AI-generated Climate Models: Bridging Practical, Material and Value-based Challenges for Ecological Restoration Application

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Restoration practitioners work across multiple time frames, restoring past ecological functions, improving present conditions, and anticipating the long-term impacts of climate change and extreme weather events on projects and communities. As Artificial Intelligence (AI) is increasingly integrated into predictive climate modeling, it may offer significant benefits to practitioners as they grapple with questions regarding how today's projects might withstand a volatile climatic future. However, AI's powerful predictive advantages come with both practical and value-based challenges to consider when incorporating AI climate predictions into on-the-ground work.

The Role of AI in Climate Prediction

AI models have revolutionized climate science by enabling more accurate and precise predictions to be made regarding future climate conditions. These models can aggregate and analyze vast amounts of data from diverse sources, such as satellite imagery, weather stations, and historical climate records. By identifying new connections between various datasets and synthesizing volumes of information far beyond what humans are able to do through traditional computing, AI models can predict future climate patterns and natural disasters with accuracy and consistency that was previously unattainable.

Artificial Intelligence (AI)

Artificial Intelligence has existed since the late 1950s. Today, AI is rapidly improving thanks to increased amounts of data being collected through sensors, satellites and the internet. AI is capable of finding patterns that humans cannot in order to make more effective and accurate predictions (Cho 2018).

Artificial intelligence (AI) is **technology that enables computers and digital devices to learn, read, write,** create and analyze (IBM 2024).

Photo Credit: Lower Columbia Estuary Partnership

As predictive climate models become increasingly utilized by climate scientists and restoration practitioners, AI's predictive role in ecological restoration may expand. For restoration practitioners, these advanced predictive tools can meaningfully guide their efforts in ecosystem restoration and disaster preparedness. The ability to more accurately anticipate droughts, floods, and other major climatic events can significantly enhance the efficiency and effectiveness of restoration projects. For example, AI has helped researchers to accurately identify 89 to 99 percent of weather fronts, tropical cyclones and atmospheric rivers (Cho 2018). In the short term, improved AI-powered weather forecasts help predict extreme weather and keep communities safe. In the long term, AI-generated climate predictions may become even more crucial for planning and implementing restoration practices that continue to work for ecology and community long into the future.

AI tools can more accurately predict future climate and ecological conditions of landscapes being restored, thereby reducing the risk of project failure due to unforeseen climate and ecological changes. This predictive capability could provide restoration planners with insights into the characteristics of plants that can endure increasingly stressful climate conditions, enabling them to select species more likely to thrive in future environments rather than those suited only to historical or current conditions. For example, future AI models could analyze historical and predicted soil moisture levels, temperature fluctuations, and precipitation patterns alongside information on temperature related plant dormancy requirements, flowering and seed formation patterns and the life cycles and climate tolerances of pollinators, pathogens and pests to inform conversations regarding resilient plant species for a given area.

AI may be productively applied as an information input that triangulates on the ground observations and helps entities direct limited resources and capacity to specific locations within large landscapes. For example, AI can model the spread of invasive species, predicting their potential impact on native ecosystems and helping practitioners implement targeted early detection and rapid response interventions to control or eradicate them. Furthermore, AI-powered tools can simulate various restoration scenarios, allowing practitioners to evaluate different approaches and select the most effective strategies for long-term sustainability. By integrating these predictive insights, restoration projects can be more adaptive and resilient in the face of a changing climate.

The predictability offered by advanced AI climate models can not only enhance the technical aspects of restoration projects but may also benefit the mental health of restoration workers and their teams. While these AI models can't tell the future, they can arm restoration workers and their teams with cutting edge insights into future climatic conditions. While some may argue that looking at models predicting severe future climate conditions could negatively impact

Photo Credit: Lower Columbia Estuary Partnership mental health, the empowerment and proactive planning facilitated by these predictions may also ultimately provide a greater sense of preparedness, mitigating anxiety and fostering resilience among individuals and teams.

Advanced models can also support public awareness, decisionmaker and private sector buy-in to ecological restoration investments by presenting more refined future scenarios of extreme weather events, fire risk, flood risk, and species declines with and without conservation, restoration and stewardship investments.

AI tools can predict future climate and ecological conditions of landscapes being restored with potential implications for planning, community engagement, communications, project design, monitoring, and more. Additional work is needed to consider implications for how AI generated information can be most responsibly used and with consideration for potential risks, liabilities and other complex issues with attention to audience and purpose. For example, construction design standards and regulatory mapping can require the use of specific information and data sets to communicate risk. Sharing multiple, different potential future scenarios or conditions, particularly from the same entity, can introduce confusion and may not always be helpful.

AI-generated information may also have unintended impacts on property values, insurance eligibility and rates, and more. While AI is likely already applied in the development of many existing models, different levels of social trust can be placed in different institutions who release or endorse models, and entities will want to be cognizant of unintended endorsements they may make in sharing or socializing new AI generated models. For example, information on fire risk shared by a state forestry agency will likely have a different reach, credibility and weight assigned to it than those applied by for-profit online realty services.

AI-generated models can provide predictability around what challenges conservation and restoration sites may face in the future, and bolster confidence that restoration plans will succeed in the long term, and help identify needed next steps to increase resilience. This predictability may reduce some of the anxiety around the uncertainty about future climate conditions, enabling teams to feel more confident in their planning and decision-making processes. With the ability to anticipate and prepare for potential challenges such as droughts, floods, and other extreme weather events, practitioners may be better equipped to develop proactive strategies, fostering a sense of accomplishment, purpose and empowerment. Having tools to more effectively get ahead of and effectively manage these challenges may reduce workplace stress and improve overall mental well-being of individuals and teams. Models could also help build compelling cases for investment and policy improvements.

Practical Challenges in Implementation

While AI models offer significant benefits for predicting future climate conditions and aiding restoration efforts, there are several practical implementation challenges of note:

1. Data accessibility and quality: The accuracy of AI models heavily depends on the quality and quantity of the data they analyze. Inconsistencies among data sources, scales, and collection methods can lead to inaccuracies in predictions, undermining the reliability of AI-driven insights.
2. Technical expertise required to utilize AI models effectively: The complexity of these models demands a certain level of technical knowledge to interpret and apply the predictions with an understanding of model gaps, limitations and weaknesses. Models can become detached from their creators and associated metadata, making it laborious or impossible to trace data inputs. Users may lack the necessary training or resources to fully leverage these AI tools, creating a gap between the potential of AI technology and its credible applicability.
3. New frontiers of big data and resilience thinking: Challenges in assessing progress towards or away from ecosystem recovery goals are numerous and include:
   - Information gaps on gains as well as losses (status and trend data),
   - shifting baselines and trajectories of degradation and restoration through time at species and process-based scales,
   - feedback loops among biotic and abiotic systems in conversation with built systems.

   The volume of data, assumptions and variables is overwhelming from technological as well as cognitive perspectives. AI may present novel ways of overcoming current challenges in modeling complex systems. This in turn will require new thought paradigms and cognitive tools and frameworks for risk management, resilience planning and decision making.
4. The accessibility of AI requires new ways to address risk and uncertainty: This may portend a future society with an ever-growing reliance upon big data, or we may see fissures in this reliance and a re-emergence of practices and values based upon collective values, intuitive and/or intergenerational knowledge systems. Perhaps more likely, we will see spectrums of these in conversation, conflict and collaboration.
5. Cost and resource constraints: Developing and maintaining AI models is resource-intensive, requiring substantial freshwater, energy and human resource investments.[1] For many organizations involved in ecological restoration, especially nonprofits and community organizations, the costs associated with managing AI technology to ensure reliability can be prohibitive. The energy and water intensiveness of AI processing may also run counter to the objectives of ecological restoration practitioners, and it is unclear whether these costs can be mitigated.

1 https://www.forbes.com/sites/cindygordon/2024/02/25/ai-is-accelerating-the-loss-of-our-scarcest-natural-resource-water/

Value-Based Challenges

In addition to the material challenges, values-based challenges must be considered as well. Values about nature are diverse, and perceptions of the value of nature vary greatly amongst individuals, even within a community that holds similar values. Just as climate conditions will change over time so will values in relation to nature, and these shifts can be much harder to predict. AI could provide planners and communities with new ways of modeling ecological changes as well as changing human values, which could raise new questions, insights, and challenges.

Community engagement is another vital component of successful restoration practices. While AI provides valuable technical insights, these must be balanced with field verification, local knowledge and traditional practices. Engaging communities in the interpretation and application of AI models could foster more sustainable and accepted restoration efforts.

Identifying consensus based pathways for managing limited resources that support different and sometimes competing objectives in the present is already a challenge, doing so while potentially anticipating community needs and values decades in the future introduces new complexities. AI may in time provide resources to support new understandings and ways of thinking about the human dimensions of integrated, long term planning, growth and natural resource stewardship.

AI in Integrated Practice

Training and resources to support restoration practitioners in utilizing AI technologies will allow these experts to shape application of AI models. Establishing collaborative efforts between restoration organizations and academic institutions, governmental agencies, and the private sector could bring crucial perspectives and insight into this emerging field. Partnerships with organizations specializing in AI and climate science can support co-generation of tools that will be useful in applied contexts, facilitating the exchange of best practices and innovations. Additionally, developing and adhering to ethical frameworks for AI use in climate prediction is vital to ensure responsible and equitable application, including transparent data practices, community consent, and mechanisms for addressing biases that exist in the data.

The integration of AI into ecological restoration presents both significant opportunities and challenges. While AI's advanced predictive capabilities can greatly enhance restoration implementation and elevate broader public and decisionmaker understanding of and value for restorations. The path forward, if thoughtfully charted, could involve an integrated approach that combines technological advancements with a deep understanding of ecological and social complexities, hopefully leading to more informed and impactful restoration practices.

Citations

Cho, R. (2018, June 5). Artificial Intelligence-a game changer for climate change and the environment. State of the Planet. *https://news.climate.columbia.edu/2018/06/05/artificial-intelligence-climate-environment/*

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