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ADDRESSING THE TRIPLE PLANETARY CRISES: STRATEGIES AND POLICIES

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Abstract

The world faces three interconnected planetary crises: climate change, biodiversity loss, and air pollution. These challenges pose significant threats to human health, ecosystem stability, and economic prosperity. Addressing these crises requires a comprehensive, integrated approach that leverages strategic policies and innovative solutions to mitigate their impacts and promote sustainable development. Climate change, driven by greenhouse gas emissions, is causing global temperature rises, extreme weather events, and sea-level rise. These changes disrupt ecosystems, impair food and water security, and increase health risks. Concurrently, biodiversity loss, accelerated by habitat destruction, pollution, and climate change, diminishes ecosystem services essential for human well-being, including clean air, water, and soil. Air pollution, primarily from industrial activities, transportation, and residential heating, contributes to respiratory and cardiovascular diseases, exacerbating the public health burden. This article explores strategic approaches and policy solutions to tackle these intertwined crises. Key strategies include promoting renewable energy, enhancing energy efficiency, and implementing carbon pricing mechanisms to reduce greenhouse gas emissions. Protecting and restoring natural habitats, coupled with sustainable land-use practices, are vital for conserving biodiversity and maintaining ecosystem services. Addressing air pollution requires stringent emissions standards, the adoption of cleaner technologies, and urban planning that prioritizes green spaces and public transportation. Policy integration across sectors and scales is crucial for effective implementation. International cooperation, informed by scientific research and guided by frameworks like the Paris Agreement and the Convention on Biological Diversity, is essential to align efforts globally. Additionally, public awareness and community engagement are fundamental in driving behavioural changes and supporting policy measures. By adopting a holistic approach that addresses climate change, biodiversity loss, and air pollution simultaneously, we can safeguard environmental health and ensure a sustainable future. This article highlights the urgency of coordinated action and the need for innovative policies to navigate the complexities of the triple planetary crises.

Keywords: *Climate change, biodiversity loss, air pollution, sustainable development, environmental revolution*

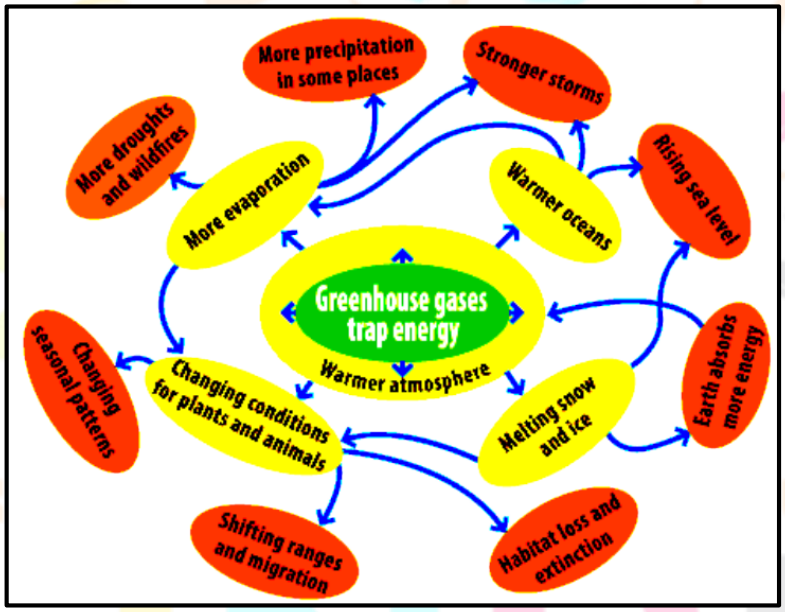
I. Introduction

The triple planetary crisis refers to the three main interlinked issues that humanity currently faces: climate change, biodiversity loss and pollution (Air). Each of these issues has its causes and effects and each issue needs to be resolved if we are to have a viable future on this planet. NASA defines climate change as significant, long-term alterations in Earth's climate patterns, including temperature and precipitation, caused by human activities like fossil fuel combustion and deforestation, as well as natural factors. The IPCC describes it as identifiable changes in the climate's state, including its mean and variability, persisting for decades or longer due to natural processes and human activities. The UNFCCC attributes climate change to human activities that modify the global atmosphere's composition, in addition to natural climate variability. The WMO outlines climate change as variations in temperature, precipitation, humidity, atmospheric pressure, and other atmospheric conditions over time scales from decades to millions of years, which can be natural or human-induced and impact ecosystems, societies, and economies. The EPA sees climate change as significant, lasting changes in Earth's climate patterns, including temperature, precipitation, and sea level, caused by human activities like fossil fuel burning,

deforestation, and industrial processes, as well as natural factors. According to NOAA, climate change is long-term shifts in temperature, precipitation, and other atmospheric conditions occurring over decades or longer due to natural variability and human activities like fossil fuel burning, deforestation, and land use changes.

Climate change (Figure 1) is the most urgent challenge humanity faces today. It involves long-term shifts in temperatures and weather patterns that will ultimately transform the ecosystems sustaining life on Earth. Human activities are the primary drivers of climate change, with energy use, industry, transportation, buildings, and agriculture being major sources of greenhouse gas emissions. The impacts of climate change are already evident through more intense and severe droughts, water shortages, wildfires, rising sea levels, flooding, melting polar ice, extreme storms, and declining biodiversity. Climate change is affecting human health in multiple ways, threatening essential elements of well-being such as clean air, safe drinking water, nutritious food, and secure shelter. It risks reversing decades of progress in global health (**Box 1**). Between 2030 and 2050, climate change could lead to approximately 250,000 additional deaths annually from malnutrition, malaria, diarrhoea, and heat stress. Direct health damage costs are projected to be between US$ 2–4 billion per year by 2030. Developing countries with weak health infrastructure will struggle the most without support to prepare and respond. Greenhouse gas emissions from fossil fuel extraction and combustion are major contributors to both climate change and air pollution. Policies and individual actions, such as changes in transport, food, and energy use, can reduce greenhouse gas emissions and offer significant health benefits, particularly by reducing air pollution. For instance, transitioning away from polluting energy sources or encouraging public transportation and physical activity can lower carbon emissions and decrease the burden of air pollution, which causes 7 million premature deaths annually (www.who.int).

Figure 1 – Climate Connections



***Source**: Michael Shafer and Phrao Chiang Mai (2017)*

Box 1 - Key facts on Climate Change

- ✓ Climate change is directly contributing to humanitarian emergencies from heatwaves, wildfires, floods, tropical storms and hurricanes and they are increasing in scale, frequency and intensity.
- ✓ Research shows that 3.6 billion people already live in areas highly susceptible to climate change. Between 2030 and 2050, climate change is expected to cause approximately 250000 additional deaths per year, from undernutrition, malaria, diarrhoea and heat stress alone.
- ✓ The direct damage costs to health (excluding costs in health-determining sectors such as agriculture and water and sanitation) is estimated to be between US$ 2–4 billion per year by 2030.
- ✓ Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond.
- ✓ Reducing emissions of greenhouse gases through better transport, food and energy-use choices can result in very large gains for health, particularly through reduced air pollution.

***Source**: WHO, 2023*

Climate change is also eroding key social determinants of health, including livelihoods, equality, and access to healthcare and social support. These climate-sensitive health risks disproportionately affect the most vulnerable and disadvantaged groups, such as women, children, ethnic minorities, low-income communities, migrants or displaced persons, the elderly, and individuals with pre-existing health conditions. (**Figure 2**).

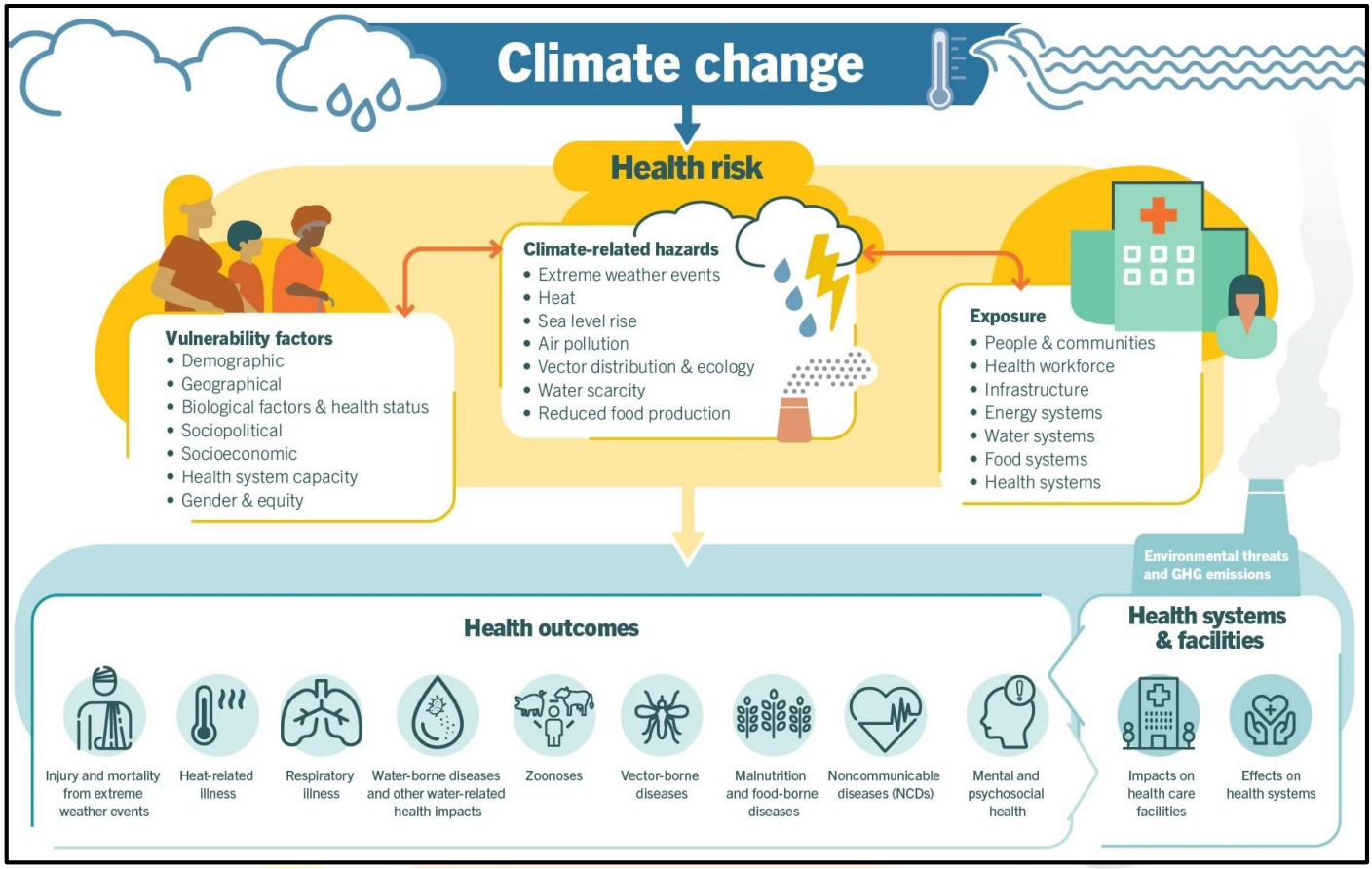
WHO data shows that 2 billion people lack access to safe drinking water, and 600 million people suffer from foodborne illnesses each year, with children under 5 accounting for 30% of these fatalities. Climate stressors increase the risks of waterborne and foodborne diseases. In 2020, 770 million people faced hunger, primarily in Africa and Asia. Climate change impacts food availability, quality, and diversity, worsening food and nutrition crises.

II. Climate change, Biodiversity and health

Health is defined as complete physical, mental, and social well-being, not merely the absence of disease. Biodiversity, which encompasses the variety of living organisms across ecosystems, is vital for ecosystem functioning and provides essential goods and services for human health. The connections between biodiversity and health are evident across different scales and are influenced by various policies and activities. Key drivers of biodiversity loss—such as land-use change, habitat destruction, pollution, invasive species, and climate change—directly affect human health. Human health is also influenced by social, economic, and environmental factors, with different roles and impacts for men and women in biodiversity conservation. Integrative approaches like the ecosystem approach, eco-health, and One Health are important for bridging social and natural sciences. Ecosystems provide clean water, which is crucial for health, but freshwater systems face threats from water demands and human activities, impairing water quality and incurring social and economic costs. Water infrastructure affects biodiversity, livelihoods, and health in both positive and negative ways. Ecosystems help regulate air quality and biodiversity components act as bioindicators for monitoring. Biodiversity in agriculture is key for food security and health; its loss increases vulnerability and reduces sustainability. Pesticides harm wildlife, human health, and agricultural biodiversity, while effective pollination is critical for food security and adapting to climate change.

Globally, agricultural practices are increasingly utilizing biodiversity. Access to wildlife in various ecosystems is crucial for human nutrition, with declines posing significant health risks, especially in low- and middle-income countries. Harvesting wild edible plants and animals presents both benefits and risks. Food-based approaches are essential for combating malnutrition and can also help mitigate climate change and reduce biodiversity pressures. Reduced contact with nature affects human microbiota, leading to immune dysfunction and disease. Understanding these factors can guide gut-related therapies. Innovative designs may enhance exposure to beneficial microbial biodiversity. Recognizing microbial diversity as an ecosystem service can improve public health and conservation efforts. Pathogens can both benefit and threaten health and biodiversity. Human activities increase disease risks, and high-biodiversity areas may protect against disease transmission. Rising invasive species and climate change exacerbate health risks. Biodiversity is crucial for discovering new medicines and addressing health challenges.

Figure 2 - An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors. Climate change impacts health both directly and indirectly and is strongly mediated by environmental, social and public health determinants.



***Source**: WHO, 2023*

Understanding biodiversity and ecology is essential for addressing epidemic diseases and gaining insights into life processes. Traditional medical knowledge, evolving with local contexts, encompasses medicines, food, rituals, and customs. Wild-sourced medicinal and aromatic plants, increasingly traded globally, are used in traditional medicine and industries like pharmaceuticals and cosmetics, though threats to these resources are rising. Sustainable use of these resources supports biodiversity, livelihoods, and health, focusing on affordability and cultural acceptability. Developing sui generis models can protect indigenous rights over traditional knowledge. Integrating traditional medical care into public health strategies and interacting with nature can improve mental health and treat behavioural issues. Biodiversity is central to cultures and well-being, with changes impacting community health, especially where ecosystem services are vital. While local links between health, culture, and biodiversity are documented, universal evidence is limited. Pharmaceuticals and Active Pharmaceutical Ingredients (APIs) harm biodiversity and human health. Antibiotic misuse leads to resistant bacteria, and endocrine-disrupting chemicals affect wildlife and human health. Climate change exacerbates health impacts and affects agriculture, food nutrition, and fisheries.

Disasters can arise from impacts on critical ecosystems or the collapse of essential ecosystem services, leading to conflicts over resources and further ecosystem damage. Building disaster-resilient societies depends on maintaining resilient ecosystems and sustainable service delivery. Biodiversity enhances ecosystem resilience, aiding climate change adaptation and disaster mitigation. Growing human populations and consumption pressure the biosphere, threatening biodiversity and health. Transformative change is needed to achieve food security, reduce poverty, protect biodiversity, address climate change, and meet other development goals. Behavioural changes are essential for improving health and protecting biodiversity. Strategies should integrate health and biodiversity, involving local communities and using common metrics and tools for a unified evidence base. Developing precautionary policies that value ecosystem services and leverage biodiversity-health linkages is crucial. Measuring health impacts of ecosystem changes and using economic valuation can guide resource allocation and attract stakeholders. More research is needed on biodiversity-health linkages. Integrating these concerns into the post-2015 development agenda and evaluating interactions between sustainable development goals are essential. Health is a fundamental human right and an indicator of sustainable development, while conserving biodiversity is vital for ecosystem function and health services.

Biodiversity delivers essential ecosystem services vital for human well-being now and in the future. Climate plays a key role in ecosystem functioning, impacting human health both directly and indirectly through its effects on terrestrial and marine ecosystems **(Box 2)**. Ocean acidification, driven by atmospheric carbon levels, affects marine biodiversity. Terrestrial biodiversity is influenced by climate variability, such as extreme weather events

(e.g., droughts, floods), which directly impact ecosystem health and the availability of goods and services. Long-term climate changes can alter ecosystems' viability and health, leading to shifts in the distribution of plants, pathogens, animals, and human settlements. **(Box 3). Biodiversity loss**, which involves the decline or disappearance of animals, plants, and ecosystems, is driven by factors such as overfishing, habitat destruction (e.g., deforestation for development), and desertification caused by climate change. Biodiversity forms the foundation of life on Earth, connecting all living things. Its loss threatens food supplies and access to clean water, jeopardizing our future on the planet. The right to health is universally recognized, and healthy ecosystems are crucial for sustaining life and its processes. While our biological resources are shaped by both natural and human influences, increasing anthropogenic pressures and global changes are transforming them. When human activities jeopardize these resources and ecosystems, they risk the livelihoods, health, and well-being of millions. Well-functioning ecosystems provide clean air, fresh water, medicines, and food security while also mitigating disease and stabilizing the climate. However, according to a joint report by the World Health Organization (WHO) and the Convention on Biological Diversity (CBD), biodiversity is being lost at unprecedented rates, impacting human health globally. The loss of biodiversity can directly affect human health if ecosystem services fail to meet societal needs and can indirectly influence livelihoods, income, local migration, and potentially contribute to political conflict.

Box 2 – Key facts on Heat and Health

- ✓ Heat is a significant environmental and occupational health hazard, leading to heat stress, the foremost cause of weather-related fatalities. It can aggravate existing conditions such as cardiovascular disease, diabetes, mental health issues, asthma, and heighten the risk of accidents and the spread of certain infectious diseases. Heatstroke, a medical emergency, carries a high fatality rate.
- ✓ Due to climate change, the number of individuals exposed to extreme heat is rapidly increasing across all regions of the world. For those over 65, heat-related deaths rose by approximately 85% from 2000-2004 to 2017-2021. Studies from 2000-2019 indicate about 489,000 heat-related deaths annually, with 45% in Asia and 36% in Europe. In Europe alone, the summer of 2022 saw an estimated 61,672 excess deaths due to heat. Severe heatwave events can cause sharp increases in mortality; for instance, 70,000 people died during the June-August heatwave in Europe in 2003, and a 44-day heatwave in the Russian Federation in 2010 led to 56,000 excess deaths.
- ✓ Heat vulnerability is influenced by physiological factors like age and health status, as well as exposure factors such as occupation and socio-economic conditions. The adverse health effects of heat are predictable and largely preventable with targeted public health and multi-sectoral policies and interventions. WHO has provided guidance for public health institutions to identify and manage extreme heat risks. Addressing climate change, along with comprehensive preparedness and risk management, can save lives both now and in the future.

***Source**: WHO (2024)*

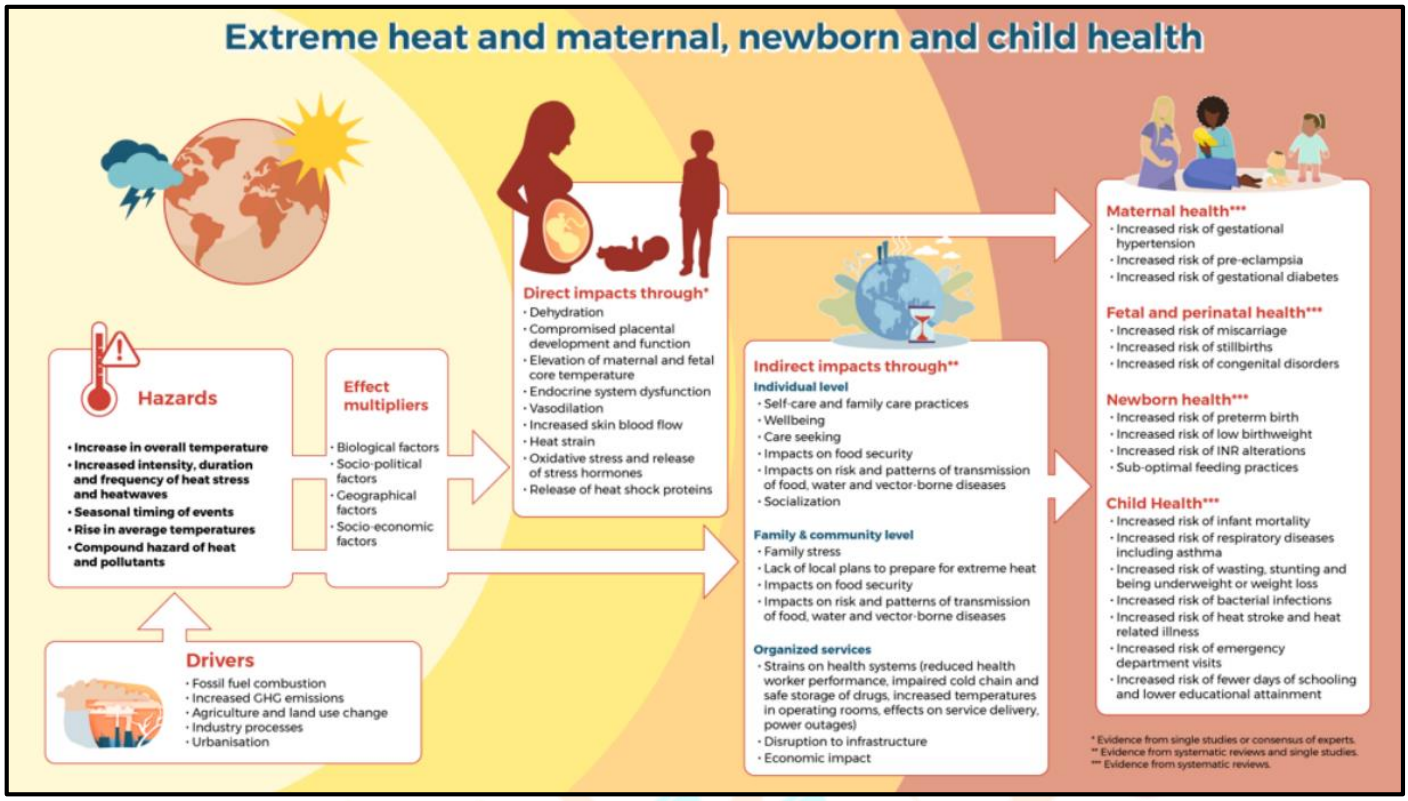
Box 3 - Key Facts on Biodiversity and Health

- ✓ Biodiversity offers numerous essential goods and services for life on earth. Effective natural resource management can establish a community's baseline health status. Environmental stewardship helps secure livelihoods and enhance community resilience, while the loss of these resources can lead to increased morbidity and mortality.
- ✓ Biodiversity underpins human and societal needs by providing food and nutrition security, energy, medicinal and pharmaceutical development, and freshwater, all of which are essential for good health. Additionally, it supports economic opportunities and leisure activities that enhance overall well-being.
- ✓ Factors such as land use change, pollution, poor water quality, chemical and waste contamination, climate change, and other causes of ecosystem degradation contribute to biodiversity loss and pose significant threats to human health.
- ✓ Human health and well-being are closely linked to the health of local plant and animal communities and the integrity of the ecosystems they form.
- ✓ Infectious diseases result in over one billion human infections and millions of deaths annually worldwide. Approximately two-thirds of known human infectious diseases are zoonotic, with most recent emerging diseases associated with wildlife.

***Source**: WHO (2015)*

Pregnant and postpartum women, as well as newborns and children, are particularly vulnerable to climate risks due to various physiological, clinical, and behavioral factors **(Roos et al. 2021)**. While climate hazards like extreme heat, poor air quality, drought, heavy precipitation, and wildfires all heighten this vulnerability, this report will specifically address the impacts of extreme heat (**Rylander et al. 2013**). Infants and children face greater climate-related health risks than adults because of their ongoing physiological and cognitive development and their reliance on caregivers **(Nakstad et al. 2022; Perera et al. 2022)**. Strong epidemiological evidence links high temperatures and air pollution to increased risks of adverse outcomes such as stillbirths, preterm births, low birth weight, and infant mortality. **(Roos et al. 2021; Rylander et al. 2013)**

Figure 3 – Conceptual Framework of Climate Change Impacts on MNCH.



***Source**: WHO (2024)*

Biodiversity, climate change, and health are closely interconnected. Healthy ecosystems provide essential benefits like clean air, water, and soil. Climate change disrupts these ecosystems by affecting water systems, degrading land, reducing biodiversity, impacting agriculture, and causing ocean acidification. Additionally, the loss of biodiversity and ecosystems worsens climate change by releasing stored carbon and reducing natural carbon sinks. **(WHO, 2015; UK NEA, 2021)**

The conceptual framework aims to depict the direct (pathophysiological mechanisms) or indirect (individual, community and health services) pathways through which heat exposure (hazards) can lead to adverse MNCH outcomes. Underlying health conditions, geographical location, socio-economic and socio-political factors can all additionally multiply the effect of extreme heat on MNCH.

As much as 24% of deaths are estimated to be attributable to environmental risks to health that are largely preventable **(Prüss-Ustün et al. 2019)**. Acting on these environmental risks can be key to reducing many communicable and noncommunicable diseases and injuries. As much as 31% of deaths from ischaemic heart disease, 25% of strokes, 20% of lung cancers, 43% of acute respiratory infections and 33% of cases of Chronic Obstructive Pulmonary Disease (COPD) could be prevented by reducing air pollution. In addition, 69% of diarrhoeal diseases could be prevented through providing safer Water, Sanitation and Hygiene (WASH); 40% of road traffic injuries could be reduced by changing the built environment and land use, and increasing occupational safety and traffic regulations; and 73% of unintentional poisonings could be prevented by improving the management of chemicals and restrictions regarding their use **(WHO, 2021; WHO, 2023)**. Thus, taking preventive action by creating healthier environments should be an important component of most disease control strategies. Essential to ensuring good health are clean indoor and outdoor air, a stable climate, adequate WASH facilities, the safe use of chemicals, protection from radiation, sound waste management, healthy and safe workplaces, health-supportive cities and built environments, sustainable and healthy diets, and the preservation of biodiversity and ecosystems.

Climate change impacts health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods; increased malnutrition, as many current food systems do not deliver healthy and sustainable diets; increases and alterations in zoonoses and food-, water- and vector-borne diseases; and mental health issues through, for example, fear about the future or the damage to and loss of natural habitats. Furthermore, climate change is undermining many of the social determinants of good health, such as livelihoods, equality and access to health care and social support structures. The indirect effects of climate change result from, for example, food, nutrition and water insecurity; increasing transmission of vector- and water-borne diseases; the disruption of health care systems and water and sanitation supplies; increased health inequalities; and climate-induced displacement and migration of communities. There are several contributors to global climate change, including fossil fuel combustion and industrial processes, food systems (including related agricultural practices, deforestation and other land-use changes and consumption),

transportation and energy use. In addition, the health sector is a significant contributor to climate change, being responsible for approximately 5.2% of global greenhouse gas (GHG) emissions **(WHO, 2023; Romanello et al. 2022)**. All people are exposed to the hazardous effects of climate change, but some groups are particularly vulnerable. This includes people living in small island developing states and other coastal regions; megacities; and mountainous, polar and drought-prone regions; as well as children, Indigenous communities, ageing populations, people with underlying health conditions and those living in low-income countries **(WHO, 2023)**

Actions to address the health risks of climate change encompass both mitigation and adaptation.

(a) Mitigate climate change by reducing or preventing emissions of GHGs; many of these actions have co-benefits, including for health; for example, they also reduce air pollution, save energy, improve the healthfulness of diets or help to increase physical activity among populations by introducing greener mobility options. Some co-benefits are described in other sections of the Compendium (such as Chapter 2. Air Pollution, Chapter 9. Safe Environments and Mobility, Section 12.1 Cities and Other Settlements, Section 12.2 Housing and Section 10.2 Healthy Diets and the Environment).

(b) Adapt and increase resilience to climate change by enhancing the ability to anticipate, respond to, cope with and recover from the effects of climate change. This is necessary not only to maintain essential functions of the health system but also to continue improving population health even in the face of an unstable and changing climate.

Many actions will achieve both decarbonization and resilience-building goals. For example, the increased use of renewable energy in healthcare facilities can reduce GHG emissions and improve the climate resilience of the facility.

III. Air Pollution

Air pollution is the leading cause of disease and premature death worldwide, with over seven million people dying early each year due to pollution. Remarkably, nine out of ten people globally breathe air with pollutant levels exceeding WHO guidelines. Pollution sources include traffic, factories, wildfires, volcanoes, mold, and indoor combustion from polluting fuels, which alone caused an estimated 3.8 million deaths in 2016. Air pollution, from any chemical, physical, or biological agent, alters the atmosphere's natural characteristics. Major sources include household combustion devices, vehicles, industrial facilities, and forest fires. Key pollutants of concern are particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, all of which contribute to respiratory and other diseases. According to WHO, nearly 99% of the global population inhales air that surpasses WHO safety limits, with the highest exposures in low- and middle-income countries. Air quality is linked to climate and ecosystems, as many pollution drivers, like fossil fuel combustion, also emit greenhouse gases. Thus, policies to reduce air pollution can simultaneously benefit health and climate, reducing disease burden and aiding climate change mitigation.

Combined outdoor and indoor air pollution causes around 7 million premature deaths annually, primarily from stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections. Common sources include cookstoves, vehicles, industrial facilities, and forest fires. Key pollutants with significant health impacts are particulate matter (PM2.5 and PM10), ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO), though air pollution consists of many more pollutants (**WHO, 2020**).

Air pollution, driven primarily by human activities since industrialization, is predominantly caused by combustion processes, including the burning of fossil fuels and biomass for energy **(WHO, 2021)**. Key sources include transportation, industry, power generation, biomass burning (e.g., forest fires, agricultural waste), and construction activities **(WHO, 2020; WHO, 2019)**. Additionally, pollutants can travel long distances, exacerbating local urban pollution. Over 90% of people live in areas with unhealthy air, leading to approximately 4.2 million deaths annually. The major health impacts of ambient air pollution include ischemic heart disease (38% of deaths), stroke (20%), and chronic obstructive pulmonary disease (43%). Children and older adults are especially vulnerable, with air pollution linked to respiratory issues, adverse birth outcomes, developmental problems, obesity, and increased mortality **(WHO, 2018; UNICEF, 2017)**.

Nearly half of the global population lives in households exposed to smoke from cooking with dirty fuels and technologies, with women and young children particularly affected due to their proximity to cooking areas **(WHO, 2018)**. Fine particulate matter (e.g., PM2.5 and PM10) from this pollution causes an estimated 3.8 million deaths annually (2016 data). Of these deaths, 27% are attributed to ischemic heart disease, 18% to stroke, and 54% to chronic obstructive pulmonary disease. Household air pollution accounts for 45% of pneumonia deaths in children under 5 and 28% in adults. Additionally, small particulate matter and other pollutants from indoor smoke cause airway inflammation, impairing immune function and blood oxygen levels. Second-hand tobacco smoke and radon exposure contribute to 1.3 million and 84,000 deaths per year, respectively (2019 data).

Tobacco causes significant harm to both the environment and human health, contributing to over 8 million deaths annually. Of these, more than 7 million are due to direct tobacco use, while around 1.3 million deaths result from second-hand smoke, which causes cancer and various diseases. Tobacco smoke also pollutes the air and leaves

harmful residues on surfaces, affecting both smokers and non-smokers. In the U.S. alone, cigarette smoking cost $600 billion in 2018, including $7 billion due to lost productivity from second-hand smoke-related deaths. The full impact of tobacco on health, the environment, and productivity is likely underestimated and requires further research. Tobacco smoke contains over 7,000 chemicals, many of which are carcinogenic. Children and infants are especially vulnerable to the health risks of second-hand smoke, which is most common in private settings like homes and disproportionately affects women and children. **(Institute for Health Metrics and Evaluation, 2023; Matt et al. 2023, WHO, 2017; WHO, 2022; WHO, 2023)**

Growing tobacco is resource-intensive, requiring heavy use of pesticides, fertilizers, and water, which leads to soil degradation and reduced land productivity for other crops. Tobacco farmers face health risks, including green tobacco sickness from nicotine absorption and exposure to harmful substances like tobacco dust and pesticides. They also risk contaminating their homes, leading to secondary exposure for their families, particularly affecting children and pregnant women. **(WHO, 2023)**

Indoor moisture can cause microbial pollution from bacteria and fungi, especially mould. This can increase respiratory symptoms, allergies, and asthma, and disrupt the immune system. **Persistent dampness** and microbial growth indoors should be minimized to prevent health issues. **(WHO, 2009)**

Chemicals, both natural and human-made, are integral to our environment and daily lives. Manufactured chemicals include pesticides, petroleum products, and processed metals, while by-products like toxic gases and industrial emissions also play a role. In 2017, the chemical industry was the second-largest global manufacturing sector, with sales expected to nearly double by 2030. People encounter chemicals through food, water, products, air, soil, and recreational waters. While many chemicals are safe or beneficial, others can be hazardous to health and the environment. Exposure levels and health impacts vary by social and biological factors, affecting men, women, and children differently.

In 2019, chemicals caused an estimated 2 million deaths from poisoning, heart disease, respiratory issues, and cancer. Pollution also harms ecosystems, impacting human health. Major concerns include air pollution, arsenic, asbestos, benzene, cadmium, dioxins, fluoride imbalances, lead, mercury, and hazardous pesticides. **(WHO, 2020; WHO, 2021)**

A chemical incident involves the uncontrolled release of a toxic substance, potentially harming public health and the environment. These incidents can result from industrial accidents, natural disasters, conflicts, terrorism, pollution, or contaminated products. Examples include factory explosions, chemical contamination of food or water, oil spills, transportation leaks, and chemical releases during conflicts. Between 2000 and 2020, over 1,000 such incidents affected more than 1.85 million people. Some incidents can have international impacts, such as contaminating air or water across borders. **(CRED, 2023; WHO, 2015)**

Exposure to solar UV radiation can cause both acute and chronic health effects, including skin cancers, cataracts, and immune system issues. UV radiation levels vary based on sun position, latitude, altitude, cloud cover, and ground reflection. In 2000, over 60,000 deaths from skin melanoma were linked to UV radiation. Risks come from both sun exposure and artificial tanning devices. Children, outdoor workers, and people with fair skin are particularly vulnerable to skin cancer. **(WHO et al. 2002; IARC & WHO, 2009; Lucas et al. 2006)**

Electromagnetic fields (EMF) include those from consumer products, fixed installations, medical devices, and other technologies in various environments.

Radiation exposures in health care involve millions of patients benefiting from medical radiation each year, necessitating a balance between enhancing access and ensuring safe usage to protect patients and healthcare workers.

Radon is a radioactive gas from uranium in soil and rocks that accumulates in buildings and mines, increasing lung cancer risk, with smoking and radon exposure combined elevating this risk; it caused 84,000 deaths in 2019.

Key pollutants with strong public health concerns include particulate matter (PM), carbon monoxide (CO), ozone (O3), nitrogen dioxide (NO2), and sulfur dioxide (SO2). Both short- and long-term exposure can cause health issues, and some pollutants have no safe threshold. The WHO global air quality guidelines cover these pollutants, along with others with best practice recommendations but no specific limits.

Particulate Matter (PM) consists of inhalable particles like sulphate, nitrates, and black carbon, categorized mainly by size into PM2.5 and PM10. PM2.5, from sources like fuel combustion and chemical reactions, and PM10, from pollen, sea spray, and dust, can penetrate deep into the lungs and bloodstream. Major indoor sources include inefficient stoves and cooking, while outdoor sources include traffic, industry, and construction. Both short- and long-term exposure to PM is linked to cardiovascular, respiratory diseases, and lung cancer. PM is a key indicator for assessing air pollution's health effects.

Nitrogen dioxide (NO2) is a reddish-brown gas that dissolves in water and acts as a strong oxidant. It primarily comes from high-temperature fuel combustion in heating, transportation, industry, and power generation. Household sources include furnaces, fireplaces, and gas stoves. NO2 can irritate the airways, worsen respiratory diseases, and contribute to ozone formation, making it a key pollutant linked to asthma and other respiratory issues.

Ground-level ozone (O3), a key smog component, forms from photochemical reactions involving volatile organic compounds, carbon monoxide, and nitrogen oxides (NOx) from vehicles and industry. Ozone levels peak during sunny weather and can also be generated by household air cleaners. Excessive ozone exposure can impair breathing, trigger asthma, reduce lung function, and cause lung disease.

Carbon monoxide (CO) is a colourless, odourless gas from the incomplete combustion of fuels like wood, petrol, and coal in stoves, fires, and vehicles. It diffuses into the bloodstream, reducing oxygen delivery to cells and causing tissue damage. Exposure can lead to breathing difficulties, dizziness, flu-like symptoms, and, at high levels, can be fatal.

Sulfur dioxide (SO2) is a colourless, water-soluble gas mainly produced by burning fossil fuels for heating, industry, and power. Exposure to SO2 is linked to increased asthma hospital admissions and emergency room visits.

Lead (Pb) can be found in household dust from items like paints, ceramics, pipes, and batteries, and in ambient air from leaded fuel. It poses significant health risks, especially for children and pregnant women. Children exposed to lead may experience behavioural and learning issues, lower IQ, hyperactivity, slowed growth, hearing problems, and anaemia, with severe cases potentially causing seizures or death. For pregnant women, lead exposure can lead to reduced fetal growth and premature birth. Adults may face cardiovascular problems, increased blood pressure, decreased kidney function, and reproductive issues.

Polycyclic Aromatic Hydrocarbons (PAHs) are found in the atmosphere as particulates, resulting from incomplete combustion of organic matter, fossil fuels, and tobacco smoke. Short-term exposure can irritate the eyes and respiratory system, while long-term exposure is associated with an increased risk of lung cancer.

Formaldehyde is a colourless gas with a strong odour, commonly found indoors as a volatile organic compound (VOC). It is emitted from building materials, household products, and indoor combustion sources like smoking and cooking. Short-term exposure can irritate the eyes, nose, and throat, while long-term exposure is linked to nasopharyngeal cancer.

Black carbon, also known as soot, is a key component of PM2.5 produced by incomplete combustion of fossil fuels, biofuels, and biomass. It comes from both human activities, like diesel vehicles and cookstoves, and natural sources, such as wildfires. As a potent warming agent, black carbon contributes to regional environmental disruption and accelerates glacier melting. Exposure to black carbon is linked to cardiovascular health issues and premature mortality.

Ultrafine particles (UFP), with a diameter of 0.1 micrometres or less, mainly come from combustion in transportation, industry, and residential heating. Exposure to UFP is linked to an increased risk of pulmonary, cardiovascular, and ischemic heart diseases.

Moisture build-up, mould, and bacterial growth can result from structural faults, poor heating, insulation, or ventilation. These issues produce allergens and irritants that can trigger asthma attacks in those allergic to mould and cause irritation to the eyes, skin, nose, throat, and lungs in both allergic and non-allergic individuals.

Air pollution involves harmful contaminants like dust, fumes, and gases in the atmosphere, which primarily affect health through the respiratory tract. These pollutants can cause inflammation, oxidative stress, and systemic issues, impacting almost every organ and increasing the risk of diseases such as stroke, heart disease, lung cancer, and chronic respiratory conditions. Fine particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide are of particular concern, as they can penetrate deep into the lungs and bloodstream, causing widespread damage. Children, the elderly, and pregnant women are especially vulnerable. Air pollution also affects pregnancy outcomes and may contribute to other health issues like diabetes and cognitive impairments. Both ambient and household air pollution share similar health risks, with fine particulate matter being a major contributor. Additionally, home fuels can cause burns, poisonings, and injuries. Desert dust episodes further exacerbate air pollution and pose a growing public health concern, particularly for respiratory diseases, with important regional and international implications.

Strategies and Policies for Mitigation of Climate Change, Biodiversity Loss, Air Pollution

Climate Change	Biodiversity Loss	Air Pollution
Strategies		
• Increase the share of energy from renewable sources such as wind, solar, and hydroelectric power. • Enhance energy efficiency across sectors, including residential, commercial, and industrial. • Implement economic instruments to internalize the cost of carbon emissions. • Promote low-carbon transportation options.	• Expand and effectively manage protected areas to conserve critical habitats. • Restore degraded ecosystems and promote reforestation. • Implement land use planning that prioritizes biodiversity conservation. • Prevent and manage the spread of invasive species that threaten native biodiversity.	• Implement and enforce stringent air quality standards and regulations. • Promote the use of renewable energy sources and reduce reliance on fossil fuels. • Reduce emissions from the transportation sector. • Reduce emissions from industrial activities. • Develop urban areas in a way that minimizes air pollution.

• Protect existing forests and promote reforestation and afforestation. • Implement sustainable agricultural practices and improve land use planning. • Develop infrastructure that can withstand climate impacts. • Invest in innovation to develop new technologies and methods for mitigating climate change. • Enhance public understanding of climate change and promote sustainable behaviours. • Collaborate with other nations to address climate change on a global scale.	• Promote agricultural and forestry practices that conserve biodiversity. • Reduce pollution that harms ecosystems and biodiversity. • Address climate change to protect biodiversity. • Ensure infrastructure projects minimize their impact on biodiversity. • Strengthen laws and policies that protect biodiversity. • Increase public awareness and understanding of biodiversity conservation. • Create economic benefits for conserving biodiversity. • Collaborate globally to address biodiversity loss.	• Promote sustainable agricultural practices to reduce air pollution. • Reduce indoor air pollution from cooking and heating. • Increase public awareness about the sources and effects of air pollution. • Enhance air quality monitoring and data collection. • Collaborate with other countries to tackle transboundary air pollution. • Use economic tools to incentivize pollution reduction. • Support research and development of new technologies to reduce air pollution.
Policies		
• Implement subsidies and tax incentives for renewable energy projects, mandate renewable energy targets, and invest in research and development for advanced renewable technologies. • Establish energy efficiency standards and regulations for buildings and appliances, promote energy-saving technologies, and offer financial incentives for energy-efficient upgrades. • Introduce carbon taxes and cap-and-trade systems to incentivize emissions reductions and generate revenue for climate initiatives. • Invest in public transportation infrastructure, incentivize electric vehicle (EV) adoption through subsidies and charging infrastructure development, and implement policies to reduce reliance on fossil fuel-powered vehicles. • Enforce regulations against deforestation, provide incentives for forest conservation, and support tree planting initiatives. • Promote agroforestry, regenerative agriculture, and soil conservation techniques; provide support for farmers transitioning to sustainable practices; and enforce land use policies that prevent habitat destruction. • Establish building codes and standards that incorporate climate resilience, and invest in resilient infrastructure projects such as flood defenses and climate-proof transportation systems. • Increase funding for climate-related research, support public-private partnerships in clean technology development, and foster international collaboration in scientific research. • Implement educational programs in schools, launch public awareness campaigns, and provide resources for individuals and communities to reduce their carbon footprint.	• Establish new protected areas, enforce regulations within these zones, and implement community-based conservation programs to involve local populations in the management and protection of biodiversity hotspots. • Launch large-scale habitat restoration projects, provide incentives for reforestation and afforestation, and support initiatives that rehabilitate wetlands, coral reefs, and other critical ecosystems. • Integrate biodiversity considerations into urban and rural planning, enforce zoning laws that limit habitat destruction, and promote land-use practices that maintain ecological integrity. • Strengthen biosecurity measures, develop rapid response plans for new invasions, and support research and monitoring programs to track and control invasive species. • Encourage agroforestry, organic farming, and sustainable forestry practices through subsidies and technical support, and implement certification schemes for sustainable products. • Enforce strict regulations on pollutants, promote the use of environmentally friendly technologies and practices, and support clean-up initiatives for polluted habitats. • Implement climate adaptation and mitigation strategies, promote renewable energy, and integrate climate considerations into biodiversity conservation planning. • Conduct environmental impact assessments, incorporate wildlife corridors into infrastructure planning, and promote green infrastructure solutions. • Update and enforce national and international biodiversity laws, enhance penalties for violations,	• Establish national air quality standards based on WHO guidelines, enforce emissions limits for industries, and impose penalties for non-compliance. • Subsidize renewable energy projects, provide tax incentives for solar, wind, and hydropower, and implement policies to phase out coal and oil power plants. • Invest in public transportation infrastructure, promote the use of electric and hybrid vehicles through incentives, and implement strict emissions standards for vehicles. • Require the installation of pollution control technologies in factories, implement emissions trading systems, and encourage industries to adopt cleaner production processes. • Create green spaces and parks to absorb pollutants, promote green roofs and walls, and implement zoning laws that separate industrial areas from residential zones. • Encourage the use of precision farming to minimize the use of fertilizers and pesticides, support the adoption of no-till farming, and provide incentives for organic farming. • Promote the use of clean cooking technologies, such as electric stoves and clean fuels, and provide subsidies or financing options for low-income households to transition away from traditional biomass and kerosene stoves. • Implement educational campaigns to inform the public about air pollution and its health impacts, and encourage community participation in air quality monitoring and pollution reduction initiatives. • Invest in air quality monitoring networks, use satellite technology for real-time data collection, and make air quality data publicly

• Adhere to international agreements like the Paris Agreement, support climate finance mechanisms for developing countries, and participate in global climate initiatives and conferences.	and support capacity-building for law enforcement agencies. • Develop educational programs and campaigns, engage local communities in conservation efforts, and promote citizen science initiatives to involve the public in biodiversity monitoring. • Provide financial incentives for conservation activities, support eco-tourism and sustainable livelihood projects, and implement payment for ecosystem services schemes. • Participate in international treaties and agreements, support cross-border conservation initiatives, and contribute to global biodiversity funds and programs.	accessible to inform policy decisions and public actions. • Participate in international treaties and agreements, share best practices and technologies, and support global initiatives aimed at reducing air pollution. • Implement carbon pricing mechanisms such as carbon taxes or cap-and-trade systems, provide grants and loans for green technology adoption, and create economic disincentives for high-polluting activities. • Fund research into clean energy technologies, air pollution control measures, and health impact studies, and foster public-private partnerships to accelerate innovation.

***Source**: Compiled by authors*

Gandhi's Call for an Environmental Revolution

Mahatma Gandhi, the father of our nation, anticipated global environmental challenges at the start of the 20th century. He remarked, "It is impossible to imagine a divine presence in a land marred by the smoke and noise of mill chimneys and factories, where roadways are filled with rushing engines and crowded cars driven by people who are largely aimless" (Hind Swaraj, 1909). He also criticized "modern civilization" as a disease, predicting that it would ultimately destroy itself through its own excesses. Thus, this century demands an Environmental Revolution, where various economic actors play crucial roles in environmental protection. These actors include "Green Consumers with environmental ethics, Green Political Parties with ecological wisdom, Green Movements with public involvement, Green NGOs operating at the grassroots level, Green Employees within environmentally responsible corporations, Green Insurance for clean companies, Green Bank Loans for eco-friendly businesses, Green Incentives for sustainable products, and Green Energy sources for a cleaner environment."

IV. Conclusion

Climate change represents the greatest existential threat to our planet, characterized by long-term alterations in global climate systems. This interconnected system includes the sun, Earth, oceans, wind, rain, snow, forests, and deserts, along with human activities **(Michael Shafer and Phrao Chiang Mai, 2017)**. If we don't reduce greenhouse gas emissions from burning fossil fuels, rising temperatures could lead to severe consequences, such as widespread crop and fishery collapse, the extinction of numerous species, and the uninhabitation of entire communities. Although these dire outcomes might still be preventable, climate change is already causing significant suffering and death. Its effects are visible today through intense wildfires, powerful storms, and other extreme weather events. As temperatures continue to rise, we're seeing more extreme and unpredictable weather, including ice melt, droughts, hurricanes, and floods. Rising sea levels could displace millions of people, leading to starvation and economic collapse as industrial and transportation infrastructure becomes submerged. According to the IPCC, global temperatures have increased by 1.1°C since the pre-industrial era, and they could rise by up to 4°C by 2100 if we fail to address the root causes of climate change. Heatwaves, which are increasingly frequent and severe, are now the leading cause of weather-related fatalities. Other impacts include prolonged droughts, intensified wildfires, stronger storms, diminished food security, increased agricultural pests, and ocean acidification. Climate change effects include melting sea ice, rising sea levels, flooding, warmer ocean waters, and marine heatwaves. Global warming stems from human activities that boost carbon gases in the upper atmosphere and increase tiny particles, known as "black carbon" (soot or smoke), in the lower atmosphere. Black carbon, resulting from incomplete combustion of biofuels and biomass, is the second-largest contributor to global warming after CO2. Other major greenhouse gases include methane (CH4), nitrous oxide (NOx), fluorinated gases, and sulfur hexafluoride (SF6). Biodiversity encompasses the entirety of genes, species, and ecosystems within a region. It can be classified into three hierarchical categories: genetic diversity, species diversity, and ecosystem diversity, each representing different aspects of living systems. Genetic diversity refers to the variety of genes within a species, species diversity pertains to the range of species within a region, and ecosystem diversity involves the "boundaries" of communities, or the associations of species within an area. The loss of biodiversity is driven by several factors, including habitat loss and fragmentation, the introduction of non-native species, overexploitation of plant and animal species, pollution of soil, water, and air, global climate change, and industrial agriculture and forestry. The primary causes of biodiversity loss include overexploitation for commercial purposes, the introduction of exotic species that can threaten native flora and fauna through predation, competition, habitat alteration, or disease, pollution that stresses ecosystems, industrial and agricultural waste that harms both terrestrial and aquatic environments, global warming, and ozone depletion that may drastically alter the climate, impacting species survival. Those species well-adapted may survive, while others perish. Additionally, the

indiscriminate use of toxic agrochemicals and pesticides contributes to this loss. The consequences of biodiversity loss include the extinction of species, disruption of the sustainable provision of goods and services, fragmentation of ecological communities, degradation of habitat patches, impoverishment of natural communities, and ultimately, the destabilization of the entire life-support system of the Earth. Air pollution involves any physical, chemical, or biological alteration in the atmosphere. It results from primary pollutants, such as sulfur dioxide (SO_2) released from factories, and secondary pollutants like smog, which forms through the interaction of smoke and fog. Various activities contribute to air pollution, including the burning of fossil fuels and vehicle emissions that produce greenhouse gases, as well as the use of insecticides, pesticides, and fertilizers in agriculture, which release harmful chemicals like ammonia. Additionally, carbon monoxide (CO), organic compounds, hydrocarbons, and industrial chemicals, along with dust and substances from mineral processing, negatively impact the health of workers and nearby residents. Cleaning products and paints also contain toxic chemicals that pollute the air and impair breathing. The consequences of air pollution include diseases such as respiratory disorders, heart disease, pneumonia, and asthma, which are either directly or indirectly linked to poor air quality. Transition to renewable energy under COP28, improve energy efficiency by adapting renewable energy technologists, capture carbon, impose a carbon tax and adapt polluters pay principles as advocated by A. C. Pigou- a noted welfare economist. Build resilient infrastructure and adopt adaptive agricultural practices, support global agreements like IPPC, and protect and restore ecosystems, by using modern conservation and preservation of natural resources like land, water, forests, mineral and energy resources. Raise awareness and promote sustainable practices with the involvement of global support and participation by people from both developed and developing countries.

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