Envisioning a biodiversity science for sustaining human well-being

Kamaljit S. Bawa[a,b,1], Nandan Nawn[c], Ravi Chellam[d], Jagdish Krishnaswamy[a], Vinod Mathur[e], Shannon B. Olsson[f], Nitin Pandit[a], Prabhakar Rajagopal[d,g], Mahesh Sankaran[f], R. Uma Shaanker[h], Darshan Shankar[i], Uma Ramakrishnan[f], Abi Tamim Vanak[a,j,k], and Suhel Quader[l]

Contemporary losses of biodiversity, sometimes referred to as the sixth mass extinction, continue to mount (1, 2). A recent assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) estimates that one million of approximately 10 million species that exist now are threatened with extinction along with the ecosystems they inhabit (3). Yet, in the post-coronavirus disease 2019 (COVID-19) world,

India and other nations need new frameworks that integrate science with policies to enhance human well-being, restore and conserve nature, and build capacity. Image credit: Sandesh Kadur (photographer).

[a]Ashoka Trust for Research in Ecology and the Environment (ATREE), Srirampura, Jakkur, Bengaluru 560064, India; [b]Department of Biology, University of Massachusetts, Boston, MA 02125; [c]Department of Policy Studies, TERI School of Advanced Studies, New Delhi 110070, India; [d]Metastring Foundation, Sadashiva Nagar, Bengaluru 560080, India; [e]National Biodiversity Authority, Chennai 600113, India; [f]National Centre for Biological Sciences (NCBS), Tata Institute of Fundamental Research, Bengaluru 560065, India; [g]Biodiversity Informatics, Strand Life Sciences, Bengaluru 560024, India; [h]University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru 560065, India; [i]Institute of Trans-Disciplinary Health Sciences and Technology (TDU), Bengaluru 560064, India; [j]Wellcome Trust/Department of Biotechnology (DBT) India Alliance Program, Kaushik Society, Banjara Hills, Hyderabad 500034, India; [k]School of Life Sciences, University of KwaZulu-Natal, Durban, South Africa 4001; and [l]Education and Public Engagement Programme, Nature Conservation Foundation, Kodigehalli, Bengaluru 560097, India.

The authors declare no competing interest.

[1]To whom correspondence may be addressed. Email: kamal.bawa@gmail.com.

First published September 30, 2020.

investments in conservation are likely to decline further. To arrest biodiversity losses, much of the recent debate advocates two traditional approaches: Put more land under wilderness (4, 5), and mitigate drivers of change through improved governance and policies (2).

However, in the populous tropics, where most biodiversity resides, conservation of our ecosystems will remain elusive until there is a clear demonstration of the relevance of biodiversity to people's well-being, most of whom live below the poverty line. Although nature-based solutions for addressing our most pressing challenges such as climate change, water scarcity, agricultural intensification, and health are well known (3), the link between biodiversity and human well-being has remained elusive. A major constraint, at least in the tropics, has been the lack of investment in biodiversity science that can build human resources and demonstrate the potential of biodiversity in 1) tackling climate change, natural disasters, stagnating agricultural productivity, water shortages, polluted air, and newly emerging infectious diseases such as COVID-19, 2) increasing human well-being, and 3) fostering future socioeconomic development.

Here, we outline a National Mission on Biodiversity and Human Well-being for India that calls for a considerable increase in investment for this new framework for integrating biodiversity science with human well-being. This will demonstrate the linkages between such an investment and 1) realization of United Nations Sustainable Development Goals (SDGs) and Targets, 2) the country's commitment to better the human condition pursued through several other similar large-scale national initiatives and policies in conformity with international obligations, and 3) enhancement of the capacity of institutions and human resources, including millions of citizens, for research and conservation action. We suggest that our framework provides a model for other nations and regions for integrating science with policies to enhance human well-being, restore and conserve nature, and build capacity. Without such efforts, countries in the global South, extraordinarily rich in biodiversity, critical for planetary health, will continue to lose biodiversity despite well-intentioned ideas and concepts originating from the North.

The Case of India

We focus on India because we have worked in this country for decades and because it typifies the challenges faced by other tropical countries rich in biodiversity. Home to nearly 8% of global biodiversity on just 2.3% of global land area (6), India is one of Vavilov's eight centers of global crop diversity and contains sections of four of the 36 global biodiversity hotspots (7). India's unique and diverse ecosystems, distributed across many landscapes, rivers, and oceans are economically valuable too. Based on the net present value (NPV) rates (8) proposed for forests based on flow of selected goods and services* with a 50-year horizon and social rate of discount at 4%, the (asset) value of India's forests (9) adjusted for inflation was estimated to be at INR 128 trillion in 2018 (or 1.78 trillion USD using current exchange rates). India's ecosystems are critical to the quality of life of its people and those of the neighboring South Asian countries that together account for one quarter of the global population. If India can sustain and enhance its biodiversity, restore ecosystems, and establish credible linkages among ecological security, climate change action, and human well-being, the models and lessons from India would have wide applications in biodiversity conservation worldwide.

India faces a number of challenges in the sustainable use of biodiversity, but the country's investments in transdisciplinary biodiversity science are not commensurate with the severity of these challenges. Rates of habitat degradation, both terrestrial and aquatic, are high (10). India is also among the countries with the highest rates of habitat conversion (11). The management of India's remaining natural ecosystems is largely under the control of the state, with local communities in many places contesting this control that constrains access for them. Consensus on the governance of commons—the greening of which through planting of trees is supposed to meet targeted INDCs (Intended Nationally Determined Contributions) (12)—is a central and controversial issue in conservation of biodiversity and restoration of degraded lands.

India is rich in agro-biodiversity, but agricultural yields per unit area are lower than global averages for most cereal crops (13), and a substantial number of Indian farmers, mostly small landholders, live in poverty. The government of India proposes to double the income of small landholders (14), but pathways to pursue this goal are uncertain. India's agro-biodiversity has the unrealized potential to raise yields, provide food and nutritional security, and build resilience to climate change. Addressing many of these issues would help align the role of India's biodiversity towards "sustainable intensification" of agriculture (15).

India's traditional health systems, based on indigenous biodiversity in the form of thousands of species of medicinal plants, have provided personalized medicine for centuries. When integrated with molecular and systems biology, this potential can be further enhanced to identify new pharmaceuticals and treatments to provide better health care to millions. Nonetheless, such integration has so far attracted little investment.

Finally, there is insufficient engagement across all segments of society in biodiversity science. This has resulted in a human resource problem that threatens to hold back the measures undertaken to protect and harness India's biodiversity and associated ecosystem services. Relative to its size, amount of biodiversity, and scientific prowess, India still has very few researchers trained in the interdisciplinary concepts and techniques for biodiversity science. Equally notable is the lack of widespread awareness and interest in biodiversity and its importance among the Indian public.

Clearly substantial investments need to be made in biodiversity science in countries, such as India, based

*Timber/wood, fuelwood, fodder, non-wood forest products (NWFP), carbon storage, carbon sequestration, gene-pool conservation (bioprospecting), bamboo, pollination, and seed dispersal, water purification, soil conservation, and water recharge.

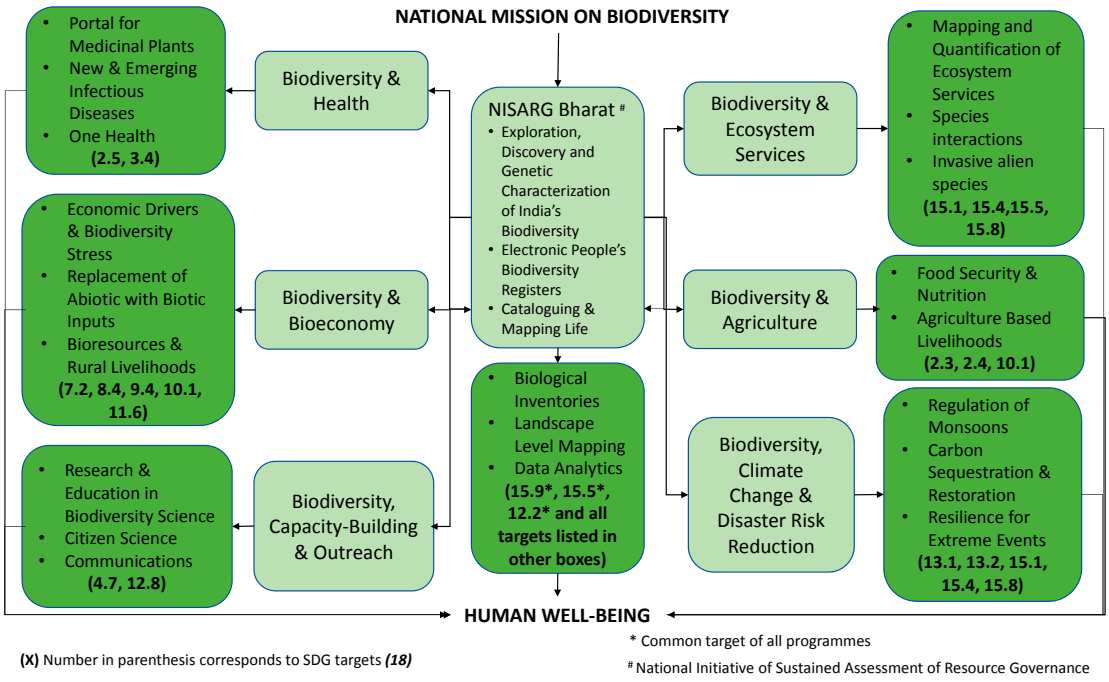

Fig. 1. There are myriad linkages between investments and the realization of United Nations Sustainable Development Goals.

on new approaches that rely on integration of diverse concepts and tools, science and policy, knowledge and societal goals, and the use of geospatial data and informatics, artificial intelligence, genomic data, and new methods of genetic manipulations (16). This will allow India and other nations to address critical issues in governance of commons, conservation of endangered species, assessment and monitoring of biodiversity, public health, bioeconomy, food security, and nutrition, restoration of ecosystems, and climate change mitigation. Such investments and approaches can help the region achieve the targets of the SDGs.

Concept and Content

In July 2018, a group of Indian conservation biologists and ecologists gathered to form a consortium (called the Biodiversity Collaborative) to develop a comprehensive program to strengthen biodiversity science in India over the next 10 years. The Prime Minister's Science, Technology, and Innovation Advisory Council endorsed the proposal for the program in October 2018. The Principal Scientific Adviser (PSA) to the Government of India, K. VijayRaghavan, formally announced the launch of "National Biodiversity Mission" along with eight other such science initiatives in March 2019 (17). In September 2019, the office of the PSA awarded a seed grant to the Biodiversity Collaborative to develop the program for the National Mission on Biodiversity and Human Well-being.

The mission has two components. Its centerpiece, NISARG Bharat (National Initiative for Sustained Assessment of Resource Governance), will document and map India's biodiversity, including its rich biocultural diversity, to enable conservation and sustainable use of biological resources. The three subprograms, *Exploration, Discovery, and Genetic Characterization of India's Biodiversity*, *Electronic People's Biodiversity Registers*, and *Cataloguing and Mapping Life* (Fig. 1), will focus on different aspects of this ambitious effort. Collectively this component will expand current efforts aimed at leveraging national investments in exploration, assessments, and monitoring of biodiversity and ecosystems (such as https://www.indiabiodiversity.org/), enhance the use of digital tools and artificial intelligence to map India's biodiversity, people, cultures, and biodiversity management regimes, identify vulnerable areas, and act as the database manager to facilitate the implementation of the entire mission, including citizen engagement (https://citsci-india.org/), and the realization of several SDGs and associated targets [(18) Figure 1].

The second component will consist of six programs, each with field-based projects to realize the identified SDGs.

The *Biodiversity and Ecosystem Services* program will work to quantify ecosystem services provided by biodiversity in different habitats, assess synergies and trade-offs between various services, evaluate and suggest strategies for effective restoration of habitats to enhance service provisioning and mitigate impacts of climatic change, and explore landscape level approaches to the conservation of biodiversity and endangered species.

The *Biodiversity, Climate Change, and Disaster Risk Reduction* program will work to assess vulnerability of ecosystems and different biomes in India to climate change and climate disasters by evaluating both historic trends in responses and future projections for different climatic stressors, including extreme events, and develop strategies for integrating ecosystem- and

nature-based solutions for enhancing resilience to climate change.

The *Biodiversity and Agriculture* program will aim to reconcile the traditional tension that exists between increasing food production on one hand and preserving biodiversity on the other. By launching a first-ever quantitative inventory of the contribution of biodiversity in forests, rivers, estuaries, and agro-ecosystems to India's food and nutritional security, citizens will be empowered with credible information on the judicious use of bioresources.

Any approach to conserve biodiversity must be inspired, established, and maintained by the people living within those ecosystems as a collective effort between citizens and their governments.

The *Biodiversity and Health* program, with a focus on improving healthcare, expands on two ongoing initiatives. First, it will transform the current databases on India's medicinal plants developed by the Institute of Trans-Disciplinary Health Science and Technology in Bengaluru, India, into a searchable, interactive citizen's portal to provide information about human, livestock, and crop healthcare. The other subprogram builds on the relationship between biodiversity loss and changing land use patterns on zoonotic diseases (e.g. https://www.monkeyfeverrisk.ceh.ac.uk) and aims to operationalize an integrated "One Health" system of surveillance and disease management.

The *Biodiversity and Bioeconomy* program will build on the ongoing work on valuation of India's ecosystems (https://seea.un.org/sites/seea.un.org/files/india_assessment_2019.pdf) and bioenergy development (http://dbtindia.gov.in/sites/default/files/BioenergyVision.pdf) with an expanded scope. It will estimate the potential of local ecosystem services to support and enrich local economies without altering the structures and functions of the ecosystem while realizing the benefits of local livelihood opportunities.

The *Biodiversity Capacity Building and Outreach* program seeks to build more capacity in biodiversity science through efforts that will catalyze a new generation of Indians to synthesize interdisciplinary concepts to address real-world problems related to biodiversity. The program will, for example, support biodiversity-related training programs and mainstream biodiversity into India's public consciousness by strengthening citizen science and science communication across mass, digital, and social media platforms.

Moving Forward

Any approach to conserve biodiversity must be inspired, established, and maintained by the people living within those ecosystems as a collective effort between citizens and their governments. We have been taking steps to build broad-based support.

First, the Biodiversity Collaborative on behalf of the Government of India has held a series of national and regional consultations for more inclusive participation of institutions, researchers, and conservationists. Thematic consultations to expand the scope for participation from across India and to develop road maps for the major programs are underway.

Second, the program is designed to link with other national missions, for example, National Mission for Green India, National Wildlife Action Plan, National Mission for Sustaining the Himalayan Ecosystem, and to India's commitment to multi-lateral environmental agreements such as the Convention on Biological Diversity (CBD) and UN Framework Convention on Climate Change (UNFCCC).

Third, India faces several pressing policy and governance challenges. The effective and time-bound implementation of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, and ensuring both legitimate forest tenurial rights and forest conservation will require changes in governance, now dominated by top-down approaches. Additional challenges include restoration of degraded lands and wetlands, ensuring ecological flow regimes in rivers, and assessment and monitoring of biodiversity in the face of rapid environmental change and resource exploitation, especially in a world impacted by COVID-19. Scientific inputs from the mission, especially those related to geospatial informatics, policy, and institutional analyses, and local perceptions and indigenous knowledge can assist in the development of strategies and policies for conservation and ecosystem management.

Fourth, more than 50% of the resources for the mission will be distributed in the form of grants to scores of institutions for work on major thematic areas and for strengthening their training programs. We expect a thousand or so graduate students and fellows to benefit from the program over the next 5 years.

Finally, by enhancing communication and information exchange among researchers, students, government officials, business professionals, and the public at large, the mission will generate a strong national community committed to sustaining and enhancing biodiversity everywhere from classrooms to courtrooms to boardrooms.

This vision of biodiversity science aims to serve humanity and to meet our most pressing challenges in agriculture and food security, health, climate change and disaster risk management, ecosystem functioning, bioeconomy, and capacity building as well as in policies and strategies related to conservation, besides restoration, sustainable and equitable use, and decentralized management of biodiversity. Furthermore, we propose that biodiversity science may turn out to be the most critical science in meeting Sustainable Development Goals and Targets. By investing in this vision, India and other countries can embark on a path in which the maintenance of biodiversity is recognized as a fundamental cornerstone of development planning and human well-being. We urge researchers and practitioners in other countries to develop similar large-scale programs that seek to integrate biodiversity science, policies, and societal well-being and to build capacity of their institutions and citizens, especially in the aftermath of the COVID-19 pandemic, which will call for increasing society's commitment to a just, equitable, and sustainable world.

Acknowledgments

We thank Madhu Verma for converting the 2014 values reported in reference 9 into 2018 prices. We thank Sujata Arora, Ketaki Bapat, J.R. Bhatt, Vijay Chandru, Dhruv Gangadharan, C.S. Jha, Kriti Karanth, Satyajit Mayor, Jagdeesh Rao, Asmita Sengupta, Kartik Shanker, Renu Swarup, and K. VijayRaghavan for ideas, discussions, and support, and Abhishek Chari for help with the figure.

1 R. Dirzo *et al.*, Defaunation in the anthropocene. *Science* **345**, 401–406 (2014).
2 S. Diaz *et al.*, Pervasive human driven decline of life on earth points to the need for transformative change. *Science* **366**, eaax3100 (2019).
3 IPBES, *Global assessment report on biodiversity and ecosystem services*. (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, 2019). https://ipbes.net/global-assessment.
4 E. O. Wilson, *Half Earth: Our Planet's Fight for Life* (W. W. Norton, New York, 2016).
5 J. Baillie, Y. P. Zhang, Space for nature. *Science* **361**, 1051 (2018).
6 T. N. Khoshoo, Census of India's biodiversity: Tasks ahead. *Curr. Sci.* **69**, 14–17 (1995).
7 R. A. Mittermeier, W. R. Turner, F. W. Larsen, T. M. Brooks, C. Gascon, "Global biodiversity conservation: The critical role of hotspots" in *Biodiversity Hotspots*, F. E. Zachos, J. C. Habel, Eds. (Springer, 2011), chap. 1, 10.1007/978-3-642-20992-5_1.
8 M. Verma *et al.*, *Revision of rates of NPV applicable for different class/category of forests* (Indian Institute of Forest Management, Bhopal, 2014), http://iifm.ac.in/wp-content/uploads/2016/06/IIFM_NPV_07NOV.pdf.
9. P. Ghosh, Pricing forests: Net present value assessed. Down to Earth https://www.downtoearth.org.in/news/pricing-forests-net-present-value-assessed-7982 (2015). Accessed 17 September 2020.
10 P. S. Roy *et al.*, Development of decadal (1985–1995–2005) land use and land cover database for India. *Remote Sens.* **7**, 2401–2430 (2015).
11 J. E. M. Watson *et al.*, Persistent disparities between recent rates of habitat conversion and protection and implications for future global conservation targets. *Conserv. Lett.* **9**, 413–421 (2016).
12 R. Seidler, K. S. Bawa, Opinion: India faces a long and winding path to green climate solutions. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 12337–12340 (2016).
13. Organization for Economic Cooperation and Development, Crop production (indicator) (2019). https://doi.org/10.1787/44db9980-en. (Accessed 20 July 2019).
14 R. Chand, *Doubling of farmers income: Rationale, strategy prospects and action plan* (National Institute for Transforming India, Delhi, 2017), http://agricoop.nic.in/sites/default/files/NITI%20Aayog%20Policy%20Paper.pdf.
15 I. K. Dawson *et al.*, *Contributions of Biodiversity to the Sustainable Intensification of Food Production: Thematic Study for The State of the World's Biodiversity for Food and Agriculture* (Food and Agriculture Organization of the United Nations, Rome, 2019), http://www.fao.org/3/ca4003en/ca4003en.pdf.
16 P. Taberlet, A. Bonin, L. Zinger, E. Coissac, *Environmental DNA: For Biodiversity Research and Monitoring* (Oxford University Press, Oxford, 2018).
17 PIB, Nine science and technology missions with focus on science for people and people for science (Press Information Bureau, Government of India, 2019) https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1567633. (Accessed 20 July 2019).
18. United Nations, "Annex: Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development" (Resolution 71/313, United Nations, New York, 2017; https://undocs.org/A/RES/71/313).