Artificial Intelligence and Environmental Civil Society Organisations

Duberry, Jérôme

How to cite

DUBERRY, Jérôme. Artificial Intelligence and Environmental Civil Society Organisations. In: Global Environmental Governance in the Information Age: Civil Society Organizations and Digital Media. Routledge (Ed.). Abington : [s.n.], 2019. p. 145–172. (Emerging Technologies, Ethics and International Affairs) doi: 10.4324/9781315109596

This publication URL: https://archive-ouverte.unige.ch/unige:143505

Publication DOI: 10.4324/9781315109596

7 Artificial intelligence and environmental civil society organizations

1. Introduction

In an interview with the BBC in December 2014, Professor Stephen Hawking warned the world against the dangers of full artificial intelligence (AI) that "could spell the end of the human race."[1] He further argued that "It would take off on its own, and re-design itself at an ever increasing rate,"[2] in which case "Humans, who are limited by slow biological evolution, couldn't compete, and would be superseded."[3] He is not the only expert to suggest a careful approach to artificial intelligence. Elon Musk, the founder of Tesla and SpaceX, shares this gloomy perspective, stating that "AI could become an immortal dictator from which we would never escape."[4] However, as much fear as it triggers, AI also inspires great expectations. Russian President Vladimir Putin explained that AI represents the future for all humankind and that "It comes with colossal opportunities, but also threats that are difficult to predict. Whoever becomes the leader in this sphere will become the ruler of the world."[5] Similarly, former Google CEO Eric Schmidt compares AI to space technology during the cold war, calling for a national security strategy on AI[6] as it is becoming a vital element for state power.

Beyond the arenas of politics, business, and academia, AI has become mainstream over the last few years, along with popular movies such as *The Terminator*, *The Matrix*, and *Ex Machina*. Indeed, AI is becoming more and more visible in our daily lives through voice-powered personal assistants (PAs) such as Google Assistant, which can book a table and chat with people on the phone, or self-driving cars.[7]

AI is a general-purpose technology, similar to electricity in the sense that its applications are endless, and it will affect society at large, much more than the invention of a submarine for instance.[8] The humanoid robot Sophia, developed by Hanson Robotics, has given a face to AI and a glimpse of the future interaction between robots and humans. Its speech at the United Nations (UN),[9] but also on various news channels, surprised many, and even scared some journalists, when it demonstrated the ability to laugh, to tell a joke, and to offer a romantic recommendation.[10]

Max Tegmark, in this book entitled *Life 3.0*,[11] associates the emergence of general artificial intelligence to a third phase in evolutionary history. For about

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four billion years, biology restricted the evolution of the (human) body and brain. Through learning and culture, humans have developed the capacity of the latter. AI represents the third phase, where body and brain can be re-engineered and expanded without biological limitations.[12] As *The Economist* argued: “The implications of introducing a second intelligent species onto Earth are far-reaching enough to deserve hard thinking.”[13] In 2015, AlphaGo® software won against a professional Go player without handicaps on a full-sized 19×19 board.[14] This victory was possible only by combining strategy and calculation skills. AlphaGo developed its strategy skills by playing against itself millions of times. This leads us to think that AI could develop superior negotiation skills, which could be applied to contract negotiations or hostage situations.[15] Most concerns are not related to current AI applications, but rather to its future developments, questioning whether they will lead to technological singularity, when human beings will no longer be the most intelligent species on the planet.[16]

Artificial intelligence holds many promises for accelerating the achievement of the Sustainable Development Goals (SDGs), in particular in predicting the effects of climate change and the path of storms, monitoring the spread of diseases, helping understand human decision-making processes in terms of energy consumption and protection of the environment, or identifying areas most in need of attention. Various research projects have used the power of AI to predict poverty in Nigeria, Uganda, Tanzania, Rwanda, and Malawi.[17]

AI is increasingly taking a leading role in making sense of the large volumes of data recorded by satellites, drones, smartphones, and sensors throughout the planet. This new technology already allows us to better understand our planet, from its urban communities to its most remote and untouched areas, from high mountain peaks to deep oceans. AI can support global environmental governance in multiple ways. This chapter focuses on the use of the technology by civil society. However, some illustrations of its use by local public authorities and international organizations will be mentioned in the final remarks. Civil society uses AI in multiple ways, but mainly for two purposes: providing better environmental services, and producing new scientific knowledge. This chapter will first discuss the concept of artificial intelligence, and then examine two applications, namely implementing field projects and producing knowledge.

2. Artificial intelligence explained

John McCarthy was the first to coin the term “artificial intelligence” in a proposal for the famous 1956 Dartmouth Conference, which started AI as a field of research.[18] Although AI encompasses a broad range of activities, it involves machines that accomplish duties that are specific to human intelligence, and includes tasks such as planning, understanding language, learning, and problem solving.[19]

The term “artificial intelligence” is somewhat misleading. Indeed, the term “artificial” implies that it is unreal, while “intelligence” refers to the human capacity to manage complex tasks and operations. In fact, AI is real, and its impact on many fields is already substantial. Furthermore, the use of AI today is not restricted to tasks that would be considered as *intelligent*, but includes rather simplistic ones such as recognizing objects in pictures.[20]

Since its first developments, research in AI has been divided into two separate camps. On the one hand, symbolic AI, introduced by Newell & Simon in 1976, refers to a system based on rules and knowledge, where computers manipulate symbols rather than letters or numbers. This approach solves problems through their symbolic representation. Such symbols can be arranged in lists, hierarchies, and networks, allowing the detection of relationships between them; these are called production rules, and they are similar to If-Then statements. A form of symbolic AI is the expert system, which uses production rules to make deductions and decisions. Also called the Good-Old-Fashioned Artificial Intelligence (GOFAI), symbolic AI is defined by an exclusive emphasis on symbolic reasoning and logic.[21] For instance, IBM's Deep Blue, the AI technology that won a chess tournament against Garry Kasparov in 1997, used this approach.[22]

On the other hand, non-symbolic AI, also called computational or connectionist AI, focuses on calculation according to rules that have been pre-established. This approach solves problems through calculation, using systems of large networks of simple numerical processors that communicate with each other and perform tasks in parallel.[23] Connectionist AI is intended to imitate how a human brain functions and in particular its complex network of neurons.[24] Some current applications of connectionist AI are well known: Google's automatic transition system (which looks for patterns), Facebook's face recognition algorithm, and AI enabling self-driving cars.

AI encompasses a wide range of applications, and it can be classified in three categories: Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Super Intelligence (ASI).[25]

The first category of AI corresponds to the most visible and current applications of AI. ANIs have exceptional calculation capabilities, but they are restricted to a specific area, such as IBM's Deep Blue® that beat Gary Kasparov at chess in 1997. More recent applications include Apple's Siri®, search engines, algorithms of social media platforms, web cookies that identify users online, digital advertising, data miners, self-driving cars, traffic control software, etc. Although highly efficient for their dedicated tasks, ANIs cannot embark on other operations that were not pre-determined by the creators of the ANI. Millions of YouTube videos are captured in a large number of languages thanks to the ANIs that efficiently convert sound into text, and then translate it.[26]

Contrary to the case with humans, performing complex calculation is simple and fast and does not require much effort for AIs. However, tasks that are based on perception and anticipation, and that require assessing and processing random situations, for instance voice and image recognition,[27] are difficult. In other words, "AI has by now succeeded in doing essentially everything that requires 'thinking' but has failed to do most of what people and animals do 'without thinking', that, somehow, is much harder."[28]

This is in fact what the second category of AI aims to overcome. AGIs correspond to the capacity of the human brain to process information, solve complex problems, perform tasks, and make decisions in many different fields. AGIs could on one hand help human beings grow beyond their biological legacy and increase the diversity of the human experience, while on the other hand develop the capacity to independently control their own judgments, concerns, feelings, forces, vulnerabilities, and biases.[29] This second category of AIs is for the future, and rare are the scientists who agree on when it will become available. Some believe it will become reality already in 2030, whereas others believe it will simply never happen.

The third category relates to AI that outperforms the human brain in all tasks including scientific creativity, general wisdom, and social skills.[30] After reaching AGI, ASI will appear quickly[31] as AGI will develop its capacity exponentially according to an "intelligence explosion" or "technological singularity" phenomenon.[32] This is the stage of AI development that society and governments fear the most, since it illustrates how human beings can be superseded by machines.

Algorithms are at the heart of AI. Similar to a lever for a watch, algorithms enable AI to perform calculations. Algorithms correspond to a set of pre-defined instructions that indicate what to do in specific situations. In fact, AI often uses a number of interrelated algorithms that work hand in hand. The simplest algorithm is the one that provides the instruction to the computer to activate the switches (or transistors) that make up a computer: if the transistor is on, it is equal to 1; if it is off, it is equal to 0.[33]

The instructions involve the use of several transistors that are linked to each other. For instance, if transistors B and C are off, then transistor A must turn on. This combination of actions based on the conditions "IF," "AND," and "OR" represents the basis of all algorithms. This allows computer algorithms to receive data, process them, and then produce a specific outcome such as: "IF" circumstance A "AND" circumstance B, "OR" circumstance C, then prescribe "X medication."[34] Another feature of algorithms is that instructions must be accurate and non-ambiguous. In other words, a home-made recipe for a chocolate cake could not be reproduced exactly by a computer every time, since how much is a spoonful of sugar exactly? Therefore, such a recipe is not an algorithm.[35]

Machine learning is when an algorithm develops the capacity to create new algorithms. Called "learners," these algorithms function differently. As input, they receive large amounts of data (such as millions of pictures of cats) and the desired outcome[36] (such as the capacity to identify all types of cats in pictures). As output, the learner analyzes all pictures and creates a set of instructions (a new algorithm) that can describe and therefore identify all kinds of cats. In that sense, big data are closely linked to machine learning, since they provide the input for learners to create new algorithms.

As part of the connectionist AI approach, machine learning is the ability of a machine to learn by itself. So instead of hard coding software routines with specific instructions to accomplish a particular task, machine learning trains a

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program to learn how to act in situations for which it was not programed. The training refers to providing large amounts of data to the program so that it can learn and extract meaning from those data.[37] A good example of machine learning is image recognition. A computer program is fed with large numbers of images from social media platforms for instance. Each picture is identified by users as a cat, car, or specific person. The program can then learn to identify the characteristics of each object or person, which will enable it to later recognize them by itself even when they are not tagged by users. In a way, the program has learned to define what a cat, car, or specific person looks like.[38] This is a characteristic of AI, since previously, the computer had to be instructed specifically about all possible forms of an object or a person to be able to perform an identification.

Machine learning consists of many different approaches such as decision tree learning, inductive logic programming, clustering, reinforcement learning, Bayesian networks, and deep learning. The latter is probably the most well-known to the general public. It involves Artificial Neural Networks (ANNs), which consist of interconnected "neurons" with multiple layers. Each layer is dedicated to a specific aspect of the learning process: the edges of a photo for instance.

Prior to discussing AI's concrete applications, some of its main technical applications will be considered. First, AI has the capability of environmental perception by collecting and transforming pictures, sounds, texts, articles, and large amounts of data. Second, AI has the ability to process that information and make sense of it; it can identify patterns and schemes, similar to human interpretation, although it cannot draw true meaning out of its analysis. Third, AI can make decisions and act upon them based on the collection of data from its environment and its analysis. Lastly, AI can learn through the data collection and analysis, which enables it to constantly improve its capacity to succeed in performing specific tasks.[39]

Based on these abilities, AI planning corresponds to the capacity of AI to choose a sequence of actions that should (according to its representation of the model of the world) have a specific and pre-defined impact on the real world. Some complex forms of AI planning deal with uncertainty, involving multiple agents and an environment that cannot be fully observed, which means that external conditions can be only partially assessed but not with certainty.[40]

Machine perception refers to this ability of AI to combine pieces of information collected from numerous sensors in the physical world, and interpret them to create one single image of the world. It functions similarly to the human eye, which collects information from the outside world; this information is then combined in the brain to form one single image through a principle called sensor fusion. Some applications of machine perception include handwriting recognition, image processing, and document analysis.[41] The capacity of AI to understand human language is called natural language processing (NLP). Among its multiple applications are text mining, responding to enquiries, and language translation.

Many robots use AI to assess their environment and perform specific tasks. Moravec's paradox states that skills that require thinking or reasoning, in other words high computational capacity, are easy for AI and difficult for humans. On the other hand, unconscious skills, such as recognizing a face or learning how to

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move in an environment, are easy for humans but extremely difficult for AI. One reason is that unconscious skills were developed over millions of years of evolution. And while they seem easy for humans, they are nevertheless highly complex.[42] This implies that motion and coordination in a multi-agent environment and affective computing, which describes the ability of AI to assess, interpret, and simulate human affects,[43] are more difficult for AI than solving a mathematical problem.

AI can help solve a large number of contemporary challenges. As discussed in this section, AI[44] is at an early stage. The scope of its impact is yet to be determined. Nevertheless, it is already possible to envisage some of its current applications in the field of global environmental governance, and in particular, how civil society is embracing this technology to improve its roles as service provider and knowledge broker. The Sustainable Development Goals, by offering a global agenda for development, provide an ideal framework to envisage how AI can empower global and local development. As shown in this chapter, AI can support many SDGs. The following section will examine some current and emerging AI applications.

3. Implementing field projects

Civil society participates fully in the implementation of field projects throughout the globe. Either independently or through the delegation of an international organization or a state, civil society has developed field expertise and know-how in terms of protection of the environment. The environmental services this group of actors provides are numerous, starting from protecting endangered species and ecosystems to tracking poaching crimes and overfishing. They also support other actors in educating and training parts of the population to better manage natural resources.

On land, biodiversity loss seems unstoppable. Thanks to image recognition technologies, game theory, and AI analysis capacities, animals in the wild are better monitored and protected with real-life data and accurate prediction models.[45] Poaching incidents can be reduced, pests and viruses can be detected at an early stage, and migrations can be protected by creating temporary wetlands in collaboration with farmers.[46]

Forests can provide one-third of the solutions to climate change and are essential for the conservation of biodiversity.[47] However, they are under multiple threats: deforestation, but also degradation with a decline in density and underbrush, which leads them to be more vulnerable to fire for instance. Despite the current advances in techniques to assess restoration efforts remotely, the lack of real-time data continues to make it difficult to evaluate whether or not the concessions and payments made to the states and enterprises in charge of forest protection are effective.[48] In that context, satellite and aerial mapping, along with the analysis capacity of AI, can provide in real time substantive and accurate information about the degradation of underbrush, thinning of upper-story trees, evolution of water levels, and the increase of new trees in designated areas.[49] Hence, this illustrates how AI can help achieve SDG Goal 15, which seeks to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."[50]

The Chesapeake Conservancy, in collaboration with Microsoft, has tackled the need to more accurately understand changes in complex ecosystems such as watersheds. The initiative aims at creating high-resolution land cover maps to support scientists and decision makers in protecting nature in the United States. Data are collected from a range of sources such as drones, airplanes, and satellites and stored on a cloud system. AI is then used to analyze these large volumes of data to produce up-to-date land cover maps offering more than 900 times the information that was available previously, allowing for precision conservation measures.[51]

When considering wildlife protection, one of the main issues that comes to mind is poaching. For instance, an average of 96 African elephants are killed by poachers every day, leading scientists to believe that this animal could disappear entirely in the coming decades if nothing is done.[52] Traditional attempts to stop poaching are based on rangers who regularly patrol large geographic areas. For rangers to know where poachers will be and how they will act is essential. In that respect, AI can help their work substantially.

With an elephant killed every 14 minutes, and two rhinos every day, these endangered species are at high risk. The Lindbergh Foundation collaborated with the tech company Neurala to create the Air Shepherd program, a combination of surveillance drones and artificial intelligence to protect elephant and rhino populations in Africa.[53] First, the use of drones equipped with infrared sensors helps spot poachers at night and sends their location to rangers who can then stop them before they reach the animals. Since the drones produce terabytes of video, AI assists human analysts to identify animals, vehicles, and poachers. Furthermore, AI helps predict where poachers will most likely be in order to intercept them in advance.[54] Air Shepherd was deployed at Liwonde National Park and Nkhotakota Wildlife Reserve in Malawi, Ezemvelo KZN Wildlife in South Africa, and Hwange National Park in Zimbabwe. Furthermore, in collaboration with the World Wide Fund for Nature (WWF) and Google, Air Shepherd was extended to Hwange National Park to stop poachers from poisoning watering holes.[55]

The Protection Assistant for Wildlife Security (PAWS) applies AI to collect data from previous poaching incidents, but also from terrain specificities such as hills, mountains, rivers, lakes, and forests as well as known migration paths for certain animals.[56] AI processes the data to detect where the next poaching activities are most likely to occur, and can thus guide rangers by providing them with the best route to patrol large geographic areas. The objective is to understand poachers' strategies and behaviors, to make predictions of their future moves, but also to adapt protection strategies as the poachers change theirs.[57] Moreover, AI helps rangers identify where the animals will be.[58]

Thanks to a continuous feed of data originating in the field, AI and in particular machine learning always adapt the routes and become more and more precise.

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PAWS also selects some routes randomly to prevent poachers from identifying any patrolling pattern. PAWS is based on an algorithm that was developed according to the Stackelberg security game theory. This model of real-world security scenarios helps one to understand how adversaries think, when they will most probably attack, and how best to allocate resources. The security forces first deploy a mix of actions to protect an area for instance, and the attackers surveil these actions and then respond in the form of an attack. This algorithm is used today by a wide range of security forces, including US Homeland Security, the Transportation Security Administration, and the Coast Guard, to predict where to best locate security forces to stop smuggling and terrorism.[59]

The green version of this security game theory, called Green Security Games, adds the specificity of wildlife conservation conditions by taking into consideration the fact that interaction between defenders and attackers takes place over multiple rounds. First, the data collected about previous poaching are analyzed by the AI application to understand how the attackers behave. Second, it generates the best route for rangers to patrol. Third, the rangers (defenders) use this route to patrol the area. Fourth, the attackers observe the strategy executed by the defenders and respond by attacking an animal. This generates new data, which is fed to PAWS, and the loop starts again.[60]

In 2014, PAWS was first tested in a national park in Uganda and in a protected area in Malaysia.[61] Specifically, the Ugandan Wildlife Authority (UWA) fed PAWS with 14 years of data, including GPS coordinates, corresponding to more than 125,000 observations of poaching, and stemming from animal sightings, traps, animal carcasses, and other evidence. Some shortcomings were identified; for instance, the specific topography of the area (high altitude) and patrol schedules needed to be taken into consideration in the algorithm calculation. Nevertheless, in both cases PAWS proved to be useful in guiding rangers to poaching hotspots in these areas, and succeeded in decreasing the number of human activity signs sighted per kilometer.[62]

PAWS provides a good example of collaboration between AI and human intelligence. In this case, and contrary to other examples in this chapter, AI technology does not replace human interventions, but rather empowers them. This is the case with the next generation of PAWS, which is called INTERCEPT. At Uganda's Queen Elizabeth National Park, INTERCEPT led to catching a poacher and discovering a dozen elephant traps before they could be activated.[63]

Another AI-based wildlife preservation initiative was led by Deakin University in Australia with the objective to substantially improve animal monitoring. To date, the institution in charge of park management has used cameras and sensors to track animal movements and population. However, weather conditions trigger cameras and sensors that take irrelevant photos, leading to a large number of pictures without any animals. These photos had to be verified one by one by humans, which limited their positive impact on park management strategies. Thanks to AI, and in particular to machine learning and pattern recognition, these photos can be verified by the algorithm, which can sort through thousands of photos and keep only the ones with animals. The machine-learning feature of the algorithm will

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also allow it to identify what breed of animal has been caught by the camera. This new initiative will dramatically improve the efficiency and effectiveness of park management in the state of Victoria, Australia.[64]

The BeeScanning app[65] is an AI initiative dedicated to beekeepers.[66] Honeybees suffer from various threats, and in particular Varroa destructor. These red mites feed on the bees by crawling on their bodies and sucking their blood, which can lead to the destruction of entire hives if not dealt with in time. Consequently, every year, millions of honeybee colonies disappear,[67] which can have disastrous effects on the global food supply. Therefore, the objective is to detect honeybee hives that are infected by these red parasites as early as possible in order to treat them. Moreover, BeeScanning can also help identify which bees are most resistant to the red mites, which will allow scientists to comprehend the Varroa-resistant strain of bees.[68] The beekeeper takes a photo of the hive with the BeeScanning app. The photo is uploaded into the database, and then AI analyzes the images and determines if the bees are infected or not. The image analysis technology is based on Artificial Neural Networks, which have the ability to improve their detection capabilities over time. A deep learning professional trains the ANN to identify the red mites in the data collected. Through a process of errors and corrections, the ANN learns how to identify the abstract features of Varroa destructor. It then becomes faster and more accurate than the human eye in identifying early signs of the red mites in a hive. BeeScanning has a performance error of about ±5% in lab environment conditions.[69] Moreover, the data collected about performance, location, and date can help scientists in developing innovative protection solutions.

In the developing world, access to accurate data about wealth distribution and poverty remains a challenge, with few censuses being conducted, and data rarely collected from the poorest areas, where not even births and economic activities are recorded. However, data are crucial to establishing effective development plans and assistance mechanisms. AI can help overcome this lack of data through the analysis of satellite imagery for instance, allowing poverty to be mapped by using satellites to detect the lack of lighting infrastructure.[70] By allowing the analysis of large volumes of accurate and up-to-date data, AI can support efficient resource allocation and help reach SDG Goal 1 entitled "End poverty in all its forms everywhere."[71] Furthermore, thanks to predicative analysis from data emanating from the field (low-cost sensors, wireless-connected) and from the air (satellites and drones), AI can improve arable land productivity and reduce the environmental impact of agriculture through precision agriculture or data-driven agriculture.[72]

Indeed, SDG Goal 2 strives to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture."[73] With two billion individuals relying on local agriculture to provide food, an increase in agricultural productivity can have a substantial impact on poverty reduction. However, climate change leads to rapidly changing environmental conditions, and a higher level of hazards, which makes planning for crop planting and harvesting even more of a challenge for local communities. In that context, AI can support agriculture by providing additional information to farmers to help them mitigate risks and increase their productivity, which leads to decreasing poverty overall.[74]

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An AI project supported by Microsoft is focusing on farming in collaboration with the government of India, the Gates Foundation, BASF, Bayer, Land O'Lakes, and Mahindra. Similar to big data enabling precise farming, AI supports data-driven agriculture. In a world where the growing population puts additional pressure on natural resources and arable land, where water levels are decreasing and desertification is on the rise, data can be a solution to increase food production and respond to the additional need for food in the coming decades. FarmBeats is a combination of multiple technologies, including machine-learning algorithms, sensors, and drones, that provide insights to farmers so they can better maximize harvesting productivity, reduce costs, and decrease the environmental impact of agriculture, such as the amount of water used.[75] However, data-driven agriculture is a complex task to implement, since in many cases, there is no electricity or internet where the data must be collected. FarmBeats offers a solution to this issue. Low-cost sensors are not connected through Wi-Fi but through TV White Spaces radios, which allow the collection of data even without internet or electricity in the field. Machine-learning algorithms combine the data collected in the field with aerial imagery, best practices, and prediction data to produce almost real time and accurate actionable insights to local farmers.[76]

If AI can help civil society to improve its capacity to implement field projects and better protect the planet, and its most endangered species and ecosystems, the technology can also support the production of new knowledge that can then feed into policy- and decision-making processes on the international stage.

4. Producing knowledge

The AI capacity to analyze large volumes of data coming from satellite imagery is crucial to helping achieve the SDGs. Due to the interrelation and interdependency between the SDGs and the challenges that global environmental governance aims to tackle, the possibility to assess multiple criteria at the same time and on a global scale can support effective policy- and decision-making processes in today's world. The analysis of data stemming from weather conditions, animal population abundance and distribution, changes in ecosystems such as deforestation and desertification, and the spread of pests and viruses, among others, can help produce accurate prediction models based on multiple criteria and real-time conditions. Thanks to its predictive capacity, AI supports the development of accurate climate change models, and helps prepare for climate-related issues and disasters, in support of SDG Goal 13 to "Take urgent action to combat climate change and its impacts."[77]

Project Premonition is part of Microsoft's initiative entitled AI for Earth Project, which aims at providing AI capacity to solve some of the current major environmental challenges.[78] The objective of Project Premonition is to provide accurate data about biodiversity. Traditional data collection is time and resource intensive. Project Premonition innovates by utilizing mosquitoes as field scientists. The idea is to collect and analyze the blood taken by these insects from other animals to gather important information about the biodiversity in a specific area. Project Premonition combines several technologies to achieve this objective: drones are used to identify mosquito hotspots, robotic traps collect them, and cloud-scale genomics and machine-learning algorithms analyze the blood to identify each animal they bit. This innovative collaboration of technology, human expertise, and nature allows scientists and conservationists to gather more accurate and real-time information about the state of nature in a specific ecosystem.[79]

SDG Goal 14 entitled "Conserve and sustainably use the oceans, seas and marine resources" can be vastly enhanced thanks to the AI capacity to analyze large volumes of data stemming from wildlife abundance and distribution, allowing for a better understanding of migration, threats, and adaptation to current challenges such as overfishing, climate change, and ocean acidification, to name only a few.[80]

Overfishing, plastic pollution, and global warming are some of the numerous challenges that threaten marine wildlife. Coral reefs are particularly vulnerable to these changes, resulting in a 40% loss of corals worldwide in the last 30 years.[81] The XL Catlin Seaview Survey aims to track and communicate these transformations globally. It is a vast network of public and private scientific organizations including the Global Change Institute (GCI) of the University of Queensland, Google, Underwater Earth, Fourth Element, Lady Elliot Island, Mission-Blue, World Resources Institute (WRI), International Union for Conservation of Nature (IUCN), National Oceanic and Atmospheric Administration (NOAA), Scripps Institution of Oceanography (UC San Diego), and Living Oceans Foundation.[82]

The XL Catlin Seaview Survey started in 2012 and is developing a record of the coral reefs in the world in high-resolution, 360-degree panoramic vision to better monitor coral abundance, health, structure, and biodiversity globally, thereby supporting policy and decision makers in assessing and protecting coral reefs.[83] Monitoring produces large volumes of images, which are not possible to sort manually. The XL Catlin Seaview Survey utilizes an Artificial Neural Networking algorithm to identify what is on the photos and classify all the data.[84] About 81% of the time, the features in coral photos that are identified by the algorithm coincide with those identified by the human eyes of scientists; this percentage is in fact similar to that of two experts who compare their analyses of a coral photo. This combination of semi-automated data collection and monitoring opens the door to a new era of under-sea mapping of reefs in the world, which will allow scientists not only to have more accurate and up-to-date data about marine life, but also to dedicate more resources to research rather than to data collection and processing.[85]

CoralNet is an initiative from the University of California San Diego, which aims at reducing the annotation bottleneck. Indeed, while large amounts of data about marine life are collected, their analysis remains slow when each photo must be inspected manually. CoralNet uses an image analysis technology, which allows 50–100% automation.[86] HyperDiver is a project that monitors underwater wildlife with high precision, and then feeds these data into a machine-learning software similar to CoralNet, allowing the identification with high accuracy of proper taxonomic types including sponges, macroalgae, and seagrass.[87]

FishFace is a project that uses machine learning to identify wildlife diversity in deep oceans. The idea behind this project, which won the 2016 Google Impact Challenge, is to provide accurate data in order to better protect wildlife. Indeed, 90% of fisheries in the world are overexploited and lack stock assessment data.[88] To address overfishing requires having access to accurate and updated data about fish population distribution and abundance. This requires significant resources when done traditionally, which explains the lack of data in the developing world. The Nature Conservancy has developed innovative instruments to assess fish stocks affordably and in collaboration with fishers, government, and industry in Indonesia. FishFace uses machine learning to identify fish species. Data are collected through recycled smartphones used by fishers on their boats in the region. Thanks to image recognition technology, FishFace can quickly and accurately identify fish species and length from the photos taken by fishers, which will not only provide precise and up-to-date data about fish stock in the region, but also enable the fish to be sorted before arriving at the processing facility. The objective is to develop an affordable and efficient framework for fisheries assessment and management in the developing world.[89]

AI can further support the fight against plastic pollution. Although plastic production started in the 1950s with exponential growth since the 1980s, only a minority of the population was aware of the problem before the first decade of the 21st century, when social media helped raise awareness about the scale of plastic pollution in the ocean.[90] Thanks to the use of drones to map hotspots of plastic wastes, and AI to help identify plastics in the thousands of aerial photos taken, the NGO Plastic Tide[91] provides an accurate, open-source map of the most polluted coastlines. This then allows governments to better target clean-up measures, and better assess the effectiveness of policies to reduce plastic waste such as a ban on plastic bags for instance. Originally started in the United Kingdom, Plastic Tide aims to develop its operations globally.[92]

Moreover, citizen science and artificial intelligence go hand in hand to protect wildlife. Thanks to the power of citizen conservationists who collect large volumes of data throughout the world, and to AI that can help analyze these big data, scientists now have access to a wealth of insights never foreseen. In this context, AI allows for innovative forms of collaboration between academia, governments, civil society, and the private sector, helping reach SDG Goal 17 entitled "Revitalize the global partnership for sustainable development."[93] Furthermore, AI can support remote learning programs and improve participation and completion rates thanks to virtual mentors and responsive individualized learning programs. Remote education offers a wide range of courses, in particular related to nature conservation, which are accessible 24/7 around the globe for free or at a more affordable price than traditional onsite education, supporting SDG Goal 4, "Ensure inclusive and quality education for all and promote lifelong learning."[94]

Most wildlife research initiatives lack resources. Collecting and managing data are often not systematic and, in the long run, are often dedicated to a one-off analysis for a specifically funded research project. With limited global or regional data sharing between projects, this leads to a difficulty in reaching a critical mass of data for endangered species. In addition, traditional data collection strategies and manual data processing, such as verifying images manually, are resource and time intensive, leading to limited scales and to some delay between the observation phase and the recommendations. ICTs and in particular AI can help overcome these limitations in terms of scope, scale, repeatability, continuity, and return on investment[95] by providing highly efficient and less resource-intensive data collection, management, and analysis instruments.

iNaturalist is one of the most popular nature apps, which enables users to identify plants and animals in their surroundings; it was developed in a collaboration between the California Academy of Sciences and the National Geographic Society. iNaturalist has succeeded in creating a community of citizen conservationists all around the world who can share their observations through this app, and receive information from a network of more than 750,000 scientists.[96] The idea of this initiative is to combine two objectives: to connect people to nature by enabling them to better understand nature around them, and to collect scientifically valuable biodiversity data. Once a photo is taken by a user in the field, AI along with computer vision models make a suggestion about the sighted species; this suggestion can then be confirmed by a scientist, which subsequently enables the AI to better identify species throughout the world. The data collected also allow scientists to track changes in terms of species population and abundance, receive almost real-time pest invasion information, and apprehend how plants and animals adapt to changes such as climate change or desertification.[97]

The civil society organization (CSO) Wild Me developed a new collaborative platform called Wildbook to help scientists benefit from citizen science, computer vision, and AI, and generate new insights about wildlife species. This initiative is a collaboration between Wild Me and the University of Illinois-Chicago, Rensselaer Polytechnic Institute, Princeton University, but also Microsoft, Pineapple Fund, and Amazon Web Services. Wildbook offers technological solutions to collect and store large volumes of data originating in the field. It allows scientists to monitor individual animals and their behavior in the wild, collect and analyze biological samples, engage citizen conservationists, build a research network, and create new animal biometrics.[98] Thanks to AI, images showing animals with distinctive features such as stripes, spots, wrinkles, or notched markings can easily be identified and large-scale databases about wildlife population movements at specific times of the year can be generated. In addition, AI allows these data from the field to be combined with geographic, environmental, behavioral, and climate data, affording better comprehension of what animals do, when, where, and why.

Wildbook allows individual animals in photos collected by citizen conservationists to be recognized through two stages. First, the detection process, based on deep convolutional neural networks (DCNNs), detects animals and some of their specific features, creates bounding boxes surrounding each of them, and annotates the bounding boxes with the description of these features. Second, the identification process assigns a name to the annotations generated by the detection phase. The specific features of each animal and their location on its body produce a specific score for each individual animal.[99] Wildbook supports a wide range of conservation projects and institutions, including WWF Norppa Galleria for Saimaa ringed seals, MantaMatcher for manta rays, Giraffespotter for collaborative giraffe research, Princeton University for zebras and giraffes, and SPLASH Catalog for humpback whales (*Megaptera novaeangliae*), to name but a few.[100]

Developed by the same CSO Wild Me, the Wildbook for Whale Sharks is a project that aims at identifying whale shark (*Rhincodon typus*) encounters and individually catalogued whale sharks. Through citizen science, photos of whale sharks are taken, with observation data such as location, time, sex, and scars. These data are verified by a scientist, and then uploaded into the database. Two spot pattern-matching algorithms, functioning similarly to facial recognition software, are used to analyze the skin patterning behind the gills of each animal, including any existing scars. This analysis provides a ranked selection of possible matches with existing whale sharks in the database, and if there is no match, a new profile is created.[101]

Another aspect of knowledge production is related to reporting on and monitoring compliance. Indeed, assessment is often challenging in global environmental governance due to its complexity and large number of conventions, treaties, and the like. Many governmental agencies and IOs have their own reporting formats, which leads to a juxtaposition of different reporting formats and data sets for the same agreement or the same objective. In the field of biodiversity conservation, more than 155 multilateral and bilateral agreements cohabit, each one with its own reporting and monitoring process. This makes monitoring highly complicated. AI technology can prove useful to solve this challenge thanks to its capacity to analyze large volumes of structured but also unstructured data. It can help CSOs provide a global overview of all activities and reporting for a global issue such as biodiversity. It can help better assess where resources are spent for a global objective, and based on prediction models, enhance how they will be allocated in the future. This lends more efficiency and effectiveness to donor funding, making recipients of these funds more accountable as well.[102]

In a digitalized world, criminals use social media platforms to illegally trade tiger products, such as their teeth, claws, parts of their skin, and other parts of this animal that are used in traditional medicine. The World Wide Fund for Nature (WWF) has collaborated with the company Tiger Beer, 13 Asian countries, and six artists[103] to counterattack, using the same channel (social media), and they have launched a communication campaign entitled #3890Tigers campaign – 3890 refers to the estimated number of tigers left in the world today. The objective of this initiative is to raise awareness of the declining population of tigers in the wild. AI is used in this case to transform pictures and selfies that people have taken into unique artwork. Each portrait is intertwined with a tiger to showcase how people can live harmoniously with tigers. This artwork is then shared on social media, which enables WWF to give this cause visibility. The communication campaign pledges to end the illegal tiger trade and aims at doubling the tiger population by 2022.[104]

Duberry, J. (2019). Global Environmental Governance in the Information Age: Civil Society Organizations and Digital Media. Routledge.

5. Concluding remarks

With about two billion 1-megapixel photographs produced every day,[105] collecting data from satellites is no longer an issue. To the contrary, the volumes of data collected require the use of specific technologies to analyze these large data sets and make sense of them, both for the global good and to protect the planet. According to Stuart Russell, UC-Berkeley, lead of the AI for Good breakthrough team on AI and satellite imagery, "We have recorded the whole world for a long time," which has led to having access to this unprecedented data set. However, due to the complexity of the world, humans have a hard time making sense out of it. However, "with AI, perhaps we can."[106]

AI is increasingly taking a leading role in making sense of the big data recorded by satellites, drones, smartphones, and sensors throughout the planet. Indeed, this technology can be applied to help solve a large number of contemporary challenges. As discussed in this chapter, AI supports civil society in its roles of service provider and knowledge broker. It allows the development of innovative solutions to combat poaching and better protect endangered species and ecosystems, among others. It also allows the production of new knowledge about life on land and under the seas, and a more precise understanding of our planet and its environmental complexities.

However, civil society is not the only actor of global environmental governance to benefit from this technology: local public authorities, businesses, and international organizations also embrace AI to improve their services and develop new knowledge.

AI can empower SDG Goal 11 entitled "Make cities inclusive, safe, resilient and sustainable"; autonomous public transportation, efficient resource allocation, urban planning based on predictive models combining satellite imagery, economic activities, transportation flows, private consumption, entertainment and recreation activities, and crime rates are some examples of the application of AI to develop smart and sustainable urban areas.[107] Furthermore, by integrating data from production and consumption on a large scale and with real-time data, AI can improve the efficiency of food production, distribution, and consumption, reduce waste, and reach SDG Goal 12, "Ensure sustainable consumption and production patterns."[108]

Renewable sources of energy are intermittent. Thanks to real-time data collection and analysis, AI can develop accurate consumption prediction models, and thus increase the use of green energy and its integration into the traditional electric grid, supporting SDG Goal 7 entitled "Ensure access to affordable, reliable, sustainable and modern energy for all."[109] Furthermore, big data and the Internet of Things (IoT) generate large volumes of data. Analyzed by AI, the consumption patterns allow accurate sanitation predictions to be made based on real-life and real-time data and not models from past years. Thanks to these predictions, clean water distribution and sanitation can be planned more accurately, in support of SDG Goal 6 entitled "Ensure access to water and sanitation for all."[110]

Artificial intelligence can help improve the integration of supplies of renewable energy into the existing electricity power grid. Indeed, solar, wind, hydroelectric, biomass, and geothermal power are some of the most well-known sources of renewable energy. However, they provide energy irregularly contrary to gas or nuclear power plants for instance, which can be managed according to the electricity consumption demand. This irregularity is one of the main challenges associated with renewable energies, and AI can help overcome this issue by providing almost real-time control over the supply and demand of electricity. Indeed, by 2020, the European Union aims to implement more than 200 million smart electricity meters for private consumption. These meters are connected to the electric grid and provide real-time data about individual consumers. These large volumes of data are collected and then analyzed by AI to develop electricity demand prediction models based on consumer constraints and preferences. Based on this analysis, AI can adapt the supply of electricity almost in real time. Indeed, smart meters can reduce the electricity provided by temporarily dimming lights or switching off electric heaters. The smart meter functionalities, combined with AI, allow the integration of a larger share of intermittent renewable sources of energy into the electric grid, leading to more sustainable energy production and consumption.[111]

AI can also support communities and cities in increasing their efficiency when providing public services. For instance, the city of Melbourne in Australia is developing an AI-based platform that in real time can adapt the delivery of clean water to the demands for clean water that are coming, also in real time, from the inhabitants of the city.[112] This leads to reducing by about 20% the amount of energy used to treat water. Python, the name of the platform, combines historical and real-time consumption data to ascertain the most efficient use of water pumps without any human intervention.[113] Started as a pilot in one water treatment plant, it is rapidly expanding to others in the city. To ensure that the delivery of water would continue even if there were an incident, the AI can only optimize the process. In addition, Melbourne Water has implemented cybersecurity provisions, one of which is that the AI platform is not connected to a wider network.[114]

AI has multiple applications to help reach SDG Goal 16 entitled "Promote just, peaceful and inclusive societies." It can help organizations develop new services and provide broader access to e-government services and information thanks to a smart and automated voice assistant.[115] It can also help improve trust between various stakeholders. The International Telecommunication Union (ITU), along with a network of other international organizations, has developed a platform called TrustFactory.ai.[116] This platform is an incubator to support projects on three aspects related to trust and AI: trust in AI technologies, trust in AI developers, and trust among users of AI technologies, which includes a large number of stakeholders such as developers, policy and decision makers, local communities, NGOs, businesses, and individuals, to cite only a few.[117]

Although AI presents some challenges in terms of governance and power – the fear of humans of being controlled by AI one day – this new technology already allows us to better understand our planet, from its urban communities to its most remote and untouched areas, from high mountain peaks to deep oceans, and to understand how our planet adapts to the rapid changes it must face stemming from human activities, climate change, and pollution, to cite only a few.

This chapter aimed at providing an overview of the current uses of AI in relation to nature conservation and sustainable development. It is not exhaustive by far. Due to the fast-changing environment of this disruptive technology, AI will most certainly become a major instrument in the future of environmental governance, from policy making to field and operational projects. The next challenge for the environmental community and society at large is to develop AI skills in order to benefit the most from this technology and help protect the planet.

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Concluding remarks

This book was motivated by a deep concern about the urgent necessity to protect nature and to find a global response to this need. Today's world is organized around information and data, with ongoing technological, industrial, organizational, and commercial innovations; an increased level of complexity due to the multiplicity of forms of authority and the interdependence of global issues; and an unforeseen number of changes in the environment – climate and biodiversity loss, to cite only two. These new technological and environmental conditions raise many concerns, starting with their global scope and their speed. In this sense, technology and the environment could be seen as similar: they change fast, and their impact is at all levels – local, national, regional, and international – and on all sectors of the economy and on all social-economical groups of society. However, the impact is not homogenous for all and varies greatly from sector to sector, from one country, region, or community to another, and from one social-economical group of society to another. Indeed, the capacity to adapt to these changes depends on the capacity to adapt to environmental changes such as rising sea levels or higher temperatures, and to technological changes such as the emergence of new jobs and the disappearance of others.

This complexity calls for new collective governance procedures that allow all stakeholders not only to be part of the rule-making processes, but also to gain additional ownership of the implementation of these decisions. The responsibility of governing the environment and digital technologies is at all levels, not only among actors on the international stage but also among citizens who use these digital tools, and whose daily choices and behaviors have a direct impact on the environment. In this sense, new collective governance procedures also imply that all actors, from the citizen to the state representative, perceive their responsibility to tackle these issues. Since the generalization of ICTs did not lead to the emergence of a global citizen identity, maybe the challenges to managing common global public goods, such as technologies and the environment, could lead to a global understanding of a common fate requiring people to face these global challenges, whose impacts on society and institutions are yet to be understood fully.

International decision-making mechanisms face the challenge not only of legitimacy, but also of efficiency and effectiveness. In that respect, digital technologies can prove to be a double opportunity. On one hand, secretariats and organizations

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can become more efficient by using ICTs to improve their internal processes and reduce their communication costs. On the other hand, ICTs can also replace some of their tasks, in particular the most routine and administrative tasks, which will require, for some of them, showing flexibility and adaptation, but also having the autonomy to redefine their role and added value on the international stage. This is an opportunity since it will allow more resources – human and financial – to be dedicated to field projects and research. In that respect, ICTs could help bridge the gap between the mandate given by state parties and the actual concrete resources. In that sense, ICTs could help organizations to become more effective and visible.

In the early 2000s, when social media platforms emerged, optimists would praise how digital technology will change the organizations through enhanced communication tools, and empower individuals and civil society, raising awareness and spreading democracy throughout the world. At the same time, pessimists already stressed the repercussions of technological advancements: tottering digital security, and increasing inequality – especially due to the unequal internet penetration rates. Today, digital technologies and the challenges they represent have emerged in the public debate, and the pessimist view seems to have won the public debate. While more and more citizens use social media platforms, the impact of ICTs on political processes, in particular democratic political processes, raises a lot of concerns.

While technological determinism recognized the absolute power of ICTs to transform societies into democracies, the Arab Spring and Winter, among other examples, showed that this form of determinism is inaccurate[1]. Digital technologies have an impact on societies, but not in such a deterministic manner. And their impact can be positive, improving the communication skills of civil society for instance, while it can also be negative, by propagating fake news and influencing the votes of millions of citizens through the manipulation of facts. If this book focuses on the positive side of digital technologies, it also acknowledges the danger they represent when not well governed. Hence, these technologies require, as does the environment, efficient and effective governance mechanisms for us to benefit the most from them. States have perceived the opportunities, but also the menaces, that this new digital online space – also called cyberspace – represents, and have developed new cyber-capacities to compete and collaborate. Ongoing cyber-attacks, where states fight against each other to advance their interests, and criminal groups that pursue criminal activities and make immense profits are additional illustrations of the impact of ICTs on the international stage and on the individual lives of citizens, which calls for better governance of ICTs.

In addition, ICTs are not neutral. They are developed in a specific cultural context, and reproduce the values, customs, and habits of the country they come from.[2] The idea of using ICTs to empower civil society probably stems from an ethnocentric view, where civil society's participation in local to international decision-making processes is perceived as positive. However, this view is not universal and raises multiple questions concerning the representability of civil society organizations. Indeed, CSOs pursue not only substantive goals, such as the protection of the environment or the representation of the interests of local and

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indigenous communities, but also organizational goals, including their growth, influence, and autonomy.[3] Hence, their use of ICTs reflects these two categories of goals, and their activities on the international stage as well. Necessarily, and similarly to other actors, they need to raise additional funds, and attract the attention of citizens at the local level and governmental actors on the international stage. Their legitimacy stems from multiple sources, starting with their scientific expertise and knowledge of the field. The environmental CSOs mentioned in this book have a long history of conservation projects, advocacy campaigns, and monitoring undertakings. Although some critics may raise some concerns about the category of goals they pursue – substantial or organizational – their accomplishments are well-established and have led to the emergence of the legal framework to protect the environment that we know today, and to the better protection of species and ecosystems. Moreover, their legitimacy comes from the large community of citizens who actively support their work. Although CSOs are not elected, it is undeniable that they have represented the interests of parts of the populations – and of the world – that were once not as well represented on the international stage as they are today. In 2016 IUCN Members decided to create a new category of Members dedicated to indigenous people and communities, which is one illustration among others of the crucial influence of civil society on international decision-making processes. Hence, ICTs help CSOs gain additional legitimacy by allowing a closer bond between CSOs and the ones they claim to represent, and by improving their efficiency and effectiveness both in terms of advocacy and in terms of conservation field projects.

This book focused on the use of current and emerging ICTs by environmental civil society organizations, and how they empower these organizations to reinforce their competences to participate in global environmental governance. Although the international stage continues to be based on the state system, civil society organizations make extensive use of ICTs, and in an information age, their capacity to use these current and emerging technologies leads them to gain more visibility and credibility.

The participation of civil society and other stakeholders as well as the role of technologies are considered to be already in the premises of the emergence of the concept of sustainable development. Civil society rose as a global movement of actors on the international stage in parallel to the generalization of ICTs and globalization. These three aspects of our contemporary world are intrinsically connected. The emergence of new forms of authority accentuates the complexity of global environmental governance, while enriching the decision-making processes with a variety of points of view and interests, scientific expertise, and local knowledge. In this informational society, with information and data at its core, the Net generation shows unprecedented levels of ICT mastery since its members were born in an internet age. In this context, where transparency, cooperation, and participation are the new normal for this generation, civil society adapts by developing new forms of governance without institutionalization, and new forms of technology-intensive activism. These new forms of action on the international stage, combined with an increased access to information, better education, and

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an increased awareness of global issues such as the environment, represent a new opportunity for the protection of the environment.

Among the numerous tools used by civil society to reach out to its audiences, websites are the oldest ones. The analysis of 15 CSOs accredited to UNEA indicates that they first and foremost use their websites to provide information to a wide audience. However, few have developed consultation and mobilization features on their websites. This analysis also shows that web traffic is a strong indicator of the number of participation features on their websites. CSOs with high web traffic have developed substantially more information, consultation, and action features on their websites, which also show higher levels of usability and maturity. Conversely, organizations with less web traffic have developed less content and implemented fewer technology features. This leads one to conclude that web traffic is an indicator of participation, either as an incentive to develop participation features or as a consequence of the presence of such features on the website. It seems, in any case, logical to pursue the idea that a website, with well-developed content, along with numerous consultation and action initiatives, accessibility and ease-of-use, and high sophistication, can only increase opportunities for transparency and interaction. However, among the endless number of websites available, only a few get referenced on the first page by search engines. This means that for smaller organizations with a limited online advertising budget, a website might in fact not result in more visibility. When searching for key words such as "environment," "climate change," or "biodiversity," the main international governmental and non-governmental organizations come first and get most of the attention. This leads one to conclude that although websites are in principle extraordinary tools to promote content and the work of an organization, they can also reinforce the inequalities between small organizations and the big ones.

The second type of digital technology most used by civil society is social media. At a time when information is increasingly consulted on social media first, and when individuals spend more and more time connected and in front of a screen, these platforms are crucial for civil society to increase its visibility and reach out to its audience. The analysis of the social media presence of some CSOs accredited to UNEA confirms the dominant narrative that hints that social media instruments have become an integral part of the advocacy strategies of CSOs. A large majority of organizations are present on Facebook and Twitter. The digital divide remains an issue with the number of NGOs from Europe and North America surpassing African ones by far. Moreover, and similarly to websites, social media tends to increase the inequality between small and large organizations, with the top 15 organizations with the most likes (on Facebook) and followers (on Twitter) concentrating most of the visibility. This implies that a fairly small number of organizations, mainly from Europe and North America, concentrate most of the attention on these two platforms, and therefore inhibit organizations from other continents from raising awareness about other issues and proposing other perspectives about nature conservation. It shows that social media platforms have not only allowed a large number of organizations to reach out to global audiences, but also contributed to inhibiting smaller organizations from raising awareness about other issues and to reducing the plurality of sources of information for citizens.

Furthermore, the choice of advocacy tactics, tone of voice, regularity of publishing, and story line depends on how organizations are positioned in global environmental governance. Their communications were coherent throughout the month chosen for the analysis, and clearly illustrate the variety of advocacy strategies that are possible thanks to social media platforms. Finally, this analysis also partly confirms previous research, in the sense that the sample of CSOs examined mainly used social media to inform their audience. As Lovejoy explains, "Although nonprofit organizations have become more interactive in their use of Twitter as opposed to their websites alone, we found Twitter is still used by many nonprofit organizations as an extension of information-heavy websites. These organizations are missing the bigger picture of its uses as a community-building and mobilizational tool."[4] However, the call to action comes second in terms of social media tactics, and many organizations use these platforms to mobilize their audience and involve them to support their work, change a behavior, take part in local projects and protests, or increase the awareness of an issue. A similar analysis of other platforms used in Asia would reveal highly relevant information.

With the emergence of civil society as actors in global environmental governance, ICTs are increasingly used to foster decision-making processes. This was one of the main promises of the internet: it was supposed to allow new stakeholders to take part in governance processes at all levels since the internet allows the communication of the many to the many. The multi-stakeholder decision-making process developed by the International Union for Conservation of Nature (IUCN) gives the same voting rights to state and civil society Members, and enables Members to make proposals in the field of nature conservation at large. Its progressive digitalization offers an opportunity to analyze if ICTs can improve the participation of stakeholders, and in particular civil society, in a decision-making process. The online discussion platform and the online voting procedures allowed Members to reach a consensus online on more than 90% of the topics debated. Furthermore, the analysis shows that this digital process allowed state and nonstate Members to participate at similar levels: in other words, it did not favor the most resourceful actor and succeeded in providing equal opportunities to both categories of Members. If this case of digital participation is conclusive, it is also due to two factors associated with technology adoption. Indeed, participating in the electronic discussion system required Members to adopt a new technology. This is not as straightforward as it may seem. Indeed, a barrier often prevents users from adopting a new technology, whether this is due to its complexity or to the user's limited understanding, competence, or time. This barrier can be either psychological or technological. For both cases, the electronic discussion system was successful in developing a technology that was accessible to all constituents and could be easily used. Furthermore, to adopt a new technology, overcome the barriers mentioned previously, and change the habit of discussing and debating motions from on site to online require clear and direct motivation. This means

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that in the case of the electronic discussion system, Members clearly saw the direct benefits of adopting this new technology. Lastly, the digitalization process of this governance mechanism allows the organization to reduce significantly its environmental footprint, since it allows participants to make propositions and take decisions remotely.

Further research to assess the impact of ICTs on other global decision-making mechanisms is required and would help to gain additional understanding of their potential impact. In addition, an analysis of all forms of civil society participation and consensus-building processes in global environmental governance could help bring forward general trends and show the role of new ICTs in this evolution. In particular, additional research should be conducted to examine the influence of civil society organizations on treaties and global agreements to protect nature. If some global environmental governance mechanisms are more legitimate than others, the next stage would be to define if the global civil society has gained more influence on the final version of treaties because of new ICTs. Moreover, levels of participation in the discussion process were low and average in the voting process. Further research should enable one to understand how to increase these levels of participation.

In terms of emerging technologies, blockchain is one of the most prominent, with numerous articles and videos online mentioning its benefits for people and organizations. This global digital ledger offers innovative solutions in terms of trust, fundraising, transparency, incentives, and distributed governance. Blockchain technology provides a new set of skills to CSOs. It has the potential to positively affect any type of decision-making process involving multiple parties globally. Good governance is key to managing natural resources sustainably. Values of trust, transparency, inclusive participation, and effective implementation are the building blocks of future global governance systems that will ensure a healthy and prosperous future for all. Furthermore, blockchain technology can increase the visibility of sustainable and unsustainable production practices globally. This would help consumers to make a choice when buying products and services. The network itself, thanks to its structure, ensures trust among all agents and allows information such as land property rights to be recorded safely. Local communities with rights to natural resources could receive direct payments in bitcoins as a reward and incentive to protect their nearby ecosystems and species. However, this technology also raises numerous concerns, including data security and privacy, the right to be forgotten, high levels of computing capacity and therefore a high level of electricity consumption, and finally access to this technology, which remains unequally distributed in the world.

As mentioned previously, information and data are at the center of the knowledge economy and the informational society. Individuals, organizations, and governments produce and consume large amounts of data. Big data allow CSOs to develop a wide range of innovations in fields relating to global environmental governance. The analysis focused on the knowledge production and distribution capacity of CSOs. As shown, civil society is increasingly becoming tech-savvy and gradually embracing these emerging technologies to increase its positive impact on the protection of the environment, the combat against climate change, and the loss of biodiversity, to name only few. However, big data technologies are not without critics, in particular with regard to questions of privacy and confidentiality, compatibility of data sets, and biases. Indeed, these large data sets are not always based on a common standard, which reduces their impact and opportunities for innovation and nature conservation. Moreover, data collected by citizens can be inherently and unintentionally biased, which leads researchers to focus more attention on data integrity. Due to their intrinsic features, big data require new non-human instruments and techniques in order to be handled properly.

Big data technologies are linked to another innovation, which is increasingly used by civil society in the environmental field: artificial intelligence (AI). It is increasingly taking a leading role in making sense of the big data recorded by satellites, drones, smartphones, and sensors throughout the planet. Indeed, this technology can be applied to help solve a large number of contemporary challenges, and enhance organizations' knowledge production and field implementation capacity. AI can help in predicting the effects of climate change and the path of storms, monitoring the spread of diseases, understanding human decision-making processes in terms of energy consumption and protection of the environment, or identifying areas most in need of attention. These are some of the numerous AI applications that CSOs have employed in the last several years to protect the planet. Although AI presents numerous challenges in terms of ethics, governance, and power, this new technology already allows us to better understand our planet, from its urban communities to its most remote and untouched areas, from high mountain peaks to deep oceans, and to understand how our planet adapts to the rapid changes it must face stemming from human activities, climate change, and pollution, to cite only a few. AI will most certainly become a major instrument in the future of environmental governance, from policy making to field and operational projects.

In this fast-changing context, where innovations keep emerging and triggering numerous others, this book aims at providing an overview of the current uses of current and emerging ICTs by CSOs in global environmental governance. It does not aim to provide an exhaustive list. However, it wishes to show that digital technologies can be beneficial to environmental CSOs but at different degrees. In a world with information at its core; citizens who spend an increasing amount of time consuming and producing information online; and citizens who are more aware of environmental challenges; current and emerging ICTs allowing organizations to increase their visibility, to advocate, to engage with local communities, and to conduct scientific experiments and field projects, civil society has the opportunity not only to pursue its key roles in global environmental governance, but to enhance some of its key competences, including advocacy, making proposals, fundraising, promoting sustainable behaviors, monitoring, knowledge production and distribution, and field project implementation. Hence, digital technologies strengthen the participation of CSOs in global environmental governance.

This book aims to contribute to building additional knowledge on the prevalence, limits, and opportunities of new ICTs. It wishes to show how current and

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emerging ICTs can be deployed to support global environmental governance, and in particular a multi-stakeholder approach to the protection of the environment, the foundation of our lives. As mentioned previously, however, this will be possible only if ICTs are used for the common good, hence well governed. This means that ICTs are both an opportunity for global environmental governance actors and a pitfall. If not well managed, ICTs can increase insecurity, mistrust, and chaos among populations. Therefore, it is equally essential to develop good governance practices for the environment and digital technologies, which are open to all stakeholders, and which put the sustainable well-being of human populations at the center of decisions.

Notes

1 See Ess, Charles, 1996. The political computer: Democracy, CMC, and Habermas. In Ess, C. (ed.). *Philosophical perspectives on computer-mediated communication*. Albany: State University of New York Press, pp. 197–230.
2 See Ess, Charles, 2018. Democracy and the internet: A retrospective. *Javnost – The Public*, 25, pp. 1–2, 93–101. doi:10.1080/13183222.2017.1418820
3 Velazquez Gomar, J.O., 2014. Environmental policy integration among multilateral environmental agreements: The case of biodiversity. *International Environmental Agreements*, 16, p. 528. doi:10.1007/s10784-014-9263-4
4 Lovejoy, K., Saxton, G.D., 2012. Information, community, and action: How nonprofit organizations use social media. *Journal of Computer-Mediated Communication*, 17(3), p. 351. doi:10.1111/j.1083-6101.2012.01576.x