence. Although it is currently within the realm of science fiction, it raises fundamental questions about:

- **Legal Identity:** The extent to which it is possible to grant the machine rights or classify it as an independent moral entity².
- **Proactive Protection:** The escalation of calls to establish strict legal frameworks that ensure the alignment of these entities with human interests and the protection of core human values before they become a reality³.

The Second Section: Artificial Intelligence in Confronting Environmental Problems and Climate Change

Based on the concepts of climate change and artificial intelligence established in the first section, the research now moves towards the applied approach to review the essential role of these technologies in confronting environmental crises. Artificial Intelligence is no longer just a technical luxury; it has become a fundamental pillar for global sustainability, given its superior ability to improve resource management and foresee natural disasters with accuracy that ensures the reduction of economic and human repercussions.

In light of the qualitative leaps in predictive big data analysis, this section seeks to identify practical applications that contribute to decoding complex climate phenomena and providing solutions to reduce carbon emissions. This is what we addressed through two subsections: AI applications in environmental management and climate change forecasting (First Subsection), and the most prominent AI applications in tackling climate change (Second Subsection).

¹ Feil-Seifer, D., & Mataric, M. (2018). 'Socially Assistive Robotics.' Annual Review of Biomedical Engineering.

² Bostrom, N. (2014). Superintelligence: Paths, Dangers, Strategies. Oxford University Press.

³ UNESCO, Report "Ethics and Artificial Intelligence," Paris, 2020.

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First Subsection: Applications of Artificial Intelligence in Environmental Management and Change Forecasting

Artificial Intelligence (AI) is considered one of the most prominent technical leaps in the current era. It has proven highly efficient in addressing the escalating environmental challenges resulting from accelerating human activities. In light of rising greenhouse gas emissions and the erosion of natural resources, a need has emerged for innovative tools to restore the balance between the requirements of sustainable development and the protection of ecosystems.

In this context, the pivotal role of AI emerges in analyzing big data and modeling climate forecasts with high accuracy, enabling decision-makers to anticipate risks and develop effective adaptation policies. Accordingly, this section is dedicated to deconstructing these roles through two branches; the first branch addresses AI applications in enhancing sustainability, while the second focuses on AI as a tool for forecasting climate changes and natural disasters.

Branch One: Applications of Artificial Intelligence in Environmental Sustainability

Current environmental and climate crises have imposed unprecedented challenges on societies and nations, making the employment of AI an inevitable necessity to strengthen the pillars of environmental sustainability. The importance of machine learning algorithms lies in their superior ability to improve pollution monitoring systems and reduce emissions, as well as the role of predictive models in formulating smart and sustainable city plans.

First: AI as a Tool for Advanced Monitoring and Analysis

AI has emerged as an advanced technical solution to raise the efficiency of air quality assessment, particularly in tracking Carbon Dioxide (CO₂) as the primary cause of global warming¹. These technologies rely on the algorithms' superior capability to process and analyze big data derived from heterogeneous sources, including:

- Fixed ground monitoring stations.
- Smart and portable sensors.
- Satellite imagery and spatial data.

¹ Jha, S. et al., "Artificial Intelligence in Air Pollution Monitoring: A Review."

Given that this data is often overlapping or irregular, AI represents the ideal means to transform it into accurate and actionable information.

Second: Predictive Modeling and Pattern Detection

Scientific studies have proven that the employment of Artificial Neural Networks (ANN) and Deep Learning techniques allows for the detection of complex emission patterns and the identification of pollution hotspots and sources with extreme precision¹. Furthermore, Long Short-Term Memory (LSTM) network models have shown exceptional effectiveness in analyzing time series of environmental data, enabling the prediction of future emission trajectories and changes in air quality. This supports proactive environmental decision-making at both local and international levels².

Third: Preventive Intervention and Energy Efficiency Optimization

The role of AI does not stop at monitoring; it extends to preventive operations. Intelligent systems have been developed capable of early detection of gas leaks and irregular emissions in industrial facilities, thereby reducing the scale of environmental losses. Additionally, integrating AI with energy management systems contributes to lowering energy consumption and reducing the carbon footprint of institutions, in line with international obligations stemming from the 2015 Paris Climate Agreement³.

On the urban environment level, smart sensor networks linked to AI algorithms have become a fundamental pillar for real-time pollutant monitoring, issuing instantaneous warnings to residents when safe levels are exceeded⁴. Simulation models also contribute to understanding the dynamics of pollutant dispersion based on wind movement and meteorology, supporting the planning of sustainable cities and the establishment of "Low-Emission Zones."

Fourth: International Models and Experiences

International experiences confirm the efficacy of these technologies. China has adopted smart platforms to analyze industrial pollution, leading to a significant reduction in sulfur dioxide levels⁵. In the European Union, the **Copernicus** program stands out, utilizing Artificial Intelligence to analyze

¹ Goodfellow, I., Bengio, Y., & Courville, A., Deep Learning, MIT Press, 2016, p. 45.

² Zeinalipour, K. et al., "Application of Machine Learning Models for Carbon Monoxide and Nitrogen Oxides Emission Prediction," arXiv, 2025, p. 2.

³ Alatalo, T. et al., "Reducing Emissions Using Artificial Intelligence," Applied Sciences, Vol. 15, No. 2, 2025.

⁴ Lee, J. et al., "Smart Sensors and AI in Urban Air Quality Management," Journal of Cleaner Production, 2021.

⁵ Liu, Q. et al., "AI Applications in Industrial Pollution Reduction in China," Environmental Science & Technology, 2021.

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satellite imagery to enhance environmental oversight and monitor atmospheric emissions with high precision¹.

Fifth: Challenges and Future Prospects

Despite the numerous advantages, AI applications in this field face fundamental challenges, most notably:²

1. Scarcity of accurate and reliable data in some developing countries.
2. High costs of the infrastructure required to operate smart monitoring systems.
3. Difficulty of technical models in adapting to sudden climate changes or emergency industrial accidents.
4. The urgent need to enhance international cooperation in sharing environmental data.

Branch Two: Artificial Intelligence as a Tool for Forecasting Climate Changes and Natural Disasters Artificial Intelligence has become one of the essential technical pillars in the field of climate forecasting and disaster monitoring, given its superior ability to process "**Big Climate Data**" with extreme speed and accuracy. This development contributes to raising the efficiency of early warning systems and formulating proactive response plans that reduce the scale of human and material losses.

First: Deep Neural Networks (DNN) These are considered among the most prominent technologies in short-term forecasting (from hours to a few days). They simulate the functioning of the human brain through layers of artificial nodes to extract non-linear relationships between weather elements such as temperature, atmospheric pressure, and wind speed.³ They are characterized by their ability to absorb and process vast amounts of data at a speed exceeding classical statistical models.⁴ A study by the Indian Institute of Technology (2021) showed that using these networks improved the accuracy of monsoon rain forecasting by **12%**. Furthermore, global centers such as the **European Centre for Medium-Range Weather Forecasts (ECMWF)** have adopted these technologies as part of the digital transformation to confront extreme weather phenomena⁵.

¹ Khan, M. et al., "Challenges of AI in Environmental Applications," Sustainability, 2022.

² World Economic Forum, Harnessing Artificial Intelligence for the Earth, Geneva, 2018.

³ Goodfellow, I., et al., Deep Learning, MIT Press, 2016, p. 125

⁴ Reichstein, M., et al., "Deep learning and process understanding for data-driven Earth system science," Nature, Vol. 566, 2019.

⁵ ECMWF Annual Report 2022, Reading, UK, p. 42.

Second: Long Short-Term Memory (LSTM) Networks These were specifically developed to process **Time Series Data**, making them ideal for forecasting extended medium and long-term climate phenomena¹. Their strength lies in their ability to store important information for long periods and recall it to link the past temporal context with the present².

These networks have proven their superiority in predicting floods, droughts, and heatwaves. A Chinese study (2022) indicated that the **LSTM** model outperformed traditional (**ARIMA**) models by **25%** in rainfall prediction accuracy³. Furthermore, Arab Gulf states have begun adopting these models to confront the challenges of water scarcity and drought.

Third: Convolutional Neural Networks (CNN) These networks are renowned for their high capability in image analysis, making them a central tool in processing satellite imagery and weather radars⁴. They extract precise visual features such as cloud shapes, density, and hurricane paths. The **European Space Agency (ESA)** utilizes **CNN** models to improve the speed of predicting tropical storm trajectories, providing critical time for taking preventive measures⁵. They are also used to track polar ice melt and monitor vegetation cover.

Fourth: Hybrid Models These represent the latest trend by merging multiple intelligent models (such as combining **CNN** with **LSTM**) or integrating intelligent models with traditional physical models. This approach combines the flexibility of AI in data analysis with the discipline of the physical laws of thermodynamics. The **GraphCast** model, developed by **Google DeepMind** (2023), is considered a revolution in this field; it provides accurate ten-day forecasts in mere seconds, with quality comparable to the best global models, while significantly reducing the massive computational costs required by traditional models⁶.

Second Subsection: Prominent Forms of Artificial Intelligence in Tackling Climate Change Artificial Intelligence has become a pivotal scientific tool that has fundamentally transformed strategies for dealing with contemporary environmental and climate challenges, particularly in facing the steady rise in temperatures, the frequency of natural disasters, and the degradation of ecosystems. The core strength of these technologies lies in

¹ ESCWA, Innovation and Technology for Sustainable Development 2030, Beirut, 2019.

² Mohammed Rabie, Physical Geography: Climate and Regions, Dar Al-Fikr Al-Jamia'i, 2012.

³ Li, Y., et al., "Rainfall Prediction Using LSTM Model," Atmosphere, Vol. 13, 2022.

⁴ Abu Zaid Mohamed, Op. Cit., p. 105.

⁵ ESA, *AI for Earth Observation: Early Warning Systems Report*, 2021.

⁶ Lam, R., et al., "GraphCast: Learning Skillful Medium-Range Global Weather Forecasting," Nature, Vol. 623, 2023.

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their superior ability to analyze big climate data, build sophisticated early warning systems, and formulate effective sustainability models aimed at reducing risks and protecting natural resources. Accordingly, this section focuses on studying two fundamental aspects: **(Branch One)** AI techniques for reducing environmental pollution, and **(Branch Two)** AI applications in natural resource management.

Branch One: AI Techniques for Reducing Environmental Pollution

Environmental pollution is one of the most serious challenges threatening human health and the stability of natural systems, in addition to its fundamental role in exacerbating the climate change crisis. In this context, Artificial Intelligence has provided innovative solutions to address this dilemma by accurately monitoring pollutants, analyzing complex environmental data, and predicting emission sources before they occur, making it a central tool for supporting the transition toward a sustainable, low-carbon green economy.

First: Environmental Analysis Using Artificial Intelligence Techniques

Artificial Intelligence (AI) techniques have brought about a qualitative revolution in the environmental monitoring and analysis system, becoming a fundamental pillar for understanding changing environmental dynamics. Their importance is manifested in the superior ability to process Big Data flowing from meteorological stations, satellites, and smart sensors deployed across urban, industrial, and agricultural sectors. This enables the identification of pollution sources, their dispersion patterns, and their health impacts with high objective accuracy.

1. Algorithms and Machine Learning in Pollution Detection:

These technologies rely on machine learning algorithms, such as Artificial Neural Networks and Classification & Clustering algorithms, which allow for the detection of complex relationships between environmental variables. Examples include linking gas emission density to population growth or intensive industrial activity. This deep analysis assists decision-makers in adopting proactive strategies to reduce pollutants rather than merely relying on subsequent treatment¹.

2. Internet of Things (IoT) and Real-Time Monitoring:

AI is employed in monitoring air and water quality through digital platforms supported by the Internet of Things. Smart sensors collect real-time data on concentrations of pollutants such as Sulfur Dioxide (\$SO_2\$),

¹ Mounir Saleh, Op. Cit., p. 67.

Nitrogen Oxides (NO_x), and fine particulate matter¹. This data is sent to advanced systems that analyze it in real-time, issuing immediate alerts to authorities and citizens when safe limits are exceeded.

3. Computer Vision and Water Resource Protection:

In the field of the marine environment, Computer Vision techniques are used to monitor oil spills and the accumulation of plastic waste through the analysis of satellite imagery and Unmanned Aerial Vehicles (Drones). This enhances response speed to minimize environmental and economic losses.

4. Existing Challenges:

Despite these promising horizons, these trends face obstacles represented by²:

- The scarcity of accurate local data in some developing countries.
- The high cost of technical infrastructure.
- The urgent need for human cadres that combine environmental expertise with data science.

Branch Two: Artificial Intelligence Applications in Natural Resource Management

Natural resource management is the cornerstone of achieving sustainable development, especially in light of escalating environmental pressures resulting from climate change and the overexploitation of vital resources. Artificial Intelligence has provided strategic tools for monitoring these resources and optimizing their utilization through the intelligent analysis of big data and accurate prediction of future transformations.

First: Water Quality Monitoring via Artificial Intelligence Techniques

The employment of Artificial Intelligence (AI) in monitoring water quality represents a qualitative leap that ensures accurate and real-time tracking of water purity levels, overcoming the limitations of traditional laboratory testing. This system is based on a network of sensors distributed across strategic locations (such as rivers, dams, and treatment plants), which measure vital indicators including temperature, turbidity, pH levels, and the concentration of heavy metals and dissolved oxygen.

¹ Sami Al-Khatib, "Artificial Intelligence as a Tool to Combat Environmental Pollution," Arab Journal of Environmental Sciences, Issue 12, 2021, p. 77.

² Khaled Al-Zoubi, "Smart Technologies in the Face of Climate Change," Environmental Studies Journal, University of Damascus, Issue 6, 2022.

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1. Real-time Analysis and Early Warning: This data is transmitted instantaneously via the Industrial Internet of Things (**IIoT**) to analytical platforms processed by deep learning algorithms. This allows for the detection of any deviation from approved environmental standards¹. The operational strength of these systems lies in issuing proactive warnings when early signs of pollution are detected; they also integrate with Geographic Information Systems (**GIS**) to create precise maps of pollution sources².

2. Contribution to Automated Reporting: These systems contribute to generating "accurate automated reports" valid for use in environmental litigation, thereby reinforcing the "polluter pays" principle. Countries such as Germany and India have applied this approach to monitor rivers and predict failures in treatment plants³.

3. The Algerian Context and Strategic Necessity: In Algeria, there is an urgent need to adopt these solutions, especially given the challenges facing waterways such as "**Oued El Harrach**" in the capital or "**Oued M'zab**" in Ghardaia, where industrial and domestic sewage intersect. Integrating smart monitoring is not merely a technical luxury but a means to activate Algerian legal texts and ensure the protection of water resources from depletion and pollution⁴.

Second: Forecasting Droughts and Floods Using Artificial Intelligence

Predicting hydrological disasters is one of the most prominent successes of AI in environmental risk management. These systems rely on processing time-series data of precipitation, soil moisture, and river flow.

1. Advanced Predictive Models: Recurrent Neural Networks (**RNN**), particularly **LSTM** models, are considered the most effective tools for monitoring gradual changes leading to drought. Conversely, Convolutional Neural Networks (**CNN**) are used to analyze satellite imagery and detect abnormal water accumulations or desertification encroachment. This helped India, for example, reduce the losses from the "Kerala" floods in 2018⁵.

¹ Abdelkader Quraishi, *Artificial Intelligence and its Environmental Applications*, Dar Al-Khaldounia, Algeria, 2021, p. 118.

² Huda Bin Youssef, "Remote Sensing Technology in Water Resource Management," *Journal of Environmental Sciences*, University of Constantine, 2020.

³ Fatima Zahra Shams El-Din, "Artificial Intelligence and Water Monitoring: Global Experiences," *Journal of Sustainable Development*, Cairo University, 2022.

⁴ Samir Brahimi, "Protection of Water Resources in Algeria: Reality and Challenges," *Journal of Law and Environment*, University of Algiers 1, 2023.

⁵ Ahmed Mansour Al-Ali, *Op. Cit.*, p. 92.

2. Probabilistic Modeling and the Precautionary Principle: These algorithms are integrated with traditional hydrological models to simulate stream capacity and surface runoff volume¹. Probabilistic learning models (such as Bayesian modeling) provide quantitative estimates of the likelihood of a disaster. This establishes the "**Precautionary Principle**" in environmental legislation, allowing authorities to make sovereign decisions such as declaring a state of emergency or the immediate evacuation of threatened areas².

Conclusion:

Climate change constitutes one of the most prominent challenges threatening the future of all humanity, given its direct and indirect impacts on environmental, economic, and social balances across various countries of the world, without distinction between developed and developing nations. This complex phenomenon has become the "topic of the hour" due to the repercussions it carries that threaten the stability of ecosystems, as well as water and food security.

Faced with this distressed reality, a need has emerged for sophisticated mechanisms that transcend traditional obstacles, allowing for an understanding of climate change dynamics and proactive prediction with accuracy and efficiency. Among the most important of these mechanisms is Artificial Intelligence (AI), as an advanced technological tool capable of absorbing massive amounts of climate data.

AI has proven effective in:

- **Protecting biodiversity** by tracking endangered species through the analysis of environmental behaviors.
- **Monitoring climate phenomena** and analyzing their indicators with precision and clarity, providing a clearer picture for decision-makers.
- **Improving air quality** by monitoring carbon emissions and urban pollution, and providing instantaneous solutions.

Through the theoretical study conducted, we have reached a set of results, the most important of which are:

- Artificial Intelligence can effectively contribute to achieving the **Sustainable Development Goals (SDGs)**, particularly in the field of future environmental planning.

¹ Samira Ben Salem, Op. Cit., p. 65.

² Nawal Boujehar, Op. Cit., p. 74.

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- Climate changes result from a complex interaction between **natural factors** (such as solar cycles and volcanoes) and **human factors** (industrial activities, deforestation, etc.).
- The employment of AI enables the development of **early warning systems** to mitigate the human and economic damages resulting from natural disasters.
- The necessity of **encouraging scientific research** in universities regarding the relationship between the environment and modern technology, especially Artificial Intelligence.
- **Generalizing the use of AI** within bodies tasked with environmental management, particularly at the level of municipalities and provincial directorates (Wilayas).

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