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Health Impacts of Climate Change on Human Health: The European response

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INTRODUCTION

Global surface, ocean temperatures and sea levels are significantly increasing, and the rate of change continues to accelerate. Increased temperatures alter the timing of the seasons and length of the frost season, as well as the amount, timing, and phases of precipitation and storage of liquid water. In the latter half of the twentieth century, annual precipitation increased in many midlatitude and polar regions. Globally almost all glaciers are shrinking. Arctic sea ice area or extent has rapidly decreased. Thus, nonrandom climate changes are already detectable and are starting to challenge biological system stability and societal well-being.

Human health has always been influenced by climate and weather. Changes in climate and climate variability, especially changes concerning weather extremes, directly impact on the environment that provides humans with clean air, food, water, shelter, and security. Climate change, together with other natural and human-made health stressors, threatens human health and well-being in different ways. Indeed, the influences of climate and weather on human health are significant and varied. They range from the clear threats of temperature extremes and severe storms to less obvious connections. For instance, weather and climate affect and influence the survival, distribution, and behavior of mosquitoes, ticks, and rodents that carry diseases like Malaria virus or Lyme disease. Moreover, climate and weather can also affect water and food quality in vulnerable areas of the planet, with serious implications for human health. Another important implication concerns mental health. The effects of global climate change on mental health and well-being are integral parts of the overall climate-related human health impact. Obviously, certain populations, including children, the elderly, the poor, and those with underlying health conditions, are at increased risk for health impacts from climate change, and therefore need more protection than the general public. Overall, climate change has led to devastating effects on the survival, health, and security of human societies. Diseases and disabilities result from many factors such as skin cancer, dengue, asthma, and malaria are expected to increase due to climate change.

This topic raises several questions: how climate change affects human health? How can the European Green Deal contribute to improving the health of European citizens? Will the measures in the package be adequate to cope with such global problem? To attempt to address these questions, the paper is structured as follows. In the first chapter, we will outline the direct impacts on human health related to climate change. We will focus on the impacts of heat waves, the causes of circulatory, cardiovascular, and respiratory diseases together with health loses caused by natural disasters.

In the second chapter of the paper, we will analyze the indirect effects on climate change through the natural system focusing on airways diseases, food and water diseases and vector-borne diseases. Instead, the focus of interest of the third chapter is the indirect effects through socio-economic systems. These concern the topic of food and water insecurity, the risks related to occupational health and vulnerable populations alongside with mental illness and stress caused by climate change.
Ultimately, in the last chapter an overview of the European response to the climate change's challenges, the so-called Green Deal, is presented. We will analyze four main aspects of the Deal, namely the short-term health benefits, the implementation of green spaces in urban areas, the transformation of energy-efficient housing and the Farm to Fork strategy. In this chapter, we will try to assert whether the European response is adequate or different solutions should be adopted.

CHAPTER 1

DIRECT IMPACTS

Climate change is expected to raise overall temperature distribution and contribute to an increase in the frequency of extreme heat events, or heat waves. For a healthy and sustainable human population to be viable, certain factors must be ensured, such as clean air, safe water, safe and sufficient food supply, and tolerable temperature. Globally, it has been shown that climate and its variability can impact the prevalence and incidence of disease and other human health implications.

Climate scientists state that the evidence is unequivocal. The increasing global temperatures and climate change in the past century are due to human caused emissions of greenhouse gases.

Overall, climate change has led to devastating effects on the survival, health, and security of human societies. Diseases and disabilities result from many factors such as skin cancer, dengue, asthma, and malaria are expected to increase due to climate change.

1.1 EXCESS OF HEAT-RELATED MORTALITY AND INCIDENCE OF HEAT EXHAUSTION: HEAT WAVES

As a result of anthropogenic climate change, global mean temperatures are rising, and are expected to continue to increase regardless of progress in reducing greenhouse emissions. According to the Intergovernmental Panel on Climate Change (IPCC) global temperatures are expected to increase between approximately 0.8°C and 4.9°C by the end of this century, and there will likely be an increase in extreme heat events associated with climate change[1].

Temperature, particularly temperature extremes, is associated with a wide range of health impacts. Direct impacts of climate change on human health could be defined as the set of injuries, disease, and deaths due to extreme weather events. Indeed, extreme heat events can trigger a variety of heat stress conditions. An example is given by the increased frequency and intensity of heat waves. Heat waves, which are continuous extreme hot days, form when high pressure in the upper atmosphere remains over a region for several days or weeks. A heat wave can be described as a period when daily mean temperatures go above a specified high threshold temperature (e.g., 95th or 99th of the distribution) for at least two consecutive days in a given location. Therefore, a heat wave is usually reported relative to the historical weather patterns and temperatures for the season in a specific area[2]. Mortality

[1] Huynen MMTE, Martens P, Akin S-M. *Climate change: an amplifier of existing health risks in developing countries.* Environ Dev Sustain, 2013; 1425-42.

[2] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; 11-12.

and morbidity have already increased as a result of high temperatures and heat waves, creating a global health burden and enormous economic losses.

Humans typically regulate their core body temperature to maintain an internal temperature of approximately 37°C, primarily through vasodilation and sweating[3]. In this physiological process, heat is initially sensed by the skin, brain, and spinal cord. When body temperature increases, the brain, specifically the hypothalamus, sends signals to dilate blood vessels and increase blood flow to activate sweating.[4] Through vasodilation, venous blood returns closer to the skin, transporting fluid to the sweat glands and increasing heat loss from the skin to the environment. Evaporation of sweat from the skin occurs extremely efficiently to cool the body and maintain a stable body temperature.

In conditions of extreme heat, the ability to lose heat through sweating may be compromised, especially with concomitant high humidity. Illness and death caused by heat stress can occur in many scenarios from either indoor or outdoor exposures. Heat stress occurs in humans when the body is unable to cool itself effectively in a process known as thermoregulation. When multiple organs experience heat stress, the body will still attempt to thermoregulate itself as efficiently as possible.

However, excessive sweating can lead to dehydration, and vasodilation is usually maintained regardless of low blood pressure (hypotension), which could cause heat syncope[6]. Moreover, the decrease in sweating further inhibits cooling and at a body temperature of 38–39°C, heat collapse may occur. According to Lipman[5] and as summarized in Figure 1, the traditionally considered heat illnesses include heatstroke, heat syncope, heat cramp, heat exhaustion, heat fatigue, heat edema, and heat rash.

[3] Parsons, K.. Human Thermal Environment. *The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance*. CRC Press, 2014; 55.

[4] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; 11-12.

[5] Lipman, G. S., Eifling K. P., Ellis M. A., Gaudio F. G., Otten E. M., and. Grissom C. K. *Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Heat-Related Illness: 2014 Update.* Wilderness and Environmental Medicine, 2014; 55–65.

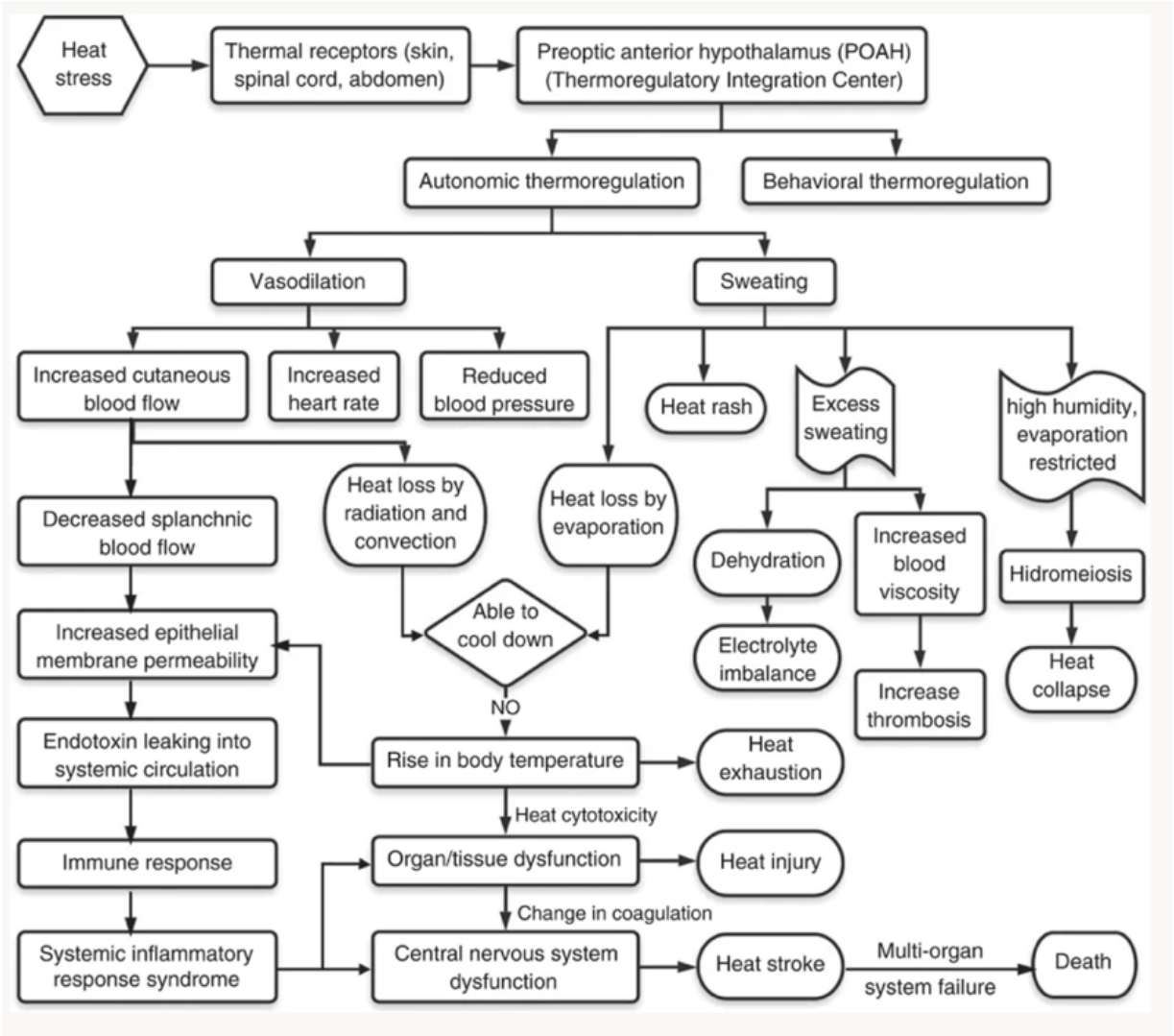

Figure 1: Major mechanisms of heat stress on the body
Source: Luber G, Lemery J, Knowlton K, Sorensen[6]

In addition to heat waves, elevated average surface temperature was also associated with increases in mortality[7] . Bunker et al.[8]conducted a thorough review on studies worldwide and their meta-analysis suggested that 1°C increase in temperature was associated with increases of 3.4 percent (3.1 percent, 3.8 percent), 3.6 percent (3.2 percent, 4.0 percent), and 1.4 percent (0.1 percent, 2.8 percent) in cardiovascular, respiratory, and cerebrovascular mortality, respectively. On the other hand, the study

[6] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice.* John Wiley & Sons, Inc. 2021; 11-12.
[7] Song, X., Wang S., Hu Y., Yue M., Zhang T., Liu Y., Tian J., and K. Shang, *Impact of Ambient Temperature on Morbidity and Mortality: An Overview of Reviews*, Science of the Total Environment, 2017, 241–254.
[8] Bunker, A., Wildenhain J., Vandenbergh A., Henschke N., Rocklov J., Hajat S., and R. Sauerborn. *Effects of Air Temperature on Climate-Sensitive Mortality and Morbidity Outcomes in the Elderly; A Systematic Review and Meta-analysis of Epidemiological Evidence.* EBioMedicine, 2016, 258–268.

conducted by Huang Yi et al.[9] claims that older people are main susceptible group affected by non-optimal temperature. The study aims to determine how mortality of older people with different ages are affected by temperatures. For the purposes of the study, the scholars collected data of all-cause death of 256,037 people aged between 65 and 104 years of age from a prefecture located in the north subtropical area in China with most serious aging rate in 2000, 2010 and 2020. A distributed lag nonlinear model was used in the research to estimate non-optimal temperature associations to mortality. Results show that heat wave had much higher relative risk than cold spell compared with moderate high and low temperature because of steeper slope of relative risk at the period of moderate-extreme conversion of high temperature[10]. Consequently, elderly people are more vulnerable to the effects of heatwaves, due in part to poorer physical health and the effects of cognitive impairment on the perception of heat-related health risk.

However, increase in mortality during heat waves have been observed throughout the world and not only in the Asian region. Indeed, according to World Health Organization[11] 2003 European heat wave resulted in over 70,000 excess deaths, and mostly among the elderly. The study in central Italy pointed out that a 1 °C increase in temperature above a threshold was associated with an increase in mortality of up to 15.97% among people aged 75 years or more, over a lag period of 30 days[12]. More precisely, the combination of extreme daytime maximum temperatures and warm nocturnal temperatures is particularly hazardous for them. According to the study it is possible to highlight the evident lag effect for heat- and heatwave-related mortality and morbidity with the maximum death rate and hospital emergency department presentations occurring two to three days after peak temperature.

1.2 AGGRAVATED CIRCULATORY, CARDIOVASCULAR, AND RESPIRATORY DISEASES

Temperature extremes most directly affect health by compromising the body's ability to regulate its internal temperature, thermal stresses due to climate change could also lead to cardiovascular and respiratory diseases. Several effector mechanisms inside the body are involved in regulating body temperature. The most important ones for heat are sweat production to lose heat from the skin and skin blood flow to transport heat from the body core and the muscles to the skin.

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[9] Yi Huang Y., Yang J., Chen J. , Shi H. , Lu X., *Association between ambient temperature and age-specific mortality from the elderly: Epidemiological evidence from the Chinese prefecture with most serious aging.* Environmental Research, 2022

[10] Ibid.,3-4

[11] World Health Organization Annual Report 2017

[12] Morabito, M.; Crisci, A.; Moriondo, M.; Profili, F.; Francesconi, P.; Trombi, G.; Bindi, M.; Gensini, G.F.; Orlandini; S. *Air temperature-related human health outcomes: Current impact and estimations of future risks in Central Italy.* Sci. Total Environ. 2012; 28–40

During heat stress, the proper functioning of both systems is essential for thermal regulation. If they are unduly stressed and cannot match the thermoregulatory demands, this leads to excessive strain on the body and eventually may cause heat illness. Additional effector mechanisms are an increase in some hormones (antidiuretic hormone and aldosterone), in respiratory rate and in heart rate[13].

As explained in previous paragraph, the primary response to thermoregulation stress is vasodilation, which reduces blood pressure and increases the risk of hypotension. Increased blood flow volume to the extremities increases heart rate leading to stress on the cardiovascular system.

In addition, increased blood viscosity due to loss of body water or changes in coagulation may lead to increased thrombosis. All these changes could contribute to ischemic stroke and heart disease[14]. Thus, high associations between temperature increases and ischemic stroke and heart disease could be highlighted.

Another direct impact of heat waves is related to respiratory diseases. The World Health Organization defines allergic respiratory diseases as common chronic conditions caused by immune system disorders; asthma, rhinitis, and hay fever are the most common. Indoor and outdoor allergens, tobacco smoke, air pollution, cold air, and even rapid urbanization are considered environmental risk factors for these diseases[15].

Air pollution and climate change can be considered as potential drivers for the increased prevalence of respiratory allergy because of the body's immune response to temperature and allergens. Indeed, increased temperatures may trigger the release of inflammatory factors as well as enhance the growth of allergens and/or the transmission of viruses. Air pollutants, such as ozone, which are positively correlated with ambient temperature especially during the summer, may also cause or exacerbate respiratory symptoms and may have synergistic effects in combination with temperature. Rising emissions of greenhouse gases in the atmosphere have warmed the planet substantially and are also accompanied by poor air quality. The increased prevalence of allergic airway disease worldwide can be partially attributed to those global environmental changes. Climate change and air pollution pose adverse impacts on respiratory allergies, and that the mechanisms are complex and interactive as shows Figure 2.

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[13] Christina Koppe C., Kovats S., Jendritzky G. and Menne B, *Heat-waves: risks and responses*, Health and Global Environmental Change, WHO Europe, 2004, 20-21.

[14] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; 18-19.

[15] Bousquet J. *Global Surveillance, Prevention and Control of Chronic Respiratory Diseases: A Comprehensive Approach*, World Health Organization, 2008.

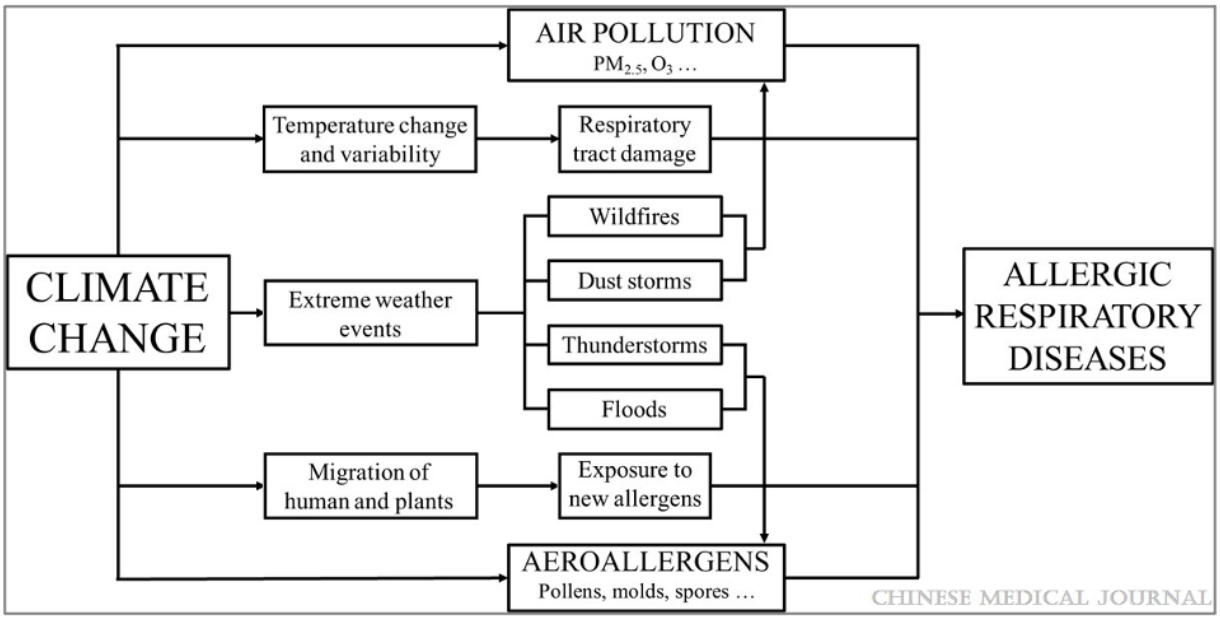

Figure 2: Comprehensive pathways of climate change, air pollution, aeroallergens, and allergic respiratory diseases. Source: Chinese Medical Journal

Adverse weather conditions, such as extreme temperatures, can act directly on the respiratory tract to induce allergic respiratory illnesses. In particular, temperature variation increases the risk of asthma and the aggravation of asthmatic symptoms. According to the study conducted by Qiu et al[16] an increase of 1°C in diurnal temperature range was correlated with a 2.5% increase in daily emergency asthma hospitalizations in Hong Kong (China) and the effect was greater in the cold season than in the warm season. Moreover, extreme heat might increase airway resistance rapidly and by stimulating thermosensitive bronchopulmonary nerves trigger asthma symptoms as explained Li S et al.'s study[17] . Different studies conducted around the globe, highlighted the impacts of high temperature in patients with asthma. An example is given by the study in Kentucky (USA) which demonstrated a 112% increase in airway resistance after hyperventilation of warmed air vs. a 38% increase after hyperventilation of room temperature air in patients with asthma[18].

High temperature can also be responsible for an increased number of hospitalizations and emergency department visits of asthma such as analyzed in the time-series study by Lam et al.[19] It relieved that relative risk for asthma hospitalizations increased when the daily mean temperature rose over 27°C in the hot season.

[16] Qiu H, Yu IT, Tse LA, Chan EY, Wong TW, Tian L., *Greater temperature variation within a day associated with increased emergency hospital admissions for asthma.* Sci Total Environ, 2015; 505–513.
[17] Li S, Baker PJ, Jalaludin BB, Marks GB, Denison LS, Williams GM. Ambient temperature and lung function in children with asthma in Australia. Eur Respir J, 2014;1059–1066.
[18] Hayes D Jr, Collins PB, Khosravi M, Lin RL, Lee LY., *Bronchoconstriction triggered by breathing hot humid air in patients with asthma: role of cholinergic reflex.* Am J Respir Crit Care Med, 2012; 1190–1196.
[19] Lam HCY, Li AM, Chan EYY, Goggins WB. *The short-term association between asthma hospitalisations, ambient temperature, other meteorological factors and air pollutants in Hong Kong: a time-series study*. Thorax 2016, 1097–1109.

1.3 HEALTH LOSSES CAUSED BY DISASTERS

Another observed direct impact concerns the health losses caused by disasters. The United Nations Office for Disaster Risk Reduction (UNDRR) defines a disaster as "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that exceed the ability of the affected community or society to cope using its own resources"[20]. The so-called climate-related disasters (CRDs) are caused by oceanic and atmospheric hazards that are influenced by the global climate. The global increase of extreme weather events such as riverine flooding, cyclonic winds, storms, and droughts is related to climate change which acts as a force multiplier, exacerbating many of the world's global health challenges. On the one hand, disasters caused by extreme weather events can be associated with high precipitation, or low precipitation. On the other, disasters caused by extreme oceanic events (i.e., associated with sea level rise) have been associated with soil and groundwater salinification resulting in loss of food and water security. Both types of events can result in significant impacts on people's health and well-being, including the loss of many lives. CRDs occur as a result of the combination of population exposure to a climate-related hazard (e.g., EWE and sea level rise), the conditions of vulnerability that are present (e.g., dependence upon local human, shelter, food, and water resources), and insufficient resilience to reduce or cope with the negative consequences (e.g., living in a low-resource nation). Without outside assistance, these events often overwhelm the capacity of the population to respond effectively, and the resulting mismatch between needs and resources may result in a disaster declaration. Even the hazards that cause disasters may vary, the potential health consequences and subsequent public health and medical needs of the population do not. Climate disasters include seasonal floods, hurricanes, and typhoons. Seasonal floods cause increased incidence of diarrheal diseases, respiratory infections, dermatitis, and snake bites. The risk of compromised water supplies depends on the condition of the community's water supply before the disaster. Saline contamination is a long-term issue following sea surges and tsunamis. Prolonged flooding endangers local agriculture and sometimes means large-scale food assistance will be needed.

The primary health concerns are overcrowded living conditions and poor water and sanitation in temporary settlements and other areas where services have deteriorated or are suspended. Sickness and death result from high winds, heavy rainfall, and storm surges caused by tropical storms, such as hurricanes and typhoons. Moreover, survivors of such disasters require psychosocial services.

According to EM-DAT 2019[21], during the period from 1969 to 2018, 10,950 CRDs caused an estimated 3.6 million deaths (57 percent of all disaster-related mortality) worldwide and $2.6

[20] United Nations Office for Disaster Risk Reduction, UNDRR, https://www.undrr.org/terminology

[21] EM-DAT: The International Disaster Database. 2019. http://www.emdat.be/

trillion (75 percent of all disaster-related losses) worldwide. As shows the tart chart (Figure 3), the most frequently occurring CRDs (hydrologic hazards consisting mostly of floods) comprised 25 percent of all disasters but were responsible for only 6 percent of global disaster mortality during this time. On the contrary, climatologic disasters (consisting mostly of droughts) comprised only 5 percent of disasters but caused 36 percent of global mortality.

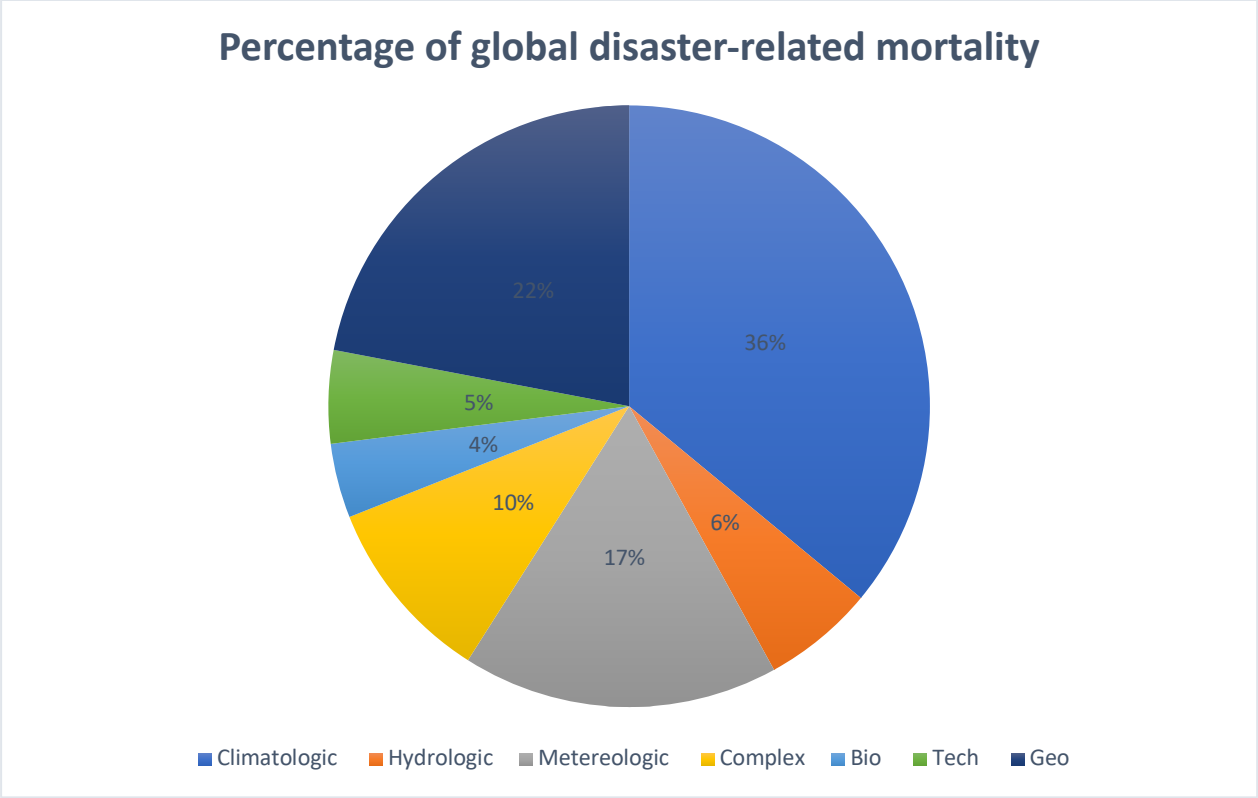

Figure 3: Percentage of global disaster-related mortality, according to category of hazard, 1969-2018
Source: EM-DAT 2019

The data show that during the examination period (last 50 years) climatologic hazards caused 1,094 disasters comprising 10 percent of all CRDs, killing 703,416 and affecting an astounding 2.5 billion people. In detail droughts comprised 62 percent of these climatologic disasters and were associated with 99.6 percent of their mortality. Wildfires, both forest and land fires, caused 36 percent of climatologic disasters and were associated with 0.3 percent of their mortality. Nearly all (99.7 percent) people affected by climatologic disasters during the past 50 years were affected by drought. As far as meteorologic hazards, they caused 5,865 disasters (comprising 40 percent of all CRDs) and were responsible for the deaths of 1.1 million and affected 2.2 billion people worldwide.

There were 5,368 hydrologic disasters during this time, representing 50 percent of all CRDs, killing 358,177 and affecting 3.7 billion people worldwide. Floods comprised 88 percent of these hydrologic disasters and were associated with 89 percent of their mortality. Landslides caused 12 percent of

hydrologic disasters and were associated with 11 percent of their mortality. Nearly all (99.7 percent) of people affected by hydrologic disasters during the 1969-2018 period were affected by floods and eighty-one coastal flooding events have resulted in the death of 3,269 persons, affected 19.3 million people, and caused $ 10 billion in damage globally. It is necessary to emphasize that most of the morbidity and mortality associated with CRD are attributable to injury. Although psychological illnesses are common after CRDs. In addition, communicable disease outbreaks have been reported after floods, cyclones and droughts, EM-DAT 2019[22] shows.

[22] EM-DAT: The International Disaster Database. 2019. http://www.emdat.be/

CHAPTER 2

INDIRECT IMPACTS THROUGH NATURAL SYSTEMS

It is possible to differentiate between indirect impacts through natural systems and through socio-economic systems. In this chapter, we will focus on impacts related to natural environments. With regard to indirect impacts via natural systems, three major groups can be identified, namely airways diseases and allergens, food-and-water borne diseases and vector-borne diseases. Accelerating climate change is anticipated to affect ambient air pollution levels by altering atmospheric chemical reaction rates, boundary layer conditions affecting the vertical mixing of pollutants, and changes in air flow affecting the transport of pollution. Several significant air pollutants, particularly ground-level ozone, particulate matter, and aeroallergens are climate-sensitive and are affected by climate change. These pollutants increase the number of air pollution days that can be harmful to health and exacerbate underlying respiratory and cardiovascular diseases, leading to increased hospitalizations, and premature mortality. Moreover, acute, and chronic ozone exposure has been associated with significant adverse health effects in humans, including cardiopulmonary and respiratory morbidity and premature mortality. Indeed, ozone not only contributes to global warming but also causes measurable negative health effects during periods of acute and chronic exposure. Diseases such as asthma and allergic respiratory diseases are exacerbated by exposure to aeroallergens which are any airborne substance, such as pollen or spores, which triggers an allergic reaction.

2.1 AIRWAYS DISEASES

Atmosphere is a complex system of gases and suspended particles. However, the composition of the atmosphere keeps on changing and hence its structure is variable in time and space. The atmosphere is mainly composed of gases like nitrogen (N2), oxygen (O2), argon, and other trace gases like carbon dioxide (CO2) methane (CH4), nitrous oxide (N2O), water vapor. Pollution is defined as the introduction into the environment of substances harmful to humans and other living organisms. Pollutants are harmful solids, liquids, or gases produced in higher than usual concentrations that reduce the quality of our environment. Poor air quality, whether outdoors or indoors, can negatively affect the human respiratory and cardiovascular systems. Human activities have an adverse effect on the environment by polluting the water we drink, the air we breathe, and the soil in which plants grow. Although the industrial revolution was a great success in terms of technology, society, and the provision of multiple services, it also introduced the production of huge quantities of pollutants emitted into the air that are harmful to human health. Without any doubt, the global environmental pollution is considered an international public health issue with multiple facets. Social, economic, and legislative concerns and lifestyle habits are related to this major problem. Clearly, urbanization

and industrialization are reaching unprecedented and upsetting proportions worldwide in our era. Anthropogenic air pollution is one of the biggest public health hazards worldwide, given that it accounts for about 9 million deaths per year[23].

Air pollution has various health effects. The health of susceptible and sensitive individuals can be impacted even on low air pollution days. Short-term exposure to air pollutants is closely related to COPD (Chronic Obstructive Pulmonary Disease), cough, shortness of breath, wheezing, asthma, respiratory disease, and high rates of hospitalization (a measurement of morbidity). The long-term effects associated with air pollution are chronic asthma, pulmonary insufficiency, cardiovascular diseases, and cardiovascular mortality. According to a Swedish cohort study, diabetes seems to be induced after long-term air pollution exposure[24]. Moreover, several national reports have mentioned the increased risk of morbidity and mortality. It is known that the majority of environmental pollutants are emitted through large-scale human activities such as the use of industrial machinery, power-producing stations, combustion engines, and cars. Because these activities are performed at such a large scale, they are by far the major contributors to air pollution, with cars estimated to be responsible for approximately 80% of today's pollution.

Pollution is the presence of undesirable substance in any segment of the environment, primarily due to human activities and discharging waste products or harmful secondary products, which are harmful to man and other organisms. Air pollution is the addition of unwanted component of gases and particles into the atmosphere by human activities like burning of fossil fuels, industrial pollution etc. and some natural phenomenon like volcanic eruptions and forest fires. All these activities release harmful gaseous and particulate components like CO2, CH4, CO, N2O, SO2, dust, soot etc. into the atmosphere, hence polluting it. The changes that are occurring now have their origin in the industrial revolution. Long lived gases that are increasing at a substantial rate because of human activities are of particular interest since they eventually lead to stratospheric ozone depletion, global warming, and disturbances in the atmospheric chemistry that many be harmful to the ecosystem.

The classification of air pollutants is based mainly on the sources producing pollution. Therefore, it is worth mentioning the four main sources, following the classification system: Major sources, Area sources, Mobile sources, and Natural sources. Major sources include the emission of pollutants from power stations, refineries, and petrochemicals, the chemical and fertilizer industries, metallurgical and other industrial plants, and, finally, municipal incineration. Indoor area sources include domestic cleaning activities, dry cleaners, printing shops, and petrol stations. Mobile sources include

[23] WHO. *Air Pollution.* WHO, 2019 https://www.who.int/health-topics/air-pollution#tab=tab_1

[24] Manisalidis I, Stavropoulou E, Stavropoulos A and Bezirtzoglou E. *Environmental and Health Impacts of Air Pollution: A Review*. Front. Public Health, 2020, 8-14.

automobiles, cars, railways, airways, and other types of vehicles. Finally, natural sources include physical disasters such as forest fire, volcanic erosion, dust storms, and agricultural burning.

Air pollution can influence the quality of soil and water bodies by polluting precipitation, falling into water and soil environments. Notably, the chemistry of the soil can be amended due to acid precipitation by affecting plants, cultures, and water quality.

Moreover, movement of heavy metals is favored by soil acidity, and metals are so then moving into the watery environment. It is known that heavy metals such as aluminum are noxious to wildlife and fishes. Soil quality seems to be of importance, as soils with low calcium carbonate levels are at increased jeopardy from acid rain. Over and above rain, snow and particulate matter drip into watery' bodies. Pollutants harm our environment either by increasing levels above normal or by introducing harmful toxic substances. Primary pollutants are directly produced from the above sources, and secondary pollutants are emitted as by-products of the primary ones.

Air pollution and climate change are closely related. Climate is the other side of the same coin that reduces the quality of our Earth. Pollutants such as black carbon, methane, tropospheric ozone, and aerosols affect the amount of incoming sunlight. As a result, the temperature of the Earth is increasing, resulting in the melting of ice, icebergs, and glaciers.

Accelerating climate change is anticipated to affect ambient air pollution levels by altering atmospheric chemical reaction rates, boundary layer conditions affecting the vertical mixing of pollutants, and changes in air flow affecting the transport of pollution.

The World Health Organization[25] (WHO) reports on six major air pollutants, namely particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Air pollution can have a disastrous effect on all components of the environment, including groundwater, soil, and air. Additionally, it poses a serious threat to living organisms.

Several significant air pollutants, particularly ground-level ozone, particulate matter, and aeroallergens are climate-sensitive and are affected by climate change. These pollutants increase the number of air pollution days that can be harmful to health and exacerbate underlying respiratory and cardiovascular diseases, leading to increased hospitalizations, and premature mortality. Moreover, acute, and chronic ozone exposure has been associated with significant adverse health effects in humans, including cardiopulmonary and respiratory morbidity and premature mortality. Indeed, ozone not only contributes to global warming but also causes measurable negative health effects during periods of acute and chronic exposure. Diseases such as asthma and allergic respiratory diseases are exacerbated by exposure to aeroallergens which are any airborne substance, such as pollen or spores, which triggers an allergic reaction.

[25] WHO. *Air Pollution.* WHO, 2019 https://www.who.int/health-topics/air-pollution#tab=tab_1

Changes in the climate affect the air we breathe, both indoors and outdoors. Taken together, changes in the climate affect air quality through three pathways—via outdoor air pollution, aeroallergens, and indoor air pollution. The changing climate has modified weather patterns, which in turn have influenced the levels and location of outdoor air pollutants such as ground-level ozone (O3) and fine particulate matter.

According to Bourdrel et al.[26] multiple cardiovascular effects have been observed after exposure to air pollutants. Changes occurred in blood cells after long-term exposure may affect cardiac functionality. Moreover, coronary arteriosclerosis was reported following long-term exposure to traffic emissions, while short-term exposure is related to hypertension, stroke, myocardial infracts, and heart insufficiency. As shows Figure 4 neurological effects have been observed in adults and children after extended-term exposure to air pollutants. In particular, psychological complications, autism, retinopathy, fetal growth, and low birth weight seem to be related to long-term air pollution. Specifically, pesticides and metals seem to be etiological factors, together with diet. The mechanisms in the development of neurodegenerative disease include oxidative stress, protein aggregation, inflammation, and mitochondrial impairment in neurons.

[26] Bourdrel T, Bind M-A, Béjot Y, Morel O, Argacha J-F. *Cardiovascular effects of air pollution.* Arch Cardiovasc Dis. ,2017; 634–642.

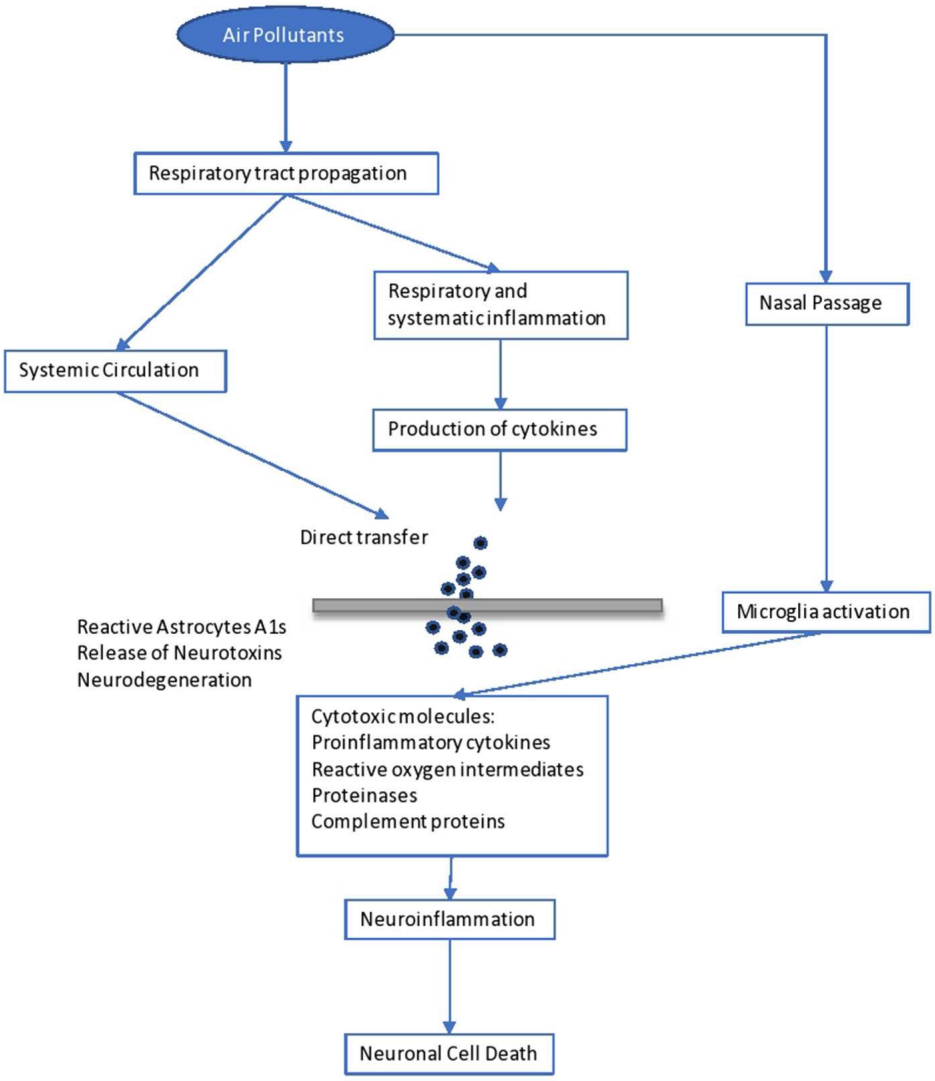

Figure 4: Impact of air pollutants on the brain
Source: Environmental and Health Impacts of Air Pollution: A Review

2.2 FOOD AND WATER DISEASES

Climate change could also increase the risk of other water-and food-borne diseases, such as temperature-related salmonellosis and cryptosporidiosis, which are associated with extreme precipitation and flooding. As stated in the study conducted by European Climate and Health Observatory[27], high water temperatures accelerate the growth rate of some waterborne pathogens, such as Vibrio species, which act through two main exposure routes namely drinking water and recreational water use. Indeed, Vibrio infections can cause gastroenteritis through the consumption of contaminated seafood, or the infection of wounds being directly exposed to Vibrio species present

[27] European Climate and Health Observatory- Published in Climate-ADAPT Jan 2021

in coastal water. This kind of infections are a major concern for public health because these wound infections are potentially serious and can result in septicaemia and death.

Exposure to pathogens and toxins occur through drinking, inhaling, or other direct contact with contaminated drinking or recreational water and through consumption of contaminated food, including fish and shellfish. Climate change impacts, namely increasing temperatures, precipitation and related runoff, hurricanes, and storm surge, affect the growth, survival, spread, and virulence or toxicity of agents of water- and food-related illness.

This diagram illustrates the key pathways by which humans are exposed to health threats from climate drivers. These climate drivers create more favorable growing conditions for these naturally occurring pathogens in coastal environments through their effects on coastal salinity, turbidity (water clarity), or plankton abundance and composition. Longer seasons for growth and expanding geographic range of occurrence increase the risk of exposure to Vibrio, which can result in various potential health outcomes from eye and hear infections to death. These exposure pathways exist within the context of other factors that positively or negatively influence health outcomes. Key factors that influence vulnerability for individuals are shown in the right box and include social determinants of health and behavioral choices. Key factors that influence vulnerability at larger scales, such as natural and built environments, governance and management, and institutions, are shown in the left box. All of these influencing factors can affect an individual's or a community's vulnerability through changes in exposure, sensitivity, and adaptive capacity and may also be affected by climate change.

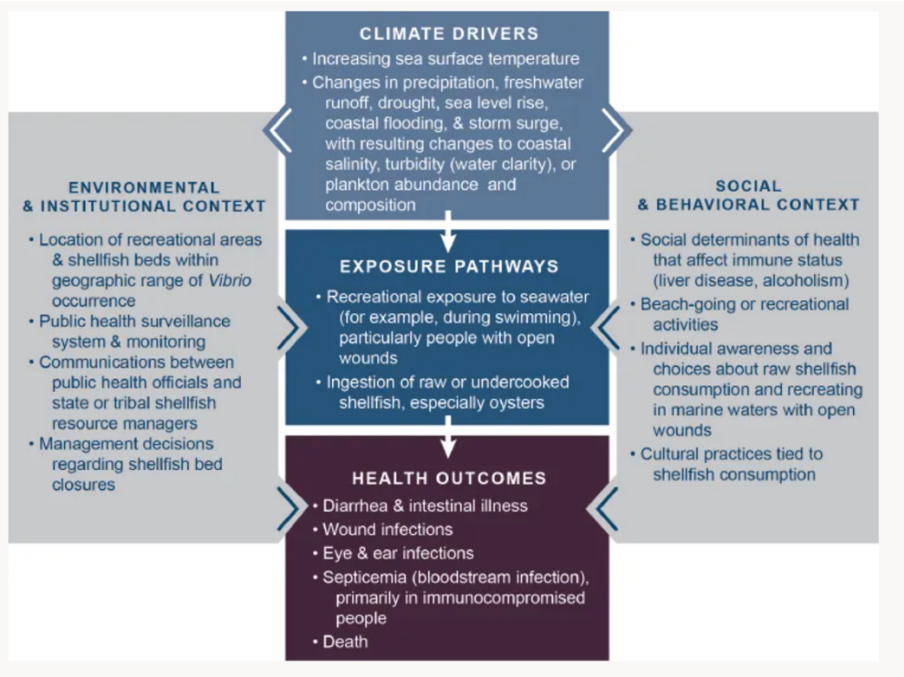

Figure 5: Climate Change and Health—Vibrio
Source: US Global Change Research Program

2.3 VECTOR-BORNE DISEASES

There is evidence that climate is one of the factors that influence the distribution of diseases borne by vectors, such as fleas, ticks, and mosquitoes, which spread pathogens that cause illness. The WHO defines vector-borne diseases as human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors. Moreover, according to its data, vector-borne disease account for close to 20 percent of all infectious diseases affecting the human population. Because vector-borne pathogens that cause disease in humans utilize an arthropod vector, environmental factors that affect the vector can affect the transmission of the pathogens to humans. We can claim that the increase in average global temperatures will affect the increase of vector-borne diseases. This is due to vectors' sensitivity to their environment. Indeed, the risk of diseases transmission increases because, even if arthropods can regulate their internal temperature by changing their behavior, they are not able to do so physiologically, thus critically depending on climate for their survival and development. Daily, seasonal, or year-to-year climate variability can result in vector-pathogen adaptation and shifts or expansions in their geographic ranges. Such shifts can alter disease incidence depending on vector-host interaction, host immunity, and pathogen evolution. Arthropods are coldblooded, which means they do not regulate their own temperature and are highly susceptible to variations in climate. In more temperate regions, warming trends increase the duration of favorable conditions for ectotherm development and reproduction. Temperature influences insect development, mortality, reproduction, and behavior. Likewise, precipitation, humidity, and vapor pressure are all important for reproductive success. Variability or alterations in any of these factors can lead to changes in availability of habitats and, in most regions of the world, variations in weather patterns associated with climate change are contributing to changes in insect habitat suitability. For example, temperature affects how long mosquitoes live, how quickly they mature to adulthood, how often they bite, and population density. Precipitation is considered to be essential to mosquito breeding as mosquito eggs are laid in or near water and mosquito larva mature in water. Moreover, humidity, which is related to precipitation, increases the lifespan of mosquitoes, giving them more opportunities to carry pathogens from one person or host to another. Ticks are similarly dependent on temperature and precipitation, requiring humid environments to prevent desiccation, and thriving within a narrow temperature range[28]. For instance, the three key features of climate namely temperature, precipitation, and humidity, can affect the transmission of malaria. Malaria is a disease that ranges from asymptomatic to severe. Symptoms include repeated fever and chills, mild to severe anemia, acute respiratory distress syndrome, and cerebral malaria. In individuals that have never experienced an infection with a malaria parasite,

[28] Luber G, Lemery J, Knowlton K, Sorensen C. Global climate change and human health: from science to practice. John Wiley & Sons, Inc. 2021; 54-56

infection can result in a high degree of morbidity and mortality. The World Health Organization (WHO) estimates that in 2017 more than 200 million illnesses and approximately 435,000 deaths from malaria occurred, with nearly one half of the world's population at risk for malaria[29].

It is possible to identify five species of Plasmodium parasites that cause malaria in humans: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium knowesi*, and *Plasmodium ovale*. The Plasmodium parasite is transmitted when an infected female Anopheles mosquito bites a human. As several studies claim, temperature changes affect malaria transmission by affecting both the Anopheles mosquito life cycle and the parasite's replication in the mosquito vector. Precipitation and humidity are both important factors in Anopheles distribution and abundance and thus may alter malaria disease risk by causing variations in mosquito abundance. Both development and survival of Anopheles mosquitoes and Plasmodium parasites within the mosquito are temperature dependent.

To sum up, it is worth noting the clear linkage between the environment and mosquito development. Thus, climate change plays a crucial role in the spread of vector-borne disease, such as malaria. As temperature increases, transmission is enhanced. At higher threshold temperatures, mortality increases. It is important to note that humidity is also crucial to mosquito survival. Moreover, precipitation provides necessary water sources for the larval stage of the mosquito to develop. Increased precipitation is generally associated with an increase in abundance of mosquitos and incidence of vector-borne diseases.

[29] World Health Organization Annual Report 2017

CHAPTER 3

INDIRECT IMPACTS THROUGH SOCIO-ECONOMIC SYSTEMS

Indirect effects of climate change also include the socio-economic dimension. Firstly, they impact on food and water insecurity and the level of undernutrition. Indeed, climate change and variability can affect all the four dimensions of food security namely, food availability, stability of food supplies, access to food, and food utilization. We can observe that its impacts are greater in low-income populations in developing countries in Africa and Asia. Moreover, climate change and variability influence the key determinants of malnutrition, including food access, maternal and childcare, access to health services, and environmental health.

Secondly, it is possible to highlight indirect impacts on occupational health and vulnerable populations. Unprotected workers are one of the populations most susceptible to experiencing the effects of climate change. They are affected by climate-related exposures for longer durations and at greater intensities than the general public. For example, outdoor workers with high physical load, such as agriculture and construction, are most at risk for heat-related illnesses and cardiac arrests. Heat exposure can exacerbate cardiovascular, respiratory, and renal disease, which can result in significant morbidity and mortality. Together with unprotected workers the elderly, the children and the poorer are expected to suffer the most from the above direct and indirect impacts. Lastly, it is crucial to address the indirect impact of climate change on mental health. There are several mechanisms by which climate change affects population mental health, including natural disasters, heatwaves, forced migration, conflict over scarce resources, and physical comorbidity. Obviously, this burden of psychopathology is borne disproportionately by the poor and marginalized who lack the resources to protect themselves.

First and foremost, climate change will lead to higher average ambient temperatures and increase the frequency and severity of heat waves. Among their many previously analyzed health effects, heat waves are also associated with an increased burden of mental disorders and suicide. Secondly, climate change will increase the frequency and severity of natural disasters such as windstorms, floods, and droughts. This will result in increased exposure to trauma, which can threaten mental health, as well as damage the material well-being of victims.

Thirdly, climate change will degrade landscapes, ecosystems, and habitats, thereby undermining agricultural productivity and ethnic, cultural, and religious traditions. Therefore, increasing instances of severe anxiety reactions, depression, aggression, and sense of loss.

Ultimately, climate change will intensify global competition for resources, which could increase the rate and consequences of global conflicts, especially in areas of poor and weak governance.

3.1 FOOD AND WATER INSECURITY

As above stated, climate change and variability affect all four dimensions of food security: food availability, stability of food supplies, access to food, and food utilization. Declining food availability leads to increasing food cost with low-income consumers particularly at risk of food insecurity and hunger. Climate change and variability also affect the key underlying causes of children's undernutrition including household food security, access to maternal and childcare, environmental health, water quality, and food safety, leading to disease and stunting. Climate variability and extremes have been leading causes of recent severe food crises requiring humanitarian assistance of millions of people in developing countries during the last years. Moreover, poor access to healthy food contributes not only to undernutrition but also to overweight, obesity. The food system is responsible for approximately 30 percent of the global greenhouse gas emissions and changing dietary patterns toward greater consumption of animal foods, particularly meat, are linked to environmental degradation, climate change, and noncommunicable diseases. To meet climate targets below 2°C by 2050, it is necessary to reduce the global greenhouse gas emissions related to the food system. These changes will have significant co-benefits for also health. According to Mbow et al[30] climate change has an impact on food security as it can adversely affect food production, availability, quality, food access, stability, and food utilization. Indeed, declining food availability caused by climate change is likely to lead to increasing food cost affecting consumers globally through higher prices and reduced purchasing power. Obviously, low-income consumers will be affected the most.

According to Springmann et al. [31] higher prices depress consumer demand, which in turn will not only reduce energy intake globally but will also likely lead to less healthy diets with lower availability of key micronutrients and increase diet-related mortality in lower and middle-income countries. As summarized in Figure 6, climate change can also affect the socioeconomic factors that determine food security and nutrition, such as livelihoods, assets, income, health access, education, food aid, institutions, inequities, human rights, infrastructure, resources, and political structures.

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[30] Mbow, C., C. Rosenzweig, L. G. Barioni, T. G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga et al. *Food Security In Climate Change and Land*: *An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, Intergovernmental Panel on Climate Change, 2017, 437–550.

[31] Springmann, M., H. C. J. Godfray, M. Rayner, and P. Scarborough. *Analysis and Valuation of the Health and Climate Change Cobenefits of Dietary Change*. Proceedings of the National Academy of Sciences of the USA, 2016, 4146–4151.

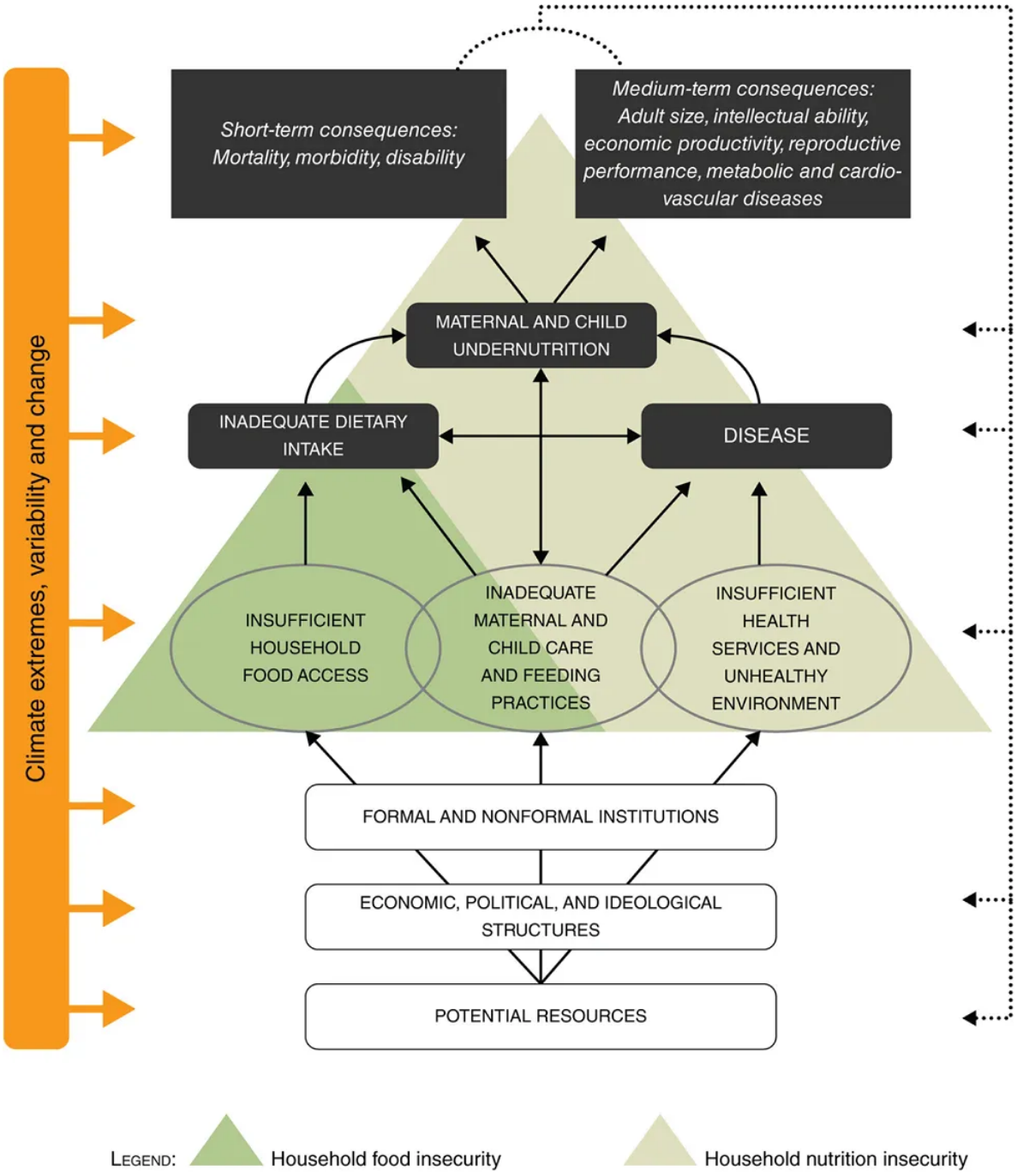

Figure 6: Framework Illustrating the Pathways Through Which Climate Change Affects Nutrition

Source: Food and Nutrition Bulletin n34, 2013

Moreover, poor access to healthy food contributes not only to undernutrition but also to overweight and obesity. It is crucial to highlight that high rate of these multiple forms of malnutrition coexist in many countries and within households. As explained by Swinburn et al.[32] the higher cost of healthy foods, the stress of living with food insecurity, and physiological adaptations to food restrictions

[32] Swinburn, B. A., V. I. Kraak, S. Allender, V. J. Atkins, P. I. Baker, J. R. H. Bogard, H. Brindsen. *The Global Syndemic of Obesity, Undernutrition, and Climate Change*. The Lancet Commission report, 2019, 791–846.

contribute to explain why food-insecure families may have a higher risk of overweight and obesity. Additionally, maternal and child food deprivation and low breastfeeding rates can increase the risk of obesity and diet-related non-communicable diseases later in life. The study lead by Food and Agriculture Organization together with the World Food Program and the World Health Organization[33], pointed out that in the last twenty years, climate shocks caused by droughts, floods, storms, and heat spells have increased in frequency and intensity in low- and middle-income countries, where undernourishment and food production are vulnerable to climate extremes, confirming once again that change and the consequent global environmental change have significant impacts on food and water security and eventually on undernutrition.

3.2 OCCUPATIONAL HEALTH

Workers are particularly susceptible to experiencing negative health impacts from climate change. Fundamentally, climate change is a stress multiplier, putting pressure on vulnerable systems, populations, and regions. Across a broad range of occupations, workers are affected by a multitude of climate-related exposures for longer durations and at greater intensities than the general public.[34] It is possible to identify several hazards faced by workers due to climate change. These include increased ambient temperature, air pollution, ultraviolet exposure, extreme weather, vector-borne disease and expanded habitats, industrial transitions, and emerging industries. As emerged in Chapter One, increased ambient temperature is associated with an increased risk of mortality from heat illness and the exacerbation of underlying medical conditions. However, excessive heat exposure represents a real problem for working people because internal heat production adds to environmental heat exposure when strenuous work is carried out. For instance, workers in outdoor occupations, such as agriculture and construction, are most at risk for heat-related illnesses. Not only due to the with high physical load, but also to economics reasons. Indeed, workers in these industries are generally paid a piece-rate and are usually experiencing poor economic conditions, which results in a greater risk.

The human body is designed to maintain a core body temperature of 37°C. In order to maintain this temperature, heat dissipation occurs through dry heat loss and evaporative heat loss (sweating). The evaporation of sweat is extremely effective and therefore becomes more and more critical with increasing environmental temperature. However, sweating imposes the greatest strain on the body

[33] Food and Agriculture Organization (FAO,) *The State of Food Security and Nutrition in the World 201*8. *Building Climate Resilience for Food Security and Nutrition*. Food and Agriculture Organization/International Fund for Agricultural Development/UNICEF/World Food Programme/World Health Organization, 2018.
[34] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; chapter 11

and can lead to dehydration. We can underline several occupational-related factors that can add additional weight and heat burden to workers' bodies. Thus, negatively contribute to the individual's ability to maintain its core body temperature. An example is given by the employment of personal protective equipment or job requirements and demands coupled with a lack of heat safety protocols which can inhibit the ability of workers to seek shade, hydration, and time for recovery. These issues are compounded especially in workers with already high heat loads, such as fire fighters, emergency response, construction, and agricultural workers. Moreover, increasing workplace temperatures are also associated with a greater risk of occupational injuries. Slips, trips, falls, wounds, lacerations, and amputations are the most commonly reported injuries under high heat exposure likely due to slippery sweaty hands, foggy glasses, hot tools, and working faster to avoid the heat.[35] Workplaces are a main source of exposure to many different types of air pollution such as particulate matter (PM10) , nitrogen (NO2) , and sulfur dioxide (SO2) with levels varying based on air conditioning use, proximity to roadways, and work environment.

The study carried out by Schifano et al. in 2019[36], showed that an increase in NO2 from the 25th to the 95th percentile was associated with a 1.30 increase in odds of occupational injury, whereas an increase in PM10 from the 25th to the 95th percentile resulted in an increase of 1.15, regardless of industry. Moreover, the same study showed the lagged effect of exposure to occupational air pollution on work-related injury was short, two to three days, during the hot season. This suggests that air pollution exposure causes acute neuropsychological effects, such as inattention, which could explain the increase in work-related injury. Even if all workers are at risk of air pollution exposure, both indoor or outdoor, certain occupations are more at risk for occupational illness caused by pollutant exposure due to the nature of their work. For example, are wildland firefighters can be considered disproportionately exposed and vulnerable group of workers. This is due to the nature of the shift work and residence in fire camps. Indeed, these workers are subjected to frequent exposure to severely unhealthy air containing polycyclic aromatic hydrocarbons, carbon monoxide, benzene, aldehydes, and fine particulate matter. Several studies show that exposure to wildfire smoke is related to negative respiratory health effects with acute declines in lung function measures across a work shift.[37] Air pollution and climate change are also drivers of the increasing burden of allergic diseases. They influence the environmental abundance of allergenic bioparticles and trig the release of allergenic

[35] Ibid. chapter 11
[36] Schifano, P., F. Asta, A. Marinaccio, M. Bonafede, M. Davoli, and P. Michelozzi. *Do Exposure to Outdoor Temperatures, NO2 and PM10 Affect the Work-Related Injuries Risk? A Case-Crossover Study in Three Italian Cities, 2001–2010,* 2019.
[37] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; chapter 11

proteins and biogenic adjuvants. For what concerns outdoor workers, the increase of their respiratory rates related results in an increase in respiratory inhalation of allergens which can lead to one of the most frequent work-related diseases, namely occupational asthma.

Another dangerous element is represented by the exposure to solar radiation. Climate change increases ultraviolet (UV) radiation levels at ground by affecting the expected recovery of the stratospheric ozone depletion and by altering UV absorbing tropospheric gases, aerosols, and clouds in the atmosphere. This kind of radiations are considered carcinogenic to humans. They increase the risk for basal cell carcinoma, nonmelanocytic cell carcinoma, and melanoma. In addition to cancer, UV exposure can damage eye structures, with long-term exposure to short-wavelength light contributing to age-related macular degeneration, which is the leading cause of vision loss in developed countries. [38] In addition, climate change increases the risk of events like storms, droughts, and floods. The frequency, intensity, duration, timing, and spatial extent of these extreme events are also modified by climate change. The health of many different types of workers, such as emergency responders, health care and public health workers, disaster recovery workers, firefighters, police, and social services can be affected by extreme weather events and natural disaster. Workers responding to these events can be exposed to storm-downed trees and electrical hazards, hydrogen sulfide, respirable dust, and mold. Moreover, climate-related disasters may also force workers to remain at the worksite and prolong work hours, causing mental fatigue that can lead to increased risk of accidents. [39]

To sum up, climate change puts pressure on vulnerable worker populations by operating as a threat multiplier. Increased heat, worsening air quality, extreme weather events and natural disasters, together with increased exposures to diseases is translated with in increased injuries, death, lost labor, economic poverty, and poor mental health of workers.

3.3 VULNERABLE POPULATIONS

The vulnerability of any given group is a function of its sensitivity to climate change related health risks, its exposure to those risks, and its capacity for responding to or coping with climate variability and change. Indigenous peoples, children and pregnant women, older adults, vulnerable occupational

[38] Grandi, C., M. Borra, A. Militello, and A. Polichetti. *Impact of Climate Change on Occupational Exposure to Solar Radiation*, Annali dell'Istituto superiore di sanità 52, 2016, 343–536.
[39] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; chapter 11

groups, persons with disabilities, and persons with preexisting or chronic medical conditions can be considered as population of concern or vulnerable populations. Some populations of concern demonstrate relatively greater vulnerability to the health impacts of climate change. As shows Figure 7, some people or communities are disproportionately affected by climate-related health risks. Indeed, people or communities can have greater or lesser vulnerability to health risks depending on social, political, and economic factors (social determinants of health).

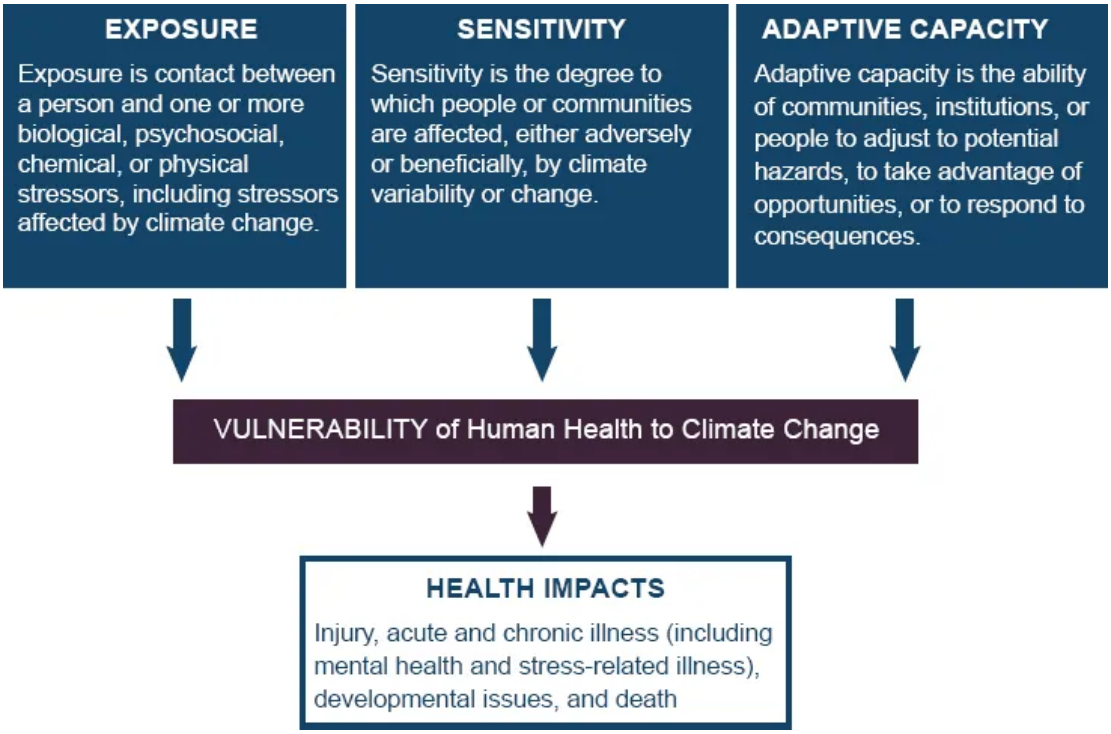

Figure 7: Determinants of vulnerability to health impacts associated with climate change

Source: U.S. Global Change Research Program, 2016

According to the Intergovernmental Panel on Climate Change (IPCC), it is possible to define vulnerability as the tendency or predisposition to be adversely affected by climate-related health effects. It encompasses three elements, namely exposure, sensitivity, and the capacity to adapt to or to cope with change. In this context, exposure is contact between a person and one or more biological, chemical, or physical stressors, including stressors affected by climate change. On the other hand, sensitivity is the degree to which people or communities are affected, either adversely or beneficially, by climate variability and change. Lastly, the adaptive capacity is the ability of communities, institutions, or people to adjust to potential hazards, to take advantage of opportunities, or to respond to consequences[40]. Some groups are disproportionately disadvantaged by social determinants of

[40] Crimmins A et al. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, U.S.* Global Change Research Program, 2016

health that limit resources and opportunities for health-promoting behaviors and conditions of daily life, such as living or working circumstances and access to healthcare services. In disadvantaged groups, social determinants of health interact with the three elements of vulnerability by contributing to increased exposure, increased sensitivity, and reduced adaptive capacity. Health risks and vulnerability may increase in locations or instances where combinations of social determinants of health that amplify health threats occur simultaneously or close in time or space. For example, people with limited economic resources living in areas with deteriorating infrastructure are more likely to experience disproportionate impacts and are less able to recover following extreme events, increasing their vulnerability to climate-related health effects. It is possible to identify several factors that contribute to the exposure to climate-related variability and change. These factors include occupation, the amount of time spent in risk-prone locations, the ability to responses to extreme events, the socioeconomic status and the infrastructure condition and access.

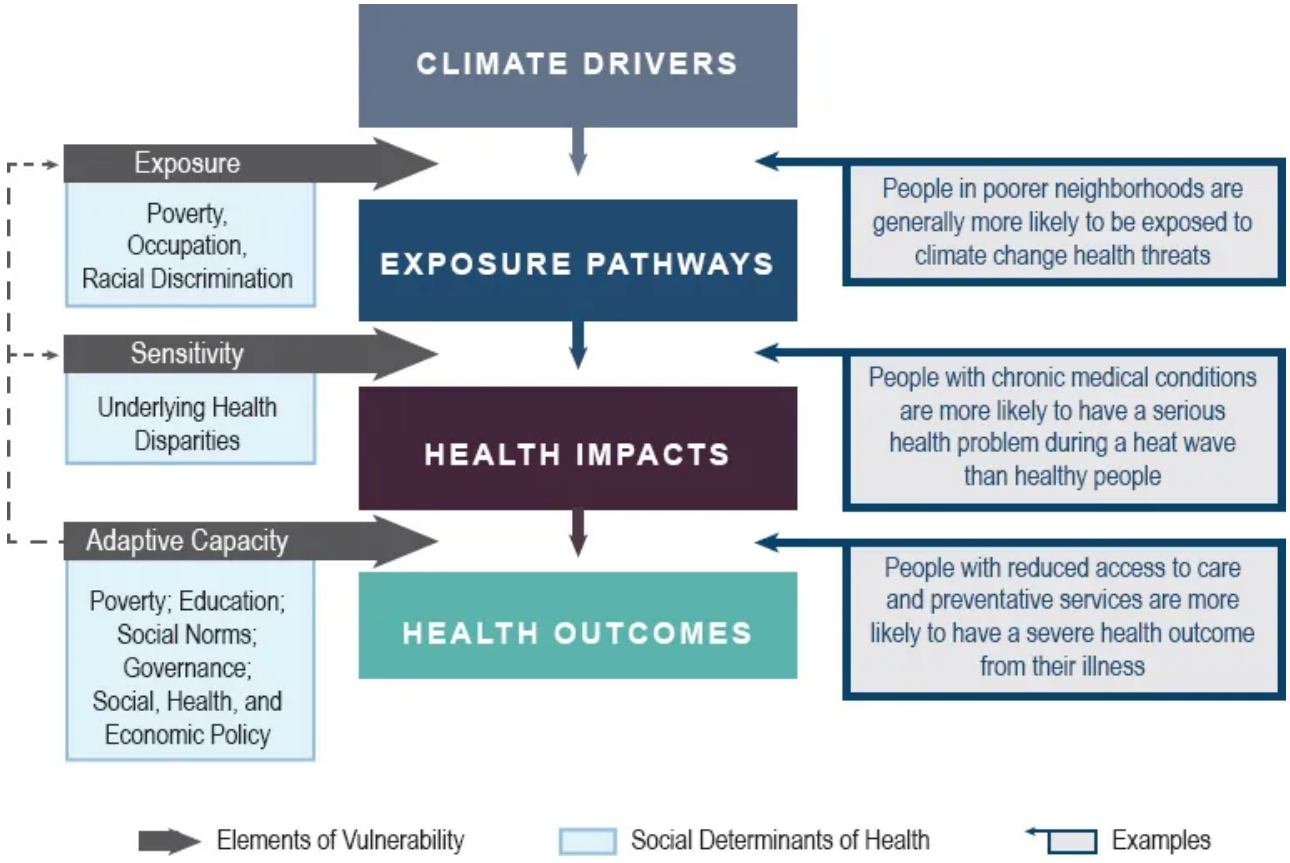

Figure 8: Intersection of Social Determinants of Health and Vulnerability

Source: U.S. Global Change Research Program, 2016

As explained by Figure 8, social determinants of health interact with the three elements of vulnerability (exposure, sensitivity, and the adaptive capacity). The left side boxes provide examples of social determinants of health associated with each of the elements of vulnerability. Increased

exposure, increased sensitivity and reduced adaptive capacity all affect vulnerability at different points in the causal chain from climate drivers to health outcomes (middle boxes). Adaptive capacity can influence exposure and sensitivity and also can influence the resilience of individuals or populations experiencing health impacts by influencing access to care and preventive services. The right-side boxes provide illustrative examples of the implications of social determinants on increased exposure, increased sensitivity, and reduced adaptive capacity.

From a broader perspective, we can claim that the poorest countries will suffer the greatest penalty of climate change even though they contribute the least for emissions. Indeed, countries the most severely affected by climate change are often those that are most exposed and those most under-resourced in terms of finances, infrastructure, and human capacity to respond. The epidemiological outcome of climate change on disease patterns worldwide will be profound, especially in developing countries where existing vulnerabilities to poor health remain like those already most vulnerable to food insecurity and malnutrition, where production is undertaken by small-holder and subsistence farmers, pastoralists, traditional societies, indigenous people, coastal populations, and artisanal fisher-folk. The added pressure of climate change to the environment will worsen this burden and pose challenging questions for public and global health.

3.4 MENTAL ILLNESS AND STRESS

Climate change may influence global mental health, both directly and indirectly, in several mechanisms (Figure 9) Above all, climate change will lead to higher average ambient temperatures and increase the frequency and severity of heat waves. Among their many effects on health, heat waves are associated with higher burden of mental disorder and suicide rates. Secondly, climate change will increase the frequency and severity of natural disasters such as windstorms, flooding, and droughts. More frequent disasters will increase exposure to trauma, which may threaten mental health, as well as harm the material well-being of victims. Thirdly, climate change will degrade landscapes, ecosystems, and habitats, thereby undermining agricultural productivity and ethnic, cultural, and religious traditions. Moreover, climate change will intensify global competition for resources, which could increase the rate and consequences of global conflict, especially in areas of poor governance. Lastly, climate change will have important influences on physical health, such as increasing the prevalence of noncommunicable diseases (NCDs) such as obesity, which will in turn increase the burden of mental comorbidity[41].

[41] Luber G, Lemery J, Knowlton K, Sorensen C. *Global climate change and human health: from science to practice*. John Wiley & Sons, Inc. 2021; chapter 10

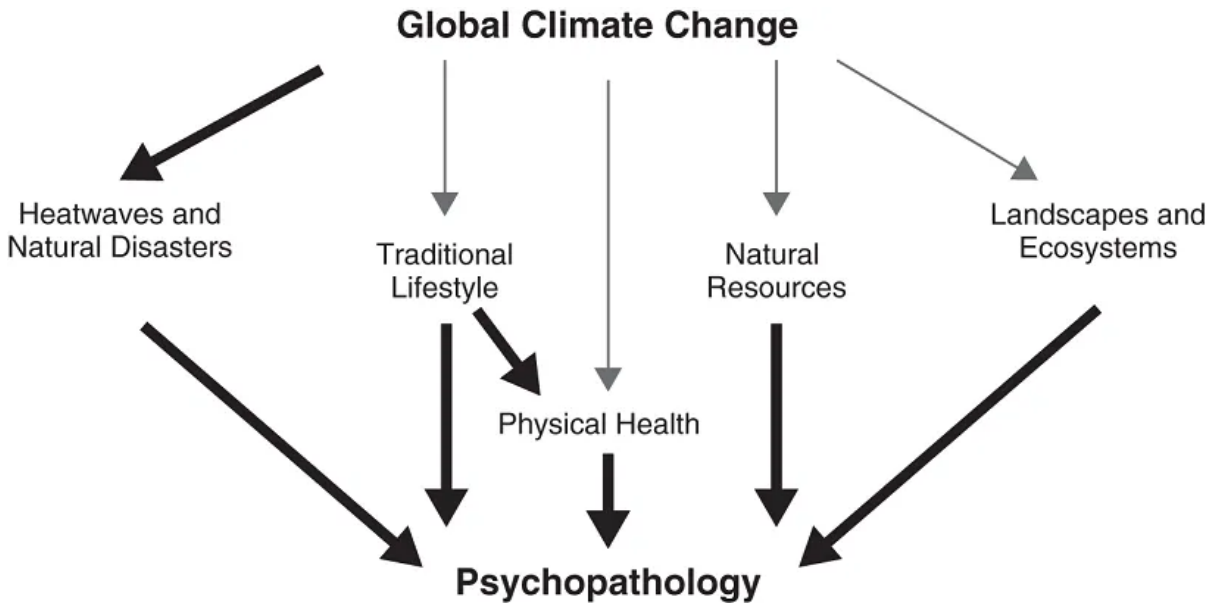

Figure 9: Mechanistic map relating global climate change and psychopathology

Source: Luber G, Lemery J, Knowlton K, Sorensen[42]

Heat waves and natural disasters resulting from climate change will create traumatic stressors that will harm population mental health. Similarly, climate change will degrade arable lands and inundate coastal regions, challenging communities and pressuring them to migrate in search of new livelihoods; exposing them, in the process, to stressors that will have negative consequences for their mental well-being. Global competition over resources depleted by climate change, such as arable land and foodstuffs, and freshwater, will inspire violent conflict with hazardous consequences for mental health. Finally, climate change will increase physical morbidity and the subsequent mental disorder that accompanies it as more people struggle with the realities of chronic disease. Importantly, the consequences of climate change will not be equitable. Because each of these mechanisms' functions through the changing availability of resources, those who have the least will suffer most. Once again, we are able to highlight the strong interdependence which characterized the several impacts, both direct and indirect, studied in the previous chapters.

[42] Ibid.; chapter 10

CHAPTER 4

THE GREEN DEAL: THE EUROPEAN RESPONSE

The European Green Deal[43], which was announced at the end of 2019, aims to respond to the growing climate crisis by achieving net zero greenhouse gas emissions in the EU by 2050.

To overcome the challenges caused by climate change and environmental degradation that pose an existential threat to Europe and the world, the European Green Deal aims to transform the EU into a modern, resource-efficient, and competitive economy. Its three main objectives are: achieving zero net greenhouse gas emissions by 2050, the implementation of economic growth decoupled from resource use and ensuring that no person and no place is left behind.

Figure 10 outlines the ambitious scope of the Deal, which also aims to establish a toxin-free environment, provide healthy and sustainable diets, and protect biodiversity. It thus encompasses a potentially ambitious agenda to support global health. In this context, it is important to emphasize the EU's intention to play a leadership role by rapidly reducing its own emissions and using its financial resources, knowledge, and leverage to encourage other nations to increase their climate actions.

Figure 10: The European Green Deal

Source: European Commission 2019

[43] European Commission. *A European Green Deal: Striving to be the first climate-neutral continent.* 2019

Short-term health benefits can arise through the implementation of successful policies in sectors that contribute substantially to emissions of CO2 and short-lived climate pollutants such as the energy, housing, transportation, food, industry, and health care sectors. Successful policies would reduce greenhouse gases, fine particulate air pollution, and ground-level ozone with consequently large health benefits. In addition, the provision of green space in urban areas envisioned by the Green Deal would influence the health of citizens in multiple ways. Another aspect of the deal that is crucial to consider is transportation. In fact, important health benefits also come from transportation strategies to promote the so-called active travel like walking and cycling, along with increased use of public transports.

The European Green Deal calls for the transformation of energy-efficient housing, achievable through retrofit programs to insulate existing homes and the installation of shutters to shade windows. This type of housing would reduce exposure to cold and heat, respectively, and thus improve the health of tenants. However, it is also important to provide adequate ventilation, which is critical to avoid the buildup of household air pollutants such as tobacco smoke and pollutants from cooking[44].

In terms of food, the "Farm to Fork strategy" is an important component of the Green Deal and specifically addresses the sustainability of the EU food system. In addition to the positive health impacts of reducing emissions and pollution through cleaner, more sustainable food production and processing, the strategy aims to actively engage consumers by encouraging dietary changes toward more sustainable foods including vegetables, fruits, and whole grains, and reducing consumption of red and processed meat. In this case, health benefits include reduced prevalence of obesity and reduced risk of ischemic heart disease and stroke.

4.1 SHORT-TERM HEALTH BENEFITS

Air pollution makes a major contribution to excess mortality from cardiovascular, respiratory, and other diseases. Significant excess death rates are related to fossil energy use, as combustion emissions from traffic, power generation, and industry typically occur in densely populated regions, such as Europe. Energy used in dwellings is an important target for actions to avert climate change. Properly designed and implemented, such actions could have major co-benefits for public health. Decarbonizing electricity production will improve health by reducing concentrations of harmful air pollutants, including fine particulate matter (PM), nitrogen dioxide (NO2), and black Carbon. Replacing fossil fuels with clean renewable energy in this sector could prevent ~3.6 million premature deaths each year worldwide (at 2015 population) from ischemic heart disease, stroke, chronic

[44] Wilkinson P, et al. *Public health benefits of strategies to reduce greenhouse-gas emissions: household energy*. The Lancet, 2009; 1917-1929.

obstructive pulmonary disease, and other causes, with about 430,000 of these being in the EU[45]. According to the study conducted by Lelieveld et al[46] and based on the two middle scenarios of the Intergovernmental Panel on Climate Change (IPCC) there is an estimated 5% chance that the temperature increase in this century can be limited to 2 °C, but the likelihood increases when greenhouse gas emissions are curbed sharply in the near term[47]. Therefore, the timing of mitigation actions is critical. Clearly, the switch from fossil to renewable, clean energy sources has the potential to prevent morbidity and mortality from aerosol pollution. Because the particles have a net climate cooling effect, removing them will increase the public health gain. The analysis presents the health benefits achieved by removing fossil-fuel-related and all air pollution emissions and considers the repercussions for climate change of policies and technologies focusing on air-quality improvement using traditional such as filters. Results show that by a rapid phaseout of fossil fuels and a reduction in using other pollution sources such as agriculture, biomass burning, and residential energy we will be able to achieve a mortality reduction up to 5.55 million excess deaths annually, limit the warming from aerosol removal, and restore the monsoon rainfall. Moreover, replacing fossil by clean, renewable energy sources could decrease the global attributable mortality by 65 percent.

This shows how the implementation of policies envisioned in the European Green Deal can significantly have a direct short-term impact on the health of European citizens. However, it is crucial to keep in mind that Europe alone cannot ensure that the global mean temperature increase is kept to below 2°C above as laid out in the Paris Climate Agreement.

Another direct short-term impact is provided by the acceleration in a shift towards sustainable transport strategies. For transport, which accounts for a quarter of the EU's total greenhouse gas emissions, achieving the climate neutrality objectives will require a 90% reduction of the sector's emissions by 2050 compared to 1990 levels, with sizeable contributions across all modes. In this context, major health benefits will be achieved if active travel, such as walking and cycling, together with greater use of public transport is promoted. As suggested by the study led by Jarrett et al[48] the increase of these activities (walking and cycling) among the urban population of England and Wales, would have been translated in a substantial reduction in incidence of diabetes, stroke, and other conditions related to a sedentary lifestyle. Obviously, this also reflets with healthcare's costs reduction. Indeed, according to the study, if English and Welsh had walked and cycled as much as

[45] Lelieveld J et al. *Effects of fossil fuel and total anthropogenic emission removal on public health and climate.* Proceedings of the National Academy of Sciences, 2019; 7192-7197

[46] Ibid.; 7193

[47] Raftery AE, A Zimmer, DMW Frierson, R Startz, P Liu, *Less than 2°C warming by 2100 unlikely.* National Climate Change, 2017; 637–641.

[48] Jarrett J, Woodcock J, Griffiths UK, et al. *Effect of increasing active travel in urban England and Wales on costs to the National Health Service.* Lancet, 2012; 2198–2205.

their counterparts in Copenhagen (Denmark) there would be a £17 billion savings for the National Health Service over a time period of 20 years. What is crucial in this context, is encouraging sedentary middle-aged and older people to walk and cycle. Indeed, health benefits occur particularly from the improvement of accessibility of suitable sustainable transport options, such as electric bicycles, which would increase the likelihood of continuing to cycle into older age.

4.2 GREEN SPACES IN URBAN AREAS

The European Green Deal highlights the importance of green space to support healthy living in urban areas. Links between green space and health have been recognized throughout history, several WHO reports have already contributed evidence and guidance on access to green space in relation to public health benefits. The WHO report on urban planning, environment and health published in 2010 states that green spaces can positively affect physical activity, social and psychological well-being, improve air quality and reduce exposure to noise[49]. Indeed, through improved air and water quality, reducing noise levels and contributing to temperature regulation, urban green spaces can effectively reduce environmental health risks associated with urban living. In addition, they deliver health and well-being by enabling stress reduction and relaxation, physical activity, improved social interaction and community cohesion. Access to natural environments can improve overall mental health, physical fitness level, cognitive and immune function, and can lower mortality rates in general.

Currently, there is no universally accepted definition of urban green space, with regard to its health and well-being impacts. However, the most common definition of urban green space that has been used in studies in Europe is based on the definition from the European Urban Atlas[50]. According to it, public green areas are areas used predominantly for recreation such as gardens, zoos, parks, and s forests, or green areas bordered by urban areas that are managed or used for recreational purposes[51]. Several studies of green spaces and health have demonstrated stronger evidence for mental health benefits, and for stress reduction[52]. People living in urban areas with more green space have been shown to have a reduced level of stress and improved well-being compared to controls with poorer availability of green space[53]. In addition, greater usage of green and blue spaces, and greater residential surrounding greenness, have been linked with improved behavioral development. This

[49] WHO. *Urban Planning, Environment and Health: From Evidence to Policy Action*. WHO Regional Office for Europe, 2010

[50] https://land.copernicus.eu/user-corner/technical-library/urban-atlas-mapping-guide

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[53] White, M. P., Alcock, I., Wheeler, B. W. & Depledge, M. H.. *Would You Be Happier Living In A Greener Urban Area? A Fixed-Effects Analysis Of Panel Data*. Psychology Science, 2013; 920-928.

includes reduced difficulties, emotional symptoms and peer relationship problems tighter with reduced rate of Attention Deficit Hyperactivity Disorder (ADHD) in children[54]. The impacts of green spaces to mental health also include improved general mood, reduced depressive symptoms, enhanced cognitive functioning, improved mindfulness, short-term memory performance and enhanced creativity[55].

There is evidence that the provision of open and green spaces is also associated with improved general physical health outcomes. Different studies around the world confirmed the impact of green spaces on cardiovascular morbidity reduction. The study led by Mitchell et al[56] found an association between low quantities of neighborhood green space and elevated risk of circulatory disease. It also reveals a significant association between a more intense use of green space and reduced risk of cardiovascular disease. A systematic review of five online databases and over 100 studies undertaken by the University of East Anglia found that people who spend more time in green spaces have significantly reduced risks for a number of chronic illnesses[57]. According to the research[58], exposure to green spaces was linked to lower heart rate, lower blood pressure, lower cholesterol, and reduced incidence of stroke, asthma, diabetes, and coronary heart disease. This has been confirmed by the WHO review that shows evidence that proximity to urban green spaces was associated pregnancy outcomes, together with reduced cardiovascular morbidity and mortality, obesity, and risk of type 2 diabetes[59]. For instance, exposure to green space within a five-minute walk of the home would stimulate its use: several studies report reductions in risk of non- communicable disease (such as strokes, heart diseases and diabetes) and improvements in mental health for those living in close proximity to green space[60]. Green spaces can also reduce urban heat islands and associated diseases, as well as lowering additional energy cooling requirements.

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4.3 TRANSFORMATION OF ENERGY-EFFICIENT HOUSING

Renovating both public and private buildings is an essential action and a key initiative of the European Green Deal. In 2020, to pursue the dual ambition of energy gains and economic growth, the European Commission published the strategy "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives"[61] to boost renovation in the EU. Its aim is to double annual energy renovation rates in the next 10 years. Although it is a very ambitious action, there is no doubt that energy efficiency measures targeting indoor and outdoor air quality can have major impacts for European citizens health. Indeed, such measures can support both physical and mental health, primarily by creating healthy indoor living environments with healthy air temperatures, humidity levels, noise levels, and improved air quality. Several analyses show that chronic thermal discomfort and fuel poverty have negative mental health impacts. They contribute to increase the level of anxiety, stress, and depression. Therefore, energy efficiency improvements targeting fuel poverty can have a positive impact on mental well-being. Obviously, impacts on mental health will be greater if combined with financial support mechanisms and strong community engagement. Energy efficiency actions in buildings, such as insulation retrofits and weatherization programs, create conditions that support improved occupant health and well-being, particularly among vulnerable groups. It is possible to underline several potential benefits for health of energy efficiency measures. These include reduced symptoms of respiratory and cardiovascular conditions, rheumatism, arthritis, and allergies, as well as fewer injuries. In cold climates, energy efficiency improvements can lower rates of excess winter mortality while in hot climates; they can help reduce the risk of dehydration and negative health impacts. Moreover, health benefits of energy efficient buildings can be realized in both homes and workplaces. The IEA study[62] found that people working in energy efficient buildings are less likely to suffer from fatigue, headaches or skin irritations. According to the study, improving the health of workers could in turn have significant implications for workplace productivity.

The European Green Deal focuses on measures and targets to improve insulation, heating and ventilation systems which can have positive impacts on air quality, reducing respiratory and cardiovascular diseases, and allergies. Particularly ventilation, as explained in the study of Thomson et al[63],plays a key role in reducing indoor dampness and the associated build-up of mold that exacerbates many health conditions.

[61] Communication From the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions a Renovation Wave for Europe - Greening our Buildings, Creating Jobs, Improving Lives, 2020

[62] IEA, *Multiple Benefits of Energy Efficiency*, IEA, 2019

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4.4 FARM TO FORK STRATEGY

The Farm to Fork Strategy (Figure11) is at the very center of the Green Deal and aims to accelerate the transition to a sustainable food system.

Figure 11: The Farm to Fork Strategy

Source: European Commission

In 2020, up to 811 million people in the world faced hunger[64], while for almost 2 billion people unhealthy food habits and diets cause diet-related obesity and non-communicable diseases such as diabetes and cardiovascular diseases[65]. The food system is also responsible for about one third of total greenhouse gas emissions, 70 percent of freshwater use, most of the global eutrophication, land-use change and biodiversity loss[66].

According to the strategy, the new food system should have a neutral or positive environmental impact, be able to help to mitigate climate change and adapt to its impacts, reverse the loss of biodiversity, ensure food security, nutrition, and public health, and making sure that everyone has access to sufficient, safe, nutritious, sustainable food. Moreover, it should also preserve affordability

[64] Food and Agriculture Organisation (FAO), *The State of Food Security and Nutrition in the World 2021*, Rome, FAO, 2021; 10.

[65] Walter Willett et al., F*ood in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems,* The Lancet, 2019; 447-492.

[66] Crippa M. et al*., Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions, in Nature Food,* FAO, 2021; 198-209.

of food while generating fairer economic returns, fostering competitiveness of the EU supply sector, and promoting fair trade[67]. It addresses comprehensively the challenges of sustainable food systems and recognizes the inextricable links between healthy people, healthy societies, and a healthy planet. It represents a clear opportunity to improve lifestyles, health, and the environment. Through the creation of a favorable food environment that makes it easier to choose healthy and sustainable diets, it will improve consumers' health and quality of life.

The strategy underlines the need of far-reaching changes along the food chain from the producer to the consumer to reduce the environmental impact of the food system. Most importantly, for the strategy to be successful, changes in the behavior of the stakeholders are necessary. These changes mostly concern individual consumers habits and are driven by the principle of interconnectedness of human and environmental health. Indeed, not only the strategy aims to reduce emission and pollution through a sustainable production and food processing, but it also focuses on encouraging consumers' dietary shifts towards increased consumption of sustainable foods, such as vegetables, fruit, whole grains, nuts, seeds, and reducing the red meat consumption. Moreover, the creation of a favorable food environment enables consumers to choose healthy and sustainable diets more easily. It will contribute to improve consumers' health and quality of life and reduce health-related costs for society. Health benefits would include reduced obesity prevalence and reduced risk of non-communicable diseases such as stroke. A study conducted in the UK found that a reduction in dietary greenhouses gas emissions of 17 percent, achievable by switching from current to WHO-recommended diets, was associated with an average increase in life expectancy of about 8 months.[68]

Previous public health authorities' interventions to limit the growing overweight and obesity rates were not yet sufficient to curb this development. Such actions focused too much on educating individuals and relying on their motivation and ability without changing the contexts in which food choices take place. On the contrary, the Food to Fork strategy aims increase the availability of healthy products in a range of food choice contexts, to lower their price, and to promote their selection through labeling may be effective in promoting healthier eating patterns[69]. For instance, based on a small number of randomized-controlled trials, Hollands et al.[70] estimated that by reducing the availability of unhealthy snacks, energy selected per snacking occasion could be reduced by 35.6 percent. If these

[67] https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

[68] Milner J, Green R, Dangour AD, et al*., Health effects of adopting low greenhouse gas emission diets in the UK*. BMJ Open, 2015; 5.

[69] Antonelli M, *A Healthier and More Sustainable Global Food System: What is at Stake for the EU?*, IAI commentaries, 2022.

[70] Hollands, Gareth J., Patrice Carter, Sumayya Anwer, Sarah E. King, Susan A. Jebb, David Ogilvie, Ian Shemilt, Julian P.T. Higgins, and Theresa M. Marteau. *Altering the Availability or Proximity of Food, Alcohol, and Tobacco Products to Change Their Selection and Consumption*, Cochrane Database of Systematic Reviews, 2019

results generalized to food purchasing more broadly and also transferred to consumption, energy intake in the population could be substantially reduced.

In addition, the Farm to Fork strategy also seeks to improve efforts to educate the public about healthy and sustainable food choices. It includes actions aimed to improve people's decision in favor of healthier diets. It focuses on building decision-making competencies, equipping people with decision rules that fit their motivation and cognitive skills to maximize their effectiveness. however, changing food consumption patterns alone may not be sufficient to prevent overweight. Indeed, weight gain results from a positive energy balance, which is influenced by both energy intake and expenditure. For this reason, measures to increase physical activity have proven to be crucial. Even though these kinds of measures are beyond the scope of the Farm to Fork strategy they are included among Council recommendations[71]. Moreover, as highlighted in the previous paragraph the European Green Deal foresees changes in transportation both to reduce GHG emissions and promote healthy alternatives such waking and cycling.

[71] European Commission, *Council Recommendation of 26 November 2013 in Promoting Health-Enhancing Physical Activity across Sectors,* 2013.

CONCLUSION

After analyzing in detail, the various effects of climate change on human health, with particular attention to direct and indirect impacts, the influence of climate change on human health is unequivocal. Consequently, the need for action on the part of the competent authorities such as institutions and governments arise.

Climate change is putting our health at greater risk, progressively increasing the incidence of deaths and diseases related to extraordinary natural events, heat waves and the spread of food-and-water borne disease and vector- borne diseases. Data show how the rise in greenhouse gas emissions along with rising global temperatures has been steadily increasing over the last few decades, with very serious health consequences. Moreover, indirect impacts through socio-economic systems are dangerously aggravated millions of people's life conditions.

At the European level, The European Green Deal provides a roadmap aimed at making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for all. Its main goal is to boost the efficient use of resources by moving to a clean, circular economy and stop climate change, revert biodiversity loss and cut pollution. Overall, as analyzed in the final section, the health benefits for European citizens as a result of implementing the Green Deal are numerous. Starting from short-term benefit, such as cardiovascular diseases reduction to more comprehensive actions, such as the implementation of the Farm to Fork strategy and its dietary implications. We can claim that the European response seems to be a concrete action to really improve the health conditions of citizens and limit the impact of climate change. Nevertheless, capitalizing on their potential will require careful design and evaluation of policy choices. Furthermore, as already foreseen in the Deal, the EU is expected to play the leadership role and serve as an example for nations around the world. In fact, the successful implementation of the Green Deal also has important implications for other countries that will look closely at the EU's experience.

Most imporantly, the Union should succeed in his role of leader and be active in designing not only a regional but also a global action plan. Indeed, climate change is a global problem, therefore there is a need to address it with a common strategy and the involvement of as many players as possible.

In conclusion, we can state that European action represents a good starting point and an example to follow but that a global climate agreement is the only real solution. Yet the question is when and if this agreement is reached, would it not already be too late?

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ABSTRACT

INTRODUCTION

For a healthy and sustainable human population to be viable, certain factors must be ensured, such as clean air, safe water, safe and sufficient food supply, and tolerable temperature. Globally, it has been shown that climate and its variability can impact the prevalence and incidence of disease and other human health implications. Human activities have increased the concentration of greenhouse gases in the atmosphere, which have augmented the greenhouse effect and increased average global temperatures by approximately 0.9°C since the 1850s. Furthermore, the fifth assessment of IPCC reports (2013) made the strongest statement that the observed warming over the past fifty years was "unequivocal." In comparison, the strength of this scientific consensus is like the evidence linking smoking to carcinogens and cancer developments. Overall, climate change has led to devastating effects on the survival, health, and security of human societies. Diseases and disabilities result from many factors such as skin cancer, dengue, asthma, and malaria are expected to increase due to climate change.

This topic raises several questions: how climate change affects human health? How can the European Green Deal contribute to improving the health of European citizens? Will the measures in the package be adequate to cope with such global problem?

Firstly, to attempt to address these questions, we will outline the direct impacts on human health related to climate change. We will focus on the impacts of heat waves, the causes of circulatory, cardiovascular, and respiratory diseases together with health loses caused by natural disasters.

Secondly, we will analyze the indirect effects on climate change through the natural system focusing on airways diseases, food and water diseases and vector-borne diseases.

Thirdly, we will look at indirect effects through socio-economic systems. These concern the topic of food and water insecurity, the risks related to occupational health and vulnerable populations alongside with mental illness and stress caused by climate change.

Ultimately, in an overview of the European response to the climate change's challenges, the so-called Green Deal, is presented. We will analyze four main aspects of the Deal, namely the short-term health benefits, the implementation of green spaces in urban areas, the transformation of energy-efficient housing and the Farm to Fork strategy. In this section, we will try to assert whether the European response is adequate or different solutions should be adopted.

CHAPTER 1

DIRECT IMPACTS

Climate change is expected to raise overall temperature distribution and contribute to an increase in the frequency of extreme heat events, or heat waves. For a healthy and sustainable human population to be viable, certain factors must be ensured, such as clean air, safe water, safe and sufficient food supply, and tolerable temperature. Globally, it has been shown that climate and its variability can impact the prevalence and incidence of disease and other human health implications.

Climate scientists state that the evidence is unequivocal. The increasing global temperatures and climate change in the past century are due to human caused emissions of greenhouse gases.

Overall, climate change has led to devastating effects on the survival, health, and security of human societies. Diseases and disabilities result from many factors such as skin cancer, dengue, asthma, and malaria are expected to increase due to climate change.

Heat waves, which are continuous extreme hot days, form when high pressure in the upper atmosphere remains over a region for several days or weeks. Indeed, a heat wave can be described as a period when daily mean temperatures go above a specified high threshold temperature (e.g., 95th or 99th of the distribution) for at least two consecutive days in a given location.

Humans typically regulate their core body temperature to maintain an internal temperature of approximately 37°C, primarily through vasodilation and sweating. In this physiological process, heat is initially sensed by the skin, brain, and spinal cord. When body temperature increases, the brain, specifically the hypothalamus, sends signals to dilate blood vessels and increase blood flow to activate sweating. Through vasodilation, venous blood returns closer to the skin, transporting fluid to the sweat glands and increasing heat loss from the skin to the environment. Evaporation of sweat from the skin occurs extremely efficiently to cool the body and maintain a stable body temperature. In conditions of extreme heat, the ability to lose heat through sweating may be compromised, especially with concomitant high humidity. Illness and death caused by heat stress can occur in many scenarios from either indoor or outdoor exposures. Heat stress occurs in humans when the body is unable to cool itself effectively in a process known as thermoregulation. When multiple organs experience heat stress, the body will still attempt to thermoregulate itself as efficiently as possible. However, excessive sweating can lead to dehydration, and vasodilation is usually maintained regardless of low blood pressure (hypotension), which could cause heat syncope. Moreover, the decrease in sweating further inhibits cooling and at a body temperature of 38–39°C, heat collapse may occur.

Thermal stresses due to climate change could also lead to cardiovascular and respiratory diseases. Increased blood flow volume to the extremities increases heart rate leading to stress on the cardiovascular system. In addition, increased blood viscosity due to loss of body water or changes in coagulation may lead to increased thrombosis. All these changes could contribute to ischemic stroke and heart disease. Thus, high associations between temperature increases and ischemic stroke and heart disease could be highlighted. An increase in mortality during heat waves have been observed throughout the world. The 2003 European heat wave resulted in over 70,000 excess deaths, mostly among the elderly according to the World Health Organization. Obviously, old people together with indigenous and traditional people are expected to suffer the most from direct impacts and ongoing temperature increases are expected to exacerbate this burden.

Another direct impact of heat waves is related to respiratory diseases. Increased temperatures may trigger the release of inflammatory factors as well as enhance the growth of allergens and/or the transmission of viruses. Air pollutants, such as ozone, which are positively correlated with ambient temperature especially during the summer, may also cause or exacerbate respiratory symptoms and may have synergistic effects in combination with temperature.

Another observed direct impact concerns the health losses caused by disasters.

The so-called climate-related disasters (CRDs) are caused by oceanic and atmospheric hazards that are influenced by the global climate. The global increase of extreme weather events such as riverine flooding, cyclonic winds, storms, and droughts is related to climate change which acts as a force multiplier, exacerbating many of the world's global health challenges. On the one hand, disasters caused by extreme weather events can be associated with high precipitation, or low precipitation. On the other, disasters caused by extreme oceanic events (i.e., associated with sea level rise) have been associated with soil and groundwater salinification resulting in loss of food and water security. Both types of events can result in significant impacts on people's health and well-being, including the loss of many lives.

CHAPTER 2
INDIRECT IMPACTS THROUGH NATURAL SYSTEMS

It is possible to differentiate between indirect impacts through natural systems and through socio-economic systems. In this chapter, we will focus on impacts related to natural environments. With regard to indirect impacts via natural systems, three major groups can be identified, namely airways diseases and allergens, food-and-water borne diseases and vector-borne diseases. Accelerating climate change is anticipated to affect ambient air pollution levels by altering atmospheric chemical

reaction rates, boundary layer conditions affecting the vertical mixing of pollutants, and changes in air flow affecting the transport of pollution. Several significant air pollutants, particularly ground-level ozone, particulate matter, and aeroallergens are climate-sensitive and are affected by climate change. These pollutants increase the number of air pollution days that can be harmful to health and exacerbate underlying respiratory and cardiovascular diseases, leading to increased hospitalizations, and premature mortality. Moreover, acute, and chronic ozone exposure has been associated with significant adverse health effects in humans, including cardiopulmonary and respiratory morbidity and premature mortality. Indeed, ozone not only contributes to global warming but also causes measurable negative health effects during periods of acute and chronic exposure. Diseases such as asthma and allergic respiratory diseases are exacerbated by exposure to aeroallergens which are any airborne substance, such as pollen or spores, which triggers an allergic reaction.

Epidemiologic studies worldwide associated precipitation events with increased incidence of waterborne diseases together with the accelerated microbial growth, survival, persistence, and transmission of pathogens. Indeed, during such precipitation events, waterborne parasites such as Cryptosporidium can infiltrate the water treatment plant and persist in the water distribution system because of the resistance of its oocysts to chlorine disinfection. Moreover, an increase in ambient temperature has also been associated epidemiologically with a rise in the incidence of Salmonella and Diarrhea in the tropics and subtropics.

For what regards vector borne diseases, we can claim that the transmission and distribution of vector-borne diseases are strongly influenced by environmental conditions including climate. Furthermore, this kind of diseases can be considered climate sensitive. Indeed, a warmer climate increase the duration of favorable conditions for ectotherm development and reproduction. Temperature influences insect development, mortality, reproduction, and behavior. Likewise, precipitations, humidity, and vapor pressure are all important for their reproductive success. For example, temperature affects how long mosquitoes live, how quickly they mature to adulthood, how often they bite, and the population density. Sustained increases in average temperatures due to climate change are causing infectious disease transmission to spread to higher elevations and latitudes and may support long-term establishment and spread of vector borne diseases. For Malaria, for instance, recent studies projected that the additional number of people at risk of infection due to year-round transmission in South America will double from 2020 to 2080.

CHAPTER 3

INDIRECT IMPACTS THROUGH SOCIO-ECONOMIC SYSTEMS

Indirect effects of climate change also include the socio-economic dimension.

Firstly, they impact on food and water insecurity and the level of undernutrition. Indeed, climate change and variability can affect all the four dimensions of food security namely, food availability, stability of food supplies, access to food, and food utilization. We can observe that its impacts are greater in low-income populations in developing countries in Africa and Asia. Moreover, climate change and variability influence the key determinants of malnutrition, including food access, maternal and childcare, access to health services, and environmental health.

Secondly, it is possible to highlight indirect impacts on occupational health. Unprotected workers are one of the populations most susceptible to experiencing the effects of climate change. They are affected by climate-related exposures for longer durations and at greater intensities than the general public. For example, outdoor workers with high physical load, such as agriculture and construction, are most at risk for heat-related illnesses and cardiac arrests. Heat exposure can exacerbate cardiovascular, respiratory, and renal disease, which can result in significant morbidity and mortality.

Thirdly, the effect of these impacts in greater on vulnerable populations. The vulnerability of any given group is a function of its sensitivity to climate change related health risks, its exposure to those risks, and its capacity for responding to or coping with climate variability and change. Indigenous peoples, children and pregnant women, the elderly and the poorer are expected to suffer the most from the above direct and indirect impacts. It is possible to identify several factors that contribute to the exposure to climate-related variability and change. These factors include occupation, the amount of time spent in risk-prone locations, the ability to responses to extreme events, the socioeconomic status and the infrastructure condition and access.

Lastly, it is crucial to address the indirect impact of climate change on mental health. There are several mechanisms by which climate change affects population mental health, including natural disasters, heatwaves, forced migration, conflict over scarce resources, and physical comorbidity. Obviously, this burden of psychopathology is borne disproportionately by the poor and marginalized who lack the resources to protect themselves.

First and foremost, climate change will lead to higher average ambient temperatures and increase the frequency and severity of heat waves. Among their many previously analyzed health effects, heat waves are also associated with an increased burden of mental disorders and suicide.

Secondly, climate change will increase the frequency and severity of natural disasters such as windstorms, floods, and droughts. This will result in increased exposure to trauma, which can threaten mental health, as well as damage the material well-being of victims.
Thirdly, climate change will degrade landscapes, ecosystems, and habitats, thereby undermining agricultural productivity and ethnic, cultural, and religious traditions. Therefore, increasing instances of severe anxiety reactions, depression, aggression, and sense of loss.
Ultimately, climate change will intensify global competition for resources, which could increase the rate and consequences of global conflicts, especially in areas of poor and weak governance.

CHAPTER 4
THE GREEN DEAL: THE EUROPEAN RESPONSE

The European Green Deal, which was announced at the end of 2019, aims to respond to the growing climate crisis by achieving net zero greenhouse gas emissions in the EU by 2050.
To overcome the challenges caused by climate change and environmental degradation that pose an existential threat to Europe and the world, the European Green Deal aims to transform the EU into a modern, resource-efficient, and competitive economy. Its three main objectives are: achieving zero net greenhouse gas emissions by 2050, the implementation of economic growth decoupled from resource use and ensuring that no person and no place is left behind. It consists in a very ambitious scope, which also aims to establish a toxin-free environment, provide healthy and sustainable diets, and protect biodiversity. It thus encompasses the European agenda to support global health. In this context, it is important to emphasize the EU's intention to play a leadership role by rapidly reducing its own emissions and using its financial resources, knowledge, and leverage to encourage other nations to increase their climate actions.
As far as the benefits for European citizens' health are concerned, there are no doubts that the implementation of the plan will benefit many people. Short-term health benefits can arise through the implementation of successful policies in sectors that contribute substantially to emissions of CO2 and short-lived climate pollutants such as the energy, housing, transportation, food, industry, and health care sectors. Successful policies would reduce greenhouse gases, fine particulate air pollution, and ground-level ozone with consequently large health benefits. Moreover, replacing fossil fuels with clean renewable energy in these sectors could prevent ~3.6 million premature deaths each year worldwide (at 2015 population) from ischemic heart disease, stroke, chronic obstructive pulmonary disease, and other causes, with about 430,000 of these being in the EU.

In addition, the provision of green space in urban areas envisioned by the Green Deal would influence the health of citizens in multiple ways. For instance, exposure to green space within a five-minute walk of the home would stimulate its use: several studies report reductions in risk of non-communicable disease (such as strokes, heart diseases and diabetes) and improvements in mental health for those living in close proximity to green space. Green spaces can also reduce urban heat islands and associated diseases, as well as lowering additional energy cooling requirements.

Another aspect of the deal that is crucial to consider is transportation. In fact, important health benefits also come from transportation strategies to promote the so-called active travel (walking and cycling) along with increased use of public transports. Health gains arise in particular from encouraging sedentary middle-aged and older people to walk and bicycle. Accessibility to appropriate sustainable transportation options will be crucial: for instance, e-bikes may increase the likelihood of continued bicycling in old age.

The European Green Deal calls for the transformation of energy-efficient housing, achievable through retrofit programs to insulate existing homes and the installation of shutters to shade windows. This type of housing would reduce exposure to cold and heat, respectively, and thus improve the health of tenants. However, it is also important to provide adequate ventilation, which is critical to avoid the buildup of household air pollutants such as tobacco smoke and pollutants from cooking.

In terms of food, the "Farm to Fork strategy" is an important component of the Green Deal and specifically addresses the sustainability of the EU food system. In addition to the positive health impacts of reducing emissions and pollution through cleaner, more sustainable food production and processing, the strategy aims to actively engage consumers by encouraging dietary changes toward more sustainable foods including vegetables, fruits, and whole grains, and reducing consumption of red and processed meat. In this case, health benefits include reduced prevalence of obesity and reduced risk of ischemic heart disease and stroke.

Overall, for the above examples, it is possible to claim that there are great health benefits from implementing the Green Deal. However, capitalizing on their potential will require careful design and evaluation of policy choices, together with the involvement of other global players.

CONCLUSION

To conclude, after analyzing in detail the various effects of climate change on human health, with particular attention to direct and indirect impacts, it is unequivocal the need for action on the part of the competent authorities such as institutions and governments. Indeed, climate change is putting our health at greater risk, progressively increasing the incidence of deaths and diseases related to

extraordinary natural events, heat waves and the spread of food-and-water borne disease and vector-borne diseases. Data shows how the increase in greenhouse gas emissions along with rising global temperatures has been steadily increasing over the last few decades, with very serious health consequences. In this context, the European response with the Green Deal seems to be a concrete action to really improve the health conditions of citizens and limit the impact of climate change.

Overall, as analyzed in the final section, the health benefits for European citizens as a result of implementing the Green Deal are numerous. Nevertheless, capitalizing on their potential will require careful design and evaluation of policy choices. Furthermore, as already foreseen in the Deal, the EU is expected to play the leadership role and serve as an example for nations around the world. In fact, the successful implementation of the Green Deal also has important implications for other countries that will look closely at the EU's experience. Since climate change is a global problem, there is a need to address it with a common strategy and the involvement of as many players as possible.

In conclusion, we can state that European action represents a good starting point and an example to follow but that a global climate agreement is the only real solution. Yet the question is when and if this agreement is reached, would it not already be too late?