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OPINION

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Saving plants, saving ourselves

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Societal Impact Statement

Humans, as a species, are very new on Earth, but we have had a profound effect on the Planet. The global ecosystem is necessary for every aspect of our lives; yet, we are not safeguarding it nor protecting the biodiversity of the other organisms we share the planet with. As a species, we depend on plants and agriculture for our very existence and they need to receive greater attention and focus. Plant scientists can work together to achieve a robust and sustainable future for all.

Summary

The future of the Earth and its inhabitants has never been more uncertain, but there is still time for us to prevent further catastrophe. Plant scientists have a crucial role to play in the preservation of plant biodiversity and crop genetic diversity, both vital goals that will have a major impact on the success or failure of humanity's attempts to prevent ecological disaster. At the 2017 International Botanical Congress in Shenzhen, China, a series of suggestions for the many important ways in which plant scientists could contribute to a sustainable future were proposed, and were accepted by the Delegates of the meeting. These included: conducting research in the context of the changing world, promoting plant science and international collaboration, building platforms for big data, generating a full inventory of plant species, protecting indigenous knowledge, and engaging the power of the public. Here, I describe this Shenzhen Declaration, the threats it aims to mitigate, and the key roles that plant scientists must play for the future benefit of mankind.

KEYWORDS

Anthropocene, biodiversity, extinction, outreach, seed banks, Shenzhen declaration

> "The world is a garden, and we are all its gardeners"—Professor Daniel Janzen, University of Pennsylvania, about 1965

Who is better prepared than plant scientists to care for our common garden in the face of environmental threats that must be overcome? Regardless of how important our short-term goals may seem, we are citizens of a world in which a large proportion of other living forms are moving rapidly toward extinction. Collectively, human beings have created a world in which only our very best efforts will ensure peace, prosperity, and sustainability for ourselves and those who will follow us. The possibility of building a durable future may still be within our grasp, but only if we undertake a level of collective effort and cooperation much greater than anything we have attempted thus far. In July 2017, a group of plant scientists gathered in Shenzhen for an especially productive meeting, the first International Botanical Congress held in China. Here, I shall review the Shenzhen Declaration, a series of suggestions for how plant scientists might contribute to the overall human effort, endorsed by the Delegates at the conclusion of the Congress (Shenzhen Declaration Drafting Committee, 2017). These

principles form part of the action plan that we so sorely need to put in place for our common benefit.

When I attended my first International Botanical Congress in Montréal, Canada, in 1959, the global human population numbered just over 3 billion. At the time of the 2017 Congress just over half a century later, our numbers had climbed to 7.5 billion, increasing at the rate of 220,000 net per day, and were projected to reach 10 billion by the middle of the 21st century. We are currently using about 170% of the world's sustainable productivity, at a level that has roughly tripled since 1959 (www.footprintnetwork.org; Figure 1). Humans are responsible for some of the most devastating ecological pressures that our planet has ever experienced, but we possess the unique capability of thinking about and modifying what we are doing. By doing so, we might still be able to adapt our behavior to allow the civilization we built over a tiny slice of geological time to persist into the future.

1 | THE EVOLUTION OF EARTH

To view our present dilemma in context requires a review of some of the highlights of geological history. Our solar system is about 4.57 billion years old, and the oldest rocks we have found on Earth date from about 200 million years later. The oldest known fossils, 3.8 billion years old, were microscopic prokaryotes that lived in an oxygen-free atmosphere; however, about 3.5 billion years ago, cyanobacteria, the first photosynthetic organisms, appeared in the fossil record. Their photosynthesis, which was at first anoxic, evolved to produce oxygen about 2.7–3 billion years ago. By 1.7 billion years ago, appreciable amounts of oxygen had accumulated in the Earth's atmosphere, but all life remained aquatic until the fungi colonized the land, with terrestrial plants appearing about 470 million years ago. Photosynthesis in plants depends on the presence of chloroplasts, which evolved from a cyanobacterium endosymbiont incorporated into the cells of their ancestors, green algae, hundreds of millions of years ago. The metabolic activities of plants on land caused the oxygen in the Earth's atmosphere to increase to its present level, about 20% of the total, by 400 million years ago, and the approximately simultaneous venturing of the first vertebrates onto land was almost certainly not a coincidence. Flowering plants and placental mammals both originated in the early Cretaceous Era, about 130 million years ago, and their evolutionary pathways subsequently intertwined.

Over the course of life's history, five major extinction events and many lesser ones have occurred. The most recent major event, at the Cretaceous–Paleogene boundary 66 million years ago, ended a 150-million-year period of dominance by the dinosaurs and other reptilian groups. This apparently opened ecological "space," within which modern mammals and birds (avian dinosaurs!) diversified. Angiosperms apparently did not suffer major losses at this time, surviving in strength to diversify extensively and continuously during the following Cenozoic, Holocene, and Anthropocene periods.

During the course of the past 40 million years, the concentration of carbon dioxide in the atmosphere has gradually fallen and the global climate has cooled overall, leading to the expansion of the world's grasslands and ultimately deserts. Primates appeared near the end of the Cretaceous Era, with humans separating from a common ancestor with the African apes some 6–8 million years ago. Our genus, *Homo*, appears first in the form of Ethiopian fossils 2.8 million years old, just before the start of the modern ice ages, the Pleistocene Epoch. The earliest fossils of our own species, *Homo sapiens*, were found in 300,000-year-old rocks from Morocco. Our ancestors migrated out of Africa at least 60,000 years ago, spreading rapidly throughout Eurasia and to Australia, reaching the Americas at least 15,000 years ago. All

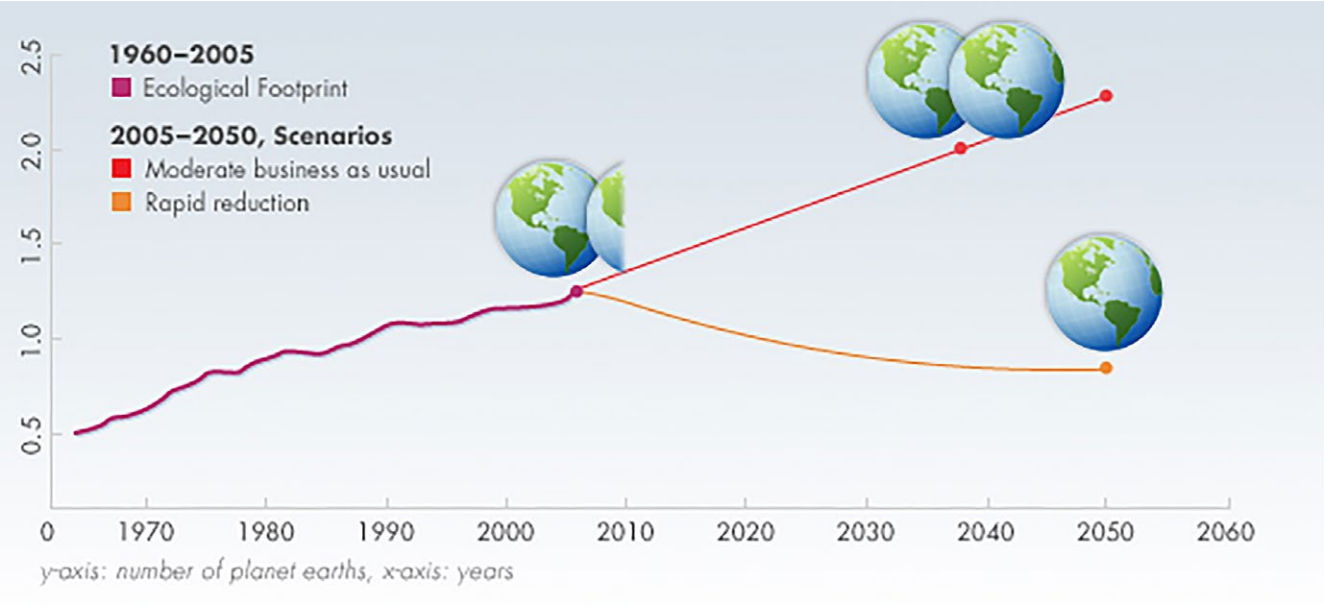

FIGURE 1 The amount of resources used annually, in terms of the total amount produced by the Earth in one year (image courtesy of Global Footprint Network, https://www.footprintnetwork.org)

of this migration took place during the recent glacial maximum, a cool period that lasted from 110,000 to 10,000 years ago.

Although they sometimes set fires to increase the abundance of game, the ecological impact of the scattered bands of early hunter-gatherers was limited before the development of agriculture about 12,000 years ago. This should not be surprising, because the total global human population at that time is estimated to have only been about one million people, including around 100,000 Europeans. The ensuing years, a tiny sliver of Earth's history, have proved exceedingly traumatic for our planet. The development of agriculture, perhaps first in the Near East but subsequently in a number of different areas, enabled people to live together permanently in settlements, a condition that had been possible only rarely and locally earlier. The inhabitants of such settlements could store enough food to carry them through unfavorable seasons or even whole unfavorable years, allowing them to remain in a particular location. Thus, early agriculturists formed villages, then towns, and eventually cities, where individuals could for the first time specialize in the various professions—activities that together form the basis of our modern civilization. When writing was invented about 5,000 years ago, we could transmit our history from generation to generation and build efficiently on what we had learned in the past.

By the time of Christ, the human population had grown to approximately 250 million people, with an estimated 44 million of them living in the Roman Empire and 60 million in what is now China. At the start of the Renaissance Era (1500 CE), the global population had expanded to about 500 million, two-thirds of whom lived in India and Ming-Dynasty China. Our total population reached one billion people in 1804, by which time the world's land surface had been completely divided into nations and colonies. The global population continued to grow to two billion people in 1927 and on to the rapidly increasing 7.5 billion people alive today (United Nations 2017).

2 | ANTHROPOGENIC THREATS

As mentioned above, we are currently using an estimated 170% of the planet's sustainable productivity, with the resources very unequally divided between nations; a disparity likely to grow as both scarcity and international competition increase. This relationship mandates the world's wealthiest nations to help build environmental stability in the countries from which they obtain raw materials and other products, because the effects of environmental depletion in the source countries eventually impact the countries receiving the resources to the same extent. Globally, stark inequality also prevails for individuals, with the British charity Oxfam estimating that the eight richest people possess as much wealth the 3.6 billion poorest of us (Hardoon, 2017). Half the people on Earth lack sufficient quantities of at least one essential nutrient and many survive on US $2 per day or less. An estimated 100 million people are in danger of starving to death at any particular time (World Bank, 2016).

We turn now to consider the incredible variety of plants, animals, fungi, and microorganisms that constitute the living fabric of our planet. Each of them—and we are no exception—depends on the continued healthy functioning of the systems of which they are an integral part. Given the dimensions and force of the human activities reviewed above, however, it should not come as a surprise that we have already driven and are continuing to drive to extinction a major proportion of these species. About 30% (150 million square km) of the Earth's surface is land, with the rest covered by water. More than a third of all land is devoted to agriculture, most of it to largely unsustainable grazing. One can only imagine how many species must have gone extinct during the spread of agriculture in regions such as the intensively cultivated Mediterranean of western Eurasia and North Africa. At the same time, invasive species of animals and plants, pests and pathogens, are spreading around the world in ever-increasing numbers, out-competing or killing others in the new regions they reach. On top of this, global climate change is not yet being controlled, despite the fact that it threatens to impact the productivity, even the habitability, of major sections of the Earth, especially if national greed is allowed to prevail over our common interest.

How can we measure the harm we are doing to biodiversity worldwide? We really have no idea of the numbers of prokaryotic species (bacteria and archaea) that may exist; one recent paper (Locey & Lennon, 2016) estimated a staggering global total of a trillion species of these groups. For the remaining living organisms, the eukaryotes, estimates of 8–12 million species seem plausible (Pimm & Raven, 2018). We have given names to no more than 2 million of them, and we know next to nothing about even the majority of species we have discovered and named. The natural rate of species loss is estimated at 0.1 species per million per year, but current anthropogenic rates are estimated to be about 1,000 times that background rate (De Vos, Joppa, Gittleman, Stephens, & Pimm, 2015). It should be noted, however, that a possible logical fallacy in these estimates is that, by definition, the longevity of species as measured in the fossil record is based on abundant, widespread species whose remains are most likely to be encountered. In contrast, current rates estimated rates of extinction are based on all species, including many that are restricted in range. Somewhat countering those issues is the fact that populations of virtually all species are disappearing much more rapidly than the species themselves (Ceballos, Ehrlich, & Dirzo, 2017), a clear indication that the overall rate is very much higher than the historical background. Huge numbers of plant species have already been lost. The International Union for the Conservation of Nature (IUCN) considers about 20% of the species it has evaluated to be in immediate danger of extinction. This proportion is certain to expand, given the enormous growth of the human population projected for the coming decades. The combination of ways in which we are changing the Earth is so powerful that as many as half of all eukaryotes are predicted to disappear by the century's end, most of which will be unknown at the time of their loss, never seen or described by anyone (Pimm & Raven, 2018).

We must certainly do what we can in the face of this incredible prospective loss, given that we and the following generation or two are the only ones for whom it will be possible to save these species, or even to see them. We are playing with fire as we exterminate them, since they are all integral parts of the survival systems on which we depend; we simply

do not know when or if those systems might reach a breaking point. Among the actions that we must take are the increase of our knowledge of biodiversity, the setting aside of protected areas, the cultivation of species, and the use of seed banks to save what we can, while we can.

3 | OVERCOMING THREATS TO BIODIVERSITY

To preserve civilization overall, we will clearly need to reach a level and sustainable human population. To speak of individual countries having a "demographic crisis," with too few young people being produced to support the aging ones, is to pretend that the Earth's resources are inexhaustible. The notion that having more children can make a country strong resembles a "Ponzi scheme"—perpetual growth with a finite set of resources. Only the socially just allocation of these resources worldwide can allow all individuals to realize their capabilities. The empowerment of women everywhere is probably the single most important action that we can undertake to enable everyone to work together for our common benefit. Advances in technology will allow us to live better and more sustainably than we could without them.

The goals listed above are our common responsibility; without them we do not really have a chance for long-term survival. Learning how to achieve them and then working to do so is imperative, and we must learn, teach, act, and vote in such a way as to advance our common cause, the search for a sustainable world. In these respects, plant scientists are no different from anyone else.

What, however, are the special contributions to be made in the research fields in which plant scientists specialize? They are many, and of profound importance. For one, plant scientists can systematically work to save plants from extinction. Here, we have a comparative advantage over our zoological colleagues, because plants are far easier and less expensive to conserve than most groups of animals. We can conserve plants by cultivating them, by storing their seeds for decades or even centuries in seed banks, and by preserving tissue cultures derived from them. Doing so effectively will necessitate the intensification of our preservation efforts as rapidly as this can be accomplished. These renewed efforts must be based on the best possible inventories of the estimated 470,000 species of extant plants, with the efficient application of this knowledge to secure samples for maintenance both within and outside of their natural habitats. The challenge is very great, but through international collaboration we would be able to save nearly all of them during the next few decades of rapid environmental change. By doing so, we would be presenting a magnificent gift to those who will follow us.

In general, the field-oriented and organismic disciplines many botanists pursue—taxonomy and systematics, morphology and development, evolution and ecology, and physiology—are in a state of transition, while molecular genetics is properly increasing greatly in importance, funding, and attention; however, new technologies that generate immense quantities of data are often limited by current infrastructure and information-management capabilities. Field-work in rapidly degrading environments is urgently needed, and applied research careers must be expanded in number and quality to enable us to address the problems we are facing in the 21st century. Although the world is deeply troubled and often divided by nationalism and selfishness, we must find a way for science to carry on despite these challenges, so that it can contribute to building what we hope will be a sustainable world in the future.

At this time of extraordinary challenge, the International Botanical Congress was held for the first time in China. The Shenzhen Declaration presents what we hope may be a blueprint for action, and this declaration was endorsed by the Delegates of the International Botanic Congress.

4 | THE SHENZHEN CALL FOR ACTION: SEVEN PRIORITIES

The Shenzhen Declaration Drafting Committee present the following seven priorities for strategic action in the plant sciences. Action in these areas will help mitigate the impacts of human activities on plant species, habitats, and distributions, and to contribute to the formation of a sustainable world for ourselves and the generations that succeed us (Shenzhen Declaration Drafting Committee 2017).

(1) To become responsible scientists and research communities who pursue plant sciences in the context of a changing world.

Plant scientists must contribute to regional and global sustainability as directly and efficiently as possible. Key efforts, such as the urgent preservation of plant diversity and the adaptation of agriculture to increasingly warm climates, must be strengthened greatly if we are to meet the challenges ahead. Our research is not conducted in a vacuum, and we cannot continue to act as if we have a great deal of time available, when we simply and clearly do not. We must confront challenges swiftly and directly to mitigate rapidly deteriorating environmental conditions.

(2) To enhance support for the plant sciences to achieve global sustainability.

Plants play a central role in functioning ecosystems. They also are our sole source of food (directly or indirectly), and provide many of our medicines, building materials, clothing materials, and other essential products. Plants deserve a far greater level of scientific attention through enhanced public and private funding than they receive at present. Integrated studies are necessary to develop robust solutions to environmental problems. Support across plant sciences, from description to use, should be provided and sustained at adequate levels.

(3) To cooperate and integrate across nations and regions and to work together across disciplines and cultures to address common goals.

Science is, by its very nature, international, and the plant sciences are no exception. Although progress has been made in moving forward together, stronger international cooperation will be needed to halt biodiversity loss, improve agriculture, and maintain a stable climate. Working together has never been more important. Stable global partnerships are badly needed to overcome barriers and provide integrated, effective solutions to urgent environmental challenges as rapidly as possible.

(4) To build and use new technologies and big data platforms to increase our exploration and understanding of nature.

New technical approaches to information and information sharing will only accelerate in the years to come, making the sustainability of data platforms imperative. Large, linked databases are increasingly revealing new connections and relationships between lives on Earth. Our rapidly advancing ability to sequence genomes leads to new ways of understanding the diversity, evolution, and functioning of life on our planet. As these and other new technologies expand, we must apply them in timely, integrated, and practical ways to organize information and address environmental problems.

(5) To accelerate the inventory of life on Earth for the wise use of nature and the benefit of humankind.

More than half of terrestrial plant species could be extinct in nature by the end of the present century. Although we have given names to many, we know very little about most of them, and there are more that await discovery. Those we know can be protected or preserved, but the urgency of finding and learning about the unknown species before they become extinct is clear. Doing so will require integration and collaboration on a scale we have not yet achieved, and time is short.

(6) To value, document, and protect indigenous, traditional, and local knowledge of plants and nature.

Indigenous, traditional, and local knowledge of nature is disappearing even more rapidly than biodiversity itself. Once lost, such knowledge, with its unique insights, can never be regained. Plant scientists must work together with holders of this knowledge to understand and achieve sustainable environmental stewardship. Cultural diversity, coupled with crop genetic diversity, will be of central importance for future food security. We will need informed collaboration coupled with urgent, rigorous planning, and implementation across cultures and knowledge systems.

(7) To engage the power of the public with the power of plants through greater participation and outreach, innovative education, and citizen science.

We need to engage the power of the public with the power of nature. People who care about the environment are motivated to do a great deal to protect it and ensure its future. The creation of an ecological civilization, where societies work together in the creation of knowledge and implementation of solutions, cannot remain only an abstract concept. We all need plants, depending on them absolutely for our very existence, but in the Anthropocene, plants also need us for their survival. Embedding this codependency into the very fabric of our societies will require global engagement across nations and cultures—it will require all of us. We believe that, by working together, we can unite innovative plant sciences with the needs and strengths of human societies, helping to create new paths to a green, sustainable future for Earth, with plants and people living in harmony. The full text of the Shenzhen Declaration (Shenzhen Declaration Drafting Committee, 2017) is also published in this issue.

Let me conclude with words spoken by Adlai Stevenson, U.S. Ambassador to the United Nations, in 1964. They are even more true today than they were half a century ago, and epitomize the goals to which we must resolve to aim:

> We travel together, passengers on a little spaceship, dependent upon its vulnerable reserves of air and soil, all committed for our safety to its security and peace; preserved from annihilation only by the care, the work, and, I will say, the love we give our fragile craft. We cannot maintain it half fortunate, half miserable, half confident, half despairing, half slave to the ancient enemies of man, half free in a liberation of resources undreamed of until this day. No craft, no crew can travel safely with such vast contradictions. On their resolution depends the survival of us all.
>
> Adlai Stevenson,
> *US Ambassador to the United Nations*, 1964

The problems we face are tremendous, beyond any that we have experienced in the past. At the same time, the available tools with which we can confront them are more abundant than they have ever been. Plant scientists must contribute all that they can, but ultimately it will be love and compassion across the globe alone that have the ability to save our civilization from our misguided actions. The interactions between botanists representing most of the world's countries at the International Botanical Congress will form an element of what we need to create a sustainable planet that will serve future generations well.

REFERENCES

Ceballos, G., Ehrlich, P. R., & Dirzo, R. (2017). The real sixth mass extinction: Biological annihilation signaled by population losses and declines in vertebrates. *Proceedings of the National Academy of Sciences, USA*, 201704949. https://doi.org/10.1073/pnas.1704949114

De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R., & Pimm, S. L. (2015). Estimating the normal background rate of species extinction. *Conservation Biology*, *29*, 452–462. https://doi.org/10.1111/cobi.12380

Ellis, E. C., Antill, E. C., & Kreft, H. (2012). All is not loss: Plant biodiversity in the Anthropocene. *PLoS One*, *7*, e30535. https://doi.org/10.1371/journal.pone.0030535

Hardoon, D. (2017). Oxfam Briefing Report. An Economy for the 99%. Retrieved from https://policy-practice.oxfam.org.uk/publications/an-economy-for-the-99-its-time-to-build-a-human-economy-that-benefits-everyone-620170, accessed 13 July, 2017.

Locey, K. J., & Lennon, J. T. (2016). Scaling laws predict global microbial diversity. *Proceedings of the National Academy of Sciences, USA*, *113*(21), 5970–5975. https://doi.org/10.1073/pnas.1521291113

Pimm, S. L., & Raven, P. H. (2018). State of the World's Biodiversity. In P. Dasgupta, & P. H. Raven, *Biological Extinction*, Cambridge, UK: Cambridge University Press.

Shenzhen Declaration Drafting Committee. (2017). The Shenzhen Declaration on Plant Sciences–Uniting plant sciences and society to build a green, sustainable Earth. *PhytoKeys*, *86*, 3–7. https://doi.org/10.3897/phytokeys.86.20859

World Bank. (2016). Poverty and Shared Prosperity (2016). New York, NY: World Bank. Retrieved from https://www.worldbank.org/en/publication/poverty-and-shared-prosperity, accessed 13 July, 2018.

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