

Global warming Induced Stress and its Impact on Biodiversity

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Abstract: Biodiversity provides numerous ecologically essential services. It includes increase in ecosystem productivity, promotion of formation and protection of soil, improvement of nutrient storage and recycling, helps in breaking down pollutants, climate stability, more food resources, faster recovery from natural disasters, etc. At least 40 % of the world's economy is derived directly from biological resources. However, biodiversity is going to decline both qualitatively and quantitatively in future due to multiple anthropogenic and few natural pressures. Among these pressures, global warming has severely affected the ecosystem and the biodiversity associated with it. The IUCN predicted that 4161 species are being threatened by climate change. The current velocity and magnitude of climate change trends leading to increased extinction rates. Global warming is being one of the causes affecting biodiversity differently across various regions globally. Under this COVID-19 pandemic condition, the environmental restoration process is also going on as most of the nations followed complete or partial lockdown as preventive measure from the spread of COVID-19. In addition to air pollution, emissions of greenhouse gases (GHGs) have also dropped throughout the world during the lockdown period. It gives us a chance to learn more about the human impact on the environment. The effect of nationwide lockdown on the environment may not be clearly understood due to a short duration, and it may be temporary. However, governments and individuals should learn from this lockdown on how to reduce pollution on a long-term basis. Even 2-3 days complete worldwide lockdown per year in the future may help to restore the environment.

Keywords: Biodiversity, Global Warming, Post Pandemic Era.

I. Introduction

The term "biodiversity" was first used in its long version (biological diversity) by Lovejoy¹ and is most commonly used to describe the number of species. Biodiversity is the variety and variability observed amongst the living forms present on the Earth; including their genetic diversity, species diversity, and the diversity in the ecosystems, which they form, develop, and regulate. However, the biodiversity is badly affecting due to various natural and anthropogenic activities like pollution, urbanization, industrialization, altered land-use and land-cover pattern, selective exploitation of natural resources, etc. After industrialization, human activities have fastened the rate of heating of Earth's surface temperature. Over the last century, the global average temperature has increased by 0.7°C, global average precipitation has also increased by 2%², and they both are going to increase in future, affecting Earth's climate. Global warming and resultant climate change further add to the pressure on the ecosystem, affecting both the quality and quantity of biodiversity. Loss of biodiversity has direct and indirect impacts on both the energy and material flow, which thus influences the ecosystem services. Global warming is affecting biodiversity in various ways viz., both plants and animals are losing their numbers, population size and distribution patterns are changing, for some their lifecycle have altered, forests are degrading, agriculture and fishery sectors are also experiencing downfall and mankind is exposed to a risk of several new diseases. Global warming, along with other anthropogenic

activities is degrading the biodiversity, which is a major source of basic needs and economy, not only for developing countries but also for developed countries. During the current COVID-19 pandemic, various countries have enforced lockdown to control the spread of the disease, which has worked miraculously for the environment as the several air pollutants levels are dropped drastically, and at the same time, medical and biomedical waste management has become a challenge. Thus, it is essential to understand the link between biodiversity, ecosystem services, and global warming for the betterment and humanity and the future of the planet.

II. Importance of Biodiversity

The diversity amongst life forms provides numerous, ecologically important services, like, it increases ecosystem productivity, promotes the formation and protection of soil, improves nutrient storage and recycling, helps in breaking down pollutants, climate stability, provides more food resources, faster recovery from natural disasters, etc. Biodiversity greatly influences human welfare also in numerous ways. Humans depend on the biodiversity of the planet for food, shelter, clothing, medicines, raw material for various industries, recreation, ecotourism, etc. At least 40 % of the world's economy, and 80 % of the economy of less-industrialized nations is derived directly from biological resources³. Humans, across the world, use at least 40,000 species of plants and animals daily⁴ and people from remote areas across the world still depend on biodiversity for their basic needs. This remarkably important biodiversity is declining at an alarming rate since the last few decades. Biodiversity loss, also called loss of biodiversity, can be defined as a decrease in biodiversity within a species, an ecosystem, a given geographic area, or Earth as a whole. Once lost, bringing it back is an impossible task.

III. Global Warming

Global warming is a gradual increase in Earth's average surface temperature primarily due to the greenhouse gases (GHGs). This term (GHGs) has become quite familiar to the layman as one of the most important environmental issues in the last few decades. It is a well-known fact that Earth is heating up, but the question is at what speed? Since the time of Industrial Revolution (1750), Earth's temperature has elevated by 0.4-0.8°C⁵, which has uneven distribution across the planet. Poles are the most affected regions on the planet experiencing a tremendous melting of ice, which has increased from 25 billion tons/ year in 1990 to a current average of 234 billion tons/ year. This molten ice has increased sea level drastically, according to IPCC current average increase in seawater level is 1.7 ± 0.5 mm/ year, which is sufficient to sink coastal areas by the end of 21st century².

Causes of global warming: Since industrialization, the human population has increased 7 folds. To meet the demands of ever-growing population, several natural resources have been extensively exploited. In the last century, certain anthropogenic activities have extensively contributed to global warming, by the release of greenhouse gases like Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF₆) along with the natural activities like volcanic eruptions and increased solar activity, resulting in climate change. These gases trap infrared thermal radiation, emitted by the sun, when it enters Earth's atmosphere, leading to a steady rise in the Earth's temperature. This continuous rise in temperature over a long period of time has given rise to global warming. Since 1850, Earth has warmed equivalent to nearly 2.5 W/m² with carbon dioxide contributing about 60 % to this figure, methane about 25 per cent, with nitrous oxides and halocarbons providing the remainder⁶. Another major cause of global warming is depletion of the ozone layer due to CFC's, once used as refrigerants and aerosol propellants. Some greenhouse gases, like methane, are produced through agricultural practices, including livestock manure. Others, like CO₂, largely result from natural processes like respiration and from the burning of fossil fuels like coal, oil and gas, deforestation. Fluorinated gases, i.e., gases to which the element fluorine is added, including hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride, created during several industrial processes, are also responsible for global warming.

Negative impacts of global warming: At present, the CO₂ concentration alone is about 398 ppm, leaving aside the other greenhouse gases arising mainly from anthropogenic causes. The CO₂ plus the other heat-trapping gases form what is referred to as "CO₂ equivalent", which now is about 470 to 480 ppm⁷. All these support the estimate by the Intergovernmental Panel on Climate Change (IPCC) that the Earth will warm by 1.4–5.8°C during the current century².

As Earth warms and temperature rises, regional climates are affected in different ways. Warmer temperature increases evaporation of surface water, which leads to more substantial rainfall and snowfall. Nevertheless, this increased precipitation is unevenly distributed across the planet, leading to more torrential rainfall in some locations and droughts in others. Heavier and more frequent snowstorms, hurricanes, more intense heat waves, and extreme rainstorms and resulting flash floods are occurring more frequently around the globe. Shrunken snowcaps and reducing glaciers in the mountains indicate comparatively less molten ice flowing into rivers, and other water bodies for fish and wildlife, and less water available for drinking and irrigation. Rising sea levels will lead to coastal flooding on the Eastern Seaboard, especially in Florida, and in other areas such as the Gulf of Mexico. Disruption of habitats such as coral reefs and vast meadows could drive many plant and animal species to either adapt or perish.

Global Warming is Affecting Biodiversity: In the fossil record, a single vertebrate (amphibian, bird, fish, mammal, or reptile) species lasts on an average at least one million years before it becomes extinct⁸, which means, in a year, not more than one out of a million species should go extinct. The current observed extinction rate since 1600 AD, for vertebrates, is 2.6 per 10,000 species per year. That is at least 260 times the background rate of extinction. According to Reed, with this rate, it would take less than 15,000 years to equal the extinction event that killed the dinosaurs in several million years of period⁹. The Evil Five Biodiversity Threats which include habitat alteration and modification, overexploitation, climate change, invasive species, and chains of extinction¹⁰ are the most critical and significant contributors to biodiversity loss worldwide¹¹. The International Union for Conservation of Nature, Red List of Threatened Species predicted that 4161 species are being threatened by climate change, 33% are at risk from climate change-induced habitat shifts and alteration, 29% are due to temperature extremes, and 28% are due to drought¹². The current velocity and magnitude of climate change trends will likely exceed the abilities of several species to survive and adapt to new environmental conditions thus leading to increased extinction rates^{13, 14}. It merely means that, if adequate measures are not taken immediately, its negative impact will be challenging to manage in the near future.

IV. Impact of Global warming on Biodiversity

Direct and Indirect Effects of Global Warming on Ecosystem: Global warming has severely affected the ecosystem and the biodiversity associated with it, at different places in the world. These effects can be grouped into Direct and Indirect Effects. Direct effects include those effects which arise from increased temperature and CO₂ levels associated with global climate change^{15, 16}. These direct effects result in several major and minor indirect effects like changes in hydrologic cycles, altering magnitude and extent of extreme weather events and frequent forest fires. Overall these changes can affect biodiversity in many ways, such as altering life cycles- phenological changes, by shifting distribution ranges, changes in abundance and migration patterns, and changes in the frequency and severity of pest and disease outbreaks.

Plants: With the increase in Earth's atmospheric temperature, regional climates will alter causing heavier precipitation, rise in sea level, faster melting of polar ice, severe drought, etc. directly and/or indirectly affecting growth and productivity of forests. When nutrients and water are abundant, higher levels of CO₂ may enable plants to be more productive, influencing the distribution of plant species and thus, forest composition. The phenological events, i.e., events of the lifecycle such as flowering, are often related to environmental variables like temperature. Changing environments are expected to lead to changes in life cycle events, and these have been recorded for many species¹⁷. The species, which fail to adapt under altered temperature, will either get extinct or shift to different altitudes or latitudes naturally. Groffman et al. found that in terrestrial environments, plants and animals moved toward higher elevations at the rate of 0.011 km per decade and to higher latitudes at the rate of 16.9 km per decade¹⁸. With the rise in atmospheric temperatures, forest fires are likely to get more intense and extensive and may result in significant ecosystem changes that would affect biodiversity through species loss or changes in species composition¹⁹. The rise in sea level is also a significant threat to coastal plant communities such as mangroves and mangrove associates.

Animals: Due to global warming, animals, which have been adapted for millions of years to live in a particular area of the planet, are under severe stress due to the sudden transformation in global temperature. It leaves only three

options to animals to adapt, move to suitable areas or die. Many animals have shifted their geographic ranges in response to rapid changes in temperature and precipitation regimes, generally pole ward and toward higher elevations. Groffman et al. found that in terrestrial environments, plants and animals moved toward higher elevations at the rate of 0.011 km per decade and to higher latitudes at the rate of 16.9 km per decade¹⁸. Recent studies indicate that climate change has the potential to alter both the migratory routes and timings of different species, which may also increase conflicts with humans²⁰. The Arctic is warming about twice as fast as the global average, causing the ice that polar bears (*Ursus maritimus*) depend on to melt away. Loss of sea ice also threatens the bear's main prey, seals, which need the ice to raise their young. The fast-encroaching sea, driven by global change, has also eaten away at the hunting grounds of the Sundarbans' famous Bengal tigers (*Panther tigris*), pushing them to target the villagers' livestock — and, increasingly, the villagers themselves. The oceans absorb most of the excess heat from greenhouse gas emissions, leading to rise in average ocean temperatures. This increase in average ocean temperature not only affects several marine species but also affects the entire ecosystem. Such elevated temperature causes coral bleaching, damaging the breeding grounds of several marine fishes and mammals. One of the other important pathways by which climate change affects African biodiversity is by reducing the amount and availability of suitable habitats and by eliminating species that are vital for the species in question^{16,21}. A loss of species from an ecosystem not only affects that species but also influences the interactions with other species as well as the general ecological functions, which are otherwise expected from these interactions.

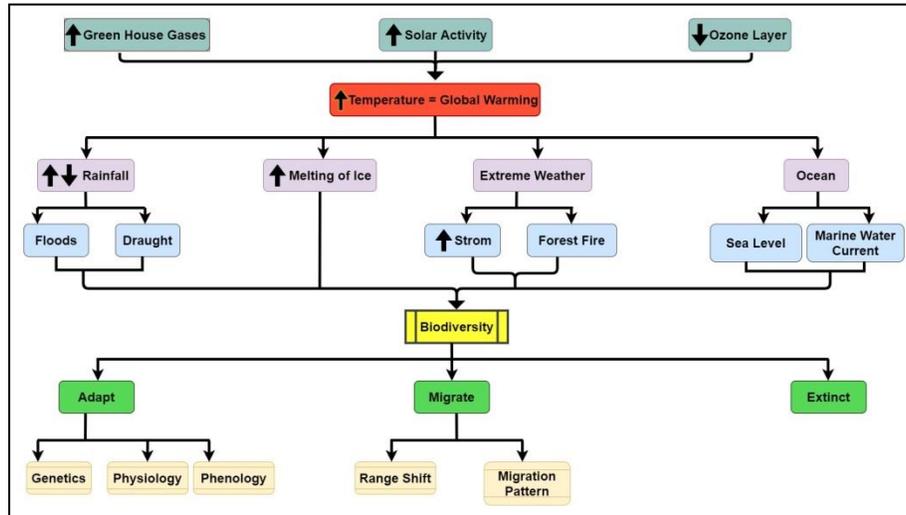
Phenology: Phenological events include changes in different stages of the lifecycle of plants and animals, which includes the growth of leaves, flowering in plants, and alterations in the timing of spawning, reproduction, and migrations in animals^{16, 22}. African elephants (*Loxodonta africana*), breeds year-round, but dominant males mate in the wet season and subordinate males breed in the dry season. Severe climatic conditions aroused due to global warming may therefore create genetic variations in population, which may bottleneck certain population²³.

Agriculture and Fishery: Agriculture and fisheries depend directly on the climatic conditions. Increases in temperature and/or carbon dioxide (CO₂) can increase some crop yields in some places, but changes in the frequency and severity of droughts and floods could pose challenges for farmers. In the meantime, hotter water temperatures are probably going to cause the territory scopes of many fish and shellfish species to move, which could upset environments. In general, the environmental change could make it increasingly hard to develop crops, raise creatures, and catch fish in same ways and same spots from we have done previously. Gebreegziabher et al. also reported that low adaptive capacity, geographical location, and topography make the region highly vulnerable to crop failure due to adverse impacts of climate change²⁴.

Disease and Pests: The impacts of climate-induced biodiversity change on human, animal, and plant health are of concern because of the potentially high cost associated with both emerging zoonotic diseases and changes in the distribution of existing disease vectors²⁵. Naturally, various pathogens are maintained either in single or multiple host species²⁶, if the only host or any one particular host species population gets severely affected, can cause zoonotic disease outbreaks and in no time spread locally or globally causing damage to civilization. Keesing et al. had shown a similar type of observations in the outbreak of Bovine Tuberculosis²⁷.

Overall, biodiversity is going to decline both qualitatively and quantitatively in future due to multiple anthropogenic and few natural pressures. Global warming is one of the causes affecting biodiversity differently across various regions globally. Since its cause and effects are seen across the planet, its mitigation becomes difficult but not an impossible task. These mitigation measures though won't stop but can be slowed down by reducing the causes of global warming and enhancing the sinks of the same. Some of the required actions include increasing carbon sequestration, use of low carbon or carbon-free energy resources, reducing the generation of greenhouse gases, use of alternate renewable energy resources, afforestation, effective land and forest use, etc by involving all the possible stakeholders across the world.

Figure 1: Impact of global warming on biodiversity: An increased level of greenhouse gases, along with enhanced solar activity and thinning of ozone layer causes global warming, which affects rainfall, melting of ice, extreme weather. These changes impacts biodiversity to adapt, migrate or extinct.



V. Positive Impact of Lockdown on Environment

Since January 2020, almost all countries of the world are facing COVID-19 pandemic, but on the other hand, the environmental restoration process is also going on. Nationwide lockdown is being adopted by many countries to avoid the transmission of COVID-19. Almost all industrial activities, public transportation, and public activities prohibited as well as hotels, restaurants, school, colleges and offices were closed in this lockdown. In several recent studies, the effect of lockdown measures on atmospheric pollution in the number of cities worldwide has been investigated. The pollution level in cities across the world significantly slowed down in this lockdown period, due to the forced restrictions in industrial and commercial activities and limitations in transportations. It gives us a chance to learn more about the human impact on the environment.

In addition to air pollution, GHGs emissions have also dropped throughout the world. Only transportation contributes 23% of global carbon emissions, while in context with the GHG emissions, 72% and 11% of the transport sector’s GHG emissions is added by the driving and aviation respectively. These emissions have temporarily fallen in locked down countries, due to the restrictions in transportation. Annually 9,000-10,000 million metric tons of CO₂, the primary component of GHGs, is emitted due to aircraft, trains and other transportation²⁸. During the lockdown, near about 900-1,000 million metric tons of CO₂ emission is going to decrease. According to European Union Emission Inventory Report (2011), annually 22,000-40,000 million metric ton CO and 800-900 million metric tons NxO, the indirect GHGs, are emitted. During the lockdown, CO and NxO levels have decreased by 220-400 million metric tons and 80-90 million metric tons respectively in European countries. The 95% of the SO_x emitted from the combustion of fossil fuel is sulphur dioxide, another indirect GHG. Nearly 8,000-9,000 million metric ton of sulfur oxide gas is emitted from ships. During the lockdown, SO_x levels have decreased by 800-900 million metric tons in European countries²⁹.

The satellite data from NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) indicate that air pollution (mostly NO₂ emissions) in countries such as China, Europe, Italy, France, USA, and Spain, etc. have reduced up to 30% (NASA and ESA, 2020). During the first two weeks of lockdown, in 27 countries drastic reduction in ground-level nitrogen dioxide (NO₂: -29 % with 95% confidence interval -44% to -13%), ozone (O₃: -11%; -20% to -2%) and fine particulate matter (PM_{2.5}: -9%; -28% to 10%) were noted using data obtained from satellite and a network of >10,000 air quality stations³⁰.

In several recent studies, the reductions in some direct and indirect GHGs like CO₂, NO_x, CO, and SO₂ were recorded throughout the world. He et al. had found that the air quality improved within a few weeks of lockdown by

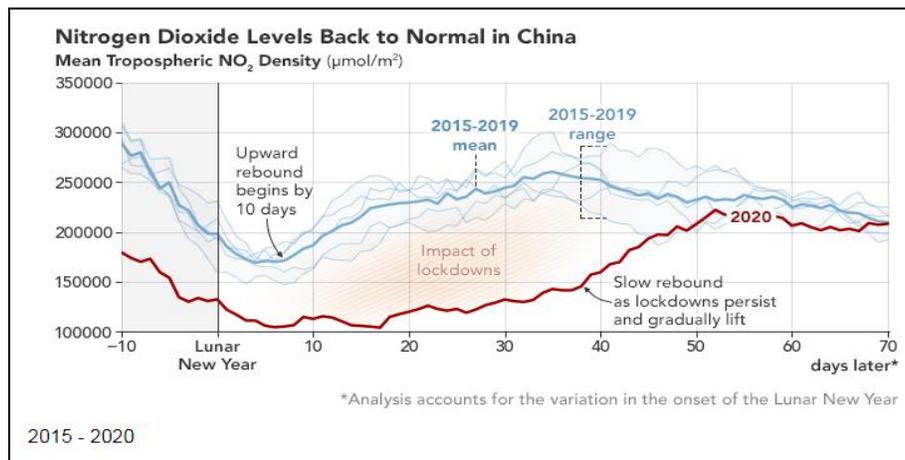
around 25% relative to the same season in 2019³¹. On average, the air quality index (AQI) in China decreased by 7.80%, and air pollutants (i.e., SO₂, NO₂, and CO) decreased by 6.76%, 24.67%, and 4.58%, respectively³². According to NASA scientists, the reduction in NO₂ pollution was first observed near Wuhan (30%), but spread across the rest of the country, and then worldwide (NASA, 2020). The reduction in CO₂ emissions also observed by 25% in China and by 6% worldwide³³. A drastic reduction on NO (up to -77.3%), NO₂ (up to -54.3%), and CO (up to -64.8%) concentrations was observed in the urban areas of Brazil during the partial lockdown. The level of pollutants related to light-duty vehicular emissions like CO showed the most significant reductions (30.3–48.5%), even in the first weeks of lockdown³⁴. There were also substantial reductions in CO and NO₂ concentrations by 49% and 35%, respectively in Kazakhstan³⁵. Tobias et al. demonstrated the most significant reduction in the concentration of Black Carbon (BC) and NO₂ (-45 to -51%) pollutants in Spain. The differences between the concentrations of SO₂ and NO₂ in Salé City (Morocco) were respectively 49% and 96%, recorded before and during the lockdown period³⁶. During the lockdown air quality of megacity Delhi, one of the most polluted megacities of the globe based on environment performance index (WHO, 2016), is significantly improved in lockdown months (last week of March to May). The concentrations of NO₂ and CO have reduced to -52.68% and -30.35% respectively. About 40% to 50% improvement in air quality in Northern India is identified just after four days of commencing lockdown³⁷.

In this lockdown measures, many industries and companies shut down their production units as well as offices. Ultimately, the electricity demand has gone down in the commercial and industrial sectors, while domestic consumption has gone up. It causes a noticeable drop in coal consumption in power stations. This contributed to a tremendous drop in air pollutants like CO₂, CO, and nitrous oxides. In Italy, the carbon footprint (CF) due to the energy consumptions during the March and April 2020 reduced approximately -20% when compared to the average CF estimated for March and April in the time frame 2015–2019. During the lockdown in Italy, an overall saving of GHGs is in between ~5.6 and ~10.6 Mt CO₂e³⁸. Even, the reduction in Chlorofluorocarbons (CFCs) emissions may also occur due to limited use of ACs and refrigerators in locked-down corporate offices. Ultimately, these reductions in GHGs and CFCs will help in reformation of the Ozone layer.

Another remarkable positive impact of COVID-19 on the environment has been observed in Venice, Italy. The water in Venice's canals became cleaner as compared to the pre-lockdown period; due to drop down in the tourist's numbers as well as motorboats, sediment churning, and other water pollutants efficiently. Similarly, in almost all tourist places, tourist's numbers are reduced, and it may help in the restoration of the environment and biodiversity.

The effect of nationwide lockdown on the environment may not be clearly understood due to a short duration, and it may be temporary. In recent data of satellite pictures of NASA, it can be clearly seen that nitrogen dioxide levels back to normal in China after a lockdown (Fig 2). But governments and individuals should learn from this lockdown on how to reduce pollution on a long term basis. Even 2-3 days complete worldwide lockdown per year in the future may help to restore the environment.

Figure 2: NO₂ level back to normal in China after lockdown (NASA 2020): Redline indicates the NO₂ level of the year 2020; it clearly indicates that NO₂ level is dropped down during lockdown period but it back to normal that is Mean NO₂ level of 2015-2019 (Blue line) after reopening China.



VI. Negative Impact of Lockdown on Environment

Due to lockdown events, the worldwide positive impact is seen on the environment, but some cases of negative impact on the environment also found. There is a tremendous reduction in the level of many air pollutants throughout the world; but on the other hand, few studies cited that there is an increase in ozone concentration due to a reduction in NO_x concentration^{34, 37, 39}. During the lockdown in 2020, the daily O₃ mean concentrations increased at urban stations by 24% in Nice, 14% in Rome, 27% in Turin, 2.4% in Valencia, and 36% in Wuhan - as compared to the same period in 2017–2019. Because the lockdown caused a substantial reduction in NO_x in all cities (~56%)⁴⁰.

The vast amount of medical wastes in the environment is generating as for precaution the peoples are wearing a mask, gloves, and using hand sanitizer on a daily basis. The empty bottles of hand sanitizers, the used surgical masks, gloves, PPE kits, and another medical waste of COVID patients is adding a bulk mass to medical wastes. According to the recent survey of an environmental NGO Ocean Asia, a 100-meter stretch of beach is covered with used masks in Hong Kong during the lockdown period. On a single day, 24 February 2020, 200 tons of clinical trash has produced in Wuhan city of China, which is four times more waste as compared to pre-COVID days. When such a vast amount of medical waste discarded in the ocean or on land, animals could accidentally eat this, and it may cause their death.

VII. Perspectives

In order to save loss of biodiversity and adverse effects on humans, every individual needs to take efforts by changing approach and actions towards environment. The scientific community should use advances in the technology to minimize the impact of global warming and to develop a better world. Several measures can be taken across all the countries, viz., making use of cleaner energies, capping GHG emission permissions, improving land use pattern for conservation of nature. It can also be achieved by providing better education, controlling population growth pattern to bring overall change in the society and most importantly creating space and opportunities for ecosystems to self-restore themselves.

VIII. Conclusion

Global warming, a gradual rise in the planet's average temperatures, is caused by increased concentrations of greenhouse gases in the atmosphere, mainly from human activities such as pollution, urbanization, industrialization, altered land-use and land-cover pattern, selective exploitation of natural resources, etc. Industrialization and urbanization on one hand has led to increase in production of goods and services which are easily available to people at cheaper rates, but on other hand rapid population growth associated with mismanagement of urbanization and industrialization has caused global warming because of the increased levels of harmful emissions. Though slow, this

global warming has altered climate in last two centuries, and is an ongoing process. Global warming is a big hazard and appropriate measures must be taken to tackle this serious problem. It is affecting biodiversity in various ways, which is a reason for economic and ecological loss to several developing countries and developed countries. If this warming is not checked globally, the mankind can witness worse types of disasters, including storms, heat waves, floods, and droughts. Since the beginning of 2020, almost all countries have enforced lockdown. Almost all industrial activities, public transportation, and other activities have been either completely prohibited or offer limited services. This has resulted in reducing the levels of many pollutants, thus improved the quality of environment. Nations around the world are upping their game in the fight against climate change, but the process will become effective only when all individuals participate in working out comprehensive programs initiated globally. Innovative solutions must be brought forward to end this hazard once and forever.

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