SUCCESS STORY

Analyzing Deforestation, Ocean Currents, Climate Change, and Other Patterns Using AI

How AI is Helping Us Better Understand the Environment

At its most basic level, AI is a sophisticated pattern recognition engine that brings massive computing power to bear on a wide range of challenges. Researchers around the world are beginning to harness AI techniques that provide improved understanding of complex, changing patterns in the environment—from ocean currents and rainfall patterns to animal migration and human population trends.

"The main problem that we have right now is that we don't understand how these systems work. Ecosystems are very complex. Everything interacts with everything and we don't know what the impact is of what we do. But, with more sensors and better machine learning to build models based on those sensors, we can actually understand how our whole ecosystem works."[1]

- Pedro Domingos, Professor, University of Washington

Challenge

AI-based solutions have the capability of creating a deeper understanding of the natural world, as well as the universe in which we live. Developing solutions that make a positive contribution to this understanding—incorporating the latest AI advances—is an important objective of many research projects today.

Solution

To confront today's foremost global challenges requires a combination of interlocking solutions. Progress can be made by providing opportunities for young developers, offering guidance to organizations involved in solving global environmental issues, and enabling forward-looking researchers to access the tools and resources they need to further their missions. AI can be a valuable component of this effort and Intel is working to build a better future with intelligent devices in homes, cities, vehicles, agricultural operations, and manufacturing plants.

Positive Contributions of AI to Planetary Research

Role of AI in Environmental Sustainability

As the pace of the Fourth Industrial Revolution quickens—with promising opportunities to enhance human society and improve environmental sustainability—the challenges confronting humankind continue to mount. Our understanding of the complex, interrelated patterns that govern processes in the Earth's biosphere relies on massive volumes of data collected and analyzed by scientists worldwide, but the sheer volume of this data has made it difficult to create models, discern patterns, and formulate predictions based on the overwhelming scope of the information.

AI-empowered systems provide a means to more deeply investigate natural processes and comprehend relationships in nature that apply throughout the ecosystem—from the meteorological patterns driving climate disruption to the migration patterns of human populations.

DEVELOP
THE FUTURE OF AI FOR ALL

"Future advances in AI will need advanced computing power (currently it takes around 83,000 processors operating for 40 minutes to run the equivalent of one second of computations performed by just one percent of the human brain), so advances in quantum computing, distributed computing, and deep-learning chips will be essential. In addition, futher understanding of advanced cognitive and emotional tasks will help bring about new applications."[2]

Safe AI

A top consideration in the application of AI technology to global challenges is the idea of "safe AI." The World Economic Forum in their report *Harnessing Artificial Intelligence for the Earth* noted, "To develop 'safe AI,' the ultimate goal is to ensure that it becomes value-aligned—that its idea of a good future is aligned with humanity's values, promising safe application of the technology for humankind. In practice, this means that the checks and balances developed to ensure that evolving AI systems remain 'friendly' must incorporate the health of the natural environment as a fundamental dimension."

The sections that follow highlight some of the projects taking place in this area and innovative applications of AI for tackling the difficult planetary stewardship problems that confront us.

Applying Emerging Technology to Solve Environmental Challenges

Todd Brady, Intel Director of Global Public Affairs and Sustainability, sees collaboration among organizations around the globe as a vital key to tackling environmental challenges, and he is finding a high degree of optimism among business decision-makers that are working on solutions.

Discussions with business, university, and technology leaders at a recent workshop—Where Technology Meets Sustainability at GreenBiz's Verge Conference—discussed perceived implementation barriers and suggested solutions. Cost concerns could be met by focusing on the long-term savings to organizations. Fostering widespread collaboration could help advance mission goals, including sharing supply chain goals and standards, opening greater communication with customers, and sharing knowledge of implementation mistakes, as well as successes.

With a mix of technologies well-suited to helping maintain environmental sustainability—including AI, IoT, and 5G communications—Intel has been partnering with many organizations, creating initiatives to address global issues. These technologies often work in concert, complementing each other to amplify results.

Access to clean water is among the foremost challenges, an issue that is exacerbated by prolonged droughts in different geographical regions. As a result, large-scale crop failures and human migrations away from drought-stricken areas are causing suffering and billions of dollars of damage. With the goal of restoring 100 percent of its global water use by 2025, Intel is refining techniques for reclaiming and purifying water used in operations. The insights gained from this research have a ripple effect influencing worldwide management practices. A pilot project by Intel in central Arizona, as one example, employs IoT sensors to monitor soil moisture and correlate local weather changes to intelligently provide improved water management for crop use.

Another example of wise stewardship is the increasing use of AI-equipped drones used to capture data in circumstances that would be difficult or impossible otherwise. Research into polar bear behavior patterns conducted by Intel and a renowned wildlife photographer took advantage of AI and drones to identify and track the bears in a challenging environmental setting. Another research project performed in collaboration with Parley for the Oceans focused on collecting information to protect the world's oceans, using drones to collect whale blow for analysis. Drones have been deployed by Intel in Costa Rica to construct models of the forest terrain and calculate the amount of carbon being stored based on tree height, health, biomass, and other factors. The collected data about carbon capture can enhance management and conservation efforts, support scientific research projects on forest health and sustainability, and enable many other kinds of applications.

"To better understand how emerging technologies can be applied today and in the future, Intel and the research firm Concentrix recently conducted a study of more than 200 business decision-makers working in environmental sustainability. The study revealed that the majority are optimistic about the power of these technologies: 74 percent of respondents agree that artificial intelligence (AI) will help solve long-standing environmental challenges; 64 percent agree that the Internet of Things (IoT) will help solve these challenges."[3]

Figure 1. Amélie's current responsibilities at WikiNet include building the company's AI components.

Treatment of Toxic Substances in Soil and Groundwater

Amélie Rolland, an Intel® Software Innovator, has always had an abiding interest in computer science and coding, particularly the ways that AI can help meet challenges around the world. She was initially inspired by one of her professors during undergraduate work, Mario Marchand, a machine-learning researcher who was passionate about the opportunities offered by AI.

"After my master's degree," Amélie said, "I joined a start-up that uses AI to help solve environmental challenges, WikiNet."

In an interview with the Intel® Software Developer Zone[4], Amélie said, "I'm currently working on a project at WikiNet that uses AI to support the treatment of toxic substances in soil and groundwater. Basically, a lot of human activities like mining, agriculture, and other industrial activities can lead to the contamination of soil and water. An example is the TransCanada Keystone Pipeline that leaked over 700,000 liters of oil in South Dakota last year. This contamination can have negative impacts on the environment, but also on our health since the high exposure can increase the risk of cancer and other diseases. The problem is also more widespread than we may think. There are over 200 million people that are potentially affected by toxic substances from contaminated sites in 50 developing countries, according to Pure Earth, a non-profit that helps clean up contaminated sites in the poorest communities. Many developing countries have also less experience in cleaning up contaminated sites because they don't see this problem as a priority, or haven't until very recently."

The overriding goal for the project, she explained, is to learn to evaluate prior cleanup efforts and then provide recommendations for treatment of the contaminated soil or water. AI components extract relevant information from environmental site reports to assess the methods that are most likely to be successful.

Lacking labeled datasets in this field, WikiNet enlisted environmental experts to perform the labeling. "We tried several different strategies," Amélie said, "always trying to improve our current labeling process. We now have our own team of environmental experts that labels our datasets and ensures that our machine learning models are trained on clean data."

For more about Amélie and her work, read *Using AI to Tackle Environmental Cleanup*.

> The most important consideration in the development of AI is, arguably, to ensure that it benefits humanity, which includes being both "human-friendly" and "Earth-friendly".[5]
>
> *- Harnessing Artificial Intelligence for the Earth*

Building Richer Climate Models with AI

Climate modeling on a global scale suffers from the same essential impediment that limits understanding of many different types of complex systems. The intricacies of capturing and analyzing vast numbers of interconnected entities, linked in innumerable feedback loops, challenges classical modeling techniques. As discussed in an article, *Can Artificial Intelligence Help Build Better, Smarter Climate Models?*, published by the Yale School of Forestry & Environmental Studies, scientists are working to improve computer models by using artificial intelligence to focus on cloud behavior and other factors that provide a clear picture of the nature of climate change.

Michael Pritchard, a researcher at the University of California, Irvine, and a group of colleagues are approaching the problem by creating an AI system that they call the Cloud Brain, to more precisely determine how cloud behavior will affect climate as carbon dioxide levels rise. One key question is whether this will increase cloud coverage, helping cool the planet, or diminish cloud cover, leading to greater temperature increases. Their approach is to embed machine learning code within climate change models to analyze fine-grained details more efficiently and much faster than can be accomplished with traditional computer programming techniques.

"The trick that Pritchard and others are attempting is to train deep learning systems with data from short-term runs of fine-scale cloud models. This lets the AI basically develop an intuitive sense for how clouds work. That AI can then be jimmied into a bigger-pixel global climate model, to shove more realistic cloud behavior into something that's cheap and fast enough to run.

"Pritchard and his two colleagues trained their Cloud Brain on high-resolution cloud model results, and then tested it to see if it would produce the same simulated climates as the slower, high-resolution model. It did, even getting details like extreme rainfalls right, while running about 20 times faster."[6]

While the results are very promising, it's still an open question whether these techniques will substantially improve the accuracy of long-term projections of climate change patterns. For instance, a climate scientist at Duke University, Drew Schindell, summed up the issue by saying, "The difficulty with all of these things is we don't know that the physics that's important to short-term climate are the same processes important to long-term climate change. Nevertheless, it's a good effort, and a good thing to do. It's almost certain it will allow us to improve coarse-grid models."

Machine learning techniques continue to be refined and enhanced for modeling data-intensive natural phenomena. At the same time, the capabilities of high-performance computing machines are improving, enabling faster and more efficient climate projections with greater accuracy.

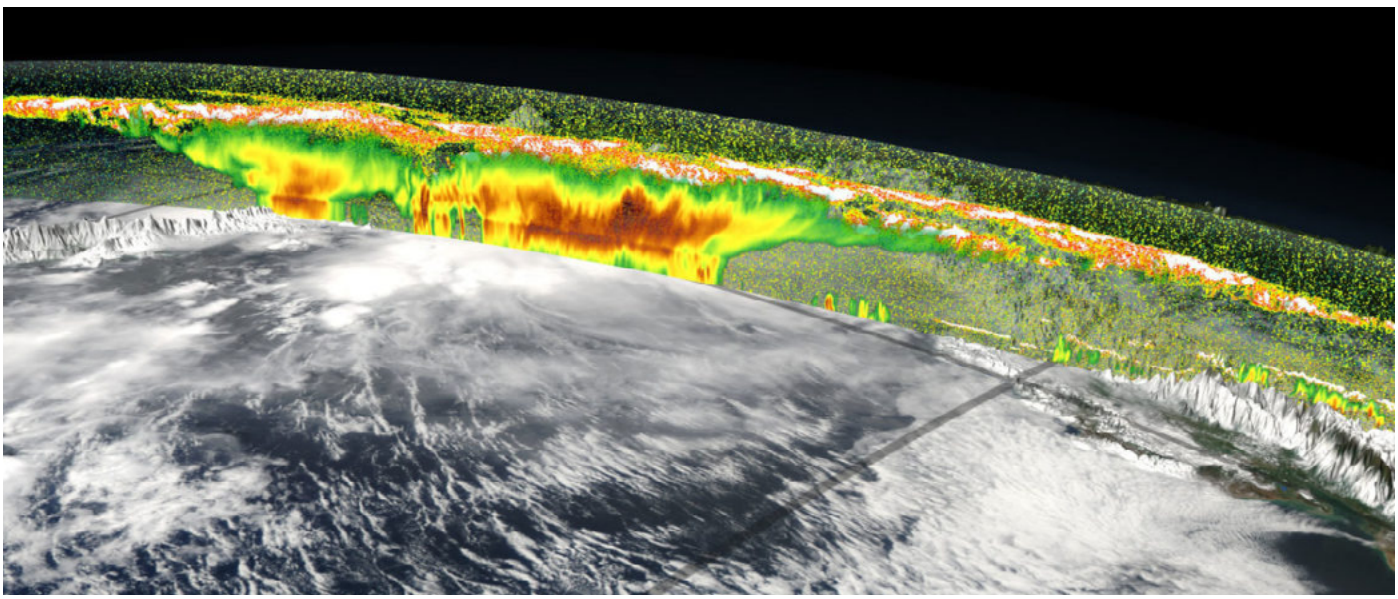


Figure 2. Machine learning applied to NASA Goddard satellite images and cloud data can help strengthen understanding of climate patterns.

Intel® AI Interplanetary Challenge

To engage the developer community and spark interest in evolving AI technologies based on Intel® solutions, Intel periodically sponsors challenges and skills-based competitions around the world. One of these, the Intel® AI Interplanetary Challenge, co-sponsored by The Planetary Society, focused on innovative applications of AI in space exploration. The winner of this challenge, Rosemarie Day, an IoT DevOps engineer and Intel Software Innovator, developed a model to retrieve data from LandSat satellites and combine it with other data sources. AI techniques, using optimized Intel® hardware, libraries, and tools, are used to classify plants and analyze deforestation in the Amazon rain forest, one of the most important regions on earth for carbon capture.

Rosemarie's work, described in the next section, examined numerous factors in areas where deforestation is widespread, assessing urbanization trends, human health issues, the magnitude of deforestation over different regions, and localized weather data. The project classifies and analyzes data using an Intel® Optimization for TensorFlow* wheel running on a platform based on Intel® Xeon® Platinum processors. The AI system that Rosemarie is developing shows promise for use in other applications where classification and analysis of environmental data can provide insights into ecosystems.

Micro Case Study – Measuring Deforestation Using Intel® AI Technologies

Rosemarie Day is developing ways to use AI for analyzing deforestation patterns as climate disruption impacts forest lands.

With a strong background in data science and a burgeoning interest in AI, Rosemarie Day developed a technique for combining satellite imagery and other data to monitor and evaluate deforestation, as well as gauge changes taking place in urban areas. The workflow she devised, based on an earlier project for determining how weather changes affect those with headaches, analyzes and classifies satellite imagery in settings in which there is a minimal availability of power.

Viewing weather changes on a larger scale, in combination with satellite images of earth, Rosemarie suggests that population growth and urbanization can be analyzed through human migration to urban areas, using data for weather and natural disasters alongside satellite imagery to detect the relevant urbanization and deforestation patterns.

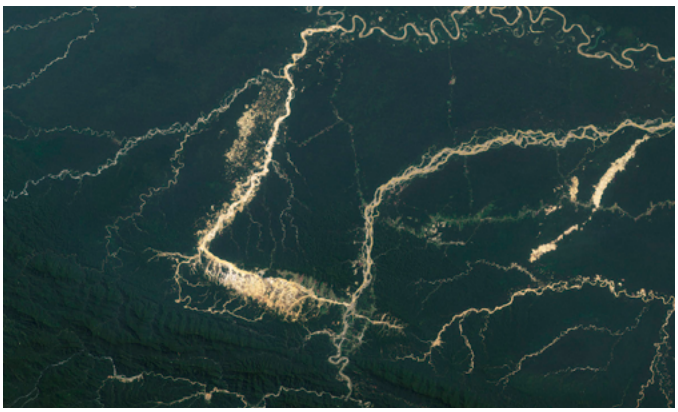


Figure 3. Satellite images of the Amazon basin show the impact of mining operations on deforestation (image courtesy of NASA).

The factors under consideration include:

- Examining deforestation to determine the impact of human logging activities
- Studying natural disasters—including droughts and fires—to see how they impact the overall health of forests
- Looking into the expansion of urban regions to determine annual growth rates

One hypothesis of this work is that health problems increase as the environment degrades, causing a rise in human symptoms, such as headaches. Effects on local weather can be correlated with reductions in trees, crops, and plants, and increases in city construction creating concrete islands.

Process of Image Recognition

As Rosemarie's work has demonstrated, AI can be used to classify plants and analyze deforestation and growth, providing a comprehensive view of how the world is changing over time. The project makes extensive use of TensorFlow, a popular deep-learning and machine-learning framework, that has been optimized for better performance on the Intel® Xeon® processor family. With this framework in place, satellite images of the earth's surface can be classified by location (country), crop or plant grown, and degree of deforestation, using these three image classifiers:

- Location Classifier
- Plant Classifier
- Deforestation Classifier

After an image classification model has been developed using the Intel Optimization for TensorFlow, the Intel® Distribution of OpenVINO™ toolkit can be run to optimize the model on an Intel® NUC machine running Ubuntu*. This creates the .xml and .bin files needed to run the inference engine on the user application. The optimized model can then be run on the Intel® Movidius™ Neural Compute Stick (NCS) hardware in implementations where an embedded, low-power solution is ideal. A different computer can be

used rather than the Intel NUC, but it must run a supported operating system that is compatible with the software (for example, an x86_64 computer running Ubuntu version 16.04). Performance differences for the different platforms should be taken into account in moving inference operations from a higher performance machine to NCS hardware.

Whereas the NCS supports low-power applications that require real-time inferencing and monitoring of the earth's surface (such as drone operations), full-scale inference operations dealing with large images generated by satellite will typically require the additional processing power available through a server or high-end workstation.

Possible low-power implementations include:

- Embedded installations on small satellites or drones where power use must be carefully controlled
- Use in the field for detecting unique satellite images that can be retrieved for further analysis, filtering out unnecessary area data or regions that are unchanged
- Targeted drone applications to detect specific weather impacts on sensitive regions

After detection reaches a certain threshold, images can be stored in the cloud for later analysis. Cloud services, such as Amazon Web Services*, provide specific storage solutions for images. These images can then be segregated and stored by region, so that scientists can go into a specific region to locate images for further analysis of the plant life and deforestation effects.

Steps for the Proposed Solution

The proposed solution for implementing the workflow includes these steps:

1. Using TensorFlow, train the model on Intel® Xeon® 8180 processors for image classification. This training should include labeled satellite data with categories for deforestation, mining, urban sprawl, and so on.
2. Perform testing on a set of this data to determine the level of accuracy and then freeze the graph when confident about the results.
3. Configure the model optimizer for the OpenVINO toolkit using the TensorFlow model.
4. Convert the TensorFlow model to produce an optimized intermediate representation (IR) of the data view. This model is based on the trained network topology of the TensorFlow model, the weights, and the bias values.
5. Test the results obtained from the IR format using the inference engine in OpenVINO on the target environment for the application. The target environment is the Intel Movidius NCS. Building an application to test the final model's inference capabilities would be a useful step at this stage.
6. Integrate the final model with the inference engine for the application into the targeted environment after testing.
7. Run the model with a threshold for detection. If results exceed a set threshold, push the image to a cloud storage repository based on the region in which the image was taken. For example, images of the US would be placed into a folder for the US.

AI is Expanding the Boundaries of Planetary and Interplanetary Research

Through the design and development of specialized chips, research, educational outreach, and industry partnerships, Intel is accelerating the progress of artificial intelligence (AI) to solve difficult challenges in medicine, manufacturing, agriculture, scientific research, robotics, and other industry sectors. Intel works closely with policymakers, educational institutions, and enterprises of all kinds to uncover and advance solutions that address major challenges in the sciences.

"Of all the Fourth Industrial Revolution Technologies, AI is expected to have the deepest impact, permeating all industries and playing an increasing role in daily life. By combining with other new technologies, AI is becoming the "electricity" of the Fourth Industrial Revolution, as innovators embed intelligence into more devices, applications, and interconnected systems. Beyond productivity gains, AI also promises to enable humans to develop intelligence not yet reached, opening the door to new discoveries."[7]

In terms of the approach that was developed, Rosemarie commented, "The first iteration of this model focused on classifying urban area in comparison with forested regions, as well as those areas that have been logged compared to those that haven't. Right now I am focusing on completing a literary review to see what others have done in this area and also building a more detailed dataset of images and labels."

Prospective Use Cases

Speculating on the potential uses for this AI-based solution, Rosemarie said, "Combined with other image classifiers, this technology can provide benefits to organizations looking to analyze satellite images for fire damage in real time, as well as low-powered solutions, such as on drones or helicopters. The three main image classifiers for this project include plant, location, and deforestation classification. Through knowledge of the plants and location, it can be determined where a fire is happening and if it is occurring in a forest or not. Using this information, other image analysis can be done to analyze the fire itself to determine how large the fire is and how quickly the fire is spreading. Another prospective use case for this type of low-powered technology would be to adapt the classifiers to look at land types and localize craters on other planets. This allows models to be run where powerful servers are not readily available for image classification purposes."

Enabling Technologies

Rosemarie is taking advantage of several Intel technologies, including the Intel Movidius NCS, Intel NUC, and Intel Optimization for TensorFlow running on a platform based on Intel Xeon Platinum processors. Together, the components provide an effective, low-powered solution that can be easily set up and implemented in a variety of locales, as well as scaled for more robust applications. Convolutional Neural Networks (CNNs) are another useful ingredient for architecting solutions of this type for satellite image classification.

> "Tropical deforestation accounts for about 10 percent of the world's heat-trapping emissions—equivalent to the annual tailpipe emissions of 600 million average US cars. Reducing tropical deforestation can significantly lower global warming emissions and—together with efforts to reduce emissions from fossil fuels—plays an integral role in a comprehensive long-term solution to global warming. To accomplish this, we need to understand the driving forces behind deforestation today and the many reasons why reducing deforestation must be a priority."[8]
>
> - Union of Concerned Scientists

Real-World Examples

Protecting Wildlife–TrailGuard AI: Cameras controlled by artificial intelligence help alert rangers to poaching activities in sensitive regions.
https://newsroom.intel.com/video-archive/video-intel-ai-for-social-good-putting-an-end-to-poaching/

Ensuring Planetary Sustainability–AI for Good. A collection technologies, guided by the latest AI advances, deepen our understanding of the Earth's biosystems and offer promise for a brighter future.
https://www.youtube.com/watch?v=magNVTCu1OM

Stopping Illegal Fishing–Artificial intelligence brings a powerful weapon to bear on those involved in illegal fishing operations.
https://iq.intel.com/using-ai-to-stop-illegal-fishing/

Balancing Demand-Side Use of Renewable Energy–AI has the capability of increasing efficiency of renewable energy services through active monitoring and distribution.
https://www.weforum.org/agenda/2018/05/how-ai-can-help-meet-global-energy-demand

Edge-to-Edge Plus AI–Cities of the future are likely to enable computer vision and AI at the edge to effectively manage traffic, weather conditions, disasters, and other activities.
https://www.forbes.com/sites/insights-inteliot/2018/10/25/how-the-iot-will-reshape-the-city-experience/

Enhancing Climate-Friendly Innovations–Climate researchers and scientists can enlist AI and deep learning to develop solutions based on precise models to tackle air pollution, as well as improve climate studies.
https://www.forbes.com/sites/bernardmarr/2018/02/21/the-amazing-ways-we-can-use-ai-to-tackle-climate-change/

RESOURCES

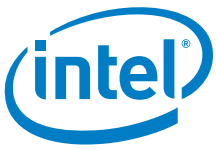
Intel® AI Developer Program–software.intel.com/ai/

Inside Artificial Intelligence–Next-level computing powered by Intel AI–intel.ai/

Intel® AI DevCloud–Free cloud computing for Intel Developer Program members
software.intel.com/ai/devcloud

Intel® Software Innovator Program–Supports innovative, independent developers
software.intel.com/intel-software-innovators/overview

Intel® Artificial Intelligence News–newsroom.intel.com/press-kits/artificial-intelligence/



[1] *AI for Good - Sustainability.* Video: https://www.youtube.com/watch?v=magNVTCu1OM.

[2] Heirweijer, Caroline, Dominic Waughray. *Harnessing Artificial Intelligence for the Earth*. World Economic Forum. January 2018. http://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf.

[3] Brady, Todd. *Applying Emerging Technology to Solve Environmental Challenges*. Intel Newsroom. December 2018. https://newsroom.intel.com/editorials/intel-study-applying-emerging-technology-solve-environmental-challenges/.

[4] *Using AI to Tackle Environmental Cleanup*. Intel Software Developer Zone. December 2018. https://software.intel.com/en-us/blogs/2019/01/03/intel-software-innovator-am-lie-rolland-using-ai-to-tackle-environmental-cleanup.

[5] Heirweijer, Caroline, Dominic Waughray. *Harnessing Artificial Intelligence for the Earth*. World Economic Forum. January 2018. http://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf.

[6] Jones, Nicola. *Can Artificial Intelligence Help Build Better, Smarter Climate Models?* Yale School of Forestry & Environmental Studies. December 2018. https://e360.yale.edu/features/can-artificial-intelligence-help-build-better-smarter-climate-models.

[7] Heirweijer, Caroline, Dominic Waughray. *Harnessing Artificial Intelligence for the Earth*. World Economic Forum. January 2018. http://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf.

[8] *Global Warming Solutions: Stop Deforestation*. Union of Concerned Scientists. https://www.ucsusa.org/global-warming/solutions/stop-deforestation.

0319/KP/MESH/PDF 337325-001US