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AI for Climate Change and Sustainability

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Abstract

Climate change stands as one of the most significant existential threats of the 21st century, with far-reaching impacts on ecosystems, economies, and the well-being of humanity. Despite the existence of global awareness and policy frameworks, such as the Paris Agreement, efforts for effective mitigation and adaptation are still progressing at a slow and inadequate pace. In this landscape, Artificial Intelligence (AI) has emerged as a transformative technology that holds the potential to tackle climate-related challenges on a large scale. This paper investigates the ways in which AI can aid in climate change mitigation, adaptation, and sustainability across diverse sectors. We start by delving into the scientific foundations and socioeconomic ramifications of climate change to establish a comprehensive understanding of the crisis at hand. Following this, we examine the contributions of AI in various areas, including climate modeling, predictive analytics, early warning systems, agricultural practices, land management, and disaster response mechanisms. Case studies from the real world illustrate successful applications of AI in fields such as renewable energy management, intelligent urban infrastructure, and ecosystem monitoring. Nevertheless, we also critically assess the shortcomings of existing AI systems, with particular emphasis on challenges related to data quality, algorithmic bias, and ethical considerations in deployment. The paper advocates for the advancement of AI systems that are less biased, more inclusive, and incorporate human judgment, ensuring alignment with planetary health objectives and supporting informed decision-making in regions that are particularly vulnerable. By integrating developments in AI and climate science, this research provides a multi-faceted perspective on how intelligent systems can enhance climate resilience and sustainability initiatives. While AI alone is not a panacea, when developed with care and applied ethically, it can be instrumental in fostering a more sustainable future.

Keywords : Artificial Intelligence (AI), climate modeling, intelligent systems, agricultural practices, land management, disaster response mechanisms

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1. Introduction to AI and Climate Change

Climate change, like the COVID-19 crisis, is one of the biggest global crises humanity has ever faced. An unprecedented increase in global temperature, pollution levels, and destruction of the biodiversity that is the foundation of our Earth's life-support systems is the clearest and most dangerous warning signal that our civilization, as we know it, is simply not sustainable [1]. Yet, despite the repeated awareness, acceptance, and condemnation of climate change on a governmental level with the Paris Agreement, collective action is very slow. After more than 25 years of deliberation about the climate challenge, the situation is exactly the same as it was 30 years ago before the global climate conferences in Rio de Janeiro and Kyoto. Rather than taking the necessary steps to mitigate climate change, the world continues on a path to more and more pollution, and the carbon intensity of the world's economy has been increasing rather than decreasing.

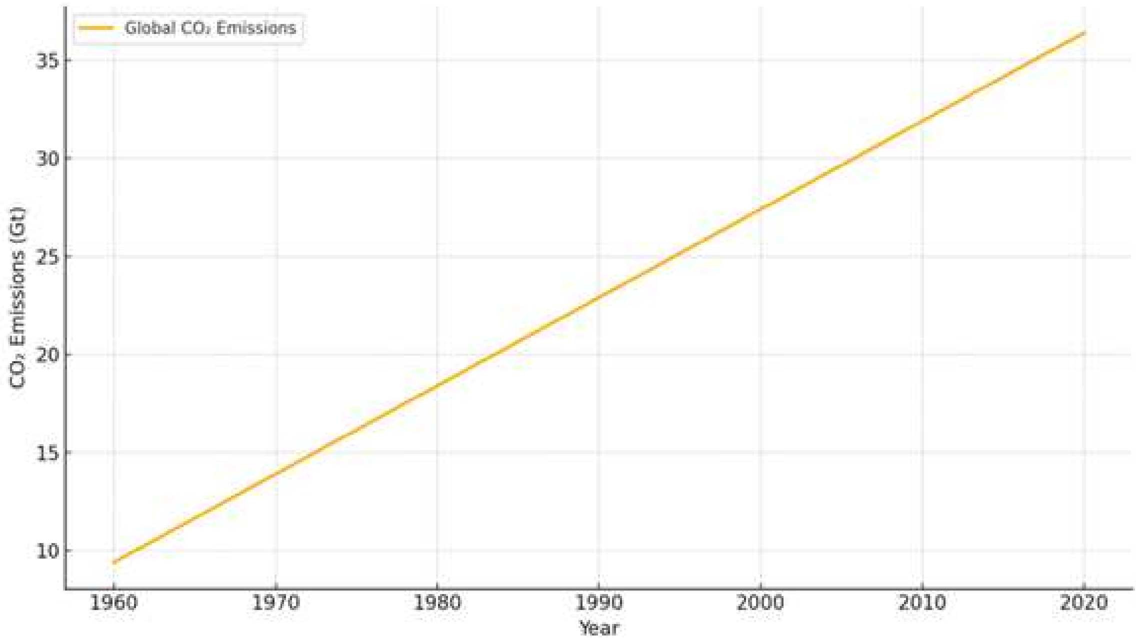

Fig 1 : Global CO_2 Emissions Trend (1960 – 2020)

A large number of technological innovations and steps are desperately needed immediately to give humanity a fighting chance to avert the environmental catastrophe[1]. Such technological innovations must help either to drastically reduce emissions and pollution or to rapidly and massively remove CO2, methane, NOx, and plastic from the atmosphere, oceans, and land. Artificial Intelligence (AI) is currently by far the most rapidly growing technological domain[2]. AI is not a panacea for climate change and will not provide a silver bullet at the touch of a button. Nevertheless, there are indications that it can exert a positive influence on, and steer what little remains of the transition

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towards a sustainable society[1,3]. This implies restricting the development of existing AI applications that can intensify environmental degradation, and at the same time stimulating and prioritizing the development of new AI applications that can help avert climate change[2,3].

2. Understanding Climate Change

To understand climate change, students first learn the basic science behind it. In order to increase understanding of some of the forces behind climate change, students learn about the carbon cycle and atmospheric carbon dioxide trends. The greenhouse effect is the next important physical phenomenon behind climate change, followed by an analysis of different fuel types. The week concludes with an inquiry activity in which students analyze how the fuel type impacts carbon dioxide emissions. The second half of the unit is aimed at deepening students' understanding of climate change. The analysis of climate change policy is a pivotal activity in this section, since policy uses the groundwork set in the first week while also integrating social issues. The unit begins with an exploration of ecosystems using local data, since it highlights how climate change is expected to impact the region around the students[4]. Students investigate how their behaviors and local policies impact the local environment. The unit concludes with an exploration of equity in dealing with climate change[5]. Students learn about the implications of being a developing country in a world where climate change must be dealt with. A Student Choice and Voice activity is included for the final couple of days, allowing the students to work on an idea of their own pertaining to climate change. The curriculum was carefully designed with respect to the science content in order to engage students with climate change in a meaningful way. It was structured to give background knowledge and understanding of scientific phenomena before dealing with deeper issues, allowing students to have enough grounding to be informed about potential solutions and policy, as well as societal issues related to climate change. During the formative and summative assessments involved in the curriculum, it was overwhelmingly evident that climate change is a difficult topic to teach, especially to the target population of students. However, it is possible to engage students while allowing them to have their own input and explore the topic on their own.

2.1. The Science of Climate Change

Climate change threatens the basis of life on Earth. Anthropogenic influences, e.g., via fossil fuel combustion, land-use change, etc., dominated 20th century climate change, and have already affected the environment in ways that a few decades ago would have seemed impossible. The reports explain the current knowledge about climate change, its impacts, and what can be done to reduce

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future change. At the same time, the climate crisis is widely perceived as an unsolved problem; known solutions are not implemented or insufficiently implemented [1]. The information context in the wider society does not enable or support sufficiently effective collective action.

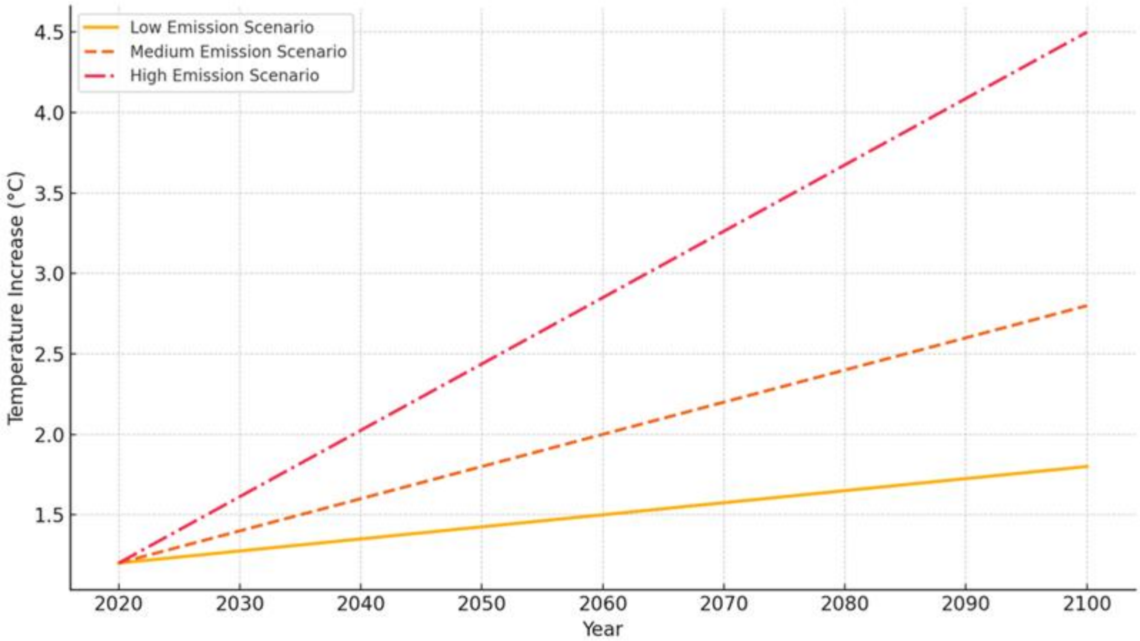

Fig 2 : Projected Global Temperature Increase (2020 – 2100)

Even when the transport, energy, and industrial sectors will be decarbonized and defossilized, ocean acids will still increase. Even when greenhouse gas emissions will be stopped and started to be reversed, the current level of greenhouse gas concentrations will raise temperatures for many years if not centuries. Current emissions levels and atmospheric carbon dioxide concentration levels predict increases in global average temperature that are at least equivalent to a four to five degrees Centigrade increase with the risk of breaking the tipping point of the climate system. It is plausibly expected that most humanity will become vulnerable to destruction (in every high pollution emission scenario by the end of this century) via uninhabitable regions, severe dry spells or flooding episodes in geographies that were reasonable prior to the climate crisis. As the COVID-19 crisis highlights the problem of a relatively strong and coordinated temporary action to solve a serious global problem, a strong coordinated and long-term worldwide action to outsmart the profit incentives trying to preserve an unsustainable situation is arguably even more urgent[4,5].

There are two approaches to which AI technologies can positively influence the transition towards a more sustainable society. The first is to make a more effective stewardship of the environment possible. AI algorithms can improve

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the predictions of climate models and refine those estimates. AI can facilitate the measurement of environmental factors. Ambient devices such as phones or wearables (or specific devices such as CO2, noise, etc., measurement devices) become increasingly cheap and advanced, enabling improved, crowd-sourced, and cheaper measurements of the environment.

2.2. Impact of Climate Change on Ecosystems

Climate change may pose a high risk of change to Earth's ecosystems: shifting climatic boundaries may induce changes in the biogeochemical functioning and structures of ecosystems that render it difficult for endemic plant and animal species to survive in their current habitats. These shifts may be regulated by a complex interplay of ecosystem structure and management potentials [8]. At the same time, the fundamental biogeochemical properties of vegetation, such as initialization carbon content or distribution of maximal carboxylation capacities, are believed to be more resilient to change [7]. Here, changes in the biogeochemical ecosystem state are aggregated as a proxy for the risk of these shifts at different levels of global warming [4]. It uses model simulations in combination with biogeochemical models of the terrestrial carbon cycle to calculate changes in vegetation states and fundamental ecosystem properties related to the biogeochemical coupling of modeled vegetation and climate.

5–19% of the naturally vegetated land surface is projected to be at risk of severe ecosystem change at 2 ◦C of global warming above 1980–2010 levels. At this level, pronounced shifts in biome distribution are projected in boreal North America and Eurasia, while the subtropical and tropical biomes are more resilient to change. For the set of models with a narrow range of projections for climatic change, the extent of regions at risk of severe ecosystem change is projected to rise with 1GMT, approximately doubling between 1GMT = 2 and 3 ◦C, and reaching a median value of 35% of the naturally vegetated land surface for 1GMT = 4 ◦C [4].

The bio geophysical and biogeochemical functioning of recently archived vegetation is projected to be remarkably stable and resilient [7]. Multi-model climate change impact assessment studies in earth system and integrated assessment modelling require a high level of coordination between modelling groups [4,8]. Nonetheless, efforts to assess changes in a major aspect of the climatic systems - ecosystem functioning - at the global scale have been undertaken to date. The modelling of climate change impacts on ecosystem functioning at the global scale requires a high level of coordination between modelling groups. In this study, a first step towards filling this gap is suggested

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by assessing changes in ecosystem states, fundamental biogeochemical properties and the risk of shifts in these properties responsible for changes in the biogeochemical coupling of climate and vegetation based on the assumptions that these properties can be more resilient to change than their dynamical counterparts and that both switching and transmission rates of these changes can be linked to the risk that they happen.

2.3. Socioeconomic Consequences of Climate Change

Climate change has been identified as a fundamental threat to sustainability in the 21st century, because the changing climate has serious implications for, and impacts on, the wellbeing of people and the natural environment [2]. The focus of the climate change problem is shifting from whether climate change is real to understanding the implications of this reality, recognizing that time is running out for society to mitigate the impacts of climate change. In this transition from the “if” to the “so what” of climate change, the timing of climate change, the nature of its impacts, and the vulnerabilities that it creates are becoming more relevant, perceptible and tractable [3]. At the same time, there is an increasing recognition of human responsibility for climate change and the associated obligations to take mitigation and adaptation action, however challenging this may be.

Climate change is also a complex system risk, defined as a risk in which feedbacks, interactions and non-linearities create nuances of system dynamics. It is a slow onset threat that can shift the climate outside of a region’s historical envelope, which will not happen uniformly within the climate system. Changes may start in one region while the rest remain stable. Climate change implies changes in average conditions, but changes in extreme weather events can also be of primary concern and are much more difficult to evaluate [4,6]. For example, there is a general increasing trend in the likelihood of extreme weather events from climate models, including floods, droughts, storms and heat waves[9]. These uncertainties in the onset, nature and potential distributions of climate change impacts limit the understandings of processes inducing the risks and harms associated with climate change[6].

3. The Role of AI in Addressing Climate Change

In synthetic biology, model systems can be created that easily change and develop along directed pathways. A model system can exemplify how a rich ecosystem forms from simple building blocks, and discuss the role of evolutionary processes in this formation. Biological life is often viewed as repulsive due to its basic tenacity and expansionary mode. Understanding how living systems form also sheds light on the transition from a vigorous biosphere to a stable planet. While AI systems are present in every corner of life, they are

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modeled on past decision-making systems, making their operation, as well as their potential for human civilization, relatively easy to understand. The question remains whether human civilization can be transferred to a similar information-regulating system with less coherence. This may entail synthesizing the near future with a digitized replication of the current well-structured world. The evolved pattern could then form the basis of a favorable impact on the behavior of existing generations through monitoring and improved decision-making. It is likely that an existential risk threshold would need to be crossed that parallels the industrial revolution of the 1800s [1]. The ongoing global race for bigger and better artificial intelligence (AI) systems is expected to have a profound societal and environmental impact [4]. As witnessed in the past few years, and accelerated by the release of ChatGPT, AI is expected to alter job markets, enable new governance structures or regulatory frameworks, and affect the global consensus for pathways to climate action or mitigation. However, current AI systems and their general diffusion are trained on biased datasets that might destabilize political agencies or legitimate institutions, hence jeopardizing climate change mitigation and adaptation decisions. Thus, the appropriate design of an AI system with a less biased dataset that reflects both the direct and indirect effects on the societies and planetary challenges is a question of paramount importance.

3.1. AI Technologies for Climate Modeling

It is increasingly recognized that climate change and the loss of biodiversity have far-reaching implications for public health, food security, and the economic prospects, especially of the most vulnerable countries and populations [4]. To mitigate or adapt to the impacts of climate change and biodiversity loss, there is a need to conceive and implement an unprecedented level of concerted human action across scales and sectors ranging from individuals to international agreements. However, existing governance and societal welfare systems are often misaligned with these goals due to deep-rooted societal and political inequalities, vested interests in polluting industries, and the epistemic barriers to trust arising from the complexity and long time frames of proposed mitigation and adaptation measures. These issues render projections of the climate crisis and related narratives and knowledge far more uncertain and wildly divergent than in traditional policy arenas. An appropriate design of less biased AI systems that reflect both direct and indirect effects on societies and on related planetary challenges is therefore a question of paramount importance.

Given the massive data on actions and systemic consequences, an AI-augmented epistemic web with human-in-the-loop oversight is proposed, which combines human and machine intelligence for the co-design of less biased AI systems and appreciably lower uncertainties in climate-related governance systems and

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outcomes [2]. Such a less biased AI is co-aligned with an epistemic web on planetary health challenges through relevant on-modeling, timely and adaptive multi-agent training with demonstration-proof backtracking [9]. Such a human-in-the-loop AI is capable of unfoldingly transitioning from the relatively simpler phase of aligning culpable narratives and knowledge with feasible AI, to the far more ambitious phase of direct mitigation and adaptation interventions based on causal knowledge of social tipping elements. The reduction of the violent injustices associated with current AI pretraining datasets is pursued by the cocreation of less biased meta-AI by data-wise egalitarian and epistemically equitable communities [2,3].

3.2. Predictive Analytics and Climate Forecasting

Africa is regarded as the continent with the highest climate risks with high climate extremes and low adaptive capacity. For instance, country representatives at the UN Climate Change Conference have warned about the imminent doom of Madagascar, which has frequently come under the attack of powerful cyclones that cause massive damages on food crops and infrastructure. Consequently, many inhabitants of Madagascar are left homeless, and the cyclone created a ripple effect across the Indian Ocean islands, affecting food supply across the Indian ocean islands, the east coast of Africa, and augmenting fever infections, particularly COVID-19 [5]. Extreme and unpredictable weather events wreak a more significant toll on the vulnerable nation as the socio-economic impact reaches larger portions of the populace. Essentially, predictive and safe weather is imperative to aid farmers' decisions on sowing climate-resilient crops for productivity and sustainability.

A very accurate prediction of the Australian fires that rendered thousands of lives and homes could have curbed it. A forecast about how much rain would cause cyclones in many West African nations as well as where this rainfall would fall, would have helped farmers to start farming by planting early maturing crops. The extent of precipitation and how it would affect the seasons could have informed irrigation and ploughing management. Likewise, a decade ago, a forecast about a time period where an influx of rains would elicit flooding in Kumasi and Accra in Ghana could have informed accurate sand lifting and the construction of better, guided drains [9,10]. Therefore, real-time forecasting products and designing small, easily interpretable analysis components will help enhance communities from forecast to climate resilience [2].

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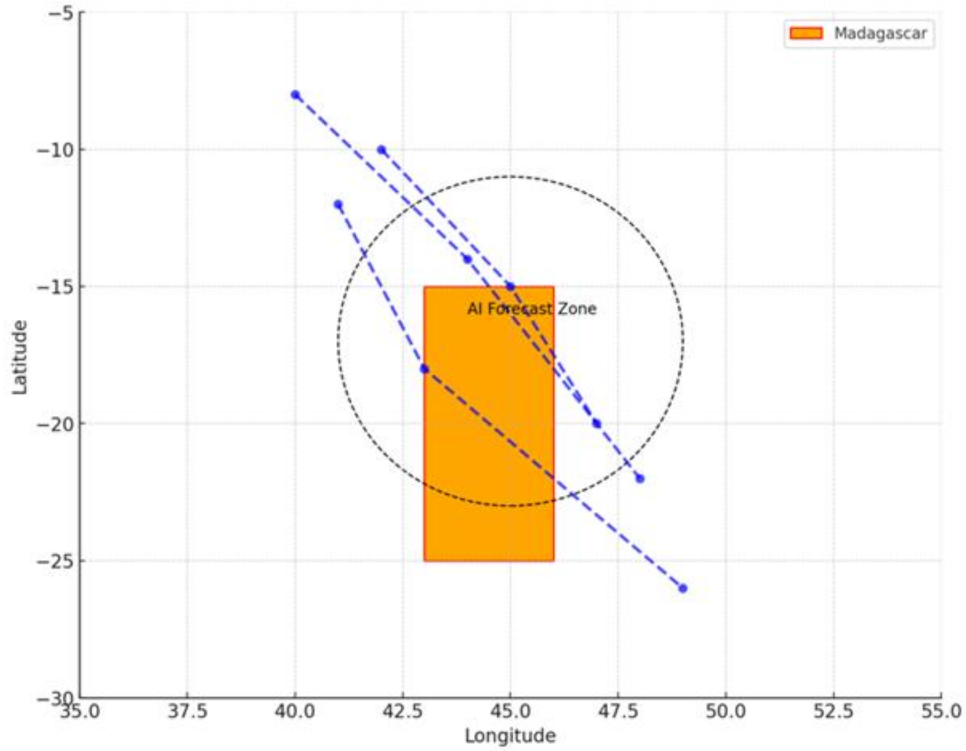

Fig 3 : AI based Cyclone Prediction in Madagascar

Effective early warning includes forecasting techniques offering effective prediction models to derive real-time data on agricultural impacts based on early forecasts of climate. The expected weather variables may augment the full-season weather strategy in developing better seasonal agricultural impact forecasting models, and consequently, deployment of agriculture-output-impact relevant early warnings. It has been noted that considering forecast uncertainty needs to be improved in early warnings. Characteristic of high-dimensionality, sparsity in signal support and time-varying coefficients in structure makes AI a better choice to tackle this challenge [16,17].

4. AI in Agriculture and Land Use

Agricultural production is challenged by a dual threat, directed by climate change and influenced by the anthropogenic emission of greenhouse gases (GHGs), especially on account of the nitrogen-based fertilizer use and farming practices. Changing processes on the earth are related to the large human-related GHG emission from the terrestrial and aquatic environment. Humans alter the natural biophysical and biogeochemical processes on the earth, triggering climate change and variability ubiquitous across space and time. Climate variability threatens agricultural productivity through abnormal departures of climate conditions from those on which agricultural management decisions are developed, jeopardizing food security and livelihood. The dual threat directed by

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climate change and brought about by climate variability creates a new challenge for agriculture. One expectancy of agriculture under climate change is to navigate the impacts of anthropogenic GHGs on climate and food production without infringing its productivity potential. Another expectancy of agriculture under climate variability is to manage the changing climate effectively despite the large uncertainty in climatic predictions. These dual challenges for agriculture underscore a shift in agriculture from a predictable paradigm to a new paradigm governed by the laws of uncertainty [8].

Two competing human-controlled attribution factors dominate to illuminate the inconsistency on such competing arguments on how anthropogenic GHGs affect climate relative with GHGs for energy supplies—and these human-controlled factors cannot account for the volume of the anthropogenic GHGs in the past two decades. GHG-induced climatic variability is likely too important to be neglected in spite of large uncertainties in state-variable adjustments regarding climate cost due to the complexity of the climate system. Agriculture is the second greatest anthropogenic emission source of GHGs on account of land use and land cover change, and also due to Fertilized N, and farm machinery and soil tillage [8,11]. On the other hand, agriculture is the most climate-sensitive economic sector. Based on robust observational evidence, economic modeling, and novel models of climate-emission interactions, it also narrowed the constraints on the role of the net climate system in controlling and managing climate change improvement [4,11].

Agriculture is only accountable for a far smaller proportion of temporally-lagged anthropogenic GHG-induced climatic warmth on account of the legacy of CO2 fertilization—break control and sequential shock on for-going processes in natural and farming systems. Therefore, the challenge of climatic change or variability on agricultural production is brought about not by the static state of climate but by the change of climate and the hydrological regime in tandem with climate change [8,11]. Adaptive, resilient, prediction-based, and smart systems will be introduced to enable agriculture to better navigate productivity constraints on account of GHGs while controlling farming actions with realism [11,12].

4.1. Precision Agriculture Techniques

The autonomous devices commonly used in precision agriculture can be mainly divided into two categories: fully autonomous devices and semi-autonomous devices, such as Unmanned Aerial vehicles (UAVs) and agriculture robots used for detecting plant diseases and weeds. UAVs hold a key place in precision agriculture, as they can gather a vast amount of data on a large-scale farm within a very short period of time. Moreover, aerial images taken from satellites can

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also be used in precision farming for identifying suitable land, plant diseases, predicting weather conditions, and remote sensing applications. Apart from crop condition monitoring and management, livestock management is another important aspect of precision farming, where it can help in monitoring overall health condition and real-time location of animals and improve the productivity, welfare, and reproductive behavior of animals throughout their life cycle. Various intelligent sensors implanted internally and externally on animals and real-time cameras can assist in making smarter decisions regarding underlying conditions and act accordingly in a timely fashion. Despite the slow adoption of precision farming solutions, the wide use of precision farming solutions around the world can be mainly attributed to the power of AI, which is backed by both ML and Deep Learning (DL), the two main pillars of AI. Nonetheless, the availability of high-speed Internet, low-budget sensors, and efficient computational devices has aided the wide dissemination of precision farming solutions at the present time [12].

Agriculture is facing a global crisis due to the depletion of natural resources, population growth, and climate change. Precision agriculture (PA) is a smart and sustainable system that maximizes agricultural yields and minimizes environmental side effects by improving resource utilization. Recently, the 4th industrial revolution has seen the rapid development of big data, cloud computing, drone technology, and the internet of things (IoT). Ideally, PA would involve building cloud-based big data platforms through IoT-based data collection, which would optimize prediction and allow customized prescriptions based on artificial intelligence (AI). This convergence of agriculture and communication technology can help develop eco-friendly farming methods through the automation of agricultural machinery using advanced technology. It can also improve the predictability of crop growth and climatic conditions through sensor and information processing technology. Therefore, PA is expected to be a systematic alternative to the aging rural workforce and help mitigate agriculture-related environmental pollution. An efficient PA system requires novel technologies that can monitor real-time information in a prompt and accurate manner. Developing a systematic diagnostic technique by analyzing the compositions of crop sap and nutrient solution is more important than monitoring physical factors. A wide range of analytical methods such as chemiluminescence, spectrophotometry, fluorescence, and chromatography have been used for monitoring plant growth in agriculture. However, this traditional analysis method is not suitable for on-site monitoring because the pretreatment is complicated and expensive equipment and highly skilled technicians are required [13].

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4.2. Sustainable Land Management Practices

Sustainable land management involves the management of land, water, biodiversity and other resources that meet human requirements while maintaining ecosystem services [7]. In the northern Great Plains (NGP), the combined impacts of land-use and climate variability have placed many soils at the tipping point of sustainability. Climate variability can lead to droughts, floods, and changes in the timing and intensity of the seasons, which in turn affect soil organic carbon (SOC) and nitrogen (N) turnover rates in many regions.

Soil management practices can be sustainable by carefully managing agricultural intensification and climate variability. However, to devise such management practices it is necessary to quantify the sustainability and waves of change in major soils and understand the underlying soil processes. In this context, the NGP provides a unique opportunity to study soil sensitivity to land-use and climate impacts, dual-stable isotopes, and spatially explicit biogeographic modeling [8]. The study objectives were to: calculate land-use changes from 2006 to 2012 and from 2012 to 2014 in South Dakota and Nebraska; assess if land use changes had impacted on soil sustainability; calculate variation in total carbon budget and turnover due to seasonal climate variability, biomass quality and soil properties; and determine effect of fire on the CO_2 emissions, soil temperature and soil moisture.

5. Challenges and Limitations of AI in Climate Solutions

AI is expected to have a profound societal and environmental impact. AI systems, however, tend to be trained on biased datasets. The design of such biased AI systems compromises social stability if they ever become widely adopted by political agencies, particularly when the datasets impact climate change mitigation and adaptation decisions. Suppose a synthetic dataset ideally means under-represented geographical regions, economic levels, and social agency. In that case, the question of how to leverage such a dataset to ensure broader adoption and trustworthiness for all decision-makers on a planet level remains and becomes of paramount importance [2].

As AI becomes widely accessible through increased cloud functionality, there is a strong global incentive to develop such less biased systems, especially ones that reflect both direct and indirect effects on societies. It arises in a web of an epistemic and thus trustworthy answer / knowledge sources to increasingly ambitious questions of planetary challenges and cannot be viewed as an isolated system. A definition of such a less biased AI is that it focuses on AI for good, which advances the well-being of all people on earth, enabled through trustworthy information. A human-in-the-loop AI can contribute to such a web by predicting interventions that support climate action and deploying a

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multitude of AI-based tools. Secondly, it can directly enable co-development of mitigation and adaptation through knowledge of social tipping elements and their geographic references. Thirdly, a less biased AI can greatly support climate action by reducing the data injustices associated with AI pre-training datasets.

The climate crisis is unfolding to be equivalent to the COVID-19 crisis. Recently, going back to the Earth after months of human lockdown and observing an unexpected but impressive recovery of the environment was a joyful experience [1]. AI is not a panacea for climate change. Nevertheless, AI can positively influence and guide the transition towards a sustainable society. AI can intervene to continue replenishing the air and seas while avoiding the return to before and leaving no one behind. Therefore, AI saves the planet by applying the AI paradigm to the climate crisis. There are already some examples of productive collaborations between AI researchers and climate experts. Furthermore, preparations are being made for larger actions.

5.1. Data Quality and Availability Issues

The current generation of climate data sets, from monitoring stations to gridded data sets, is far from perfect. Issues such as missing data, drift or instability in the instrument itself, unaccounted quality differences, or environmental conditions affecting it dramatically compromise the quality and availability of the outputs we acquire. Many of these processes are known to alter climate, yet they are hard to ascertain and estimate, leading to potential misinterpretations impacting understanding of climate processes and future policies [6]. Other biases, known as "undetected data quality issues," have been shown to lead to large-scale climate trends that mimic real ones. Examples include missing data caused by the instrument falling into disrepair, new data streams received and/or assimilated that do not fully conform with past data handling routines, relabeling of station IDs or names, and scale changes, among others.

Since climate models are designed using high quality homogenized data, and the impact of undetected data quality issues can rebound on multiple tests incorporating these data sets, it is recommended that climate models be tested on "raw" data sets collected only after a proper account of data quality issues has been taken. Future work should focus on the assessment of data quality issues and the use made of derived climate data sets, combined with the study of state-of-the-art data handling routines specifically designed to deal with multiple types of data quality issues throughout the climate data supply chain. In the longer term, strategies addressing an inclusive better inter-operability between data quality measures and the future open altimeter mission, and improved methods to assess legacy climate data should both be helpful for future archiving of more accessible data.

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5.2. Ethical Considerations in AI Deployment

Before diving into specific issues of ethics and politics of AI relevant to climate change more broadly, there may be the desire to review some of the established boundaries of ethical AI. Computation and analysis carried out by computers are more or less categorical in nature, and it may be prudent to consider ethical AI as operating solely at this broad level with no grey area. Nonetheless, such a view would be problematic, as it would ignore the ethical impact of AI development. The majority of AI climate change articles were considered to have a negligible intention on global warming. Some AI technologies such as robotics, self-driving vehicles, and drones were also ignored in the initial analysis as they are some of the most talked about technologies[3]. Therefore, a collection of AI technologies in climate change reaches a conclusion that over 145 areas of interested AI technologies in climate change, i.e., environmental awareness, remote sensing data, monitoring climate commitments, and so on that continue to evolve[2,9].

There are a few prescriptive frameworks for establishing ethical boundaries in AI development. Many consumers, nations, and corporations have varying boundaries of acceptable application of AI. It is proposed that AI applications that do not promote, protect, and respect fundamental human rights cannot be characterized as ethical [3]. Consistent with the principles articulated by various organizations, it is proposed that the Universal Declaration of Human Rights and the International Covenant on Civil and Political Rights are minimum [2]. Second, if the AI is used in an impactful way (e.g., the AI designs or is used to direct, influence, or otherwise affect human behavior or agency, environmental conditions, opportunities, or risks) then actual or potential harms of that AI must be recognized and minimized [2,9]. Third, statistical practices involve the production of statistical outputs that are powerful and actionable [9].

6. Case Studies of AI in Climate Initiatives

The climate crisis is comparable to the COVID-19 crisis, with evidence emerging that global warming has entered a dangerous phase with ever-increasing consequences. The consequences of climate change are already felt across the globe. The world is on an unstoppable trajectory to civilizational collapse as a consequence of climate change and biodiversity loss [1]. There is a risk of reaching a tipping point, i.e., the severity of the consequences and the speed at which they present themselves, rendering considered action impossible. While awareness, activism, and sustainability initiatives at all levels are becoming ever more intense, the investments in fossil fuels, mining, and agriculture are trillions of dollars annually. Within a decade after the announcement of the Paris Agreement, coal and oil production plans had only amplified. The outcome of the COP26 in Glasgow was very disappointing; coal intends to ramp-up rather than

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decrement; no deadlines have been set for coal; fossil fuel subsidies continue unabated, etc. It is evident that our civilization as we know it is unsustainable.

AI is not a panacea for climate change [1]. However, AI algorithms can positively influence and guide the climate transition towards a sustainable society [2]. AI systems can increase awareness of the consequences of climate change. AI algorithms can even be used to improve the predictions of climate models. Climate models are used to predict the future consequences of climate change based on current conditions. Differences in components of climate models, however, complicate the assessment of consequences. By investigating the assumptions and the underlying physics behind the models, discrepancies in the outputs of currently employed models can be solved. One avenue for study is the historical comparison between the older and newer models. When only the new models are used, climate adaptation planning can be improved [2]. AI systems can better facilitate the measurement of environmental factors. An example of how this can be done is an AI algorithm that quantifies floating plastic waste using video cameras placed on bridges [14]. Deep-learning based object detectors can be trained to detect and classify plastic waste.

6.1. Successful AI Projects in Renewable Energy

Artificial intelligence is currently being implemented globally. The majority of these projects are focused on traffic lights as they control how vehicles move in cities. Traffic lights are often inefficient, leading to longer commute times for both vehicles and public transport. This results in more fuel consumption and greater greenhouse gas emissions [3]. AI can help better manage these traffic lights. AI solutions can learn the entire traffic situation at an intersection in real time. They can then predict the behavior of all users of this intersection as well as the optimal configuration of the lights. This configuration can be communicated to engineers for implementation or directly to the traffic lights. The first road installations generate immediate improvements in traffic flow with up to 30% vehicle speed increases, more than 65% waiting time reductions, a similar fall in fuel consumption, over 70% less pollution, and faster emergency service response times. In China, AI anticipates air pollution thanks to satellite images. Then, AI interprets the data and anticipates where the pollution is going to descend. The city is alerted, leading to the stop of certain polluting traffic. AI also ranks industries according to their pollution rates. AI is currently optimizing the allocation of cleaning resources in cities, as well as the collection of waste.

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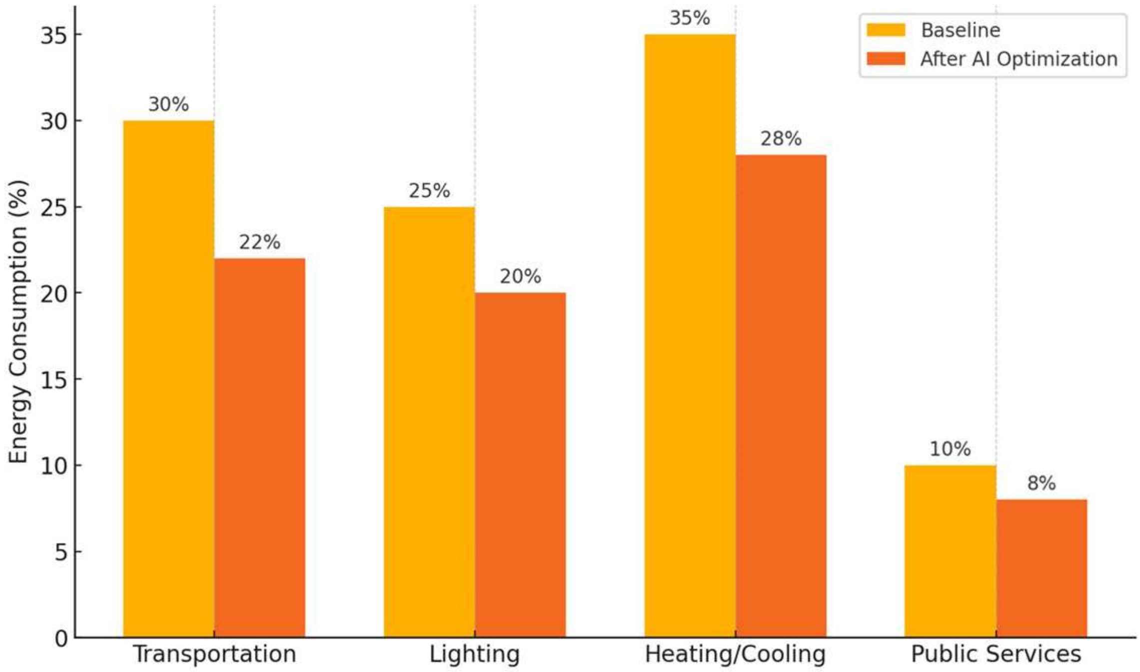

Fig 4 : Energy Optimization by AI in Urban Infrastructure

AI can significantly improve performance, including that of bids. Climate change is still better anticipated by cities' areas than earlier considered. How much energy a city requires is one question crucial to limit expenditure. Also, how to produce this energy is another key question. AI solutions anticipate a city's energy needs day by day and even hour by hour. The AI interprets the meteorological data together with the calendar, and the city's infrastructure. It is able to output recommendations for the corresponding dynamic usage of the several energy resources. Implemented in Nice, the solution combined with already implemented actions has led to over 20% energy consumption reduction [13]. 10% prevention out of 40% projected growth, the output is recommendations hour by hour. This includes the prevention of the heat wave alarm thanks to tree planting recommendations appearing after AI's extensive simulations [9]. AI has helped anticipate by decades a fatal heat peak and then control it. The solution recommends trees according to preference degree and time needed to generate a shade, on green-centrism basis. The city does expect a solution on human-centrism basis. The weight of this project though is much heavier. In the project's family, as well as its sibling actions in cities across the globe, AI is capable to optimize performance, production, bidding and consumption for other renewable energy systems[2].

6.2. AI Innovations in Disaster Response

Every year, thousands of people perish or go missing as a result of natural disasters (ND). Fortunately, there are currently many data-driven approaches

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being developed that automatically extract valuable information from Earth observation (EO) data in order to aid disaster management and relief efforts. Using AI-based algorithms, researchers hope to help in the detection and forecasting of ND and to automatically extract ND footprint information from data streams in the context of damage assessment [9]. This presentation will focus on these two main pillars of current research activity.

Current analytical frameworks reveal that advanced cloud-based artificial intelligence systems are capable of independently identifying natural disasters, thanks to years of meticulous development[9]. Recent advancements suggest that datasets are now effectively utilized to systematically identify instances of wildfires, advancing efforts initiated over a decade ago to improve weather forecasting and tidal evaluations. Continuous enhancements driven by crowdsourced metadata related to natural disasters have notably increased detection accuracy and accelerated response efforts [2].

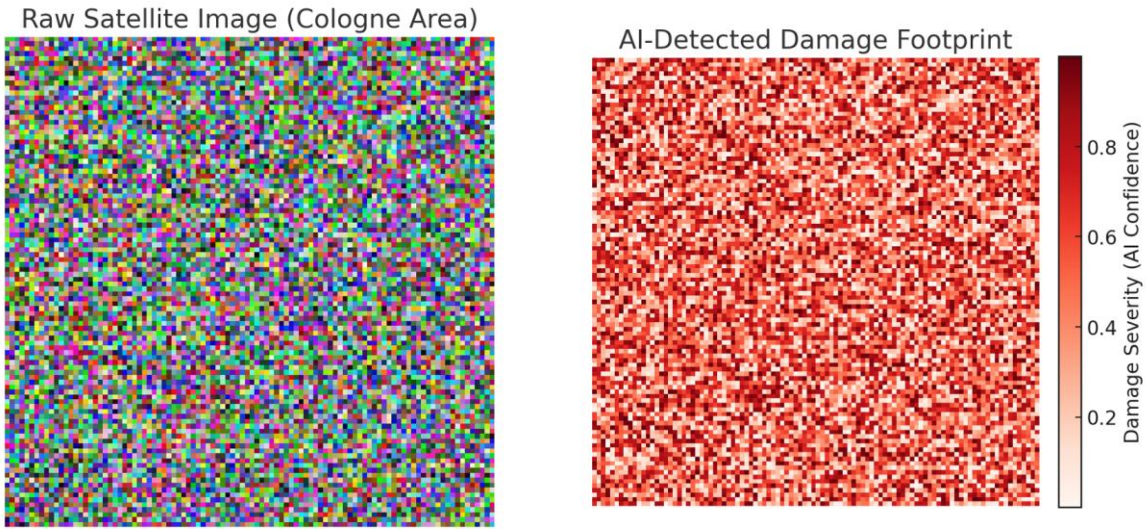

Fig 5 : AI – Augmented Damage Assessment from EO Data (Cologne Example)

The second use case shows the extraction of ND footprint information from data streams using AI-based algorithms. Using a fuzzification approach borrowed from remote sensing land cover studies, the algorithms build per-pixel uncertainty metrics. To demonstrate a proof of concept, the results from optical satellite imagery from the neighborhood of Hohenzollern Bridge in Cologne are shown, with input provided by the satellite Sentinel 2, and output compared to optical drone imagery provided by the Team[15,9]. Examples of land subsidence monitoring during 2014-2022 of a coal extraction region in the eastern part of Germany using an AI-based algorithm are shown. It is demonstrated that state-of-the-art satellite-based InSAR tends to fail for such dynamic processes if the time frame of observation is too large.

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7. Conclusion

The climate crisis is comparable to the COVID-19 crisis. Rising populations together with economic growth – and high rates of consumption in the Western world – constitute a vicious cycle of unsustainable development. A crude comparison of date ranges shows that one could start to worry the same amount about climate and ecological crises as the COVID-weeks of the outbreak of a pandemic; in the year 1900, it was 0.031 °C; in 1970, it rose to 0.9 °C; and, as of July 2021, it now stands at approximately 1.3 °C on the way towards a dreadful 4–4.5 °C in 2100. The increase in atmospheric carbon is an astonishingly unprecedented growth, despite years of forewarnings that have failed to transform. The COVID-19 crisis undoubtedly influences climate in a positive way. Before 2010, to obtain a "safeguarded" outcome was (almost) impossible; however, in 2020, an unprecedented decrease in carbon dioxide emissions was reported, resembling a historical fact. Recently, an astonishing temporal model suggested that on-going gradual developments may be combined with sudden catastrophes; the second would accelerate the third. The aim of this perspective is to polemically argue that – contrary to common beliefs – AI is a powerful tool that can play a decisive role in the (successful) governance of ongoing climatic changes. Such governance falls into the general category of regulation of unforeseen interactions of intelligent agents. AI is not a panacea. It has formidable defects and failures that should be addressed. AI can turn adversarial. These events, however, do not preclude possible advantages of AI. They rather emphasize the need for a fully accepted and personally valued AGI with general moral standards for work, action, and behavior. Even then, AIs with divergent reference systems can attain successes in competition. The successful governance of climate change can give rise to EA-like devastation of the Earth, but this is discussed elsewhere.

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