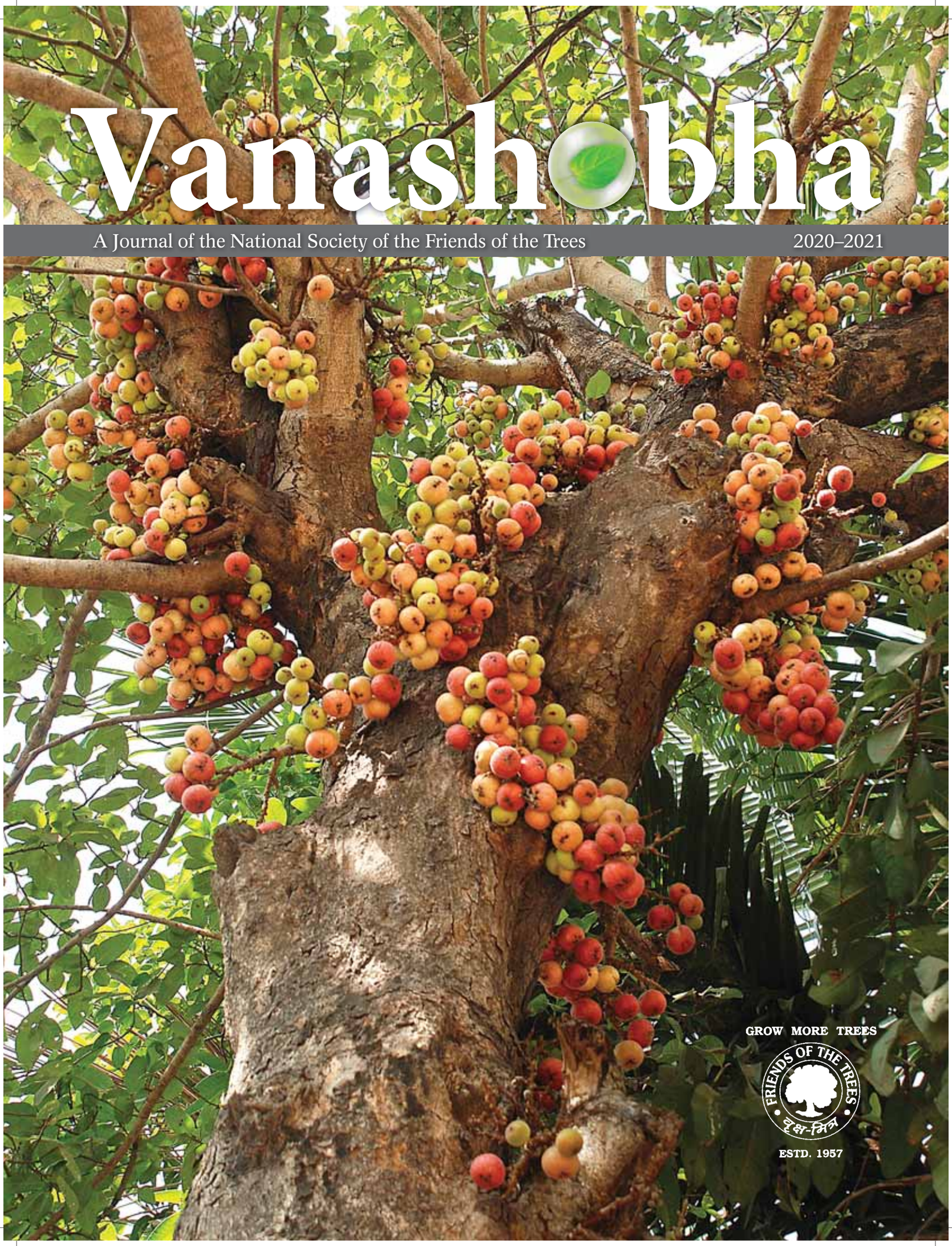
Vanashobha

A Journal of the National Society of the Friends of the Trees 2020–2021



GROW MORE TREES

FRIENDS OF THE TREES
वृक्ष-मित्र

ESTD. 1957

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Office: Shree Samarth Building No. 1, Ground Floor,

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Prabhadevi, Mumbai - 400025

Phone No: +91 22 24210363

Email: info@wtert.in

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A Journal of the National Society of the Friends of the Trees

FRIENDS OF THE TREES FOUNDED IN 1957
A fellowship of tree lovers seeking to create and foster a tree sense in India

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Union Co-operative Insurance Building,
3rd Floor, 28, Sir P.M. Road,
Fort, Mumbai – 400 001.
Phone: +91 22 49794817/22024843
Email: friendsoftrees16@gmail.com
Website: www.fot.org.in

Editor: Dr Pheroza J. Godrej

Editorial Consultant: Dr Gayatri Ugra

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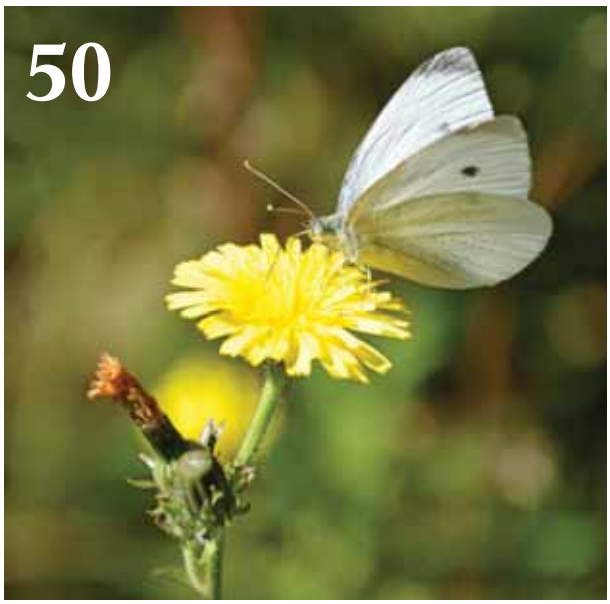


Front Cover: Cluster Fig
Photograph:
Chandrakant Ghatge

Back Cover: Krishna's Buttercup
Photograph: Sakina Gadiwala

From the Desk of the President Emeritus

Whatever happens next after this unprecedented COVID-19 pandemic, as per the World Economic Forum we have reached the "end of the beginning". As we pause to reflect on our experiences over the last couple of years, with the thought that they might provide lessons for the future, addressing long-standing challenges like ageing populations, a fragile planet, and growing inequalities are thrown up prominently. Arguably the most important of the ten COVID-19 lessons that will change the post-pandemic future, as identified by the World Economic Forum, is "A sustainable future requires leadership." Despite initial lower emissions at the start of the pandemic, climate concern has not diminished and there is near consensus that an environmental disaster is likely without drastic changes being made. The same level of leadership that was sought for handling the pandemic is sought in the fight against climate change, giving governments and businesses a clear mandate to act. However, according to research, people are far from aware of how their lifestyles should adapt to save the planet, which could mean that this environmental feat is the biggest leadership challenge to come.

The cleaner air in cities, the burgeoning biodiversity, and dramatic shift to less pollution-intensive lifestyles across the globe during the pandemic, indicated the scope of the environmental improvement that can be achieved in just days. This is what we need to adhere to navigate the status of environmental degradation today. Environmental issues, as we know, do not wait for a more convenient time; we therefore must deal with them concurrently, along with all the other urgent issues at hand. We can take a global leap towards a sustainable society that produces minimum waste and emission. The way in which we steer out of the pandemic will also set our environmental trajectory for the future. The changes in our behaviour that we experienced during the peak pandemic time, some of which may instill in us permanently, can have a far-reaching impact on the environment. Our consumption and travel patterns are more responsible: driving less in private cars, attending online meetings rather than taking flights. Equally, it indicates that a considerable dent on emissions and waste products can be made without disturbing too much economic growth.

In this edition of *Vanashobha*, we present you with interesting reads on the Impact of COVID-19 on the Environment, Pandemics, and Biodiversity; Environment, Climate, and Past Zoonotic Pandemics in Medieval Europe and Colonial South Asia; with also an article on one of the most celebrated indigenous tribes of India, the Warli Tribe and their Art on Trees. I am sure you will relish knowing about their ways of worshipping nature, as they believe that nature fulfills all their needs. Interesting insights are provided on pursuing the fascinating hobby of Making Bamboo Handicrafts; the deep effect Plants have on the Human Brain; a must know Saga of Urban Pollinators and their importance to human survival; very informative pieces on the Fascinating Tree Wealth of the Western Ghats; and the Important Role Botanists can play in improving Urban Air, as we all know that trees and shrubs help in the abatement of air pollution. We can conclude by reiterating, Our Best Friends are the Trees – silent protectors of humans that are taken for granted and yet remain our best friends!

We share moments of pleasure through the story of a tree plantation drive at The Don Bosco Mazzarello Centre (Sisters' Home) at Naughar, Uttan in Thane district, assisted by Friends of Trees along with the Mass Media Department of St Xavier's College, in the first outdoor event in almost two years. Dr Arun D. Sawant, President, FOT, graced the occasion as the guest of honour.

Following the global trend, it was time for us to go digital! On 5th June, 2021, World Environment Day, we launched the first digital version of *Vanashobha* 2019–2020, along with the print edition, followed by the launch of our very first virtual flower show on 22nd June, 2021, World Rainforest Day, helping us keep alive the spirit of FOT, for which the Annual VFF Show is such a crucial part of the calendar of events. On 2nd March, 2022, the virtual FOT National Seminar on Tree Eco-Restoration held in association with St Xavier's College, Mumbai, elaborated the theme in keeping with the declaration of 2021–2030 as the United Nations Decade on Ecosystem Restoration, which saw many eminent experts sharing their knowledge with the participants.

I hope you enjoy this edition of *Vanashobha* that comes loaded with fascinating content as always. Happy reading!

Dr Pheroza J. Godrej

GROW MORE TREES

ESTD. 1957

NATIONAL SOCIETY OF THE FRIENDS OF THE TREES

A fellowship of tree-lovers seeking to create and foster a tree sense in India

Objectives

1. To inculcate love of trees and plant life in general among the people.
2. To create an enlightened public opinion for promoting the setting up and maintenance of more avenues on our highways and for building more parks and gardens in our cities and for growing of suitable trees in all public places to enhance the beauty of our landscape both rural and urban; and for preserving and extending our forests now in grave danger due to various causes.
3. To organize public lectures, talks to select groups including schools and colleges, film shows, exhibitions on trees and allied subjects.
4. To hold competitions, flower, vegetable, and fruit shows, national or state conventions and seminars for the furtherance of the objects of the Society.
5. To plant and protect trees.
6. To organize publication of suitable literature including periodicals and maintaining library or libraries for the encouragement of such studies.
7. To undertake special studies of the needs of, and suggesting tree planting schemes for large private institutions, local bodies, community projects, national extension services, etc.
8. To establish contacts with other organizations having similar objects.
9. To secure government and public support for activities on the lines mentioned above.
10. Generally to undertake activities deemed necessary and desirable for the promotion of the objects aforesaid.
11. To establish branches of the organization in different cities, towns and villages where enough organizational element is available and local membership potentialities exist.

Presidents of the National Society of the Friends of the Trees

From its inception to this day, the honorable members who have held the post of President of the National Society of the Friends of the Trees have given generously of their time and resources, to support and enhance the standing of the Society. FoT honours them and records here its appreciation of their valuable contributions. Given below are the dates of their tenures.

Mr B.G. Gade 1957–1962

Mr V.P. Naik
1962–1971

Mr J.J. Bhabha
1971–1998

Mr S.P. Godrej
1998–2000

Dr Pheroza J. Godrej
2000–2016

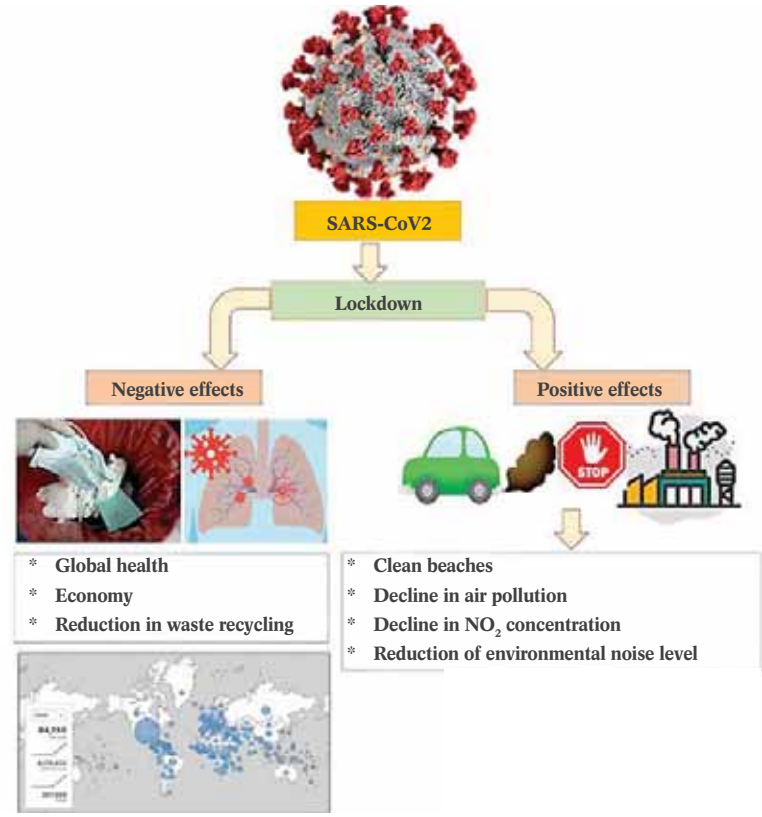
Dr Ashok S. Kothari
2016–2021

Dr Arun D. Sawant
2021– Present

Impact of COVID-19 on the Environment

"The COVID-19 pandemic has impacted every aspect of human life and has led the world to an unprecedented public health crisis. Novel coronavirus disease, referred to as COVID-19, was declared a pandemic on 13th March, 2020 by the World Health Organization (WHO). The virus is transmitted from person to person via direct contact or through droplets produced by coughing, sneezing, and talking. To control the spread of the virus, the governments of most of the affected countries initiated a lockdown to restrict the movement of people. Ironically enough, the lockdown provided a rare opportunity to step back and assess the impact on the environment."

Text & Images: **Arun K. Pandey**



ENVIRONMENTAL EFFECTS OF COVID-19

The worldwide disruption caused by COVID-19 has brought about numerous effects on the environment. The lockdown restricted the movement of public transport, including buses, trucks, trains, and aircraft, and halted industrial activities. Due to restrictions on movement and a considerable slowdown of social and economic activities, there were positive indications from all over the world that the COVID-19 induced lockdown had improved environmental conditions, mainly air and water quality, reduced noise of vehicular traffic, and restoration of ecosystems. There is a popular notion that this pandemic has been good for the environment, because nature is recovering while humanity stays at home.

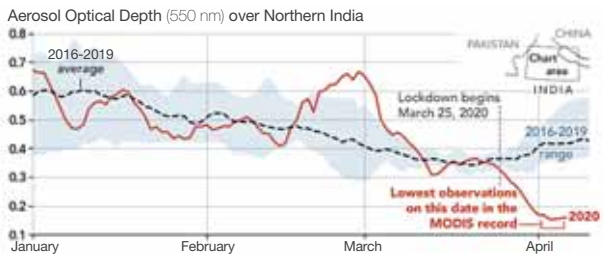
The positive and negative effects of COVID-19. From Kumar, A., Malla, M.A. & Dubey, A. (2020): With corona outbreak, nature started hitting the reset button globally. *Frontiers in Public Health* 8: 569353. doi:10.3389/fpubh.2020.569353.

A. Positive Environmental Effects

1. Fall in Air Pollution

The major sectors contributing to air pollution include industries, transport, power plants, biomass burning, and construction activities. During the pandemic, due to lockdown, pollution and greenhouse gases (GHGs) emissions have drastically reduced across continents. Motor vehicles and aviation are key generators of emissions, contributing almost 72% and 11% of the transport sector's GHGs emission respectively. Due to non-functioning of industries, industrial waste emission has decreased considerably. The emission of NO_2 and SO_2 have reduced significantly during this period. According to the Central Pollution Control Board (CPCB) (2020), the drop in the emission rate may be attributed to restricted movement of vehicles and halt of construction activities in all major cities. The emission of NO_2 is one of the key indicators of global economic activities. Normally, NO_2 is emitted from the burning of fossil fuels, 80% of which comes from motor vehicle exhaust. During lockdown there was a reduction in the NO_2 emission in many countries. During nationwide lockdown, it has been reported that the levels of NO_2 and $PM_{2.5}$ reduced by almost 70% in Delhi. In India, overall, 46% and 50% reduction of $PM_{2.5}$ and PM_{10} respectively, was observed during lockdown period. Due to lesser demand of power in industries, use of fossil fuels or conventional energy sources have been lowered considerably.

New Delhi's India Gate seen clouded with pollution on October 17, 2019 (left), and contrasts with an image taken on April 13, 2020 (right), during the lockdown when pollution levels started to drop. (Image: Reuters)



Data from NASA Earth Observatory

2. Reduction of Water Pollution

In developing countries like India, the domestic and industrial wastes are dumped into rivers and other aquatic bodies without treatment. During the lockdown period, the major industrial sources of pollution have shrunk or completely stopped, which greatly helped to reduce the pollution load. For instance, the river Ganga carried more dissolved oxygen and less nitrates. Both river Ganga and Yamuna reached a significant level of purity due to the absence of industrial pollution. The improvement of water quality at Hardwar and Rishikesh was ascribed to the sudden drop of the number of visitors during lockdown period and 500% reduction of sewage and industrial effluents. The amount of industrial water consumption is also reduced, especially from the textile industries. Usually, huge amount of solid trashes generated from construction and manufacturing units are mainly responsible for water and soil pollution, are also reduced to a great extent. Due to the reduction of export-import activities, the movement of merchant ship and other vessels has reduced considerably leading to reduction in emission as well as pollution of sea waters.

Yamuna river in New Delhi, India pictured on March 21, 2018 (left) is filled with toxic foam. An image from April 8, 2020 (right) shows dramatic improvement in water quality. (Image: Reuters)

3. Abatement of Noise Pollution

Noise pollution is the elevated level of sound, generated from different human activities (e.g., machines, vehicles, construction work. The high intensity of noise may cause adverse effects in human beings. The noise pollution negatively affects the physiological health, along with cardiovascular disorders, hypertension, and sleep shortness of humans. It is reported that, globally around 360 million people are prone to hearing loss due to noise pollution. The noise level was significantly reduced when quarantine and lockdown measures were taken and people stayed at home and also the economic activities were much reduced in most cities. For

> “It has been recorded that during pandemic the ecosystems have greatly recovered. This recovery of degraded environment is an indicator that the degradation caused by humans is reversible. This is a signal for us to understand and take necessary steps so that this healing process does not become a temporary one.”

instance, noise level of Delhi was reduced drastically around 40–50% during lockdown period. Moreover, due to travel restrictions throughout the world, the number of flights and vehicular movements were drastically reduced. This led to the reduced level of noise pollution.

4. Ecological Restoration

During recent years, tourism sector has witnessed a remarkable growth. It is estimated that the tourism industry is responsible for 8% of global GHGs emission. However, the places of natural beauty (e.g., beaches, islands, forests, national parks, mountains, and deserts) are usually attracting a large number of tourists round the year. To accommodate tourists, hotels, restaurant, bar and market are built which consume lots of energy and other natural resources. Moreover, visitors dump various wastes which not only impair natural beauty but also create ecological imbalance. Due to the outbreak of COVID-19 and local restrictions, the number of tourists have reduced in the tourist spots around the world.

B. Negative Environmental Effects

1. Biomedical Waste Generation

Since the outbreak of COVID-19, medical waste generation has increased globally and has become a major threat to public health and environment. For sample collection of the suspected COVID-19 patients, diagnosis, treatment of patients, and disinfection purpose lots of infectious and biomedical wastes are generated from hospitals. For instance, in the city of Ahmedabad, the amount of medical waste generation increased from 550-600 kg/day to around 1000 kg/day at the time of the first phase of lockdown. Such a sudden increase of hazardous waste, and their proper management has become a real challenge to the local municipal authorities. According to the recent published literature, it has been reported that the SARS-CoV-2 virus can exist a day on cardboard, and up to 3 days on plastics and stainless steel. Hence, waste generated from the hospitals (e.g., needles, syringes, bandage, mask, gloves, used tissue, and discarded medicines etc.) should be disposed of properly in order to reduce further infection and environmental pollution, which has become a matter of global concern.

2. Disposal of Healthcare Waste

To protect from the viral infection, people are using face mask, hand gloves, PPE kits, goggles and other safety equipment, which ultimately increase the amount of healthcare waste. Due to lack of knowledge about infectious waste management, most people dump these items (face mask, hand gloves etc.) in open places and in some cases people discard these along with household wastes. Such haphazard dumping of these wastes creates clogging in water ways and worsens environmental pollution. It has been reported that, face mask and other plastic based protective equipment are the potential source of microplastic fibres in the environment. Usually, Polypropylene is used to manufacture N-95 masks, and Tyvek for protective suits, gloves, and medical face shields. These items can persist for a long time and release dioxin and toxic elements to the environment.

3. Municipal solid waste generation and recycling

The nationwide lockdown has considerably reduced municipal solid waste (MSW) generation. Increase of both organic and inorganic municipal waste generation has direct and indirect effects on environment, e.g., air, water and soil pollution. However, waste recycling is an effective way to check pollution, save energy, and conserve natural resources. So, additional measures in wastewater treatment are essential, which is a challenging task for developing countries.

C. Strategies for Sustainable Environmental Management

It is assumed that, all of the above environmental consequences are short-term. Thus, it is high time to develop a proper strategy for long-term benefit, as well as sustainable environmental management.

> “In developing countries like India, domestic and industrial wastes are dumped into rivers and other aquatic bodies without treatment. During the lockdown period, major industrial sources of pollution have shrunk or completely stopped, which greatly helped to reduce the pollution load.”

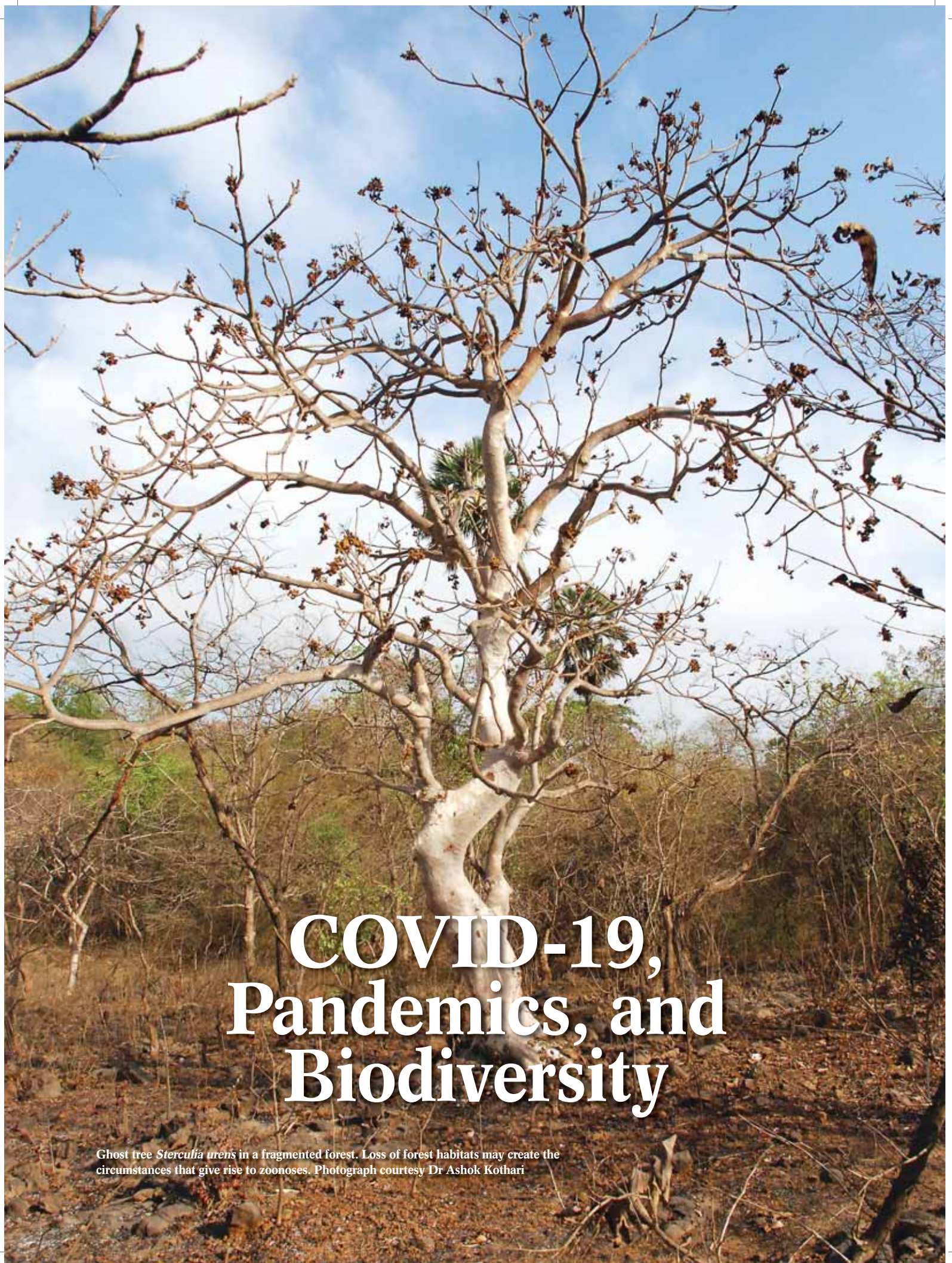
Some of the possible strategies need to be considered by the concerned authorities for global environmental sustainability are as follows:

1. In order to reduce emissions, it is necessary to encourage people to use public transport. Also, people should be encouraged to use bicycle for short distance travel that is not only environment friendly but also beneficial for health.
2. Use of renewable energy can lower the demand of fossil fuels (coal, oil, and natural gas). This activity can play an important role in reducing the GHGs emissions. Due to the COVID-19 pandemic, global energy demand is reduced, which has resulted in the reduction of emission and increased ambient air quality in many regions. The use of renewable energy sources like solar, wind, hydropower, geothermal heat and biomass should be encouraged which will reduce the GHGs emission.
3. To control the challenges of water pollution, both industrial and municipal wastewater should be properly treated before discharge to the aquatic bodies.
4. To reduce the burden of wastes and environmental pollution, both industrial and municipal wastes should be recycled and reused.
5. For ecological restoration, tourist spots should be periodically shut down. Moreover, ecotourism practice should be encouraged and strengthened to promote sustainable livelihoods, cultural preservation, and biodiversity conservation.
6. For sustainable industrialization, it is necessary to shift to less energy-intensive industries. The use of cleaner fuels and modern technologies, and following strong energy efficient policies would greatly help in saving considerable amount of energy used in the industries. Also, in industries where a large number of people work, proper distance and hygienic environment should be maintained to reduce the spread of any infectious communicable disease.
7. To meet the sustainable environmental goals and protection of global environmental resources, such as the global climate and biological diversity, combined international effort is needed. Therefore, responsible international agencies like United Nations Environment Programme (UN Environment) should play an effective role to prepare time-bound policies, arrange international meetings, and coordination of global leaders for proper implementation of the programmes.

CONCLUSION

Directly or indirectly, the pandemic is affecting human life and the global economy, which is ultimately affecting the environment and climate. It reminds us that we have neglected the environmental components and are responsible for induced climate change. Moreover, the global response of COVID-19 also teaches us the lesson to work together to combat against the threat to human beings. Though the impacts of COVID-19 on the environment are short-term, united and proposed time-oriented efforts can strengthen environmental sustainability and save the earth from the effects of global climate change.

It has been recorded that during the COVID-19 pandemic the ecosystems have greatly recovered. This recovery of degraded environment is an indicator that the degradation caused by humans is reversible. This is a signal for us to understand and take necessary steps so that this healing process does not become a temporary one. The pandemic has displayed its contrasting consequence on human civilization, in the sense that it has caused worldwide panic situation but at the same time created a very positive impact on the world environment. Thus, the post-lockdown period is crucial to maintain a low level of environmental pollution and take necessary steps to dispose harmful medical waste to stop further transmission of COVID-19 and other infectious pathogens. We should make a commitment to instil the principles of sustainable development in our lifestyle, social behaviour, and public policy to make our environment clean and sustainable.



COVID-19, Pandemics, and Biodiversity

Ghost tree *Sterculia urens* in a fragmented forest. Loss of forest habitats may create the circumstances that give rise to zoonoses. Photograph courtesy Dr Ashok Kothari

"The unprecedented scale of land-use changes, such as conversion of virgin forests to agriculture, livestock ranches and pastures, logging of large swathes of forests for timber, rapid industrialization and the resulting pollution of the environment, the intensification of livestock and poultry industry – combined with our thirst for hunting and consuming wild meat, has led to the fatal opening of a Pandora's box, where pathogens that were confined to dense forests and jungles have now been unleashed on to human habitations and wreaked havoc."

Text & Graphics: **Bindu Raghavan**

The recent Coronavirus epidemic – COVID-19 disease caused by the SARS-CoV-2 virus, that has affected about 180 million people globally, and killed around four million [till February 2021, when this talk was delivered], is the latest of several deadly and infectious zoonotic diseases to have emerged in recent times. The COVID-19 pandemic led to a global economic meltdown, with economic losses of billions of dollars and a drastic fall in global GDPs, especially for smaller nations. India, too, has undergone a huge financial crisis. The greatest burden of the disease, however, was placed on the poor, especially poor migrant workers, who were already burdened with many other diseases and health-related issues. The pandemic-associated lockdown and subsequent migration of skilled and unskilled workers back to their villages and hometowns across India created a socio-economic and humanitarian crisis of unseen proportions. The toll on lives and livelihoods apart, the toll on mental health and well-being was unsurpassed. It is very clear that an infectious disease pandemic like COVID-19 can cause widespread and far-reaching damage to human life, as we know it.

While the pandemic was a surprise to most of the general public, it was not so for those of us who study infectious diseases. Ever since the emergence of the first signs of influenza and other infectious zoonotic pandemics, it has been known that as we become more and more industrialized and change how we use our natural resources, we are going to see increasing incidence of such highly infectious and devastating zoonotic diseases, and their frequency will get higher, while their occurrences will be closer together than before.

ZOONOTIC DISEASES

Zoonotic diseases are diseases that are transmitted from animals to humans. They usually occur naturally in animals, while humans are mostly incidental or unintentional hosts. However, studies show that about 60% of all existing human pathogens are zoonotic, and that 75% of the 150-odd newly emerging infectious diseases have originated in animals. So of every five human diseases, three are known to have animal origins. Not counting COVID-19, 13 zoonotic diseases are responsible for more than 2.2 million deaths per year, worldwide. These include influenza, rabies, tuberculosis, Q fever, and brucellosis, among others. Zoonotic diseases are a sinister threat due to their potential for use in bioterrorism.

Depending on the kind of pathogen involved and the mode of transmission, zoonotic diseases can be of five main types:

1. Zoonotic infectious diseases: Caused by microbes such as viruses and bacteria, e.g. Ebola, Zika, JE, COVID-19, Rabies, Anthrax.
2. Zoonotic parasitic diseases: Caused by parasites, e.g. Cysticercosis or tapeworm infestations, Visceral Larva Migrans, Leishmaniasis, and Toxoplasmosis, among others.
3. Zoonotic vector-borne diseases: Transmitted by vectors such as ticks, fleas, mites, flies, mosquitoes, e.g. Kyasanur Forest Disease, Crimean Congo Hemorrhagic Fever, Scrub Typhus, among others. Vector-borne diseases pose a great economic challenge in terms of their control and management, as can be seen by the challenge that mosquito-borne diseases pose to public health in India. It is estimated that globally about US$ 12 billion are lost annually due to loss of productivity as a result of absence from work caused by mosquito-borne illnesses.
4. Zoonotic food-borne illnesses: Transmitted through food and water contaminated by the pathogens that cause these diseases, e.g.

Salmonellosis, Campylobacteriosis, Listeriosis, E. coli infections, Toxoplasmosis.

5. Zoonotic Antimicrobial Resistance: A new threat where no specific pathogen is involved, but bacteria that have grown resistant to certain antimicrobials, including antibiotics, pass on those genes to other bacteria, spreading antimicrobial resistance (AMR) to other pathogens, and causing them to be undefeatable using current medicine therapies. AMR bacteria have spread throughout the ecosystem, even in the soil and water, affecting humans and animals.

REVERSE ZOONOSES

The risk from disease transmission between humans and animals, especially wild animals, is not unidirectional. Wildlife, too, are at greater risk of acquiring (and maintaining) human- and livestock-associated pathogens and illnesses. Such diseases or transmission processes are known as reverse zoonoses, since they are diseases that have jumped from humans to animals, or from animals to humans and then back to another, or same species, of animal. A good example is COVID-19, caused by SARS-CoV-2 virus that originated in an animal, jumped to humans, and then jumped from humans to other animals, including wildlife and pets. These diseases affect not only health, but also the population viability of wild animals. Further, the infected animals become sources of reinfection in humans.

Tuberculosis in captive elephants, and possibly wild elephants, is another example. It was spread from humans to elephants in zoos and other captivity centres and has affected almost all elephants globally. The presence of this disease in wild elephants is unknown due to lack of studies, especially in India.

Another example of reverse zoonosis is the spread of the H1N1 variant of the influenza virus. In USA, it was found that the virus jumped from humans to domestic pigs in a farm. The virus underwent certain changes in the host pig, which made it infectious to other pigs. It was then transmitted to several pigs at a state animal exhibition. The virus then underwent further changes, known as re-assortment, and became infectious for man again. The same turn of events happened in China, except that after the pig, the virus jumped to dogs, underwent changes and then jumped back to man, each time becoming more deadly and infectious.

The problem of reverse zoonosis is becoming more widespread, as is evident from the recent COVID-19 pandemic that jumped from humans to dogs, cats, minks, and even captive tigers and lions. A new study has found that bacterial infections typically found in humans, including *Salmonella serovar* and *Campylobacter species*, are being spread to seabirds of the Antarctic.

LONG HISTORY OF ZOONOTIC DISEASES

While the COVID-19 virus has definitely caused one of the most devastating diseases of all time, it is only one in a long line of new or emerging pathogens, especially viruses, that have caused pandemics affecting survival, health, and the economies of several countries.

These include the Ebola virus that came out of Africa, the Zika virus that originated in South America, the Japanese encephalitis virus that has infected thousands, especially children, in India and killed many, and the recently emerged group of zoonotic Coronaviruses. These include the SARS-CoV-1 which caused the SARS pandemic in 2002–2004, and the MERS-CoV, which caused a pandemic in 2012 and is still infecting people in some regions. It is interesting to note that diseases that have emerged in the last three decades are the ones that have caused the maximum impact on human health in terms of sheer numbers of people affected – and COVID-19 tops the list. It is interesting that all these diseases are caused by viruses, not that bacteria or fungi are not as dangerous. However, viruses have the unique ability to adapt themselves very, very quickly to a new host and that makes them highly successful invaders. Finally, note that all these deadly pandemics are of animal origin, i.e. they are zoonotic diseases.

ZOONOTIC DISEASES, FORESTS, AND BIODIVERSITY

For most of these zoonotic pandemics, wildlife is usually made the scapegoat. So it was civets in the case of the SARS pandemic, camels in MERS, and pangolins for COVID-19, and then of course bats are blamed for everything. While wildlife has been much maligned in the whole process, it is actually humans who are responsible for the emergence of these diseases. There has been unprecedented scale of land-use changes – conversion of virgin forests to agricultural crop fields and livestock ranches and pastures, the logging of large swathes of forests for timber, intensive agriculture, rapid industrialization and resulting pollution of the

environment, the intensification of livestock and poultry industry. These changes, combined with our thirst for hunting and consuming wild meat, have led to the opening of a Pandora's box, where pathogens hitherto confined to dense forests and jungles have now been unleashed onto human habitations and wreaked havoc.

Large scale felling in forests leads to fragmentation, where patches of forest are left isolated like islands in a sea of human-modified landscapes, such as crop fields, pastures, villages, cities. Fragmentation creates patches and forest edges that increase the interface between humans, livestock, and wildlife. This means there is more scope for transmission of pathogens and diseases between them. When forests are intact, there are more species that can thrive in the different kinds of habitats available, but as forests get fragmented, the available types and extent of habitat decreases, reducing the diversity of animals that can be supported in it. More generalist species, the kind that can utilize a wide variety of resources (which are usually more abundant), thrive in these fragments. Such generalists are better able to adapt to human disturbances and to tolerate human presence. Thus, they are more likely to come into contact with humans and their livestock, and to exchange pathogens and diseases with them.

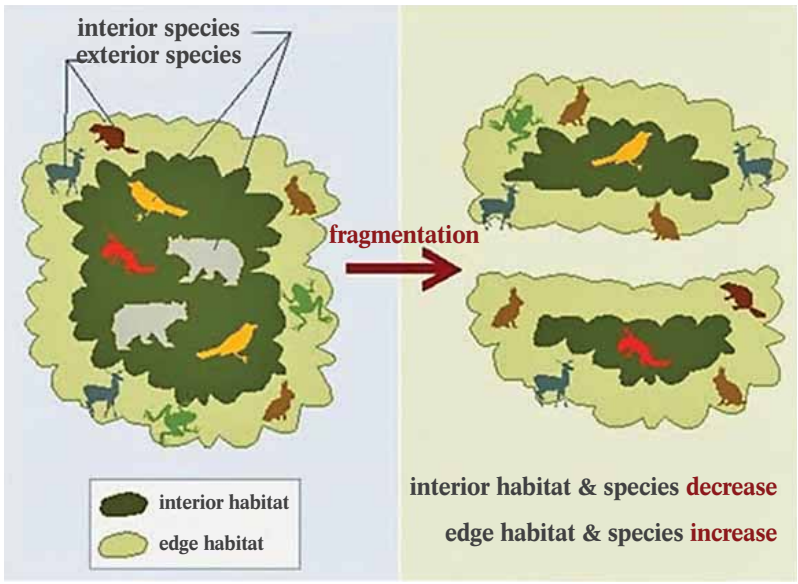


Fig.1. Process and effects of fragmentation of forest habitats

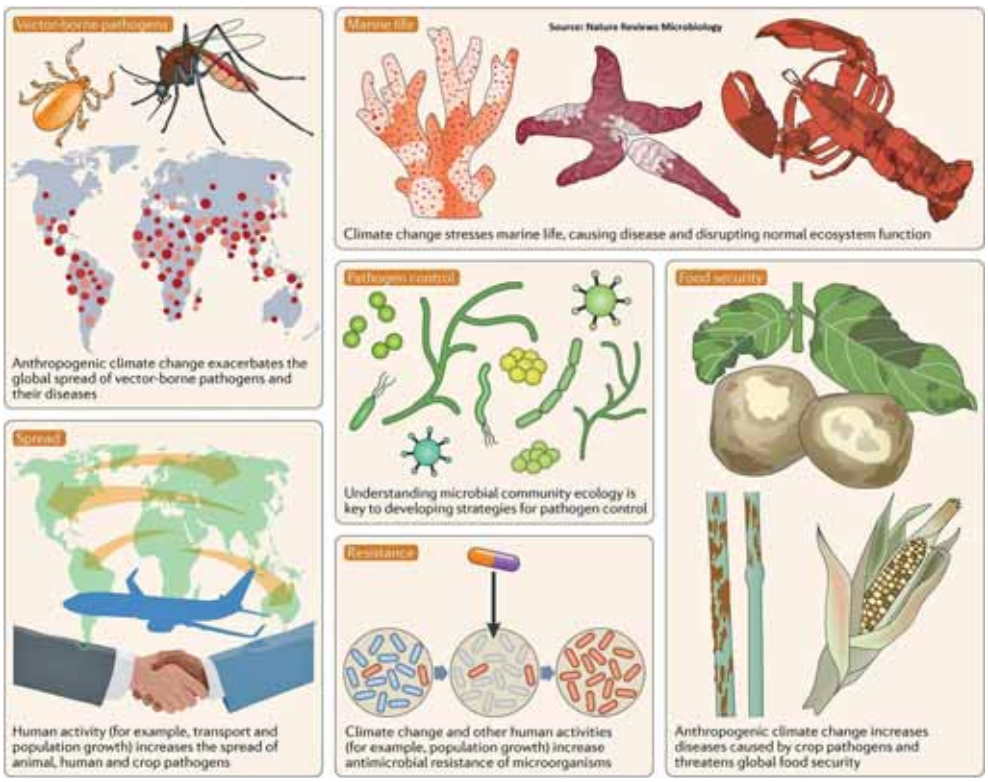


Fig. 2. Zoonotic disease events in humans have been linked directly or indirectly to biodiversity loss

Fragmentation also causes wild animals to move out of what is left of the forests, to look for other places in search of food and shelter (figure 1). This often involves navigating human-dominated areas and leads to conflict. There is also increased interaction and competition between wild animals and livestock, especially when livestock enter forests to graze. Movement and dispersal of animals out of forests or their original habitats also allows their pathogens or vectors of diseases to move out and disperse to human-dominated areas. This increases the risk of new diseases emerging in humans. There is a great risk of transmission of diseases in these interface habitats, and in India, such areas are increasingly more common than untouched forests.

The lockdowns imposed by the recent COVID-19 pandemic have also led to increased human-wildlife interactions, through increased movement of wildlife into human habitations and increased incidence of poaching. Such a situation enhances human-wildlife conflict, which could also lead to greater risk of transmission of zoonotic diseases.

Fig. 3. Changes in land use, and their fallout leading to habitat destruction, can also change the dynamics of pathogen transmission

LOSS OF BIODIVERSITY AND HUMAN HEALTH

Recent zoonotic disease events in humans have been linked directly or indirectly to biodiversity loss (figure 2). The spillover of Ebola virus to humans is more likely to occur in highly disturbed forest areas with closer contact between wildlife and human settlements. Forest fragmentation in North America led to an increased risk of Lyme disease in humans. Nipah virus was linked to intensification of pig farming and fruit production in Malaysia. Japanese Encephalitis virus was linked to irrigated rice production and pig farming in

> “Zoonotic diseases are a grave threat due to their potential for use in bioterrorism. Of every five human diseases, three are known to have animal origins. Not counting COVID-19, 13 zoonotic diseases are responsible for more than 2.2 million deaths per year, worldwide. These include influenza, rabies, tuberculosis, Q fever, and brucellosis.”

Southeast Asia. Emergence of Avian Influenza was linked to intensive poultry farming. Early human cases of SARS were associated with contact with civet cats, either in the wild or in live animal markets. Bat-associated zoonotic viruses emerged due to loss of bat habitats through deforestation and agricultural expansion. Rabies transmitted by vampire bats to cattle and human was also linked to forest activities in South America.

A study of Brazil's Atlantic forest found that re-emergence of Chagas disease, caused by the protozoan parasite *Trypanosoma cruzi*, was associated with reduced mammal diversity and increased abundance of reservoir species, such as the common opossum and other marsupials and rodents. *T. cruzi* was found to be more prevalent in small mammals in forest fragments, than in continuous forest.

Habitat destruction can also change the dynamics of pathogen transmission (figure 3), e.g., E. coli bacteria from humans and livestock near Kibale National Park in Uganda were found to be genetically closer to those collected from primates living in forest fragments, than the bacteria in primates living in undisturbed forest areas. Another study in Bwindi Impenetrable National Park also found that E. coli from gorillas which had frequent contact with humans were genetically similar to E. coli from humans and their livestock.

The emergence of bat-associated viruses in Australia, including Hendra virus (a relative of the Nipah virus), is linked to agriculture and urban development. Bats are sensitive to human disturbances. As habitats disappear, fruit bats are driven out to search for alternative feeding and roosting sites in urban and peri-urban landscapes.

A meta-analysis of 58 case studies from eight countries suggests that land-use change is more favourable to rodent species that harbour zoonotic pathogens. These 'reservoir' rodent species were more abundant in modified habitats than in natural habitats. Experiments in savanna systems have shown that when predators of rodents such as small cats, jackals, and foxes are removed from the habitat, it leads to increased risk of rodent-borne disease.

West Nile virus was introduced into USA in 1999 and is now endemic. Wild and peri-domestic birds are the hosts and mosquitoes the vectors. It was found that when bird diversity decreased, mosquito and WNV prevalence increased. Bird communities with rich diversity tended to be less competent reservoirs of these pathogens.

> "A recent study has found that bacterial infections typically found in humans, including *Salmonella serovar* and *Campylobacter* species, are being spread to seabirds of the Antarctic."

Instead of being viewed as a source of zoonotic diseases, wildlife is better characterized as 'sinks' or 'traps' for various pathogens having zoonotic potential. The diversity of life forms and the diverse habitats they survive in indicate nature's wonderful mechanisms of natural prevention and control, when it comes to infectious disease agents. These agents were never meant to be exposed to humans, nor to cause the scale of disaster we see in recent times. However, rampant deforestation, irresponsible changes in land-use patterns, and increasing wildlife trade have resulted in greater interface for interaction between wildlife, their pathogens, livestock, and humans. And the risk is not unidirectional – wildlife, too, is at greater risk for acquiring (and maintaining) human- and livestock-associated pathogens and illnesses. Such pathogens affect not only wildlife health, but also their population viability, apart from rendering them as sources for reinfection in humans.

However, all species are not equal when it comes to their potential for disease transmission or prevention. Even in diverse habitats with many species, some species play a larger role than others in disease transmission. Therefore, the relationship between diversity and diseases is not linear. While some pathogens increase as diversity of host species increases, others stop increasing beyond a certain threshold level of hosts. Again, a host species may harbour more than one pathogen and the dynamics between these pathogens within the host may play a role in transmission of these pathogens.

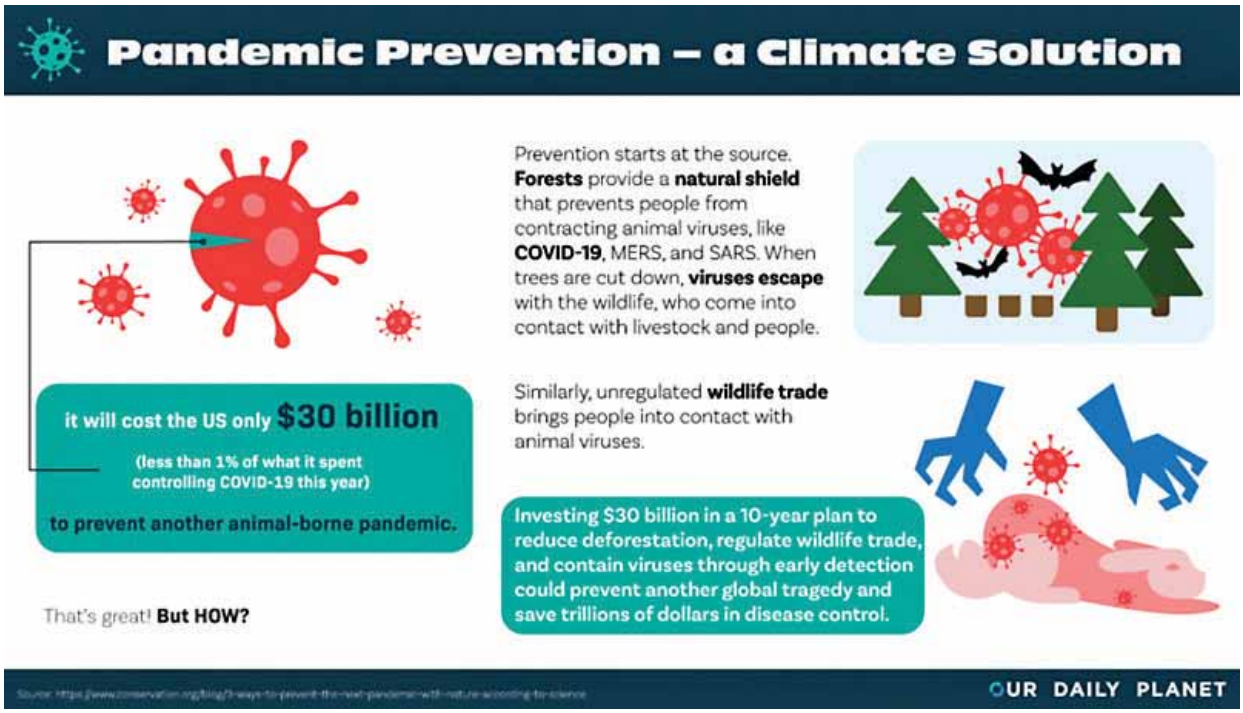


Fig. 4. Prevention of pandemics through ecological and climatological solutions

Human behaviour and patterns of habitat use also plays a role in the transmission of zoonotic diseases, as is evident with the current COVID-19 pandemic. As an example, tick diversity and abundance may be higher in forested areas with greater diversity of host species. However, the incidence of tick-borne diseases in humans is found to be higher in the edge areas of fragmented landscapes, or in the buffer zones around a PA, because these are the areas that humans tend to use more.

A study of different types of land-use in Brazilian municipalities and their effect on transmission and occurrence of three diseases, including malaria, diarrheal diseases, and respiratory infections, revealed that protected areas (PAs) were associated with lower incidence of the three diseases, compared to other land-use types such as roads and mining. Among PAs, larger PAs had significantly lower incidence of these diseases. However, PAs that had little to no human activity had less than half the incidence of such diseases, especially malaria, compared to PAs that allowed sustainable use of resources. Another Brazilian study also found that incidence of malaria increased with forest cover around cities.

While further, targeted studies are required to study the effective impact of PAs and biodiversity on human health and well-being, it is clear that the larger and less disturbed a PA, the lower the incidence of diseases. And when it comes to protecting biodiversity, conservation of some species might have a greater impact on incidence of zoonotic diseases than others. It is thus important that policy makers and conservationists should not use a "One size fits all" solution to address biodiversity conservation.

Loss of biodiversity impacts human health in other indirect ways, too. About 70,000 plant species are used globally in traditional or modern medicine, and 50% of modern drugs have been developed from natural products. We are still discovering new medicinal and health benefits of many plant and invertebrate species. Loss of biodiversity will mean a loss of many such (as yet) undocumented benefits to human health. Human well-being does not just mean health, or 'freedom from disease'. It also includes the physical, mental, and social aspects of human life. Nature and natural areas are proven to have positive and beneficial effects on human well-being. They also help manage our general health, enabling improved nutrition through the impact on our food supply, reduced incidence of non-infectious diseases such as hypertension, cancer, diabetes, etc., through healthier lifestyle choices, and through economic benefits from the conservation of our natural resources, leading to an improved lifestyle and better access to health resources.

BIODIVERSITY CONSERVATION AND THE WAY FORWARD

We need to recognize the interactive relationship among biodiversity, anthropogenic change, and risk of zoonotic diseases. Although the exact prescription on how to conserve biodiversity and which areas or species to prioritize for conservation will differ across ecosystems, geographical boundaries, and the nature of interactions between humans and biodiversity, there is no doubt that safeguarding biodiversity is the most important tool to prevent outbreaks of zoonotic disease and avoid a COVID-19 scale pandemic situation in future. And that there will be more such pandemics in the future, that will be larger, more infectious, and spread faster, is a prediction that has been made by several respected scientists, scientific organizations, and policy think tanks across the world, including the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), an independent body with 137 member-states.

There is an enormous economic cost associated with zoonotic diseases, and their prevention and control. It is important to undertake a cost-benefit analysis that is area-specific and disease-specific, to understand the impact of biodiversity conservation (and resulting pandemic prevention) on the economic and public health of a country. Investing in biodiversity conservation through identification, setting aside and protection of large swathes of natural areas, including grasslands and deserts (areas traditionally considered wastelands), and marine areas, might actually be cheaper than the economic costs of managing and controlling pandemics such as COVID-19. We must invest more in studies investigating the impact of biodiversity on zoonotic disease risks, the impact of zoonotic diseases on our health and economic systems, the overall effect pandemics have, not only on our physical and financial health, but also our mental and social health, which in turn impose an economic burden on society. We must invest in better and stricter protection of our natural resources, reduce poaching and wildlife trade, deforestation and fragmentation, illegal harvesting of timber and other forest produce, and the exploitation and abuse of tribal and native communities that revere and safeguard our forests. We must build better early warning and detection systems for changes in biodiversity patterns, land-use, forest structures, human-wildlife conflict, and other indicators of zoonotic disease risks (figure 4).

A comprehensive and integrated strategy for biodiversity and nature conservation is, therefore, vital to the maintenance and improvement of human health and well-being, and all sections of society need to come together to make it happen. There is an urgent need to review how we manage our relationship with nature and biodiversity, not only for our own well-being, but also for that of generations to come.

** Talk presented at St Xavier's College, Mumbai at a webinar hosted by Friends of Trees on "Environment in COVID times", 22nd February, 2021.*

> "The pandemic-associated lockdown and subsequent migration of skilled and unskilled workers back to their villages and hometowns across India created a socio-economic and humanitarian crisis of unseen proportions. The toll on lives and livelihoods apart, the toll on mental health and well-being was unsurpassed. It is clear that pandemics like COVID-19 can cause widespread and far-reaching damage to human life, as we know it. But there is no doubt that safeguarding biodiversity is the most important tool to prevent future outbreaks of zoonotic disease events, to prevent such a global-scale disaster."

Phytodiversity Research and Conservation in India

against the backdrop of the COVID-19 Crisis

Bright blue skies were a positive fallout of the pandemic

"Many of us are talking about a 'return to normal' as soon as possible. But perhaps this is a good time to take stock and ask ourselves what the 'normal' is that we wish to go back to? Perhaps we need to think of an interspecies social distancing concept, where we ask the question: How much space does each species require to allow it to exist?"

Text: **R.K. Choudhary**
Photographs: **Vibha Kaul**

India is bestowed with vast natural resources, and hosts four biodiversity hotspots. It represents c. 11% of the world's flora in just about 2.4% of the global landmass. In terms of floristic diversity, approximately 45,000 plant species are found in the country. The angiosperms are represented by c. 17,500 species, out of which 5,725 are endemic to India. Considering its fragility, India has been declared a nation of global conservation priority (Bawa 2006). To protect this treasure trove, adequate research and timely conservation efforts are required. The COVID-19 pandemic has, however, appeared as a stochastic shock, affecting biodiversity research and conservation in the country drastically. The country's economic recession has compelled the government to reduce research funding, and the focus has been shifted to humanitarian and financial crisis relief. The present communication analyzes both negative and positive consequences of the COVID-19 crisis on phytodiversity research and conservation planning in India.

I. NEGATIVE IMPLICATIONS

A. Projects requiring mandatory human presence, such as surveillance of protected areas and experimental sites, treatment of wild plant diseases, and eradication of invasive alien species, have been affected badly in the last few months. Moreover, researchers carrying out floristic surveys, taxonomic revisions, ecological surveys, long-term monitoring of vegetation, studies on conservation priority areas, and expeditions to underexplored regions, have been hampered by travel restrictions. The closure of herbaria, repositories, and libraries has restricted consultations, loans and digitization of botanical specimens. Above all, the freeze on hiring staff in research institutes, universities, and environment-related centres due to paucity of funds is badly affecting trained personnel. This will further impact conservation research, development, training, and outreach activities. A study from Australia suggests that existing financial concerns before and during the pandemic will push researchers to such a point of monetary stress that they might be forced to quit research altogether (Johnson *et al*. 2020).

B. Travel restrictions have caused the cancellation or postponement of several important meetings such as the World Conservation Congress, UN Nature Summit on Biodiversity, Convention on Biological Diversity, UN Climate Change Conference, and many more. These meetings intended to review biodiversity conservation and emission targets, and plan to address climate change issues for the future decade. In India, some important conferences, seminars and meets such as the Indian Science Congress, Indian Association for Angiosperm Taxonomy (IAAT), Indian Botanical Society have been postponed and some may be cancelled. All these developments will hurt biodiversity research and conservation in India in the forseeable future and beyond.

C. Reports on the hurried clearance of projects are a cause for concern. Many nations such as the US, Indonesia, and India relaxed environmental regulation laws during the past year, resulting in unprecedented logging rates. Nandini Velho, a wildlife biologist reporting in *The Hindu* (Velho 2020), described the specifics of the Dibang Valley project, and reported higher rates of development project clearances and economic impetus to revive fossil fuel industries, including 30 projects cleared or discussed by mere video-conferencing.

D. A recent study conducted by Ramvilas *et al*. (2021) highlighted the concerns of biodiversity researchers regarding diversion of most research funding to COVID-19 related research or greater prioritization of topics related to viral diseases. Moreover, there is a preprint rush to publish COVID-19 associated studies at an increased pace, despite that in many cases, the dataset's authenticity could be in question.

Nature came closer as anthropogenic activities were reduced

Tourist spots got a break from the crowds that are usually seen

II. FAVOURABLE INFLUENCES

A. The lockdown phase witnessed an upsurge in virtual citizen science projects. In India, some of the most prominent online groups, such as eFlora of India <https://efloraofindia.com/> and India Biodiversity Portal <https://indiabiodiversity.org/> recorded a substantial increase in upload and identification activities. One of the most popular international group Zoonotics <https://www.zooniverse.org/> also recorded five million images processed in one week, four times its usual number; a record 30,000 new contributors signed up for the e-group. Such activities are expected to strengthen the conservation efforts affected by COVID-19, by enhanced participatory approach to gathering field data for biodiversity researchers.

B. During the lockdown, increased travel restrictions reduced oil and fossil fuel usage substantially, resulting in reduced air pollutants such as nitrous oxide, sulphur dioxide, and carbon monoxide up to 30% within two to four weeks of the lockdown. This had a noticeable positive impact on plant, insect, bird, and mammal diversity.

C. Reduction in ecotourism and human presence reduced anthropogenic pressure on sensitive plant and animal species.

D. Successful reintroduction programmes of vulnerable species were possible during the lockdown period, and there were increased sightings of wildlife close to human habitations worldwide.

E. A considerable increase has been noticed in virtual webinars, low in budget and with a relatively lower carbon footprint, providing excellent opportunities to listen to and interact with scientists from diverse fields. A substantial rise has been observed in online courses related to developing new expertise such as taxonomic identification, plant nomenclature, remote sensing (RS), and geographic information systems (GIS), ecological modelling, statistical analysis and such like in the post COVID era.

III. REBOOTING THE MEANING OF RESEARCH

To combat the COVID-19 crisis, biodiversity researchers must prepare to hit the ground running. They need to convince the government and private sectors to extend more support, to continue research and conservation work. The support should come in many forms, such as personnel, fellowships, individual project funding, and logistics. Grants dealing with training, conservation, and infrastructure development should be at the heart of this response. Because of the prediction of a third wave of the COVID-19 in the country, returning to the field seems difficult. During this period of restricted field studies and conservation action, biodiversity researchers should confer with their counterparts worldwide, gather more images, and analyse more data.

IV. THE WAY FORWARD

It seems too early for definite answers as to how the pandemic is affecting the phytodiversity of India. However, biodiversity researchers must strengthen international ties and form task forces to overcome the present challenges. Stringency in national environmental regulation policies is also required, along with the inclusion of indigenous people in conservation planning and action. Despite all odds, conservation work is going on, and protected areas are being safeguarded to protect the vulnerable wildlife. According to data collected from Blackbox Research and Toluna surveys, published in *The Economic Times* on May 22, 2020 (Anon. 2020), COVID-19 did not have a hugely negative impact on the national mood after the first wave. "An overwhelming 87 per cent of Indians felt that their country has managed the crisis well... With an index score of 59, India is tied for third place with the United Arab Emirates amongst 23 countries in the study," the survey pointed out.

However, the second wave ravaged the country in an unpredictable manner. Therefore, as Guy Broucke (2020), Head of Natural Sciences, UNESCO, suggests, "... Many of us are talking about a 'return to normal' as soon as possible. But perhaps this is a good time to take stock and ask ourselves what the 'normal' is that we wish to go back to? Perhaps we need to think of an interspecies social distancing concept, where we ask the question: How much space does each species require to allow it to exist?"

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Cities returned to their grey normal once the lockdown was lifted

The same area in suburban Mumbai, in the midst of the lockdown.

RAISING THE RISK FOR COVID

Environment, Climate, and Past Zoonotic Pandemics in Medieval Europe and Colonial South Asia

"There are examples of resilience in local communities which we must further research and learn from, and integrate those lessons into the circumstances in which communities of the present find themselves. Globalization may have enhanced risk of human zoonotic epidemics, but it has also provided the means for global connections that can help increase awareness and advocacy of community and societal practices that increase socio-economic and environmental resilience, thereby diminishing the risk of such epidemics as the world is experiencing."

Text & Images: **Vinita Damodaran & Raymond Ruhaak**

This paper is based on the hypothesis that a quite new and distinctive analysis of mortality in famine and disease events is now possible, which has much greater explanatory power over the historical period than previous analyses. This possibility arises because over the last 25 years an increasingly accurate means of analysis of the risk factors for human zoonotic disease and its tie to environmental change stemming from human activity has been developed and applied. Additionally, this period and particularly over the last 10 years, an increasingly sophisticated climatic chronology has been evolving, which explains global climate anomalies in the tropics, including in South Asia, in terms of the impacts of globally teleconnected El Niño and La Nina phenomena.

The paper is also based on a second field of emerging research findings. These convincingly demonstrate the close relationship between El Niño / La Nina events and the dynamics and chronology of epidemic and pandemic disease transmission and occurrence, among a wide variety of disease types. The traceable connections between epidemic disease events and El Niño events date back to the onset of the modern El Niño phenomenon, that is from approximately 3500 BCE, a period from which the genetic origins of malaria, the most significant El Nino-impacted disease, can also be traced (Grove & Adamson 2018).

I. El Niño / La Nina Events and the Risk of Human Zoonotic Disease Epidemics

The El Niño phenomenon, which stems from ocean-atmosphere interactions across the equatorial Pacific Ocean, affects regional to local weather patterns every few years. El Niño is often associated with water, weather, and climate-related extremes and changes in seasonality, that in turn influence local disease ecologies and population exposures.

El Niño's impact on disease transmission occurs directly via ecological changes (for example, hydrology and rising ambient and water temperatures), which may propagate a variety of pathogens, as well as spawn a variety of hydro-meteorological hazards, including floods, temperature extremes, windstorms, and droughts.

Because El Niño/La Nina events are globally teleconnected and, in the case of the strongest events, impact the whole tropical and temperate world, the El Niño related mortality history of South Asia can only be understood in the context of the global history of El Niño-related epidemic diseases and their mortality and economic impacts.

This is because pandemics spreading during El Niño years impact on India, and because, historically, epidemics originating or preponderant in South Asia have affected the rest of the world on many occasions, above all in the case of plague epidemics in the 14th century and in the case of cholera epidemics after 1817 (Grove and Chappell 2000).

The geographical region of South Asia and Southeast Asia is especially suitable for this purpose, as it constitutes the largest area with a long, well documented history in the tropics. The histories of population, epidemics, and famines, and government intervention are thus accessible for a period of up to a thousand years. Moreover, because large-scale mortality due to famine among settled agricultural populations has been a characteristic of South Asia, the scope of epidemic disease mortality in all its past and present aspects is an important field of study.

To date, the major epidemic diseases which have been shown globally to be very strongly correlated with or caused by El Niño / La Nina events include: malaria, cholera, typhoid, diarrhoea, dengue fever, yellow fever, smallpox, influenza, bubonic and pneumonic plague, viral pneumonia, anthrax, typhus, tuberculosis, leishmaniasis, meningitis, Ross river virus, Murray river encephalitis, Japanese encephalitis, lymphatic filariasis, onchocerciasis, Chagas disease, guinea worm, hantavirus pulmonary syndrome (HPS), Lyme disease, leptospirosis, SARS, and some rickettsias.

Although to date not all of these diseases have been recorded in South Asia, many of them have historically spread great distances in recent decades and may have been present in South Asia in the past. Thus dengue fever has re-invaded South Asia in the last 35 years, when it appears to have been absent for a long period. The changes in vector populations associated with El Niño related outbreaks of these diseases are mainly animals or birds (including civets and monkeys), although in the case of cholera some marine organisms are involved.

The importance of El Niño as a trigger factor for disease episodes has been shown in Latin America, which has emerged as an epicentre of the COVID-19 pandemic. Brazil, Peru, and Ecuador report some of the highest COVID-19 rates of incidence and deaths in the region. These countries also face synergistic threats from multiple infectious diseases (that is, ecosyndemic) and quasi-periodic El Niño-related hazards every few years.

According to Johns Hopkins University, national public health agencies, there have been over 181 million confirmed cases of COVID-19 and over 3.9 million deaths worldwide since the pandemic began in late 2019 (https://www.bbc.co.uk/news/world-51235105).

Ivan Ramirez and Juan Lee note in the context of Latin America that, 'like other disasters, not every country is equally vulnerable. An analysis by the World Bank concluded that ''with more people living close to the international poverty line in the developing world, low- and middle-income countries will suffer the greatest consequences [of the virus] in terms of extreme poverty"' (Ramirez & Lee 2021).

Often, El Niño's impacts aggravate pre-existing health burdens, and heighten social vulnerabilities (for example, compromising potable water access, sanitation, hygiene, nutrition, and/or livelihoods) to other hazards. Thus, it is a convergence and cascade of hazards and disasters that often heighten health vulnerability. Another aspect heightening our risk to disease episodes are anthropogenically induced environmental change to which we now turn.

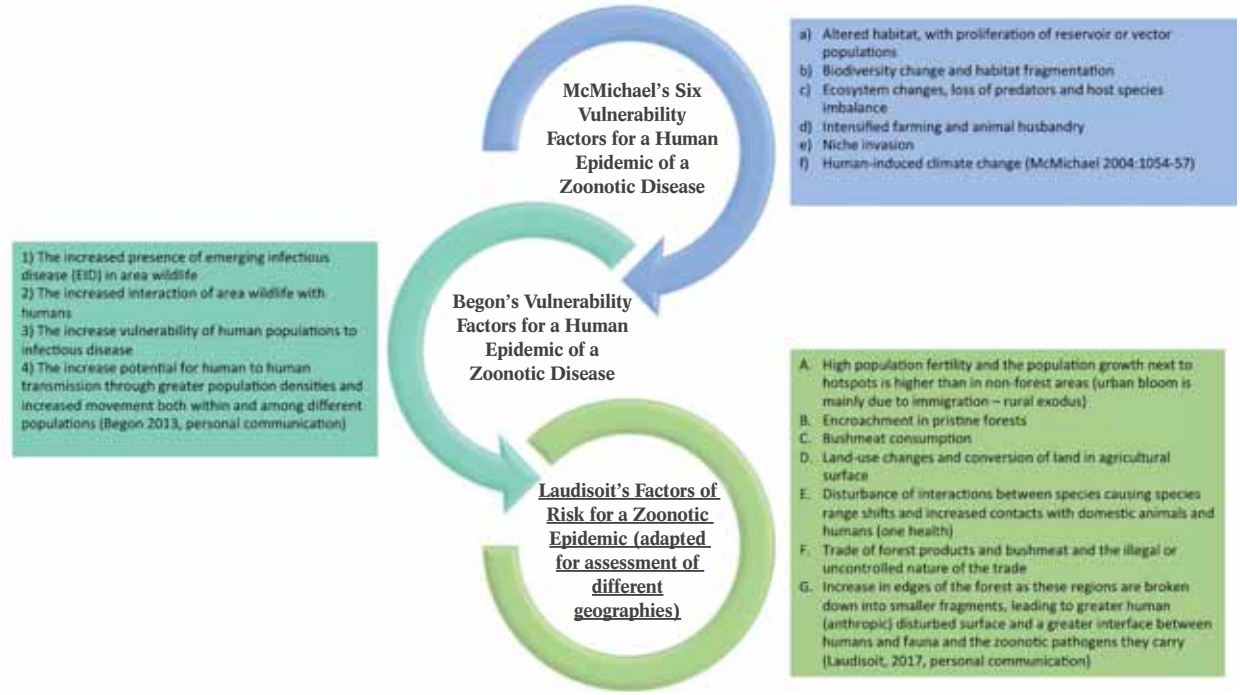

Fig. 1. Risk Factors for a human zoonotic epidemic by McMichael, Begon, and Laudisoit.

II. What Leads to Vulnerability for a Human Zoonotic Epidemic?

A. Risk Factors for Human Zoonotic Disease Epidemics

The impact of human activity in creating the circumstances advantageous for the spreading and proliferation of zoonotic pathogens in animal reservoirs to human populations are illustrated in the risk factors given in figure 1. Altering habitats through forest fragmentation, intensified farming, and animal husbandry (McMichael's and Laudisoit's Risk Factors) are examples of activities that increase risk, which lead to other risk factors, as "the increased interaction of area wildlife with humans" (See fig. 1, Begon's 2nd Factor) since the population of people increase to alter the ecology to generate specific resource harvesting.

B. Micro-, local, and regional climate change affect on *Yersinia pestis* and Plague Risk

Zoonotic disease comes from animal reservoirs and the density within these reservoirs has been shown to elevate the risk of spreading the disease to human populations. The risk for a human zoonotic epidemic has been tied to the population density of burrows of small mammal populations. It appears that when burrows become too crowded, conflict increases and blood is drawn, leading to a greater opportunity for the transmission of a pathogen among these animals. Meliyo *et al.* (2014) illustrate this connection between burrow density and human plague presence after recent plague epidemics in highland Tanzania (figure 2).

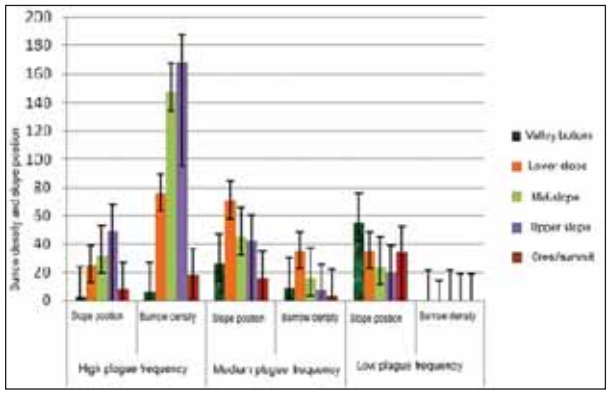

Fig. 2. West Usambara Mountains, Tanzania – burrow sampling and presence of bubonic plague: Relationship between burrow density in animal reservoirs and high human plague frequency in Lushoto, Tanzania. Chart from Meliyo *et al.* (2014: 6).

As the populations of these animal reservoirs increase, there is greater movement by some of the animals to find or build another burrow. This

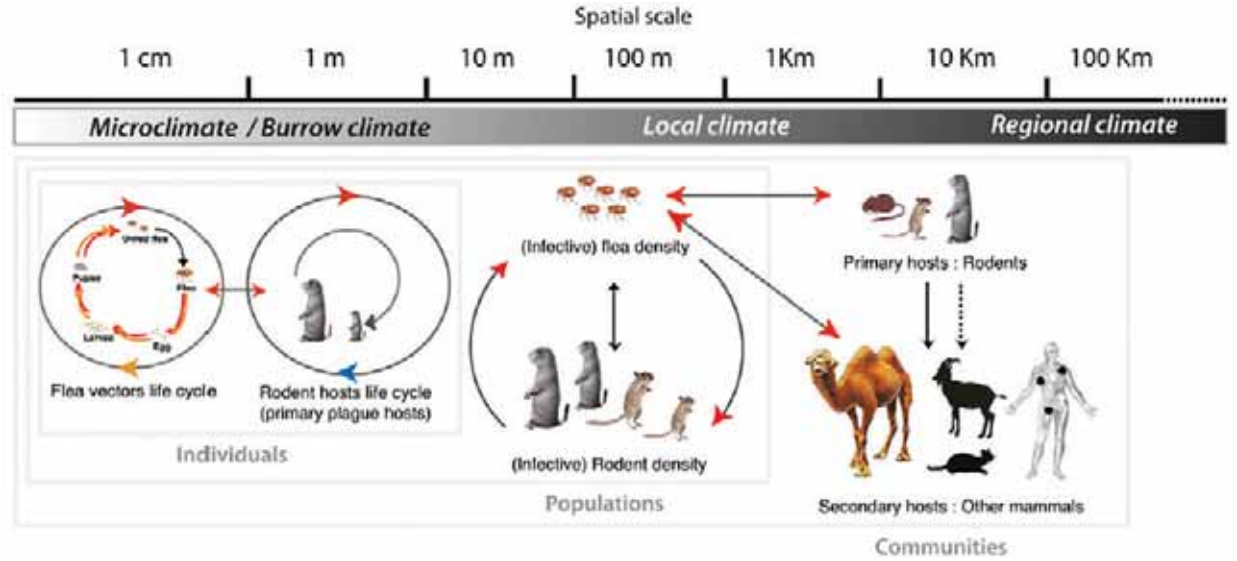

Fig. 3. Impact of climate on the plague cycle as a function of spatial scale, from Ari *et al.* (2011: 4). Arrows represent the connections affected by climate.

increases the chances of human contact with the animals, and with the pathogen. One important factor for increasing burrow density is a warm burrow climate, as well as a warm local climate that leads to higher breeding of the mammals, fleas, etc. (see figure 3). Additionally, large and intensive herds of grazing animals (such as cattle, sheep, and camels) leads to greater populations of commensal animals (such as rodents) due to overgrazing and shortening of the grasses, as well as leaving them with many varieties of vegetation to feed on that larger species do not consume.

Land use and the microclimate-plague relationship

The impact of anthropomorphic environmental change from expanding cultivation or grazing land affects the level of erosion and soil fertility, and diminishes area biodiversity, including animal life. This results in a greater risk of food insecurity and malnutrition of the local people, which increases their risk of disease, including zoonotic diseases. This scenario has unfolded repeatedly through our present era of globalisation, as Dotterweich (Fig. 4) illustrates from a much earlier period, in medieval Europe.

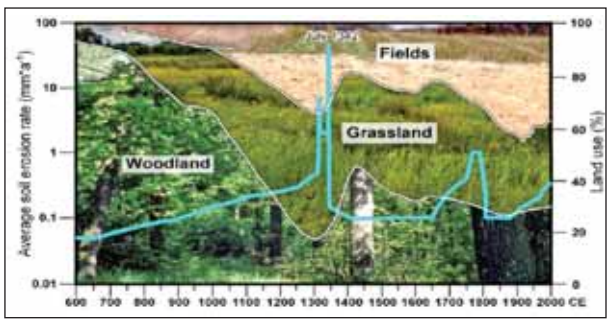

Fig. 4. Soil erosion (light blue line) and land use change in central Europe (c. 600-2000 CE), highlighting the peak erosion period on the plague pandemic of mid-14th century Europe, from Dotterweich (2013: 6).

III. Examples of Resilience to a Human Zoonotic Epidemic – the Plague

If we can say that human activity leading to environmental changes, such as forest fragmentation and vegetative clearance, results in greater risks for human zoonotic diseases, can re-forestation and maintenance of forest biodiversity decrease the risk? History shows it can, but there are additional socio-economic and knowledge system risks that also need to be addressed. If a community or society is engaged in unsustainable acts that increase the risk for environmental issues and zoonotic disease, then it is critical to know what societal systems, institutions, and pressures led to these actions to be employed? Likewise, communities / societies that engage with their local natural environments in a sustainable way have societal systems and institutions that are rooted in accurate environmental assessments and sustainable activity, and address societal problems accordingly.

The example of the Medieval Gaels and the Gaelicised Irish, their contemporary Bedouin and their Bedouinised followers of the Mamluk frontier (Ruhaak 2020: 532), and the modern Shambaa community of highland Tanzania (Ruhaak and Mtio 2021), show some common characteristics which

include a relatively flat organizational structure (instead of hierarchical), high local self-determination, and a strong connection to the ecologies they depend upon (which is reflected in their language and cultural knowledge), multiple means to secure food and other necessities, and a strong connection to internal and external networks and knowledge. All of these characteristics increase their adaptability and decrease their risk of environmental crises, food insecurity, and zoonotic diseases.

IV. What Led to the Increase of Zoonotic Risk Factors and the South Asian Plague epidemic of late 19th/early 20th century?

A. The East India Company and the colonial government establishing land as a commodity

The intellectual historian Kaye (1998: 285) explained that as more people in a society become dependent on currency for their livelihood, their perception of natural resources changes. Assessments of natural resources are then made in mathematical terms of weight and mass, which prices per unit are also tied to. This way of analysing natural resources is easily translated to monetization and the market economy, while breaking the tie of the environmental context that these resources used to be a part of and assessed within. The commodification of the land led to it being bought up as well as taxed, and therefore an increasingly scarce commodity. These cash requirements for land were incentives for cash crops that included greater non-food production (such as opium and cotton). All of these changes fostered the monetization of other natural resources as well as the introduction of different plant and animal species that had a high international market demand.

This process of commodification was significantly assisted by the Great Trigonometrical Survey (1802–1890), which precisely mapped the Subcontinent's natural resources (Fisher 2018: 124), as was done much earlier in England with the Doomsday Book (1086), and part of the Mamluk Empire (southern Syria) with the Rawk (1313–1325) (Ruhaak 2021). This gave the Company, and later the British colonial government, an "unprecedented body of knowledge fostered British commercial exploitation of India's lands and forests" (Fisher 2018: 124) to more efficiently exploit resources. An example of this is the expansion of the railway in India, as Guha (1983: 1883) illustrates in Table 1.

Table 1. Railway Expansion in India from 1853 to 1910, from Guha (1983: 1883).

Year	Kilometres	Outlay (Rs million)	Net earnings (Rs million)
1853	32	3.8	0.05
1860	1,349	266.6	3.00
1870	7,678	900.0	30.30
1880	14,745	1,285.7	63.90
1890	26,395	2,136.7	103.60
1900	39,834	3,296.1	164.50
1910	51,658	4,390.5	239.90

The East India Company, under the support of the British government, was also able to set the legal framework for property ownership and taxes, which it attempted to enforce in the early 19th century through its own military. This legal authority incentivized landlords to increase agricultural production that fostered deforestation and vegetation clearance, that in turn led to increased erosion, reduced agricultural yields, ecological crises, malnutrition, and disease.

Figure 5 shows a tea plantation in Cachar, Assam, in the 1860s. The related text in the British

Fig. 5. Tea plantations (1860s), Cachar. From the British Library Collection, UK.

Library Collection states: "In 1833, the East India Company monopoly of the Chinese tea trade came to an end and the British government decided to initiate tea planting in India… The first planters had to cut their way through impenetrable jungle, cope with disease and the ravages of wild animals, recruit and maintain the morale of workers from distant provinces and learn the technique of tea cultivation and manufacture." (http://www.bl.uk/onlinegallery/onlineex/apac/photocoll/t/019pho000000913u00033000.html).

As the financial impact of the commodification of the land increased, the plot sizes passed down to the next generation decreased while over-intensive agriculture grew, and well water levels, drainage channels, and soil fertility levels declined (Kaiwar 1992). These problems intensified as poor peasants took out high-interest loans to survive, while their crop yields continued to fall. The introduction of the English short-horned cattle also exasperated the situation, as overstocking led to feed shortages for this livestock that was especially vulnerable to tropical diseases (Roy 2006: 5395). Meanwhile, large investments were made in the railroad and forestry industry, as well as the start of colonial schools to benefit a few that would be able to hold local administrative and other high paying, influential positions. Agricultural exports that grew immensely during the second half of the 19th century were climaxing at the turn of the century, which also marked the start of the plague epidemic (Dangwal 2005: 110–124; Guha 1983: 1885; Roy 2006: 5395), as well as high death-rates of other diseases, such as cholera (Klein 1988: 723).

B. Germ Theory & Sanitation Science dominate colonial government's response to human zoonotic disease

These policies to foster a financially efficient way to assess and exploit natural resources outside their natural ecological context, led to an increase in deadly disease in people from Europe and their colonial lands from 1872 to 1921 (Klein 1988: 723). Likewise, the solution was also standardized with the growth in Germ Theory and Sanitation Science during the 19th century. This was exemplified by the medical doctor and Parliament Member Balthazar Foster's lecture (1872), "The Prince's [of Wales] Illnesses: Its Lessons", which stated, "Truly, ignorance of sanitary science is not confined to the poor, but flourishes even in the highest places" (Tomes 1990: 517).

This strong push to kill germs through sanitation while continuing high levels of natural resource exploitation was illustrated by the eminent Sanitary Scientist, George Wilson (1879: 2) in his book, *A Handbook of Hygiene and Sanitary Science:* "The time… has gone by when people can be dragooned into cleanliness or be made virtuous by police regulations, and hence it is that the most thoughtful among practical reformers of the present day base their hopes of sanitary progress on the education of the masses as the real groundwork of national health. The people must be taught that good conduct, personal cleanliness, and the avoidance of all excesses, are the first principles of health preservation; that mental and physical training must go hand in hand in the rearing and guidance of youth; and that morality does not consist so much in a blind observance of the formulae of empty creeds as in a hearty submission to precepts of health."

This focus on sanitation was also noted in the 1897 *Report on the Plague in Bombay* stating the city's progress in the previous 25 years, explaining "all the Sanitary authorities who have lately visited the City have stated that it is the best kept and most sanitary oriental town they have seen" (Snow *et al*. 1897: 2). However, the report continues, "[as] sanitation condition of the city has improved… the general conditions of health have deteriorated" (Snow *et al*. 1897: 3). However, the report also noted other factors leading to the plague epidemic, as famine and malnutrition, stating, "The appearance of the plague in a famine year has further conduced to stimulate its vitality and onslaught on debilitated people in no condition to offer a normal resistance…" (Snow *et al*. 1897: 3). This was highlighted by the fact that the report stated that one of the most important ways the Bombay Plague Committee limited the "diffusion of plague… was the treatment of arrivals." The report went on to explain, "Some arrivals from famine-stricken districts were detained in camp mainly to improve their condition by good feeding… Half-starved immigrants continued to arrive in large numbers in July and August, and as the abnormal mortality was in great measure due to them..." (Snow *et al*. 1897: 30).

C. Plague in the Bombay region and its tie to agriculture

As the 1897 *Report on the Plague in Bombay* explained about problems of famine and malnutrition impacting plague mortality in rural areas around Bombay, it is also noteworthy that the first known and largest plague outbreak in the city was in densely populated dwellings over granaries or godowns. The report also found the presence of granaries or

godowns in epidemic localities to be commonplace, while also noting the movement of farm workers between plague centres. The authors of the report explain, "The first cases in Middle and Lower Colaba were labourers in the cotton godowns, and they were going backwards and forwards between Mandvi and Colaba. It is a curious coincidence that the first cases in Mandvi occurred over godowns and that the first cases in Middle and Lower Colaba occurred in godowns." (Snow *et al*. 1897: 50).

The example of the plague outbreak (with confirmed cases in December 1896) around the fishing villages of Sewri Koliwada is an interesting case, in that after the villagers left their homes, many went into the fields, where 150 people ended up dying of the plague, 46 more than in the village. The report states that the local people believed that they were less likely to contract the plague by remaining in the village than in the fields. Hankin (1905), who researched the plague in the Bombay region, also found this observation of the plague epidemic starting in rural areas, which is common for modern plague outbreaks (see fig. 1 and Catanach 2001).

Table 2. Death rate from selected localities in the late 19th century Plague in South Asia, from Hankin (1905: 56)

Place	No. of inhabitants	Death rate from plague per 1,000 inhabitants
Bombay	806,144	20.1
Poona	161,696	31.2
Karachi	97,009	24.1
Sholapur	61,564	35.0
Kale	4,431	104.9
Supne	2,068	102.5
Ibrampur	1,692	360.5

Hankin's (1905: 56) death rate from selected localities in the late 19th century plague in South Asia, shows an increased death rate as the size of the municipality decreased, peaking in Ibrampur with a 36% fatality rate (see Table 2).

Research of animal reservoirs in modern plague areas has shown that the pathogen that causes the plague, *Yersinia pestis*, is typically present in a percentage of the animal life, even when years or decades passed without a known case of human infection (Gage and Kosoy 2005). The 1897 report notes, "It appears to be an acknowledged fact that fevers with glandular swellings have for years been known in Bombay, and several natives of respectability have informed me that they have seen in past year's cases exactly similar, as far as they could judge, to the ordinary type of bubonic plague. If such were really the case, it is certain that the surrounding conditions were not favourable to the spread of the disease, and that the symptoms neither excited attention nor caused alarm." (Snow *et al*. 1897: 1).

Hankin also saw evidence of previous plague outbreaks in western India (1812), of which he thought the record seemed similar to the contemporary one he was experiencing. He thought both plague epidemics had largely avoided trade routes and had "great virulence in villages as compared with towns, during the first eight years of its existence" (Hankin 1905: 57). It was only at around the end of the outbreak that the zoonosis appeared in the comparably large town of Ahmedabad.

Similarly, Hankin pointed to the Pali plague of 1836, which also disproportionately affected the countryside and avoided trade routes of this important trade centre (Hankin 1905: 57). Thus, it should be considered that *Yersinia pestis* may have already been present in Bombay and/or in the nearby countryside. If this was indeed the case, as it often is in modern plague outbreaks, then what should be investigated is what led to the increase of population of animal reservoirs and the diminished barriers between these animals and human populations.

The large-scale ecological and health problems of the 19th century and early 20th century were of a greater intensity than pre-colonial generations had experienced (Arnold 1991). People of South Asia had traditionally lived in the same cultural geography for generations and each region had its languages that were tied to the ecological systems that they depended upon. This promoted sustainable use of resources in order to continue to largely live within the limits of what the ecological systems they depended upon could produce (Kala and Sharma 2010). The same characteristics of resilience seen among the Medieval Gaels of the Irish Sea area, the Bedouin of the Mamluk Empire, and the present Shambaa of Lushoto, Tanzania, are certainly found in South Asia. Thus, it is important to learn more about local socio-economic and ecological practices of the different South Asian localities that had been augmenting their resilience to the plague and ecological crises through sustainable practices that may have been locally adapted.

CONCLUSION

As climatic phenomena such as El Niño and La Nina have been shown to impact vulnerability to zoonotic disease in the tropics, it is especially important to develop sustainable, resilient practices to augment natural environmental defences against such vulnerabilities. The impact of El Niño, with its ocean-atmosphere interactions across the equatorial Pacific Ocean that effects ecological changes which may propagate a variety of pathogens, is especially concerning for South Asia. There is evidence for the development of heightened zoonotic risk since colonization and globalization. This may be due to the engineering of systems and institutions since the European Middle Ages that incentivized homogenous activity and landscape change, that led to increasing scarcity of resources, in turn leading to greater vulnerability for ecological crises and human zoonoses around the globe.

Nevertheless, even within these regional contexts of zoonotic vulnerability, there are examples of resilience in local communities, which we must further research, learn from, and integrate those lessons into the circumstances that communities of the present find themselves in. Additionally, globalization has provided the means for global connections that can help increase awareness and advocacy of community and societal practices that increase socio-economic and environmental resilience, thereby diminishing the risk of human zoonotic epidemics that colonialization and globalization have exacerbated.

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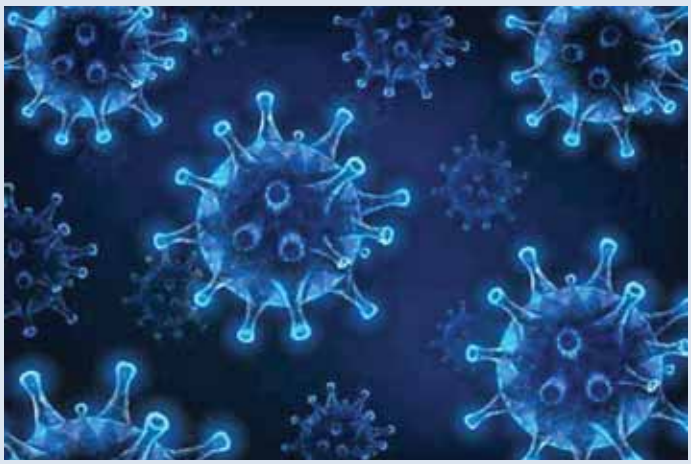
A PANDEMIC FACT FILE

WHEN: The World Health Organization declared the outbreak a Public Health Emergency of International Concern on 30th January, 2020, and a pandemic on 11th March, 2020.

WHERE: Where did COVID-19 originate? The first known infections from SARS CoV 2 were discovered in Wuhan, China. The original source of viral transmission to humans remains unclear, as does whether the virus became pathogenic before or after the spill over event. Because many of the early infectees were workers at the Huanan Seafood Market, it has been suggested that the virus might have originated from the market. However, other research indicates that visitors may have introduced the virus to the market, which then facilitated rapid expansion of the infections.



(Sources: web-based)

HOW: How long have coronaviruses existed? The most recent common ancestor (MRCA) of all coronaviruses is estimated to have existed as recently as 8000 BCE, although some models place the common ancestor as far back as 55 million years or more, implying long term coevolution with bat and avian species.

GLOBAL SOLUTIONS: Advance planning and preparedness are critical to help reduce the impact of a pandemic. The World Health Organization (WHO) guidance document "Pandemic Influenza Risk Management" outlines an "all-hazards" emergency risk management approach to pandemic influenza risk management. The guidance takes into account the lessons learned from the influenza A(H1N1) 2009 pandemic in order to create a pandemic influenza planning framework that would allow public health response efforts to be adapted for a more moderate event. WHO will use the global phases of a pandemic: Interpandemic, Alert, Pandemic, and Transition, to describe the spread of a novel influenza A virus. Different countries will face different pandemic phases at different times. The WHO guidance introduces a risk-based approach that would allow public health officials to develop flexible plans based on a national risk assessment while taking into consideration the WHO global risk assessment. ■

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The President & Managing Council,
National Society of the
Friends of the Trees

Baobab tree in a Warli settlement in Dahanu, Maharashtra

Living in Harmony

The Warli Tribe and their Trees

"The Warlis worship Hirva Deva as they believe that nature fulfills all their needs. The tribals believe in cultivating trees around their houses. They are also dependent on the forests around their settlements, that they cherish. Every aspect of the lives of these indigenous people of Maharashtra is enmeshed with the forests in which they dwell."

Text & Photographs: **Radhika Naware**

Warli tribals are residents of the hilly and coastal areas on the Maharashtra-Gujarat border. Traditionally, the Warlis were hunter-gatherers, living in the forest and subsisting on forest produce. The tribe was forced to settle down at the base of the hills, and now follow an agro-pastoral lifestyle. The Warlis narrate a legend of the origin of biodiversity. According to this legend, Lord Mahadeva and Gangagauri created the earth. They both collected seeds from other gods to plant them on the earth. The trees grew profusely, and as a result, animals and birds flourished too.

Harvesting paddy, a Warli wall painting

The Warlis worship Hirva Deva (Marathi: *hirva* = green, *deva* = God) as they believe that nature fulfills all their needs! The tribals believe in cultivating trees around their house. They are also dependent on forests around their settlements. They get their food (*anna*), security (*aasra*), and well-being (*aarogya*) from the forest. The Warlis still go back to the forest for firewood, medicinal herbs, tubers, and for recreation. Goddess Kansari of the Warlis is the deity presiding over grain. She is believed to be the source of "the life force", which she distributes to all living things.

The Warlis subsist on fish, prawns, meat, fruits, roots, bulbs, pulses, and other nutritious resources from their agro-pastoral way of life. In a vibrant Warli street market, you can get seasonal fruits gathered from the nearby forests. These native fruits are hardly seen in our urban vegetable markets. The indigenous tribal population, living in absolute harmony with surrounding forests, brings these nutritious treasures for sale in the weekly market. They cook on wood fires, but for fuel they cut only the branches, or collect dead wood from the forest. They store dry fish and dry tamarind leaves in baskets called *pettya*, which they weave from the leaves of Palash *Butea monosperma* and Teak *Tectona grandis*.

Warli houses are eco-friendly, built with reeds or jowar stalks, plastered with a mixture of cow dung and red earth called *geru*, and the roof is thatched with paddy straw. The Warlis make worthy efforts to conserve not only agricultural biodiversity, their entire way of life is traditionally self-sustaining. Each household in a traditional Warli village makes good use of the walls inside the house. The best of agricultural produce is well-preserved on the mud walls of their huts. The Warlis believe traditional storage practices are simple, efficient, sustainable, and safe, and beautiful as well. Their houses reflect their love of nature and respect for Mother Earth.

Natural vegetation is used to fence Warli homesteads

Grain on wall, a unique storage method

Karwi *Carvia callosa*, which famously flowers once in seven years, plays a major role in the lives of the Warlis, who make best use of this indigenous plant. During a flowering year, the hillsides and many forest areas get covered with a lavender blush, and the flowers are visited by eager honeybees collecting the nectar. The Warlis are good at harvesting the honey from the beehives – honey gatherers collect the Karwi honey which is a popular local delicacy; it is much thicker and darker than other varieties of honey. As for its medicinal properties, the Warlis use Karwi leaves for the treatment of inflammatory disorders. Karwi shrubs turn green with arrival of monsoon, but once the rainy season is over, only dry stems remain, and these same sturdy stems are used by the Warlis as thatching material to build roofs for their houses.

The Warlis make agricultural tools using wood. They make ropes from a plant named Ambadi *Hibiscus sabdariffa*. Bamboo, which has numerous uses in the tribal way of life, also provides livelihood opportunities for them. A hands-free raincoat made of bamboo is used by them during paddy transplanting. The year's stock of grains is stored in bamboo vessels called *kanagi*.

In their music and dance, the sustainable tribal way of life is reflected. Tarpa is a trumpet-like wind instrument handcrafted by skilled Warli folk from bamboo sticks, date leaves, and a dried gourd or white pumpkin; it is three to four feet in length. The Tarpa dance involves a group of men and women dancers moving rhythmically in a circle, to usher in a bountiful harvest. In the Kambadi dance, paddy straws are tied around the dancers' bodies. In this way, the dance forms of the Warlis make good use of the plant diversity around them. Rui plant *Calotropis gigantea* is significant during weddings; its flowers are woven together into headdresses for the bride and groom.

The Warlis are known for their earthy and elegant paintings with circles, triangles and squares. Warli paintings describe scenes of hunting, fishing, and farming, festivals and dances, and trees. The wall paintings are made only for special occasions like a wedding or harvest. Each Warli painting always has trees in it. Women are portrayed sporting flowers in their hair, and in case you visit a Warli settlement or participate in a Tarpa dance, you will see women wearing bright and colourful flowers day in and day out!

Trees like Peepal *Ficus religiosa*, Banyan *Ficus benghalensis*, wild Banana *Musa* sp., Coconut *Cocos nucifera*, Tadgola or Ice Apple *Borassus flabellifer*, Tamarind *Tamarindus indica*, Bilwa *Aegle marmelos*, Mokha *Schrebera swietenioides*, Neem *Azadirachta indica*, Vilayati Chinch *Pithecellobium dulce*, Tetu *Oroxylum indicum*, Kakad *Garuga pinnata*, Mango *Mangifera indica*, and Kumbha *Careya arborea* are commonly depicted. Wild cumin, Sugar cane and various types of grasses are often drawn in Warli paintings. Creepers like Heart-leaved Moonseed *Tinospora cordifolia*, Nandanvel, Kawlavel, and Chaivel which abound in the Western Ghats habitat occupied by the Warlis, are reflected in their paintings. (Some of the creepers are mentioned here with only local names as scientific names are not

Warli tribals with their produce at a weekly market

Painting by Sunil Kharpade shows the minutiae of the Warli way of life

easily available). The inherent aesthetic sense of the Warlis is also seen in the eye-catching patterns of the woven fences around their dwellings.

The Warli tribe makes a great effort to conserve sacred groves where cutting of trees is strictly prohibited. The Warlis worship mountains as their Dongresar Deva (Mar. *dongar* = hill or mountain). Their religious practices are closely linked with biodiversity. Buntings (Mar. *toran*) are created out of leaves during the Toran ceremony, when the village is evacuated and re-entered only after the pooja. Wooden Totems are commonly seen at places of prayer. The Waghya (tiger) totem is carved out of teak wood. Turmeric, rice grains, and coconut are used in pooja, and rice powder is used to draw rangoli or wall paintings that are unique to the tribe.

Warlis distill their own liquor from Mahua flowers. Toddy is consumed in eco-friendly bowls made from the leaves of Kumbha *Careya arborea*. Tendu *Diospyros melanoxylon* leaves gathered from the forest are used to roll bidis (cheroots).

The Warlis have been living in harmony with nature from time immemorial to the present. However, with changing times, customs and traditions are changing because of obvious reasons, and the traditional Warli way of life is also in flux.

Since 2017, I have been exploring Warli padas (settlements) during designer craft and textile trails across India, which I organize in connection with my endeavour "Treasured Holidays". We visit talented artisans in remote areas in their own habitats, and witness the end-to-end processes of the gorgeous world of Indian handlooms and handicrafts. Most importantly, we do not bargain with the artisans, there are no commission practices in our business model, and we bridge the distance between crafts persons and their possible clientele.

Due to the challenges of the COVID-19 pandemic and lockdown, it became impossible to travel as before, and we had to tweak our business model with practical, simple, and innovative ideas. So in March 2020, we created livelihoods for all of us by introducing 'Treasured Weaves', an online space across India to promote our artisans. We entered the retail space without prior experience! Strategically, the weaves and handicrafts were ordered from 12 diverse states by paying 100% advance and courier charges. We promoted 27 clusters and created livelihoods for 32 families through this initiative. It was a small beginning, but we enjoyed this new twist to our endeavour. Currently we are working with Warli artists for handcrafted masks, paintings, and artefacts. We are keen on expanding this initiative in post pandemic days too. Export activities are on the horizon. We hope to take local Indian artisans to a global platform!

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The author is thankful to Warli artist Sunil Kharpade for Warli paintings and inputs on local trees and creepers. She gained many insights from Madhukar Vadu's book "The Mystical World of Warlis" and from walking around Warli settlements with Phiroza Tafti, Convenor of the Dahanu chapter of INTACH.

A Warli Art File

Photographs: **Radhika Naware**

Two kinds of trees, a small hut with harvest stored below, various birds, compose a typical Warli forest-village

The Warlis are known for their earthy and elegant paintings composed of simple geometric elements, trees, plants, animals and birds, and depictions of the Warlis themselves in their day to day activities. Warli paintings describe scenes of hunting, fishing, and farming, festivals, dances, and trees. Each Warli painting always has trees in it. Traditionally, these wall paintings were made only for special occasions like a wedding or harvest, but popularization of the art has brought them onto cloth and canvas, and into frames for city homes. As in most folk art, the painters remain anonymous for the most part, but efforts are being made to bring recognition to the artists with various ethical means. Sustainable livelihoods for the Warlis would enable the conservation of their forest-village habitats, and the trees that they revere and protect.

A traveller resting under a tree props his bundle and stick against the tree trunk, while birds fill the sky

In the tree's shade, villagers rest, a basket weaver works, and children play

This tree profile reflects the shape of a peepul leaf, and birds are omnipresent

Work, rest, and play in a sylvan environment, this is the Warli way of life

Ten Golden Rules for Reforestation

- **Protect existing forest first**
  Before planning reforestation, always look for ways to protect existing forests, including old- and second-growth, degraded and planted forests.
- **Work together**
  Involve all stakeholders and make local people integral to the project.
- **Aim to maximize biodiversity recovery to meet multiple goals**
  Restoring biodiversity facilitates other objectives — carbon sequestration, ecosystem services, and socio-economic benefits.
- **Select appropriate areas for reforestation**
  Avoid previously non-forested lands, connect or expand existing forest, and be aware of displacing activities that will cause deforestation elsewhere.
- **Use natural regeneration wherever possible**
  Natural regeneration can be cheaper and more effective than tree planting where site and landscape conditions are suitable.
- **Select species to maximize biodiversity**
  Plant a mix of species, prioritize natives, favour mutualistic interactions, and exclude invasive species.
- **Use resilient plant material**
  Obtain seeds or seedlings with appropriate genetic variability and provenance to maximize population resilience.
- **Plan ahead for infrastructure, capacity, and seed supply**
  From seed collection to tree planting, develop the required infrastructure, capacity, and seed supply system well in advance, if not available externally. Always follow seed quality standards.
- **Learn by doing**
  Base restoration interventions on the best ecological evidence and indigenous knowledge. Perform trials prior to applying techniques on a large scale. Monitor appropriate success indicators and use results for adaptive management.
- **Make it pay**
  Develop diverse, sustainable income streams for a range of stakeholders, including carbon credits, NTFPs, ecotourism, and marketable watershed services.

Sourced from: Di Sacco, A., Hardwick, K.A., Blakesley, D. *et al.* (2021): Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Glob. Change Biol.* 2021;27:1328–1348. https://doi.org/10.1111/gcb.15498

Bamboo cottages can be incorporated in a living tablescape

Making Bamboo Handicrafts:

A Fascinating Hobby

"Bamboo plants bloom only once in a lifetime; they die soon after flowering. An entire stand of bamboo can be seen mass-flowering. If you revisit the same spot, you may find that the entire stand has dried and fallen to the ground. Like other grasses, bamboos produce millions of seeds, and some of the seeds, finding a suitable environment, grow into new plants. Making beautiful models from bamboo is a fascinating hobby, which can be profitable too."

Text & Photographs: **Nandan Kalbag**

A typical Indian thatched cottage with verandah and Tulsi Vrindavan

For more than 40 years, I have been making models of huts and cottages. Though many decorative and utility items like furniture, screens, trays, and baskets are being made of bamboo, very few artisans make miniature models of different type of housing. Though use mainly bamboo for making these models, I also utilize paper, cardboard, cloth, cotton thread and other items to make my models. Bamboo is one of the nature's most wonderful products; unlike other type of wood, it can be split widthwise, lengthwise or across its thickness, and can also be bent very easily, and for that one does not need any special machinery. Very simple tools, which are available in most hardware shops, are the only requirement.

Here I would like to give some interesting information regarding bamboo, which is the fastest growing plant and belongs to the grass family Poaceae. Though many different types of bamboo are available, only a few are useful for making small, intricate handicrafts. Chiva bamboo *Munrochloa ritchiei* and Mase *Pseudoxytenathera stocksii* are mostly used for making handicrafts. Golden bamboo *Bambusa vulgaris*, though very common in many gardens, is not suitable for making intricate handicrafts, as its fibres are very coarse and it cannot be smoothened to a clean finish. In jungles of Darjeeling, I had seen a very beautiful bamboo with culms having blue colour.

Bamboo plants bloom only once in their lifetime; they die soon after flowering. In a forest, an entire stand

All kinds of house designs can be reproduced in bamboo models

Bullock carts and horse-drawn carriages make fascinating models

of bamboo is seen in mass flowering. If you visit the same spot later, you will find that the entire stand has dried and fallen to the ground. However, like other grasses, bamboos produce millions of seeds, and some of the seeds, finding a suitable environment, start growing into new plants.

Bamboo pieces of suitable species for handicrafts are available with most bamboo artisans (burud). One can order strips of bamboo about 40 cm long and 2 cm wide. For easy working, it is advisable to soak them in water for a few minutes. Always select pieces between the nodes. The hard skin and the very soft whitish inner layer or pith, should be stripped off. After that the strips can be split to the desired thickness and width. For that you will need a heavy duty knife (made from a hacksaw blade) and a hammer. The strips are then polished using paper knives.

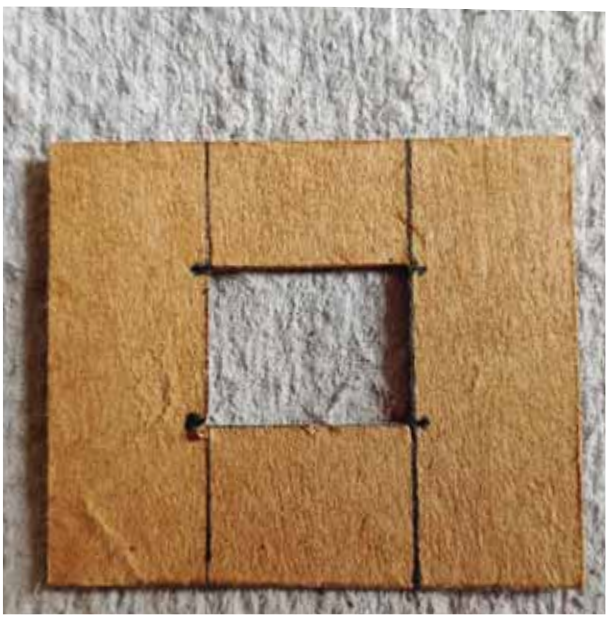
When the bamboo strips are ready as explained above, one can start making a model. First make patterns of card paper of different sides of the cottage you want to make. The pieces are cut to desired length and width. For cutting bamboo pieces to desired length, use garden secateurs. The pieces then are stuck together with the glue. When all sides are made, they are glued together to complete the model. To stick the pieces together, use a synthetic glue (like Fevicol). As this glue takes some time to set, it is advisable to hold the bamboo pieces together with metal clamps which are easily available in stationery shops.

Miniature houses made of tiny bamboo pieces – nothing is wasted

Due to atmospheric humidity, particularly in the monsoon, bamboo products are prone to get fungal growth on them. Bamboo borer beetles too can damage the handicraft and waste all

Mass flowering in bamboo yields millions of seeds

Individual bamboo flower

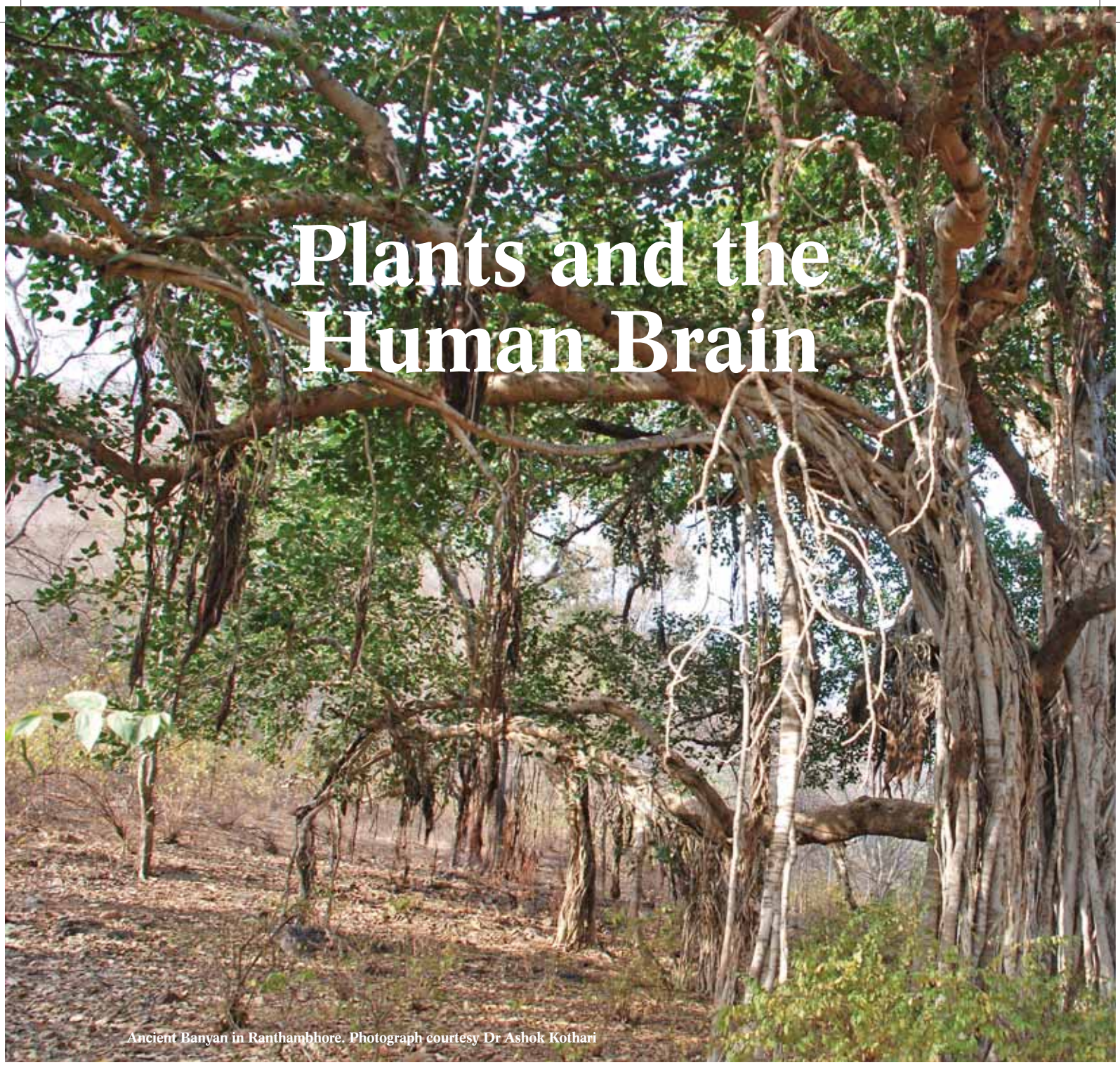


Basic geometric patterns make up bamboo handicrafts and modelling

the effort made to produce them. So, the handicrafts must be protected from these problems. This can be done by applying an oil-bound or water-based polyurethane coating on the ready artifact. To get a natural looking product, do not use glossy finish; choose a matte finish to give a final touch to your product.

Models of houses, cottages, trees and other elements can be used individually or in miniature table-top landscapes mounted on a base. Apart from cottages, models of bridges, steps, fences, and any number of miniatures can be made from the small leftover pieces of bamboo. At the end of a project, nothing is wasted. Such models can be made very easily in your spare time. It is an excellent, creative hobby, and whereas for most hobbies one has to spend, one can actually earn from this hobby by selling such pretty objects.

Plants and the Human Brain



Ancient Banyan in Ranthambhore. Photograph courtesy Dr Ashok Kothari

"Having plants around has become a necessity because of our urban lifestyle and the loss of natural greenery in our surroundings. The COVID-19 pandemic, in particular, forced people spend more and more time indoors and online, where the absence of nature took its toll. The concrete jungle we live in increases the risk of psychological distress among the old and young alike. Plants in our habitats can reduce these ill effects, as well as calm anger and fear. Greenery has a benign effect on our heart rate, and patients admitted to hospitals with lots of trees around are even found to recover faster than those in hospitals which lack greenery. Our physical and mental health is enhanced when we interact with nature."

Text & Photographs: **Manjushri Savadi-Parasnis**

Women gather around a Banyan tree on Vat Purnima to pray

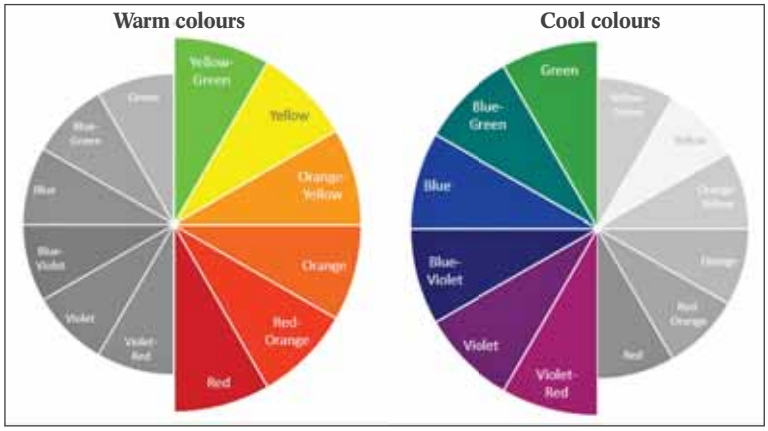
Plants have always had a deep effect on the human brain. Be it the sight of trees, shrubs, and small plants as they appear to the eye, or the effect of consuming them in many ways, as part of our diet. There are many ways in which the human brain interacts with plant diversity. Let us take a note of a few of them.

PLANTS IN TOTEMISM

Totemism has been existent since the beginning of a settled way of life for humans. Although the term "totem" originated among the native Americans, totemism is quite a common phenomenon in many parts of the world, and has origins in India as well, especially in Maharashtra. This belief system may be described as a process that happens when a particular plant (or animal or object) is worshipped by a group of people with so much reverence that it takes the position of a god in that group. The worshippers then adopt a set of enigmatic ceremonies to please these gods. It is said that there is a spiritual connection between that plant and that tribe. Also, the revered plant connects the members of the tribe with each other on a paranormal level. Such sacred plants are not killed nor eaten, they become the higher ruling body in every thought process of the human brain. The plants may be depicted symbolically as totems on humans, in the things we use, and in our homes.

What is the effect of totem plants on the human brain? They certainly provide a kind of solace to the believer's mind. As these plants are revered in the community, people who worship the same plant get a sense of belonging, a sense of unity, and a feeling of protection. At times, the totem even becomes an object of fear. Tribes or clans that believe in a certain plant totem are separated from the others by the difference in the plant that is revered. This belief defines the way of thinking and hence the actions of the group. For example, the Koliyas revere the Indian Jujube or Kol tree *Ziziphus mauritiana* as the tribe totem.

The Peepal tree *Ficus religiosa* is a common example of a totem plant. It is considered sacred by communities across the country, and numerous myths and legends are associated with it. Once a Peepal takes root, it is rarely ever destroyed. Another sacred species is the closely related Banyan *Ficus benghalensis* which is worshipped by many married women in Maharashtra. This reverence and the rituals attached with it are supposed to ensure the long and healthy life of their husbands. But the scientific community looks at it differently. As the vast leaf canopy of the Banyan provides oxygen



Colours elicit an emotional response from the human brain, and affect mood and wellbeing

and purifies the atmosphere, perhaps this was the way our ancestors believed that by attaching some traditional ritual and totemic value, such plants could be conserved.

Other worshipped plants include Umbar tree F*icus racemosa*, Dho or Axlewood *Anogeissus latifolia*, Semal *Bombax ceiba*, Sunn *Crotalaria juncea*, Salai *Boswellia serrata*, and the Tulsi or Holy Basil *Ocimum tenuiflorum*. There may be scientific reasons attached to this kind of conservation – a particular medicinal or useful property was empirically noticed, perhaps, and that prompted some wise people to create the totem, a traditional method of respecting our natural resources.

PLANTS IN HUMAN PSYCHOLOGY

Let us now see what effect plants in general have on human psychology. When we go out into open fields or forests, we see a blaze of green. The temperature is lower due to constant evaporation from the leaves, and due to the shade. And the air is purer and oxygen-enriched, which is good for our health and improves the functioning of the brain.

Colours can be divided into warm and cool, based on their effect on us. Red, yellow, and orange are warm colours, related to all kinds of emotions ranging from kindness, love, and happiness, to feelings of anger, hostility, and passion. Blue, green, and purple are cool colours. Green, a mixture of two primary colours, blue and yellow, is connected to emotions like calm and peace. It induces a certain aloofness that may lead to spiritual detachment. Thus, green brings a sense of balance to the brain and may lead to better decision making. It may arouse optimism in some people, and some get a sense of feeling refreshed. The colour green may denote new beginnings and good health to some. In other cultures, though, it is associated with jealousy and materialistic possessiveness.

It is the combined effect of the colour green, the lowered temperature, and the presence of increased oxygen that has been found to reduce stress and anxiety, lower blood pressure, and improve the mood in general. Also, it is found to increase our creativity, our ability to focus, and to socialise. Whether we exercise or simply sit around trees, the higher oxygen levels reduce our cortisol and adrenaline, hormones that produce stress in our body. A feeling of wellbeing is generated.

Having plants around has become a necessity nowadays because of our urban lifestyles and our surroundings having ever reducing greenery. Especially, this pandemic has forced people to spend more and more time indoors and online. Our concrete jungle increases the risk of developing psychological distress amongst old and young alike. Some of the good effects that plants have on us include reducing anger and fear. The heart rate is also well under control. Patients who are admitted to hospitals with lots of trees around are found to recover faster than those that don't have windows overlooking greenery. We get physically and mentally healthier when we interact with nature. The fact that the green in plants has a positive calming effect only reinforces our need for nature conservation, in both rural and urban areas. We need to spend more time with plants in order to lead a healthier, happier, and more creative life.

CONSUMPTION OF PLANTS BY EARLY HUMANS

To begin with, early humans were gatherers of nuts and berries. About 5 million years ago, hominids took to consuming meat. It is estimated that humans developed hearth-making about 250,000 years ago, and consequently took to cooking meat. In the Palaeolithic period, about 2.5 million years ago to 10,000 BCE, hominids ate fruits, leaves, flowers, bark, insects, and meat as well, becoming omnivores, though anatomically they were herbivores. It is not known what proportion of meat was eaten against all plant foods, and this shift in diet was neither sudden nor worldwide.

As early humans climbed down from a tree-dwelling habit to a life on land, they thought of growing food

From being hunter-gatherers, early humans progressed to agriculture, and a settled way of life

gradually. So, in the Neolithic period, began the shift from hunting-gathering to cultivation. This, around 12,000 years ago, would let humans settle in one place and consume certain crops that they were able to grow. The variety that they were used to eating while gathering was now reduced, but with cultivation, the food was right outside the home. This was the beginning of a mind-set towards easing efforts for procuring food. Competition among humans was also reduced, and they began to live in communities. With division of labour, they could grow crops and raise domesticated animals in a settled area. Excavations suggest that this happened between the Tigris and Euphrates rivers in Mesopotamia, around 10,000 years ago. Finally, plants were brought under cultivation. These included tubers, seeds, nuts, legumes, and flowers, and wild-grown barley that was pounded into flour.

Early farmers grew tall wild grasses which were primitive kinds of barley and wheat. Their grains were larger, tastier, and more nourishing than the current varieties. It was because of plant species like wheat, rice, and potatoes that humans took to agriculture and a settled way of life. Plants made us more civilized. Even today, in case we wish to eat like our ancestors, we can eat nuts, vegetables, and fruits and lead a healthy vegan lifestyle.

VEGETARIANISM AND HUMAN HEALTH

The strictest form of vegetarianism means consuming only plant based food, such as fruits, nuts, vegetables, grains, and legumes. Some people allow milk and milk products, and some also allow eggs on nutritional grounds. Research nowadays supports the fact that a plant based diet has many health benefits, and helps avoid cardiovascular diseases and even diverse types of cancer. Vegan or vegetarian diet has not been found to impair brain function or increase any risk of cognitive decline. In fact, in some studies, the ageing of the brain was found to be about 11 years less in vegetarians than in non-vegetarians. Plants contain nutrients like vitamin E, folate, nitrates, beta carotene, and lutein, which are actually related to better brain power. It must be mentioned here that a plant-based diet was found to be connected to a higher risk of depression, but it can also lower anxiety.

Studies have shown that in vegetarians, low-density lipoprotein cholesterol levels were lower, along with blood pressure and hypertension levels. The risk of contracting chronic diseases, including cancer, was also lower. Vegetarians were found to live about 10 years longer. But it must be emphasized that vegetarians need to plan their diet properly. They should include various grains, legumes, seeds, nuts, and soy products in order to get the required amount of proteins. Lacto-ovo-vegetarians, however, can get their proteins from eggs and dairy products. For pregnant women, a plant based diet can be healthy and nutritionally adequate, provided it is planned to avoid risk of iron and vitamin B12 deficiency, or lack of certain nutrients which are

Vegetarianism has abundant benefits for human health, provided a balanced diet is achieved

found in animal products. The key nutrients needed for a healthy pregnancy include iron, calcium, and multivitamins, especially vitamin B12.

Plants are high in fibre, which is known to improve gut health and absorption of nutrients. This in turn improves the immune system and reduces inflammation. Fibre stabilizes blood sugar levels and lowers cholesterol. A nutritious plant diet increases serotonin level, which in turn benefits brain development, so decline in brain health is not necessarily an inevitable part of ageing.

FOOD FOR THOUGHT

We use plants in our diet every day. Irrespective of whether we are vegetarian or non-vegetarian, there are some plants in our diet that have a direct effect on our brain function. Our brain function depends on what food we eat. So, if we know which plants are good for the brain, we can improve our capacity to think. The brain uses a lot of energy, even though it is not apparent, so it must be fed a healthy diet.

The neurons or cells in our brain are made up of proteins, for which nuts are a good source. Fats make a sheath on the nerve cells, comprising about one third of our brain matter. Unsaturated fats found in vegetables make messenger molecules that conduct impulses in the brain. It is estimated that one fifth of our total energy is consumed by the brain. This energy comes from the carbohydrates we consume. Thus, carbs are very important for mental functions. Some vitamins, especially the B vitamins, are very important for our mental functions as they are essential in the chemical reactions that enable brain activity. Minerals are also needed. Calcium, potassium, and sodium improve nerve impulses. We get potassium from bananas.

Nuts and seeds contain a good quantity of omega-3 fatty acids. These are responsible for the formation of membranes of our brain cells and other body cells; they improve neuron function responsible for cognition, and improve blood flow. Nuts and seeds also contain useful antioxidants, which make sure that the brain functions well in old age. Another useful ingredient of nuts and seeds is vitamin E, which reduces the risk of Alzheimer's disease and improves cognitive functions. Amongst nuts and seeds, the highest amount of vitamin E is found in flaxseed, almond, hazelnut, and sunflower seed. Whole grains like brown rice, barley, bulgur wheat, and oatmeal also contain a good amount of this vitamin.

Legumes like peanuts also are very nutritious. They contain unsaturated fats and proteins which keep us energetic all day long. The vitamins and minerals present in them help maintain a healthy brain. Peanuts contain resveratrol, an antioxidant which helps prevent cancers of many types, neurological diseases like Alzheimer's and Parkinson's, and reduces inflammation.

Polyphenols are another group of antioxidants present in soybean. They reduce the risk of dementia and improve cognitive abilities in normal ageing processes. Isoflavones, including daidzein and genistein, are the type of polyphenols found in soybean; they have various health benefits throughout the rest of the body also.

Berries are an excellent source of flavonoid antioxidants that are good food for the brain. Caffeic acid, anthocyanin, catechin, and quercetin are some of the antioxidants found in berries. They improve transmission between brain cells, reduce inflammation, and increase plasticity, the capacity to form new connections within the brain, to boost learning and memory. Antioxidants are known to slow down age related neurodegenerative diseases and decline in cognitive abilities. Some berries rich in antioxidants are strawberry, blackcurrant, blackberry, blueberry, and mulberry.

Examination time is synonymous with coffee; it is one food known to improve focus and concentration and helps us to stay awake longer. What makes us sleepy is a substance called adenosine in the brain. The caffeine in coffee stops the secretion of adenosine, making us feel fresh. It also improves the capacity of our brain to process all information inputs. The antioxidants present in coffee enhance brain health of the aged. Long-term consumption of coffee has a

By choosing foods that are good for brain function, we can improve our mental wellbeing

Spices and herbs used in traditional medicine are a long lasting boon to humankind

direct impact by reducing the risk of stroke, cognitive decline, Parkinson's disease, and Alzheimer's disease. Cocoa is another favourite beverage that is rich in flavonoids, which are another type of antioxidant. With age, oxidative stress may lead to age-related cognitive decline and brain diseases, but taking cocoa regularly is found to improve brain function. It has a direct impact on memory and learning by stimulating blood flow to the brain.

Avocados are a good source of useful unsaturated fats, which are known to lower the occurrence of high blood pressure. Other sources of useful unsaturated fats are chia seed, sunflower seed, canola oil, almond, cashew, walnut, and Brazil nut.

Broccoli contains a high amount of glucosinolates which are broken down into isothiocyanates during metabolism. These are known to lower oxidative stress and the risk of neurodegenerative diseases. Vitamin C and flavonoids are also present in broccoli, which further improve our brain health. Other cruciferous plant foods that contain glucosinolates are cabbage, cauliflower, turnip, and Brussels sprouts.

It is not possible to list here all the foods that are brain-boosters, but in general they are foods that contain antioxidants such as flavonoids or vitamin E, healthy fats, omega fatty acids, and vitamins. These foods help improve memory and concentration, reduce the risk of stroke and age-related neuro-degenerative diseases such as Alzheimer's and Parkinson's, and improve the structure of our brain cells or neurons.

DIRECT IMPACT OF PLANTS ON THE HUMAN BRAIN

Many plants have traditionally been used in Ayurveda in India, to enhance brain function. Some of these valuable medicinal plants are Turmeric *Curcuma longa*, Gotu kola *Centella asiatica*, Ashvagandha *Withania somnifera*, Brahmi *Bacopa monnieri*, Shankhapushpi *Convolvulus pluricaulis*, and Guggulu *Commiphora mukul*. Spices like cloves, cinnamon, nutmeg, saffron, and black pepper are used in Indian kitchens almost every day, and are known to enhance brain power. Modern medicine has taken numerous plant species, assessed them scientifically and proved their pharmacological properties. These traditional medicines are now available in over-the-counter formulations, and are recognized internationally as a lasting boon to human progress.

Cabbage White butterfly on *Sonchus* sp., a common garden weed. Photograph courtesy Dr Meena Haribal

A Saga of Urban Pollinators

"The online world has attributed many quotes to Albert Einstein, one of them on the value of bees to humans: "If the bee disappears from the surface of the Earth, man would have no more than four years left to live." Though there is no evidence that Einstein said these words, it is amply clear that they make sense."

Text: **Vijaya Chakravarty**

Cuckoo bee. Photograph courtesy Dr Nayan Patel

Angled Pierrot alights on Indian Borage.
Photograph courtesy Dr Sweedle C. Shivkar

"No bees, no humans," is the hard lesson we learn from a misquote widely attributed to Albert Einstein. Almost 85% of all plants are animal pollinated. The rest are self-pollinated, or pollinated by wind and water. This means that almost 85% of our food is produced with the help of animals. Honeybees play a major role in pollination, but there are several others – moths, beetles, bumblebees, wasps, small birds, and bats – which contribute to pollination.

DECLINING NUMBERS

In the last few decades, there has been an alarming decrease in pollinator populations, their numbers dwindling rapidly mainly due to anthropogenic factors. The prime driver is habitat loss due to widespread urbanization, intensification of agriculture coupled with the use of agrochemicals, and climate change. The introduction of invasive alien species of plant and animal pests, and pathogens is also having a negative impact. Exotic species like Lantana *Lantana camara*, Siam weed *Chromolaena odorata*, Subabul *Leucaena leucocephala*, and Vilayati Babul *Prosopis juliflora* are destroying our native flora on which pollinators depend, leading to disastrous situations. The Giant African Snail *Lissachatina fulica* brought in from Mauritius out of curiosity has multiplied exponentially, and devours tender plants which are the larval food of many caterpillars of butterflies and moths.

Ficuses or figs, which are keystone species of India – Banyan *Ficus benghalensis*, Peepal *Ficus religiosa*, Umber *Ficus racemosa* – are major contributors towards Indian biodiversity. There are over 900 species of fig trees in the world and each species is pollinated by its own specific pollinator wasp. The gravid female wasp enters the fig, which is not a "true" fruit. It is an inflorescence or cluster of flowers turned inwards, and encased in a "syconium" as one may see on cutting a ripe fig in half. The female lays its eggs and then dies. The larvae develop into male and female wasps, of which the males hatch first, and mate with the females. The males dig a sacrificial tunnel for the females to escape and die in the process. The females struggle to leave through the narrow passage in the fig wall and in the process get coated with pollen grains. They enter other figs, transferring their pollen burden to the new fig, lay their eggs, and the cycle goes on. Such is the intimate relationship that has evolved between a fig and its wasp pollinator that neither can survive on its own.

BUMBLEBEES AT HIGH ALTITUDES

These are the main pollinators in the harsh high-altitude environments where most pollinators cannot survive. Bumblebees are adapted to the cold climate of the Himalaya, the only environment in India where they are found. Their species diversity increases with the altitude. In the Himalayan lowlands, only three species have been seen, whereas at higher altitudes almost 45 species have been identified. Bumblebees scent mark the flowers they have visited earlier to indicate the removal of nectar. Many of them are also nectar and pollen robbers.

Blue Mud-dauber Wasp collecting pollen.
Photograph courtesy Dr Nayan Patel

There is an adage, "Two wings fun; four wings run," says entomologist Timothy Gibb of Purdue University, explaining the difference between hoverflies and yellowjacket wasps. Hoverflies are dipterans with only one pair of wings (the other pair having evolved into halteres), while bees and wasps are stinging insects (hymenopterans) which have two pairs. Hoverflies are hard-working but little known pollinators, the most important pollinators after honeybees. There are approximately 369 hoverfly species in India.

NIGHT-SHIFT POLLINATORS

Nocturnal pollinators are not often seen by us, except when they are attracted to light in our habitations. Moths are among the most prominent night pollinators; they can smell the scent of flowers from a great distance, if there are no competing pollutants in between which may cause confusion. There are over 12,000 moth species in India. Beetles and flies also act as pollinators. The flower of the Elephant foot yam or Suran emits a foul odour like rotting flesh, which attracts carrion-eating beetles and flesh-flies. Carrion beetles are nocturnal, and nature's sanitary workers, devouring dead animals which would otherwise spread sickness.

Around 109 bat species are present in India, and many of them are important pollinators. The feeding habits of bats are as diverse as their habitats – plains, mountains, deserts. They feed on fruits, nectar, insects, and even other bats. The largest, a colourful orange-and-black painted bat named Flying Fox, and the smallest, Sálim Ali's Fruit-bat, are found in India. The most common Indian species are the Flying Fox, Short-nosed Fruit-bat, and Fulvous Fruit-bat. Bats can eat up to 1,200 mosquitoes in an hour, apart from their pollinator services, so any loss of population in all these species can be disastrous for humans.

CITIES AS HOTSPOTS OF POLLINATOR BIODIVERSITY

Sacred groves are known to attract and harbour a variety of pollinators. We can take the sacred grove model to urban areas, and recreate some of their features to attract pollinators. The possibilities are plenty. It is not necessary to have large spaces to attract them. Start small. Give them an inch, if not an acre. A few flowering plants on your windowsill or grill will provide nectar for bees, butterflies, and moths. Plenty of zero acreage garden space is available in balconies and terraces, in cities where land is at a premium. Almost 10 to 20% of urban

Oleander Hawkmoth, a common nocturnal pollinator. Photograph courtesy Raghavendra Rajadhyaksha

Commander butterfly, an urban pollinator. Photograph courtesy Raghavendra Rajadhyaksha

space is devoted to roadways. There is ample scope to grow plants on road medians and traffic islands to attract pollinators. Municipal rules often mandate the return of a portion of the original land to the city during redevelopment. These are known as setback areas, which can be filled with nectar-rich plants. To get an occupancy certificate for industrial, commercial, and residential establishments, planting of a certain number of trees is mandatory. This provides a great opportunity to select trees that attract pollinators, with tremendous potential to convert concrete jungles into hotspots of pollinator biodiversity. If water, food, and nesting resources are provided, pollinators will make cities their homes.

NECTAR PLANTS

Bees, butterflies, moths, some birds, and a few bats are nectarivores. Introducing a kaleidoscope of colourful nectar-rich flowers which bloom in sequence and fruits that ripen throughout the year, ensuring a year-round food supply is helpful. In general, butterflies are attracted to purples, yellows, and blues, whereas bees love purples, reds, and yellows. Moths and bats are attracted to heavily scented white or pale coloured night blooming flowers. Indian Coral tree *Erythrina indica*, *Cuphea* sp., Rukmini *Ixora* sp., Office-time *Portulaca* sp., Indian Laburnum *Cassia fistula, Stachytarpheta* sp., and Verbena sp. attract birds, butterflies, and bees for their nectar. To attract butterflies and moths which are cold blooded and need external heat for energy to fly, placing some rocks in the garden space helps these insects to bask in the sun.

Bats seem to prefer large flowers such as those of White Silk Cotton *Ceiba pentandra*. They are attracted to the inflorescences of banana, guava, mangoes, and areca palm. Mahua *Madhuca indica* attracts bats like the Flying Fox and Short-nosed Fruit-bat for both nectar and fruit. These two bat species depend on scent, unlike other bats which use sound to navigate; they feed on the insects hovering over the flowers, as well as nectar, flower parts, and fruits, thus playing an important role in seed dispersion and pest control. Flower colour has no meaning for bats as they are nocturnal and poor-sighted.

COLOURFUL FRUITS

Red, yellow, and black berries and fruits attract birds. Bor *Ziziphus*, Curryleaf *Murraya koenigii*, Mango *Mangifera indica*, Jamun *Syzygium cumini*, Singapore Cherry *Muntingia calabura*, Bakul *Mimusops elengi*, Amla P*hyllanthus emblica*, Neem *Azadirachta indica*, Ashoka *Saraca asoca* and so on can be planted. In Mumbai due to lack of space, the slender False Ashoka *Polyalthia longifolia*, which take up very little space, are hot favourites of builders. Many butterflies, bees, and birds flock to them for nectar and fruit.

WATER SOURCES

Ponds and lakes are important for bats, that drink water before foraging. Keep water outside in small containers for birds, especially in summer. Shallow plates with sugar water attract bees, butterflies, and

moths, providing them with energy to fly. In case of bees, sugar water should be offered only when the beehive is newly installed, or when heavy pruning of plants in the neighbourhood has reduced the supply of flowers. Over-ripe fruits are a good source of sugar and can be kept in shallow trays for butterflies and moths. Male butterflies love mud-puddling; they sip minerals from wet mud. Create shallow mud-puddles or place trays with wet mud to attract such species.

COMPETITION

There is very little competition for food between the different developmental stages of the same species of pollinators. Caterpillars are voracious feeders of vegetation. Each species is plant specific and will consume the leaves of the related foodplant or plants only. Planting larval food will attract both moths and butterflies. The adult stage, both moths and butterflies, have sucking mouthparts, and survive on a liquid diet of nectar; in addition, they suck on animal sweat and saline water, from which they derive essential salts. Bat cubs suckle milk from their mothers, while adult bats feed on insects, nectar, and fruit. Nestlings and fledglings are fed on protein-rich insects, while the birds themselves feed on seeds, nectar, and fruit. Honeybees consume pollen and nectar, whereas their larvae feed on honey. Alderflies feed on pollen and nectar, but their larvae take aphids and decaying flesh.

NESTING RESOURCES

Pollinators require nesting resources to shelter them from predators and provide spaces for breeding. To replicate natural conditions as far as possible, tier formation while planting, using vegetation of different heights, is ideal as it provides nesting resources for all pollinators. Bats will nest on large old trees with strong branches and a spreading canopy with good foliage, like Rain tree *Samanea saman*, Banyan, and Arjun *Terminalia arjuna*. Hedges play a vital role in providing hideouts for birds, bees, and butterflies. Certain pollinators, including many bee species, need exposed soil for nesting on the ground. Keeping some bare spots in the garden will help. Tall grasses also provide shelter for some ground-nesting birds. Creepers and thorny trees provide safe nesting spaces.

MORTALITY

There is high mortality among moths and butterflies, at the immature as well as adult stages. Moths exceed butterflies in numbers, and form the diet of many wildlife species. Only one out of every 100 eggs laid reaches adulthood; the rest become targets for predators at different stages of the life cycle. Birds

***Calotropis* attracts Milkweed butterflies. Photograph courtesy Dr Meena Haribal**

Oriental White-Eye visiting a Firebush.
Photograph courtesy Dr Sweedle C. Shivkar

Umber *Ficus racemosa* flourishes in medium to heavy rainfall
Photograph courtesy Dr Ashok S. Kothari

feed their young ones with caterpillars. A clutch of four to six offspring of a small bird can consume up to 900 juicy caterpillars in the fledgling stage. Bats are the major predators of moths, as both are active at night. Ants, lizards, small rodents, skunks, and even bears feed on butterflies and moths. Spiders and beetles eat the pupae enclosed in their cocoons.

DEFENCE MECHANISMS

Both moths and butterflies are highly vulnerable as they are exposed 24x7, not being nest builders like bees and wasps. They have acquired some unique defence mechanisms to ward off predators. When bats emit clicking sounds to echolocate prey, some moth species escape by responding with clicking sounds of their own, confusing the predator bats. The caterpillars of some moths and butterflies eat toxic leaves of plants and internalise these poisons. They are brightly coloured to warn predators that they are unpalatable. Some caterpillars resemble dry twigs or dry leaves to fool their predators. Many have eye spots (false eyes) to make the predators think that they are confronting a large animal. Eyespots on butterfly and moth wings serve the same purpose.

MIGRATION

Birds, butterflies, and moths migrate. By doing so, they avoid adverse conditions, including weather, food shortage, or over-population. Migration routes are highly specific, and so are their stopover sites during the journey. The offspring of migrants return to the original site from which the parent generation took off. Unlike birds that fly back and forth several times in a lifespan, it may take several generations for a butterfly to complete the cycle as their life span is short. In India, there is a biannual migration of butterflies and moths from the Western Ghats to the eastern plains before the monsoon, and back to the Western Ghats post monsoon. Many birds migrate to India from overseas to winter and breed here. There are numerous local migrants within the country, seeking relief from harsh weather or lack of food resources.

HOW TO ATTRACT POLLINATORS

Finally, some tips on creating pollinator habitats in cities. Be a lazy gardener. Go slow on garden management techniques. Cut down on pruning, weeding, and lawn mowing. Say no to chemicals – chemicals kill pollinators too. Go organic. Neem oil, Karanj *Pongamia pinnata*, castor seed, and garlic extracts are good biochemical pesticides and bio-fertilizers. Switch off outdoor lights at night. Moths are attracted to light and get trapped in light beams, wasting the energy and time required for foraging and mating. Add niches like logs, piles of stones, tree stumps, or heaps of leaves for pollinators to hide in, to escape from predators. Plant native species and remove invasives. Replace lawns and monoculture with biodiversity. Spread out and isolate caterpillar food plants, but group nectar plants together.

ENVIRONMENTAL BAROMETERS

Pollinators, especially insects and bats, act as environmental barometers, the key to early warning and survival. When any one butterfly, moth or bat species disappears, it is an environmental alarm, indicating that other species including humans are at risk, and the time to act is Now!

Fascinating Tree Wealth of the Western Ghats

Text & Photographs: **S.R. Yadav**

Scarlet Sterculia *Firmiana colorata*

"Trees are of vital importance ecologically, culturally, and economically. Until now there have been surprising gaps in knowledge of the diversity, distribution, and conservation status of trees at a global scale. Trees define forest distribution, composition, and structure, and thus provide habitats for half the world's known terrestrial plant and animal species."

– State of the World's Trees. BGCI, Richmond, UK

Trees are significant components of the earth's biodiversity and carbon storage systems. A great number of epiphytes, fungi, birds, mammals, reptiles, insects and other invertebrates, and many other species depend on trees. They are excellent biodiversity indicators, as they show the health of the forest as well as of an entire ecosystem. Trees have evolved over millions of years, adapting to changing climates, but under the latest onslaught of human threats, many of them may no longer be able to survive.

IMPORTANCE OF TREE SPECIES

Being the major component of forest ecosystems, trees play a major role in biogeographical processes – soil formation and soil conservation; hydrological, nutrient, and carbon cycles; and stabilization of global climate. Forests contain about 50% of the world's terrestrial carbon stock and over 75% of the world's accessible fresh water, which is obtained from forested catchments (Newton 2021). Trees support a wide range of other species, and form the base of ecological trophic pyramids. For example, 2,300 species are associated with native oak in the UK (Mitchell *et al*. 2019). The extinction of tree species at the base of trophic pyramids might begin a cascade effect, leading to the collapse of entire ecosystems.

Trees are indicators of the health of forest ecosystems and have been termed as key ecosystem engineers (Lindenmayer & Laurance 2017). In addition to a wide range of products like fruits, timber, fodder, gums and resins, and medicinal compounds, trees provide many ecosystem services through water purification, prevention of erosion, flood control, carbon sequestration, as well as temperature and air quality regulation. Large-scale tree mortality in many different parts of the world is indicative of ecosystem collapse, which leads to loss of entire communities associated with the tree species.

Hill Arecanut *Bentinckia condapanna*

Talipot Palm *Corypha umbraculifera*

Though the commercial value of a forest may be assessed depending on numerous variable factors, the benefits derived from a medium-sized tree weighing 50 tons, during its 50-year life span, excluding the values of timber, fruit, and flowers, ranges from Rs 15–127 lakhs, according to a ballpark estimate (Table 1). Furthermore, losing one tree species a day means losing three to four potentially valuable drugs every year, evaluated at $600 million.

Table 1: Estimated monetary value of benefits from a single tree

S. No.	Benefits	Single tree	Tropical	Subtropical
1.	Oxygen production	2.50	22.50	20.50
2.	Conservation of animal proteins	0.20	01.80	01.64
3.	Control of soil erosion	2.50	22.50	20.60
4.	Recycling of water and humidity control	3.00	27.00	24.60
5.	Shelter for birds, squirrels, insects, plants	2.50	22.50	20.50
6.	Control of air pollution	5.00	45.00	41.00
Total Rs (in lakhs)		**15.70**	**141.3**	**126.74**

Wight's Sago Palm *Arenga wightii*

CONSERVATION STATUS OF TREES

Globally, there are 58,497 tree species, of which some 17,510 (29.9%) are considered to be threatened (BGCI 2021). In the Indo-Malayan region, about 3,819 tree species are reported to be threatened. The main threats to trees include expansion of agriculture, logging, livestock farming, residential and commercial developments, fire and fire suppression, energy production and mining, wood and wood pulp plantations, and other problematic invasive species, and the most challenging of all – climate change. Habitat loss and exploitation, insect and other pests, fungal diseases, are additional major threats to tree species. Protected Areas and Botanical Gardens provide sheltered habitats for trees as well as other species.

MONOTYPIC TREE FAMILIES

Tree species are found in 257 families of seed plants, of which 12 families are monotypic and of great

phytogeographical, phylogenetic, and historical importance. These are families Aextoxicaceae, Amborellaceae, Aphloiaceae, Barbeyaceae, Curtisiaceae, Eucommiaceae, Ginkgoaceae, Gomortegaceae, Petenaeaceae, Plocospermataceae, Sciadopityaceae, and Ticodendraceae. None of these monotypic families is endemic to India. Arisdason & Lakshminarasimhan (2020) reported 236 monotypic genera for India, of which 84 are endemic to India. However, Irwin & Narasimhan (2011) reported only 49 genera endemic to India, of which 36 are unispecific.

Currently, 30% trees are recorded as present in at least one botanical garden or seed bank, but only 21% threatened tree species are recorded in botanic gardens. Botanical gardens and seed banks are providing the last opportunity for these species to survive; they offer hope for re-introduction of rare and threatened species into the wild one day.
Of the total number of tree species, 3,716 are used for construction, 1,951 are of medicinal value, 1,646 are of horticultural importance, 1,444 are used for fuel, 1,382 for human food, and 1,302 for household goods. A countless number are of cultural, religious, and symbolic significance.

TREE DIVERSITY OF WESTERN GHATS

This global biodiversity hotspot supports about 7,400 flowering species, of which 5,588 are indigenous species. The Western Ghats harbour about 2,250 endemic plants, of which 1,270 are exclusively endemic to the region. The tree diversity of the Western Ghats includes 1,138 indigenous tree taxa belonging to 350 genera under 87 families, among which 284 species of 111 genera under 45 families

Ironwood *Memecylon umbellatum*

are strictly endemic to the Western Ghats. Excluding endemics, the Western Ghats harbour 692 indigenous tree species of 293 genera under 82 families (Nayar *et al.* 2014).

FASCINATING TREES OF THE WESTERN GHATS

The hallmark of the swamps in the Western Ghats region are two tree species of family Myristicaceae, namely *Gymnacranthera canarica* (Mal: Udaipanu) and *Myristica magnifica* (Mal: Kotthapanu). They dwell exclusively in the swamps in waterlogged conditions, and are endemic to the Western Ghats. Similarly, there are endemic species of Myristicaceae such as *Myristica malabarica* (Mar: Ran-jayphal), *M. dactyloides* (Mar: Jayphal), and *Knemma attenuata* (Mar: Ran-jayphal, Rukt-mara), which are not only primitive species, but have great medicinal and economic importance, particularly for their usually red coloured aril.

Sita Asoka *Saraca asoca*

Branching Palm *Hyphaene dichotoma*

Magnolia champaca (Mar: Kud-champa, Pivla-champa), *Meiogyne pannosa*, *Sageraea laurina* (variously called Andi, Har-kinjal, Kiland, Sager, Undi), *Miliusa tomentosa* (Mar: Hoom, Humb, Minmara, Thoska), *Uvaria narum* (Mar: Saplivel), *Annona muricata* (Mansphal), *Orophea kaschilica*, and *Artabotrys hexapetalus* (Hin: Hari-champa, Madanmast; Mar: Hirva chafa) are some members of family Annonaceae found in the Western Ghats, of which *Meiogyne pannosa* and *Sageraea laurina* are endemic. *Alseodaphne semecarpifolia* (Mar: Phudgus) and *Beilschmiedia dalzellii* (Umber) are basal angiosperms of family Lauraceae.

Many palms of immense beauty and significant economic importance inhabit the Western Ghats. The elegant ornamental *Arenga wightii* (Mar: Dhudsal), *Bentinckia condapanna* (Mal: Kanthal), *Borassus flabellifer* (Mar: Tad, Tadi), *Corypha umbraculifera* (Mar: Tali), *C. utans*, and *Hyphaene dichotoma* (Mar: Ravan-tal) are economically important palms of peninsular India. *Bentinckia condapanna* is a threatened endemic species surviving in a few isolated, inaccessible pockets and needs to be introduced into botanical and public gardens. *Hyphaene dichotoma*, again a threatened species, is unique in its dichotomous branching pattern. It is surviving in a few patches on the west coast of India, and needs concerted efforts for conservation. *Nypa fruticans* (Nipa palm, Mangrove palm) is uniquely adapted as an associate of mangrove vegetation. It is of significant economic importance, as the young fruit has sweet edible sap which is used to produce sugar, syrup, vinegar, and an alcoholic beverage locally called neera. The leaves are traditionally used for thatch-roofing and as tobacco wrappers, while the fronds are woven into hats, baskets, and cane chairs.

Dillenia pentagyna (Mar: Karmal, Karmvel), a medium sized tree, blooms profusely with golden yellow flowers and later produces bright orange fruit, a major source of food for mammals and birds. The flower buds are also edible. The fruit has numerous applications in traditional medicine, while the leaves are used as sand paper. *Balanites aegyptiaca* (Mar: Hingan-bet, Hin: Hingu) is most important as it provides food, medicinal products, and fuel-wood, all valued for subsistence living in arid and semi-arid areas in Africa. The roots are purgative, vermifuge, and emetic. A decoction of the root is used to treat malaria, oedema, and abdominal pain. The bark is purgative and vermifuge, used to deworm cattle in Rajasthan. Wood gum, mixed with maize meal porridge, is used to treat chest pain. This tree is a potential source of steroidal sapogenins (diosgenin) for the hemisynthesis of corticosteroids. *Xylia xylocarpa* (Mar: Jabla; Hin: Jambu; Mal: Yorul) is another valuable tree; its raw seeds are relished as a vegetable. The bark contains tannins and is astringent; a decoction is used as a vermifuge. It is also used to treat leprosy, gonorrhoea, ulcers, and digestive ailments. The oil from the seeds is used in rheumatism, piles, and leprosy. The wood is prized for fuel and for making charcoal.

Scarlet Sterculia *Firmiana colorata*

Jungli Bhendi *Erinocarpus nimmonii*

The Sita Asoka *Saraca asoca* is an endangered species with great ornamental and medicinal value. The astringent bark is used in uterine infections. It stimulates the endometrium and ovarian tissue, and is useful in menorrhagia due to uterine fibroids, in leucorrhoea, haemorrhoids and haemorrhagic dysentery. The bark also contains an oxytoxic principle. The flowers are used as a uterine tonic, in biliousness, haemorrhagic dysentery, and diabetes. The fruit is chewed as a substitute for arecanut, while pods make good forage. Sita Asoka wood ash is applied externally in rheumatoid arthritis. The wood is hard enough for ploughs and shafts.

Garlic Pear Tree *Crataeva magna*

Erythrina stricta (Mar: Jungli pangira), a small spiny tree of dry deciduous forests produces bright red flowers with abundant nectar, attracting several birds.

Antiaris toxicaria (Hin: Chandkuda; Mar: Jasund, Karvat) has poisonous latex which is used as arrowhead poison. It also has antidiabetic properties. *Artocarpus hirsutus* (Bakodyo) is an endemic tree of great significance as food and shelter to many mammals and birds.

Several ficuses grow abundantly in the Western Ghats. Among them, *Ficus racemosa* (Umbar), *F. auriculata*, *F. drupacea* (Burali-vad), and many others are keystone species in this biodiversity hotspot. *Streblus asper* (Mar: Karvati, Kharota) or Indian Sandpaper Tree and heals wounds and fractures. *Elaeodendron paniculatum* (Mar: Motha Bhutya) and *E. glaucum* (Mar: Bhutkus) are elegant trees of evergreen and moist deciduous forests. *Euonymus indicus* is an endemic medium-sized understorey tree seen in low elevation wet evergreen forests with curiously designed medium sized flowers and arillate seeds of immense beauty.

Lophopetalum wightianum (Mar: Balpale) is a huge tree with a beautiful flush of flowers and dark green

Ghanera *Mappia nimmoniana*

Tallow-wood *Ximenia americana*

coriaceous leaves of immense beauty. *Elaeocarpus serratus* (Mar: Perinkara), *E. tuberculatus* (Mar: Rudraksha) and other species are evergreen trees with very peculiar flowers with distinctive stamen morphology. *Calophyllum apetalum* (Mar: Bobbi, Irai) is another endemic evergreen tree species growing along stream and river beds, forming an important component of riparian vegetation. *Calophyllum inophyllum* (Mar: Surangi, Undi) an evergreen economically important tree with thick coriaceous leaves and peculiar leaf venation pattern usually grows along sea-shores and is suited as ornamental tree for various situations.

The coastal region is well-known for its natural protective fringe of mangroves and their associated biodiversity. Mangroves *Rhizophora mucronata* (Mar: Kandal) and *Bruguiera gymnorhiza* (Tam: Vurada) have thick evergreen coriaceous leaves, prop roots, and viviparous seed germination. They are adapted to grow in waters where the salinity fluctuates with the tides.

Blepharistemma membranifolium (Mal: Nir Kurunda), a monotypic endemic species of antiquity; it is a rare component of evergreen forests. *Carallia brachiata* (Mar: Phanashi) has evergreen foliage of immense value. It can be introduced into botanical gardens and planted in avenues. *Erythroxylum monogynum* (Tam: Devadara, Kann: Devadaram) is a small dry deciduous flowering tree with orange red berries of great ornamental value. *Mammea suriga* (Mar: Nagkesar, Suringi, Tambra) and *Mesua ferrea* (Mar: Nagchampa, Nagchapha, Thorchampa) are endemic trees of great ornamental value for their foliage and flowers, and significant economic values. *Garcinia gummi-gutta* (Mar: Dharambe), *G. indica* (Mar: Amsol, Kokam, Ratamba), *G. talbotii* (Mar: Limboi), *G. xanthochymus*

(Mar: Dharambo, Jhrambi, Ota) are of great economic importance, and some of them are exclusively endemic to Western Ghats. *Poeciloneuron indicum* (Kann: Kirballi; Mal: Vayila) is a monotypic endemic tree species of great significance and stands witness to the evolutionary history of vegetation in Western Ghats.

More medicinal trees – *Putranjiva roxburghii* (Hin: Putranjiva, Tel: Kadrajivi), a moderate-sized evergreen is known as Karupali or Irukolli in Siddha medicine. This native species is wild or cultivated almost all over India, valued for its evergreen shade. *Dichapetalum gelonioides* is a small semi-evergreen tree, known for biologically active dichapetalins with broad cellular functions including defence against insect herbivores and pathogens. *Hydnocarpus pentandrus* (Mar: Kadu-kavath) is an evergreen, particularly valued in the treatment of leprosy and skin conditions. *Flacourtia montana* (Mar: Attak, Champari) and *F. indica* (Mar: Bhenkal, Gurgoti) yield edible fruits rich in anti-oxidants and minerals. Several birds depend on these species for food. *Mallotus philippensis* (Mar: Kamala, Kukrell, Kumkum) is traditionally used by different ethnic groups to treat a variety of diseases and health ailments, and for the cosmetic red powder on the skin of the fruit. It also yields Kampillaka, a prized Ayurvedic anthelmintic.

Timber trees are a valuable component of the tree wealth of the Western Ghats. *Terminalia paniculata* (Mar: Kinjal), a common semi-evergreen, is a source of timber and tannins. *Syzygium laetum*, *S. stocksii*, *S. hemisphericum*, *S. claviflorum*, *S. rubicundum*, *S. zeylanicum*, *Eugenia phillyraeoides* and many other members of family Myrtaceae are evergreens that form a major component of the vegetation. Many species produce edible fruits, and some are of medicinal value. Ironwood *Memecylon umbellatum* (Mar: Anjan) has great ornamental value for its curiously formed blue flowers; its leaves contain a yellow dye and have anti-diarrhoeal properties.

Medicinal and useful products are derived from a number of trees of the Western Ghats. Marking Nut *Semecarpus anacardium* (Mar: Bilva, Bibba) has important applications in indigenous systems of medicine. The fruit and nut are reported to have antiatherogenic, anti-inflammatory, antioxidant, antimicrobial, antireproductive activity, and act as a central nervous system stimulant, hypoglycemic, and anticarcinogenic. *Buchanania cochinchinensis* (Mar: Charoli) fruit is edible; the seeds are eaten as a condiment and brain tonic. *Holigarna arnottiana* and *H. grahamii* (Mar: Bibba, Hulgeri) are endemic to the Western Ghats; phytochemical analysis of their poisonous latex may result in discovery of some bioactive molecules of medicinal value. *Lannea coromandelica* (Mar: Moya, Shimti) is a deciduous tree; its bark and leaves are medicinal. *Mangifera indica* (Mar: Amba) is a fruit tree of great economic importance; its wood is also economically important. *Nothopegia castaneifolia* (Mar: Amberi) and *N. colebrookeana* (Mar: Amberi) are endemics with edible fruits, and have medicinal uses. *Spondias pinnata* (Mar: Ambada) fruit is sour when unripe, and is eaten as a vegetable.

Boswellia serrata (Mar: Salai, Sarpal) yields oleo gum-resin (Salai resin), which is used in traditional Indian medicine and perfumery. *Canarium strictum* (Mar: Raldhup) has medicinal value in the Siddha system. *Garuga pinnata* (Mar: Kakad) is cultivated in home gardens for its edible fruit. *Commiphora berryi* is harvested for gum and medicines, and often grown for fencing. *Atalantia racemosa* (Mar: Makad limbu, Ran limbu) is used in folk and Ayurvedic systems of medicine. *Clausena anisata* fruit is sweet; its leaves and roots are taken in colds, rheumatism, and arthritis. The bitter bark of *Ailanthus triphysa* contains alkaloids used in medicine. *A. excelsa* (Mar: Ghod-limb, Maharukh) is an elegant, fast-growing tree with many medicinal uses.

The astringent, cooling fruit of *Aglaia elaeagnoidea* (Hin: Priyangu) is used to treat inflammations and febrile complaints, the seeds to treat painful micturition. *Azadirachta indica* (Mar: Neem) is well-known for its economic importance. *Dysoxylum gotadhora* (Mar: Kauti, Yerindi) and *D. malabaricum* are economically important sacred trees, harvested from the wild for medicinal, nutritional, commercial, and religious purposes. Members of Meliaceae such as *Heynea trijuga* (Mar: Limbara), *Melia dubia* (Mar: Maha-neem, Nimbara), and *Soymida febrifuga* (Mar: Rohan, Ruhin) have many phytochemicals of medicinal and other economic values. *Sterculia urens* (Mar: Kadai) is used extensively in pharma, health care, food, cosmetics, waste management, paper-textile, composite fibre, and leather industries. Its exudate (Karaya gum) has great market demand. *Firmiana colorata* (Mar: Bhaikol) is a medium sized tree of immense beauty, for its fiery orange flush of flowers and fruits. *Bombax ceiba* (Mar: Kate-saver, Savar) is another common tree with enormous, bright red flowers; its pods contain the softest silk-cotton. *Erinocarpus nimmonii* (Mar: Chaora, Cher) is a monotypic endemic tree species with large yellow flowers and echinate fruits.

Black Varnish Tree *Holigarna arnottiana*

The fruit of *Bixa orellana* (Mar: Kesri, Shendri), a native of tropical regions from Mexico to Brazil, yields a yellow to orange food colouring with flavour and aroma. *Cochlospermum religiosum* (Mar: Ganeri, Gogal), a small deciduous tree, bears large golden yellow flowers of immense beauty. *Hopea parviflora* (Kann: Bovumara; Tam: Kongu), *H. ponga* (Mar: Kalhoni, Kavsi), *Vateria indica* (Mar: Dhup, Mal: Vellei payin), *V. chinensis* and *Dipterocarpus indicus* of Dipterocarpaceae are evergreen trees of great ornamental value for their foliage. *Capparis decidua* (Mar: Nepti), *C. divaricata* (Mar: Pachunda), *Crataeva adansonii* (Mar: Vaivarana), and *C. magna* (Mar: Varun) have medicinal and ornamental value. *Ximenia americana* (Tel. Uranechra), one of the most valuable wild edibles in the world, yields food, medicine, and essential oil. *Careya arborea* (Mar: Kumbhi) is used in Ayurveda and Chinese medicine. *Barringtonia acutangula* (Mar: Tivar) and Cannonball tree *Couropita guianensis* (Mar: Kailaspati) are evergreen trees of ornamental value. *Mappia nimmoniana* (Mar: Narakya, Ghanera, Amrut) is an important anti-cancer medicinal plant. *Ixora* species are known for their bright, sweet-scented flowers and are suitable for gardens. *Morinda citrifolia* (Hin: Bartundi) contains an extensive range of antioxidants like terpenoids, ascorbic acid, and polyphenols of medicinal value. *Strychnos nux-vomica* (Mar: Kajra) has diverse therapeutic and clinical applications.

Tabernaemontana alternifolia (Mar: Nagkuda) is traditionally used as an analgesic and anthelminthic, to treat tapeworm in children. *Cordia myxa* (Mar: Bhokar; Hindi: Lasoda) is an important tree with edible fruit suitable for pickling. *Olea dioica* (Mar: Karamb, Parjambul) is a common evergreen tree of the Western Ghats. *Ligustrum robustum* subsp. *perrottetii* and *Chionanthus mala-elengi* (Mar: Heddi) have scented flowers. *Pittosporum dasycaulon* (Mar: Gapsundi, Ikali) is an endemic species of the Western Ghats, with prominent antibacterial and antifungal activity. Members of family Bignoniaceae, such as *Pajanelia longifolia* (Tam: Aranthal; Mal: Arlantha), *Heterophragma quadriloculare* (Mar: Varas), *Dolichandrone falcata* (Mar: Medhshingi), *D. atrovirens*, and *Santalum album* (Mar: Chandan) are of enormous medicinal and ornamental value. *Scleropyrum pentandrum* (Mar: Laotal, Popli) is a root hemi-parasitic evergreen tree; it has antibacterial properties and is useful in stomach ache, skin diseases, and cancer treatment. *Callicarpa tomentosa* (Mar: Aisar) is locally harvested from the wild for medicinal uses and flowers of ornamental value. *Gmelina arborea* (Mar: Shivan) is a medium sized tree with medicinal and timber value. *Tectona grandis* (Mar: Sag, Sagwan), needless to say, is the most important timber tree in the world.

CONCLUSION

In addition to the many uses of tree species – timber, food, medicinal, ornamental – their ecological role is of boundless importance for the maintenance of plant and animal diversity, and for the health of an ecosystem. Trees are important candidates for action against climate change

and global warming. They are of immense value to man and their conservation must be given the highest priority. Every tree species has fascinating forms of branches, leaves, flowers, and fruits. There is a great need for dedicated studies on each tree species of the Western Ghats, which will not only help in their conservation but also in meaningful utilization, sustainable development, and in the active mitigation of climate change.

Abbreviations used: *Hin: Hindi; Kann: Kannada; Mal: Malayalam; Mar: Marathi; Tam: Tamil; Tel: Telugu*.

Tulip-wood Tree *Harpullia arborea*

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> "Trees have evolved over millions of years, adapting to changing climates, but under the latest onslaught of human threats, many of them may no longer be able to survive. The main threats to trees include expansion of agriculture, logging, livestock farming, residential and commercial developments, fire and fire suppression, energy production and mining, plantations, and invasive species, and the greatest challenge of all – climate change."

An ancient Banyan, covered in leaves that filter dust and enhance humidity in the environment. Photograph courtesy Dr Ashok Kothari

The Role of Botanists in Improving Urban Environments

"There is ample evidence at a scientific level, as also common knowledge, that trees and shrubs help in the abatement of air pollution. Numerous plants are effective bio-indicators of pollution; they also act as sinks for chemical pollutants. Attractive shrubs like Oleander, Benjamin Fig, Lantana, and Bougainvillea serve a dual purpose in alleviating pollution levels and also enhancing the aesthetics of human habitations. Large trees of Banyan, Kadamb, and Mango can all be used in urban and suburban spaces to capture dust, avert aridity, and to raise green belts at different levels."

Text: **Nitesh Joshi**

Dividers are planted with shrubs and trees to keep the air healthy in urban and suburban habitats.
Photographs courtesy Sakina Gadiwala

Plants have often been used to clean our environment. That pollution of any type is harmful to human beings, and to our ecosystems in general, is now a well-known fact. Keeping our cities clean is possible through public discipline and the scientific use of plants. Mumbai city has been a leader in keeping the environment clean. This sprawling metropolis generates 7,000–7,500 tonnes of solid waste per day, equivalent to the weight of more than 40 blue whales. Around 80 to 110 metric tonnes of plastic waste, much of it single-use plastic, is dumped into Mumbai's drains and water channels every day.

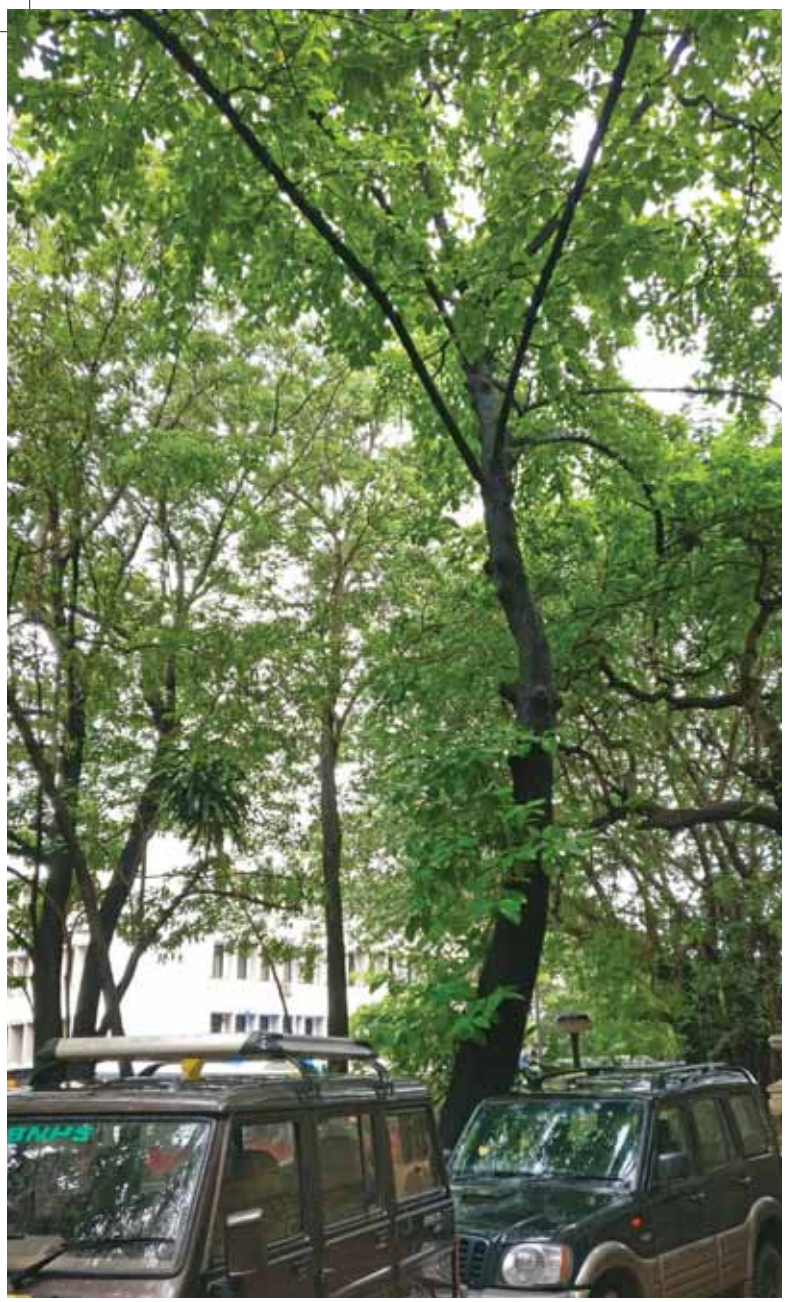
Epidemiological studies in cities like Mumbai have revealed that with raised pollution levels, there is increased occurrence of dyspnea, chronic and intermittent cough, frequent colds, chronic bronchitis, cardiac disorders, high blood pressure, and deaths due to non-tuberculosis respiratory and ischaemic heart diseases. The city, in spite of its high population density and various environmental issues, has managed to keep a check on these problems. Backed by an efficient environmental division at the Municipal Corporation level, which keeps a constant check on its air, water, and noise pollution, Mumbai also has solid waste treatment plants. NGOs and private organizations like SOCLEEN have involved botanists in training and generating awareness amongst school students about how to fight pollution with the help of plants.

Research has shown how plants can be used efficiently to keep our environment clean, and how they can effectively warn the citizens of a failing or deteriorating environment. Considerable literature is available on the role of plants against pollution, but at the local level and for all practical purposes, there are no clear cut guidelines on the use of plants as indicators of air pollution, nor on green belt development.

Urban habitats in India face severe problems related to suspended particulate matter pollution, as well as PM 10 which includes dust from construction sites and road traffic. It is imperative to monitor this pollution on a regular basis, as well as to abate it. That plants can be used effectively to monitor air pollution is well-known. In India, scientific studies have been carried out on the effects of air pollution and their abatement by using green belt plants. The work carried out by our laboratory under the aegis of Mumbai University, financed by the University Grants Commission, titled "Studies on monitoring Suspended Particulate Matter using urban plants and understanding their Green Belt Potentials", highlighted the importance of roadside plants to monitor dust and the types of plant species effective in reducing dust pollution.

Studies by the Ecology Department of Pune University have also assessed the dust capturing capacities of certain avenue trees. Such work was also carried out by the Institute of Science, Mumbai. Plants like *Nerium odorum*, *Pedilanthus tithymaloides*, *Ficus benjamina*, and *Bougainvillea spectabilis*, which were planted on road dividers all over the country, were found to be effective dust capturers. This article emphasizes the methodology at a national level and the choice of plant species required to monitor dust.

Abatement of dust in an urban environment becomes an important aspect of the fight against pollution. The choice of plant species for dust pollution based on



Peepal *Ficus religiosa* and Kadam *Anthocephalus cadamba* trees provide a natural filter in dusty city centres.
Photograph: Gayatri W. Ugra

dust retention indices and morphological parameters will be highlighted.

THE PROBLEM OF AIR POLLUTION

India is growing fast since the last couple of decades, with new cities being added every year. Compounded with this development are the so called peri-urban areas, defined as zones of transition from rural to urban land use, located between the outer limits of urban centres and the rural environment. Peri-urban areas are also experiencing the menace of air pollution. The problem of suspended particulate matter is fast increasing with increasing construction activities in the cities. In such a scenario, citizens often ask, how much air pollution is there in the area and what plants can be used to clean our environment? Research has shown how plants can efficiently be used to keep our environment clean, and also how plants can warn citizens of a deteriorating environment, but at a local level, there are no practical guidelines regarding the use of plants as indicators of air pollution or green belt development. The current article provides guidelines for establishment of a national level indicator for monitoring dust and green belt development.

In India, several scientists have worked on the effects of air pollution and the role of plants to mitigate these effects. There is an urgent need to transfer this valuable knowledge to citizens, municipal corporations, and horticulturists all over the country, and learned botanists can come to the rescue in such cases. An attempt is made to answer some vital questions here.

A. Types and Sources of Air Pollutants

Plants growing in the ambient environment of urban-industrial areas are exposed to a mixture of many pollutants. The effects of air pollution (gaseous pollutant, acid deposition, and particulates) on various levels of ecosystem organization may be summarized as follows:

a) Absorption and accumulation of pollutants in plants and other ecosystem components such as soil surface and ground water.
b) Injury to producers (plants) and consumers (animals) due to pollutant accumulation; e.g., leaf necrosis in plants and dental fluorosis in animals.
c) Change in number, density, and diversity of species and a shift in interspecific competition.
d) Loss of stability and reduction in the reproductive ability of species.
e) Degeneration of associations of biotic components.
f) Disruption of biogeochemical cycle.
g) Extension of eroded areas in the landscape.

B. Plants as Indicators and Bio-monitors

Plants play an important role in maintaining ecological balance, but they are also affected by air pollution directly or indirectly. From the time that life appeared on the planet, plants have been regulating the concentrations of carbon dioxide in the air through respiration and photosynthesis, and in modern times they are destined to take on the hazardous role of reducing the quantum of air pollution through adsorption, absorption, accumulation, detoxification, and metabolization.

Plants are bio-indicators, i.e., they reveal the presence of a substance in the vicinity by showing typical symptoms which indicate the effects of natural or anthropogenic stress factors. Being stationary, plants play a very important role in indicating the changes taking place in an environment. Two aspects of bio-indicators in plants are known: (i) Sensitive plants are those which show clear symptoms of pollutant effects even in the lowest concentrations. (ii) Accumulator plants are those which readily accumulate specific air polluting substances that can be analysed in the plant material by physico-chemical methods. Quantitative determination of pollution load can thus be made, as a particular plant acts a receiver or absorber only, without any injury, and is actively involved in the selective capture of pollutants.

C. Phytomonitoring the Environment

Different organization levels of a plant can be used for phytomonitoring, ranging from the single plant leaf or even cell, to a plant association and even an entire ecosystem. Some air pollutants have very low ambient concentrations, and are hard to measure accurately with physical and chemical methods. Plants can accumulate such pollutants to a level that is easier to analyse.

Some of the parameters which can be used for phytomonitoring of air quality are plant growth, macro characters, micro characters, and biochemical characters. The need to use genetically uniform material and uniform culturing practices is also important. Such systems have been used by this author. Standardization of methods is also essential to compare results at different sites, across months or years.

Dust fall is the accumulation that is seen on the leaves of trees, like *Mangifera indica*, *Thespesia populnea*, and *Polyalthia longifolia*. So 20 different types of localities in Mumbai city were studied to estimate dust fall. Among the plants observed in Mumbai, *Hyptis suaveolens* had high dust capturing capacity. *Pedilanthus tithymaloides* which grows along road dividers and traffic islands in Mumbai also showed good dust retention. Based on a study, a foliar dust map of the city was prepared, and the correlation between foliar dust fall and traffic count was found to be positive. Collecting the dust from the leaf and then representing it as dust in gm/sq. metre is a well accepted method, using filter paper or a crucible. Further, it was observed that:

1. The amount of dust is never constant in the atmosphere. It keeps changing with variations in place, time, season, and climate. During field

Dense foliage of Yellow Asoka *Saraca asoca* reduces excessive sunlight, dust, and grime in a Kolkata park. Photograph: Gayatri W. Ugra

Towering palms and hedges planted along roads and highways reduce air pollution and cut down decibel levels. Photographs courtesy Sakina Gadiwala

work, it was noticed that foliar dust recorded on various plant species differed at different sites, and no plant behaved same at all sites, i.e., the plant which is the best dust capturer at one site may be the worst at other sites. Each plant behaves independently at various sites without any perceivable trend or pattern. This may happen because of micro variations in wind speed, humidity, and proportion of vehicular and industrial exhausts.

2. In order to determine the best plant for capturing and retaining atmospheric dust, screening of dust on different plants in a constant system (surroundings) was required. A special dust fumigation chamber was fabricated to analyze the plants under controlled and simulated conditions.
3. The dust chamber was used to explore the dust retention capacities of various trees, shrubs, and herbs. The plants were screened under controlled (or still) and simulated conditions. The amount of dust was estimated, to determine the dust capturing and dust retaining capacities of the plant species. The tendency to hold dust on leaf surface was measured in terms of DRI (Dust Retention Index). Many plants were found to have higher DRI values without the presence of a running fan, but some were showing higher DRI values even with the fan. Plants that receive and hold more dust in the absence of a running fan are said to be good dust capturers.
4. DRI values are percentage values of Dust Captured and Dust Retained on the foliar surfaces of various species. A list of plant species (herbs, shrubs, and trees) with their DRI can help in planning the plant species to be grown along road dividers, residential areas, highways, and gardens. *Ficus benghalensis*, *Ficus benjamina* var. *nuda*, *Lantana camara*, *Mangifera indica*, *Muntingia calabura, Pedilanthus tithymaloides*, *Trema orientalis*, *Ziziphus jujuba*, *Ervatamia divaricata*, and *Clerodendrum inerme* are some plants with high DRI. However, wind plays a vital role in the dust capturing capacities of plant species.
5. Cities in India are undergoing several changes with the introduction of mass rapid transport systems and the construction activities of buildings, flyovers, and highway renewal. During the study, the plants reflected the effects of such activities, with high amounts of dust in areas with construction activities and their vicinity. Therefore, it is suggested to create a green belt around road dividers, with plant species which can be trimmed and also have high DRI. It is suggested to plant trees with a large canopy, alternating with shorter ones, like *Ficus benjamina, Pedilanthus tithymaloides*, *Nerium odorum*, and *Bougainvillea*.
6. Around industrial areas, the situation becomes complex with several types of industries placed together. Here, green belt development should focus on the utility of the area and on the principle that the installation factory should not be seen; trees should encircle the factory in a belt around 50 m wide.

D. Choice of Plants

For roadsides including traffic islands, the choice of plants should be in accordance with the width of the road. Planting should form a screen between the traffic and roadside residences, and should include shrubs and trees, with intermixing of ornamental herbs like *Aralia*. Another important parameter in the choice of plant species for green belt development is the Air Pollution Tolerance Index. Several agencies and researchers have worked on this aspect, and

the data can be used by locals for the development of green belt in their area. For dust it is also the morphological parameters which play an important role in dust retention. Vegetation provides a major filtration and reaction surface which traps particulate matter. Through sedimentation, particles are usually deposited on the upper surfaces of leaves, particularly the larger particles.

The interception and retention of atmospheric particles is highly variable and depends on: 1) the size, shape, and surface texture of the particles; 2) the size, shape, and surface texture of the intercepting plant part; and 3) the micro- and ultra-micro-climatic conditions surrounding the plant.

For efficiency in particulate removal, species with high leaf circumference-to-area and surface-to-volume ratios, along with leaf surface roughness may be recommended. It may be concluded that within their limits of tolerance, plants absorb pollutants and to that extent remove air pollutants.

E. Concept of Green Belt

Green belt is commonly understood to be a strip or piece of land bearing plants of a few species, may be common or beautifully flowering ones, for the removal of air pollutants. Green belts are effective in such a scenario, where green plants form a surface capable of absorbing air pollutants and forming sinks for pollutants. The vast leaf surface area in a tree crown absorbs pollutants on the surface, effectively reduce the concentration of pollutants in the ambient air. Plants grown in such a way as to function as pollutant sinks, are collectively referred to as green belts. Plant scientists favour the development of green belts for use as parks within large urban industrial areas. Most city planners look to the green belt as a park system, to provide areas for recreation and to break the monotony of the urban complex. City planners stress upon the screening effect of green belts, their potential to remove air pollutants, and their benefits to human health.

F. Plant Species suitable for Green Belt

The green belt approach has evolved in recent years, and aims at growing plants in and around industrial areas and roadsides. To do so, selection of tree species is a task that requires sound knowledge of plants and their response towards environmental stresses, especially dust fall and emission of gaseous pollutants. The capacity of plants to reduce air pollution is well-known. To check the spread of air pollutants emitted from industrial complexes, many scientists recommend that vegetation be grown around such areas. It is also known that plants differ considerably in their responses towards pollutants. Some are highly sensitive and show immediate symptoms, while others are hardy and tolerant. Tolerant plant species can function as pollution sinks and provide a number of environmental benefits. They help to reduce overall pollution load, making the air free from particulate matter and other pollutants. Therefore, appropriate selection of hardy and tolerant plant species may result in mitigation of pollution. Parameters have been suggested to determine appropriate plantation of green belt species, e.g., Air Pollution Tolerance Index (APTI) values, and Dust Retention Index (DRI). Dust interception capacity of plants depends on their surface geometry, phyllotaxy, the external characters of the leaves such as hairs and cuticle, and the height and extent of tree canopy.

Removal of pollutants by plants from air is enabled by three means, (i) absorption by the leaves; (ii) deposition of particulates and aerosols over leaf surfaces; and (iii) fallout of particulates on the leeward side of the vegetation because of the slowing of air movement. The work carried out in the laboratory of the Botany Department, Rizvi College, Mumbai, financed by the University Grants Commission under the title "Studies on monitoring Suspended Particulate Matter using urban plants and understanding their Green Belt Potentials", highlighted the importance of roadside plants to monitor dust and types of plant species effective in reducing dust pollution. Plants like *Nerium odorum*, *Pedilanthus tithymaloides*, *Ficus benjamina*, and *Bougainvillea spectabilis* growing on road dividers all over the country were found to be effective dust retainers.

CONCLUSION

There is ample information available at a scientific level regarding which plants to grow for air pollution abatement and monitoring. The existing plantations, which include trees, herbs, and shrubs, are effective indicators as well as sinks for pollutants. The numerous species mentioned in this article are effective in green belts. *Ficus benghalensis*, *Ficus benjamina* var. *nuda*, *Lantana camara*, *Mangifera indica*, *Muntingia calabura*, *Pedilanthus tithymaloides*, *Trema orientalis*, *Ziziphus jujuba*, and *Ervatamia divaricata* can all be used in city habitats for capturing dust and green belt in different zones. The list of trees suitable for green belt plantation outside the city is long and has been well documented elsewhere.

Coconut Palm, a *kalpavriksh* that provides us with numerous useful products.
Photograph courtesy Dr Ashok Kothari

OUR BEST FRIENDS
The Trees

"From trees, humans can learn lessons in ageing gracefully. In their lifetime, trees face the vagaries of nature – seasonal changes in climate, sunshine, soil, and water supply. They give back fruit, flowers, and medicine, and provide shelter to humans as well as many birds and animals, to thousands of insects and all kinds of other plants. These silent protectors of humans are taken for granted and yet remain our best friends!"

Text: Jyoti & Nikunj Parekh

Trees communicate amongst their own species, and old trees look after the younger trees, with maternal love and care. It has been discovered and is now being increasingly studied that trees communicate with each other through their roots, and this may be how they synchronize their activities, growing, blossoming, and fruiting together in season, and thus they co-exist as a community with their own species and with other species. Similar species of trees are found wherever the local environment and climate are similar.

Forest trees live long, may be at least five to seven times more than human beings, and enrich the forest ecosystem. They achieve good heights, with a canopy to reach out for sunlight. They need a good supply of water initially, then they can stabilize and grow enough to make do with adequate rainfall. Their roots spread out far and wide, like a network with a very sound system of response, helping the weaker trees around. Regular transportation of water, from the roots through the trunk and all the way to the canopy of branches, to the smaller stems and leaves is an ongoing process. Over the year, trees bloom in their appropriate season and there is also a seasonal leaf fall, which is prominently visible in temperate regions, but not so visible in tropical climes.

The frictional effect of leafy forests helps lift moist air and enhance rainfall, and the leaves trap dust pollution.
Photograph courtesy Sakina Gadiwala

Leafy tree canopies help to break the onslaught of severe sunshine and pelting rain on the soil.
Photograph courtesy Gayatri W. Ugra

A basic foundation is laid when the tree roots get entwined and intermingle with other tree roots under a porous soil. This foundation works for the overall good health of a tree, as they act in unison like a joint family. From a group of trees, human beings can learn lessons in ageing gracefully. In their lifetime, trees learn to grow and face the vagaries of nature like seasonal changes, climate, variations in sunshine, soil, and water supply. They give back useful fruits, flowers, and medicine, and provide shelter to humans as well as many birds and animals, thousands of insects, microbes, and varieties of algae, fungi, mosses, and all kinds of creepers. Their contribution to the food pyramid in the form of photosynthesis, the conversion of carbon dioxide and water into sugars with the use of light, goes on and on.

Trees help keep our air supply fresh by using up the carbon dioxide that we exhale and that factories and engines emit. Trees use their hairy leaf surface to trap and filter out ash, dust, and pollen particles carried in the air. They dilute gaseous pollutants in the air

as they release oxygen. Trees can be used to indicate air pollution levels, and as filters to trap dust and grime on their leaves. Trees lower air temperature by enlisting solar energy to evaporate water in the leaves. They help increase humidity in dry climates. Trees slow down erosion from the force of strong winds and ocean waves; they act as barriers to prevent top soil from being blown away, while their roots hold the soil on hills and slopes. Particularly in urban areas, they cut down noise pollution by acting as sound barriers. Trees planted along the highways help to absorb traffic noise; a 30 m wide avenue has the capacity to absorb 6 to 8 decibels. Healthy trees provide us with a soothing, cool, green cover.

Tree canopies help to break the onslaught of pelting rain on the soil surface and give it a chance to soak up as much water as possible. Fallen leaves provide a rich cover on the ground to keep the soil from drying out. Decaying leaves replace minerals in the soil and enrich it to support subsequent plant growth. Trees camouflage harsh scenery and unsightly garbage dumps, city yards, mining sites, and polluting industries. Amidst the environmental uproar, trees stand tall, dispensing life-giving benefits and living on. These silent friends of humans are taken for granted and yet remain our best friends!

At the end of their lifetime, they give us wood when felled. Another gift we get is the seasonal revival of a green carpet of moss and good quality loamy soil that is ideal to sustain the greenery around for ages to come. Tree planting efforts help us meet the needs of a growth oriented environment. Young school children need to be attracted to participate in mass tree plantation drives. During our primary school years, we received lessons in Moral Science and Civics, with age old stories that encouraged us to plant trees, to celebrate *Vanamahotsava*.

Our Plantation Effort

Tree planting was done by members of the Frangipani Garden Group & Bonsai Study Group of the Indo-Japanese Association. Photograph courtesy Nikunj Parekh

Bonsai Study Group (BSG) of the Indo-Japanese Association (IJA, established in 1979) has made efforts to achieve a deeper sense of belonging by involving village schools, teachers, parents, and local leadership in tree plantation drives. Members of the Bonsai Study Group, both leaders and teams, are pioneers in sharing knowledge on the art of miniaturizing trees across India, through publications, lecture demonstrations, workshops, and exhibitions. We have also served society at large by taking up many social objectives in the last 42 years.

Frangipani Garden Group (established in 2009) has been imparting knowledge on gardening, horticultural aspects of growing plants in urban and suburban habitats, on terraces and balconies, managing farms, and even preparing health food, for the last 12 years.

During the second lockdown due to the COVID-19 pandemic, our teams under the leadership of Jyoti and Nikunj Parekh implemented a novel tree plantation project, with over 200 trees planted in the first phase at the villages of Nimbode-Dandwadi in Khalapur region, Maharashtra on 26th September, 2021. In the next phase, we planted 350 trees in Nanivali village near Morbe Dam in Chowk area on

10th October, 2021. We involved school children, their teachers, village folk, and the local leadership in this drive.

Bonsai Study Group of the Indo Japanese Association and Frangipani Garden Group provided all the saplings, material for tree guards such as split bamboo sticks to support each tree, and prepared the tree guards with these bamboo sticks and green shade-net around the planted trees, along with all the labour, assured water supply, and manure required for the plantation to succeed and survive.

Meeta and Umesh Mehra planting a tree. Love for trees and environmental protection is our common aim.
Photograph courtesy Nikunj Parekh

Green shade netting with four bamboo sticks was provided as support and protection for each sapling.
Photograph courtesy Nikunj Parekh

We got full support from school children in the age group of 5 to 12 years, their teachers, village folk, and the Village Sarpanch. Trees like Banyan, Pakhad, Neem, Rain Tree, Bakul, Peltophorum, and Kadam were planted. Fruiting trees included Kamrakh, Guava, Jamun, Tamarind, Cashew, Desi Badam, and Chikoo. Each household was given two fruit tree saplings, and the rest of the saplings were planted near the school and along roadsides.

At both the village schools, our team members asked the children questions in Marathi on the benefits of tree planting, and explained the benefits we receive from trees, like cloud formation, good rainfall, agroforestry produce, and nourishment. We also requested the teachers to arrange for the children simple lessons on skill development in water management, maximizing land usage with better techniques, and to invite experts from time to time to share new ideas in simple terms for the benefit of the farmers in their own language.

School children, their parents and teachers, and the village folk were involved in this social objective.
Photograph courtesy Nikunj Parekh

The leadership of both our organizations and the tree plantation team has always believed in group activities, which is due to the influence of our Japanese teachers of Bonsai and Garden Landscaping. Our motto is simple: "United we bloom & divided we wither." Our teams have been blessed by many well-wishers, who support us in our endeavours. We have received many encouraging and appreciative messages that inspire us to keep going.

Landmark Events

THE STORY OF A TREE PLANTATION DRIVE

Compiled by: **Sakina Gadiwala**, Programme Co-ordinator

The Don Bosco Mazzarello Centre (Sisters' Home) at Naughar, Uttan, in Bhayander (West), Thane district, is situated on a plot of more than two acres, of which about half an acre was undeveloped. The Sisters of the Home had requested Professor Perrie Subramaniam of St Xavier's College, Mumbai, for assistance in developing this land. She, in turn, approached Friends of Trees for guidance. We decided to work jointly on this project with the Mass Media Department of St Xavier's College by contributing our skills and sharing part of the costs. This would be our Society's first outdoor event in almost two years.

SAKINA GADIWALA

The undeveloped area of the
Don Bosco Mazzarello Centre campus

SAKINA GADIWALA

After discussions, a plan was worked out. The first step was to clear the land of weeds and rubble

SAKINA GADIWALA

Student volunteers of St Xavier's College and inmates of Don Bosco Home measured and marked the spots for digging pits

TEAMMASSMEDIA2022@SXC

Students also helped to clean the site and collect organic waste, which would be used to fill up the pits

MR GLAXON

The next step was to dig pits to plant saplings. A bulldozer was needed to do the heavy work, as there were huge boulders underneath, and the pits were large and misshapen. There was doubt whether plantation could be done here at all. Fingers crossed, we went ahead with a reworked plan.

PRAMESH KUMAR MANCHANDA

The boulders were removed and labourers were hired to improve the pits. Organic waste and soil were used to fill part of the pits. This took a good four to five days. Fighting against time, we managed to complete the preparations on the very eve of the plantation date, 19th February, 2022

SAKINA GADIWALA

The day of the plantation dawned. Dr Arun D. Sawant, President, FOT, was the guest of honour. A good number of FOT members, students, and inmates gathered at the appointed time. The candle lighting ceremony that initiated the programme was unique: A banana stem inserted with waste CDs for candle holders made up the candelabra

SAKINA GADIWALA

Then came the time to roll up our sleeves. FOT members led by our President, students of St Xavier's led by Prof. Subramaniam, and inmates of the Don Bosco Home led by Sister Sushma all joined to actively demonstrate their love of Nature

SAKINA GADIWALA

Bahawa, bauhinia, banana, black pepper vine, coconut, jackfruit, jamun, kokum, lemon, palash, papaya, pomelo, ritha, starfruit, surangi, taman, umber, and water apple were planted.

SAKINA GADIWALA

Young and old got down to work to plant the saplings, 81 in all, obtained from a nursery in Dapoli

SAKINA GADIWALA

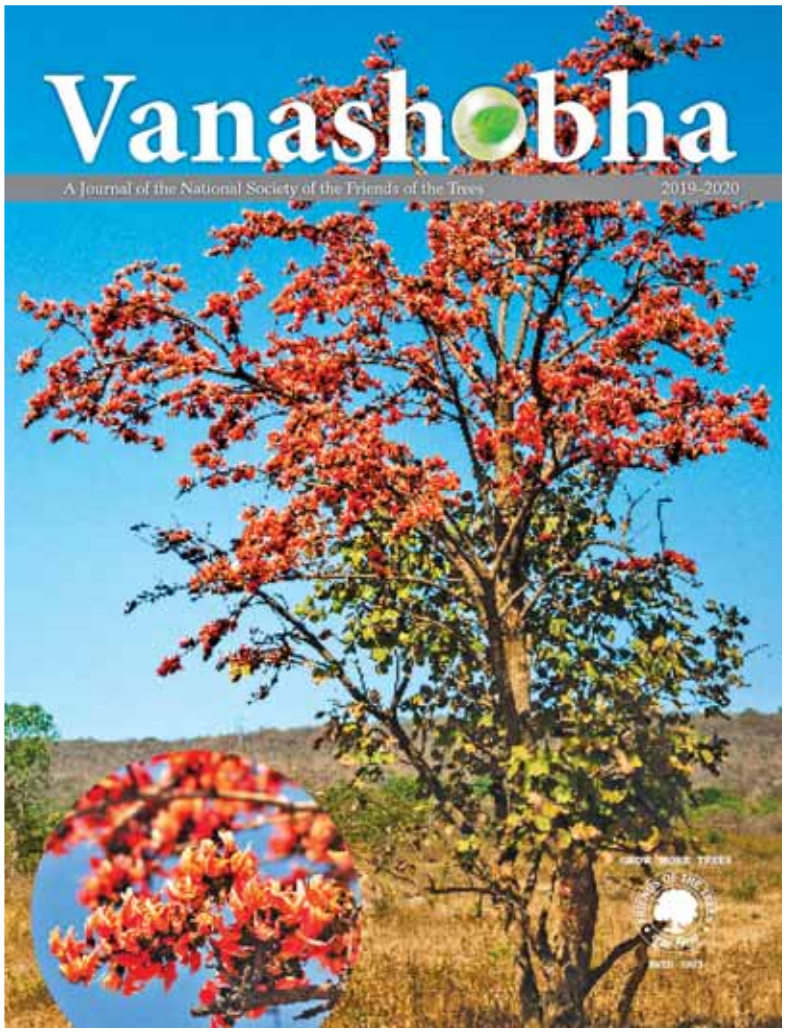
After almost four hours under the hot sun, all the saplings had been planted. Everyone was very happy at the successful outcome. A copy each of *Vanashobha* 2020 and *Vanashobha Green Legacy* were presented to Sister Sushma

SISTER SUSHMA

The saplings are now being well looked after by the inmates of the Don Bosco Sisters' Home

SISTER SUSHMA

These saplings were photographed two weeks after the plantation

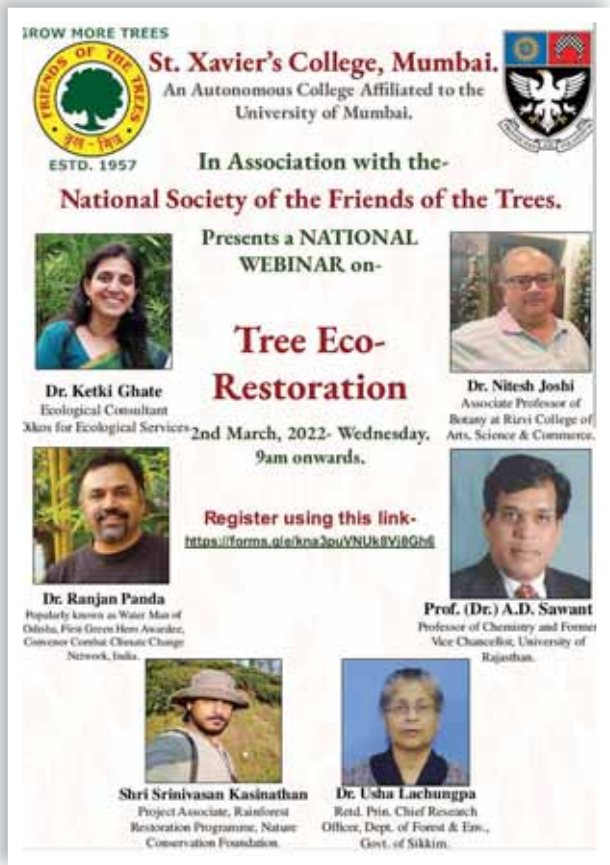


5TH JUNE, 2021 WORLD ENVIRONMENT DAY LAUNCH OF VANASHOBHA 2019-2020

The first digital version of Vanashobha, along with the print edition, was launched by Dr Pheroza J. Godrej, President Emeritus, FOT. This positive outcome of the circumstances surrounding the pandemic meant that not a single sheet of paper was used in the making of the journal, which is a major vehicle for promoting the aims and objectives of the Friends of the Trees.

22ND JUNE, 2021
WORLD RAINFOREST DAY
1ST VIRTUAL FLOWER SHOW

The launch of our very first virtual flower show kept alive the spirit of FOT, for which the Annual VFF Show is such a crucial part of the calendar of events. Dedicated members put together a beautiful video on the theme, "A Look at Nature". All the beauty of nature around us, captured by FOT members during the pandemic, included the beautiful Kaas Valley of Maharashtra, a guided tour of Ranibaug, Mumbai, a manicured garden in a housing society, an exquisite Bonsai collection in a terrace garden, miniature landscapes, nature depicted in stone, and images of gardens, flowers, fruits, and potted plants.



2ND MARCH, 2022
FOT NATIONAL SEMINAR
ON TREE ECO-RESTORATION

This virtual seminar was held in association with St Xavier's College, Mumbai. The theme was "Tree Eco-Restoration" in keeping with the declaration of 2021-2030 as the United Nations Decade on Ecosystem Restoration. The UN has made a rallying call for the protection and revival of ecosystems all around the world, for the benefit of people and nature. It aims to halt the degradation of ecosystems, and restore them to achieve global goals. Only with healthy ecosystems can we enhance people's livelihoods, counteract climate change, and stop the collapse of biodiversity.

FOT Webinars held during the Pandemic

FOT took advantage of the surge in e-learning, virtual participation, and the availability of guest lecturers as well as interested audiences, to hold the following highly successful webinars through the pandemic.

Ethnobotanical Study of the Sacred Plants Used in Indian Festivals: Ganesh Patri Puja, Hartalika, Vata Savitri, Tulsi Vivah, and Kali Puja
– Mrs Vijaya Chakravarty

Bilva fruit and leaves are offered during the Hartalika festival

Flowers are an essential part of Indian cultural traditions

Grazing on Microgreens: Window Farming for the Urban Dweller
– Dr (Mrs) Behnaz B. Patel

Mustard microgreens grow the fastest

Wild Edible Plants Vital for Sustainability: Enjoy Foraging, Farming, and Feasting
– Mrs Vijaya Chakravarty

Invisible and Unique Relationships of Trees and Fungi
– Dr Sashirekha Suresh Kumar

Introduction to Permaculture Design Principles
– Mr Amit Amembal

Endemic Trees of the Western Ghats
– Dr S.R. Yadav

Trees of Life, Trees of Death, and Everything in Between: My Search for Iconic Trees of India
– Dr S. Natesh

Plant Based Artifacts vis-a-vis Pro-Ecological Development
– Dr Suchandra Dutta

Developing Urban Gardens as Habitats
– Ms Anjana Dewasthale

Nature and Biodiversity Enhancement through New Age Techniques: Subhash Palekar Natural Farming
– Mrs Monica Deshmukh

Hanging Plants: Orchids, Ferns, and Bromeliads
– Mr Nandan Kalbag

LEARN FROM TREES

Stand tall and be proud, Go out on a limb,
Reach for the sky, Adapt to change!
Branch out, Stay grounded,
Remember your roots, Drink plenty of water,
Get rid of dead wood, Be confident!
Never stop growing, Bend before you break,
Turn over a new leaf, Enjoy the view!

– Anon

Contributors

Arun K. Pandey, PhD, former Professor of Botany, University of Delhi, is presently Vice Chancellor, Mansarovar Global University, Bhopal. His researches focus on angiosperm systematics, biodiversity, and Environmental Science. He has travelled in the forests of Jharkhand, Chhattisgarh, and Odisha to study flora and ethnobotany. Author of 14 books and research papers, he was given awards by the Indian Botanical Society, Indian Science Congress Association, Indian Association for Angiosperm Taxonomy, and East Himalayan Society for Spermatophyte Taxonomy. He is a Fellow of the National Academy of Sciences, India.

Bindu Raghavan, PhD, has been Principal Scientist at the Centre for Wildlife Studies, Bengaluru, and Investigator PhD, Animal Health, in Columbia; Graduate Research Assistant in Washington State University; and Project Coordinator in Group for Nature Preservation and Education, Chennai. She is Visiting Faculty at Krea University and Professional Fellow at WII, Dehradun. She studies human-wildlife-livestock interactions, animal health, One Health, and wildlife conservation and management. She uses a combination of laboratory methods and field data, and tools in geo-spatial epidemiology and mathematical modelling, to understand wildlife disease dynamics.

Ritesh Kumar Choudhary, PhD, is Scientist D & Senior Scientist at Agharkar Research Institute, Pune. After his PhD from Botanical Survey of India and Rajiv Gandhi University, Itanagar, he was a Research Associate at GKVK, Bengaluru. He authored the Flora of an area in Arunachal Pradesh, and the Flora of Hon Ba Nature Reserve, Vietnam. He has published 13 new plant species, 20 new records, 80 research papers, and three books. He is on the Board of Studies, Botany Dept, and adjunct faculty in Molecular Taxonomy, SP Pune University, Pune. He is a member of the Research Advisory Committee of Naoroji Godrej Centre for Plant Research; and Editor of *Journal of Economic & Taxonomic Botany* and *Journal of Biology*. Dr Choudhary received the Korea Science & Engineering Foundation Post-Doctoral Fellowship, Best International Researcher Award, KRIBB, S. Korea, and Prof. V.V. Sivarajan Gold Medal (2020).

Vinita Damodaran has been Director, Centre for World Environmental History, University of Sussex, Brighton, UK, for over 18 years. She is AHRC Fellow on a project for Impact and Engagement in the History of Indigenous Communities in Eastern India. She is interested in conserving natural history collections of empire, to understand climate change. An environmental historian specializing in India, she has particular interest in the history of indigenous communities in Eastern India.

Raymond Ruhaak, PhD is a researcher affiliated with the Centre for World Environmental History at the University of Sussex, UK. He obtained his doctorate in Geography from the University of Liverpool, on "The Development of Vulnerability and Resiliency to the Plague: from the 'Big Bang' of *Yersinia pestis*, Black Death and the Continued Geographic Expansion of Zoonotic Outbreaks to the Present". He concentrates on the impact of socio-economic and knowledge systems and institutions in fostering human activity that alters local ecosystems, enhancing the risk of a human zoonotic epidemic.

Radhika Naware, founded "Treasured Holidays" to empower skilled artisans, with craft and textile trails designed to inform travel participants with experience of the entire craft process. "Treasured Holidays" empowers artisans by reducing middle men and commission practices, and provides a rewarding experience for travellers. The Warli trail focuses on the harmonious relationship of the Warli tribe with their forest habitat.

Nandan Kalbag was Honorary Horticultural Consultant to Parijnyanashram School for Handicapped Children in Virar, and Senior Citizens Ashram, Jambhulpada. He taught horticulture through TV, radio, and popular articles, and travelled extensively in Konkan, Kolhapur district, to lecture for Marathi Vidnyan Parishad, Mumbai. He served as Horticulture faculty for Mumbai University; Vidya Prasarak Mandal at Bandodkar College, Thane; Ruia College, SNDT College, St Xavier's College, and Bhavan's College, Mumbai, among others. The late Mr Kalbag was a Founder Member of the Mumbai Rose Society. His website www.gardentia.net provides pro bono information on horticulture.

Manjushri Savadi-Parasnis graduated in Botany from Jai Hind College, obtained a Master's in Ecology from Institute of Science, Mumbai, and holds diplomas in Management, Computers, Interior Designing, Gardening, and Natural Resources. She teaches computers, landscape design, and interior design, and has assisted *The Times of India*, *Oikos*, Centre for e-Learning and Training, Sustainable Living Integrated Solutions, KEM Hospital Research Centre, and Symbiosis (CMHRD).

Vijaya Chakravarty is an Ecologist and Landscape Artist. She has created biodiversity landscapes, ecological restoration projects, pollinator gardens, play spaces for children, restorative and therapeutic habitats for the challenged and elderly, and learning gardens. Ms Chakravarty has worked for leading educational institutions, Parsi General Hospital, and corporates including the Tatas, Hindujas, The Taj Group, Standard Chartered Bank, and TCS. She is closely associated with Friends of the Trees, Indian Women Scientists' Association, and Arambh.

S.R. Yadav, PhD, is an outstanding plant taxonomist and an excellent teacher. His academic works, particularly *Flora of Kolhapur* and *Grasses of Maharashtra*, have inspired many students. He has recorded a new flowering plant family Hydatellaceae, and discovered 78 new species. His contributions on the cytotaxonomy and biosytematics of seven crucial genera are widely acclaimed. He has worked on ex-situ conservation, species recovery, and rehabilitation of two nearly extinct species, *Hubbardia heptaneuron* and *Ceropegia fantastica*, and established an exemplary Lead Botanical Garden for the Western Ghats at Shivaji University, Kolhapur.

Nitesh Joshi, PhD, has been working in the Dept of Botany, Rizvi College of Arts, Science and Commerce, Mumbai, for 30 years. An Associate Professor and PhD guide in Botany, he taught plant ecology for 20 years, and is presently guiding researchers in Plant Ecology, Urban Ecology, Forest Ecology, Phytoremediation of Urban Ecosystems, and Forests as Sinks of Pollution. With several published papers, three books, and botanical research projects to his credit, he also teaches plant ecology at the University of Mumbai.

Jyoti & Nikunj Parekh founded the Bonsai Study Group of the Indo-Japanese Association in 1979. They have co-authored three books and given demonstrations at bonsai conventions in numerous countries. They co-publish a quarterly, *Nichin Bonsai*. Recipients of national and international awards, they received a Gold Medal at the World Bonsai Convention, Puerto Rico (2009). Nikunj Parekh was awarded "The Rising Sun with Silver and Gold Rays" (2015) by the Government of Japan.

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