The nature – climate change – mental health nexus: A literature review

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Executive summary

Background and purpose

Growing attention is being paid to the interlinkages between climate change, nature, and human health. In particular, climate change and climate change-related events have been linked to a range of mental health challenges. Noting the potentially devastating effects of mental health ailments on society both in terms of general well-being as well as economically (mental health care was estimated to be more than 4% of gross domestic product in 2015 across the 27 EU countries and the United Kingdom [1]), the value of healthy and resilient environments are being increasingly recognized. In this context, green spaces have been found to act as both preventative measures and therapeutic approaches to lessen the negative impacts from climate change on mental health. By promoting access to and utilization of green spaces, individuals and communities can benefit from the positive effects of nature on mental health.

Nature-based solutions[1] offer opportunities for individuals to recover from mental health challenges posed or exacerbated by climate change. Access to green spaces encourages physical activity, potentially improving overall health and better equipping the population to handle stress and mental health issues. Implementing nature-based solutions in urban areas fosters a sense of place and identity, strengthening community bonds and providing a stronger sense of belonging. Nature-based solutions are highly valuable for communities and urban resilience as they provide restorative effects, promote community cohesion, support biodiversity and ecosystem services, and contribute to climate change adaptation.

This report highlights the significance of considering mental health as an integral component of climate action and nature-based solutions. Nature-based solutions and green space management not only support individuals in coping with mental health challenges but also contribute to building community resilience and promoting overall well-being. Furthermore, the report emphasizes the importance of addressing the mental health implications of climate change and recognizes the potential of green spaces and nature-based solutions as effective tools for mitigating and managing these impacts. Valuable insights are provided for policymakers, healthcare professionals and communities. The findings underscore the need for integrated approaches that prioritize mental health and nature-based interventions within climate change adaptation and mitigation action, ultimately enhancing the societal resilience and the mental health of individuals and communities facing the challenges of a changing climate.

How can climate change affect mental health?

- Climate change affects our surroundings through unpredictable and often extreme weather events, as well as through more general changes in local climates. These changes threaten several existing aspects of society, such as the health care system, urban living and well-being, agriculture, and food production.
- Society is facing increasingly frequent and severe threats from floods, heatwaves, ambient air pollution, and noise, which could lead to challenges such as post-traumatic stress disorder (PTSD) and emotional distress. A more indirect consequence of climate

[1] **Nature-based solutions**. On the Fifth session of the United Nations Environment Assembly (UNEA-5) [2], resolution 5 defined Nature-based Solutions as 'actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits' [3]. Furthermore, the NbS should act according to social and environmental safeguards and the 2030 Agenda for Sustainable Development.

change on mental health is eco-anxiety[2], which is becoming increasingly frequent for several demographic groups.

- Demography and socio-economic status are important indicators for how severe the consequences of climate change can be for mental health. There is a strong correlation between the impairment of social and economic conditions and mental health challenges.

How can green space and nature-based solutions affect mental health?

- Nature can provide physical and psychological shelter from extreme weather and climatic changes and contribute to building both ecological and social resilience to climate change, e.g. through climatic regulation and water retention.
- Nature provides a variety of ecosystem services, i.e. the perceived benefits humans receive directly and indirectly from the natural functioning of ecosystems. Examples are recreation and leisure, sense of place and attachment, spaces for community development and activities, sense of wonder, and ecotherapy.
- Nature could serve to relieve stress, contribute to higher levels of recreation, and is being used for such purposes in therapeutic settings.
- The perception of nature and recreational preferences is demographically and socio-economically conditioned. Access and exposure to nature is often not fairly distributed.

What are important future research needs & opportunities?

Longitudinal studies: Longitudinal studies are valuable to understand the long-term effects of nature-based solutions and climate change on mental health. Future research should focus on assessing the sustained impact of nature exposure and engagement on mental health and well-being over time.

Funding: Increased funding is needed to support research on the relationship between climate change, nature, and health. A key argument for the importance of this funding is the opportunities of nature as a measure to build both ecological and social resilience.

Transdisciplinary research and multifunctional nature-based solutions: Transdisciplinary approaches hold great potential to bring together experts from various fields to develop a holistic understanding of the multifunctionality of nature-based solutions and their potential impacts on health and well-being.

Bottom-up research and policy initiatives: Engaging local communities is critical, incorporating their perspectives and knowledge, and evaluating grassroots initiatives' effectiveness in promoting health and well-being. This can lead to more inclusive and community-driven approaches in addressing the impacts of climate change and nature on mental health.

Policy analysis: Comprehensive policy analysis at both national and international level can serve to assess the effectiveness and implementation of nature-based solutions within existing frameworks and evaluate policy coherence, identify good practices, and help to understand the socio-political factors that influence the integration of nature into health policies, and health into environmental policies. Findings can provide insights to policymakers to develop evidence-based strategies that maximize the (mental) health benefits of nature and address related challenges of climate change.

[2] The American Psychology Association (APA) describes **eco-anxiety** as 'the chronic fear of environmental cataclysm that comes from observing the seemingly irrevocable impact of climate change and the associated concern for one's future and that of next generations' [4].

1 Introduction

1.1 Background

The mental health and well-being of individuals are intricately linked to their environment, encompassing various factors like social structures, cultural background, healthcare infrastructure, access to nature and green spaces, and individual demographics. Additionally, the consequences of climate change, such as floods, drought, changes in precipitation, heatwaves, and disruptions in agriculture and nature conservation, further influence the environment and can impact mental health and well-being. Resultant mental health challenges and the need to address these holistically are increasingly recognized, as evidenced by actions like the EU's development of a mental health legislation[3].

Within the nature-climate change-health nexus, nature and green spaces play a dual role. On the one hand, the availability and access to these spaces can impact an individual's mental health. At the same time, green areas can help mitigate climate change and reduce its negative impacts. The experienced effect of nature and green spaces is highly individual, but studies support the contributions of areas such as parks, urban- and peri-urban forests, natural forests, and street tree canopy to stress relief and reduced anxiety [5] as well as serving as places for recreational activities, such as sports, social gatherings, and spiritual practices [6]. Nature and green spaces can also impact physical properties of local environments, such as air quality, humidity, heat stress, and soil quality [7].

Nature-based solutions have been recognized in this context for their potential to simultaneously influence ecological and human health conditions while delivering a range of additional societal benefits. Nature-based solutions can be understood as 'actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits'. [3]. Yet causality between climate change / nature and mental health is often difficult to establish and the methodologies necessary to strengthen the knowledge foundation (e.g., longitudinal studies) are often too expensive to be conducted in practice. Furthermore, evidence on the effect on mental health is usually conditional and not generalizable across location, demographic groups, or local climate. There is thus the need to critically review existing literature and evidence around the effects of climate change and nature on mental health and human well-being to understand the current state-of-the-art and identify areas needing further research.

This literature review explores the potential of nature to mitigate the negative impacts of climate change as well as to improve humans' mental health and well-being in response to these impacts. In doing so, we are able to outline the current state of the art in mental health and related inequality and inequity challenges within in the research community. Figure 1 illustrates the explored linkages.

[3] COM (2023) 298 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions on a comprehensive approach to mental health. Brussels, 07.06.2023. URL: https://health.ec.europa.eu/system/files/2023-06/com_2023_298_1_act_en.pdf

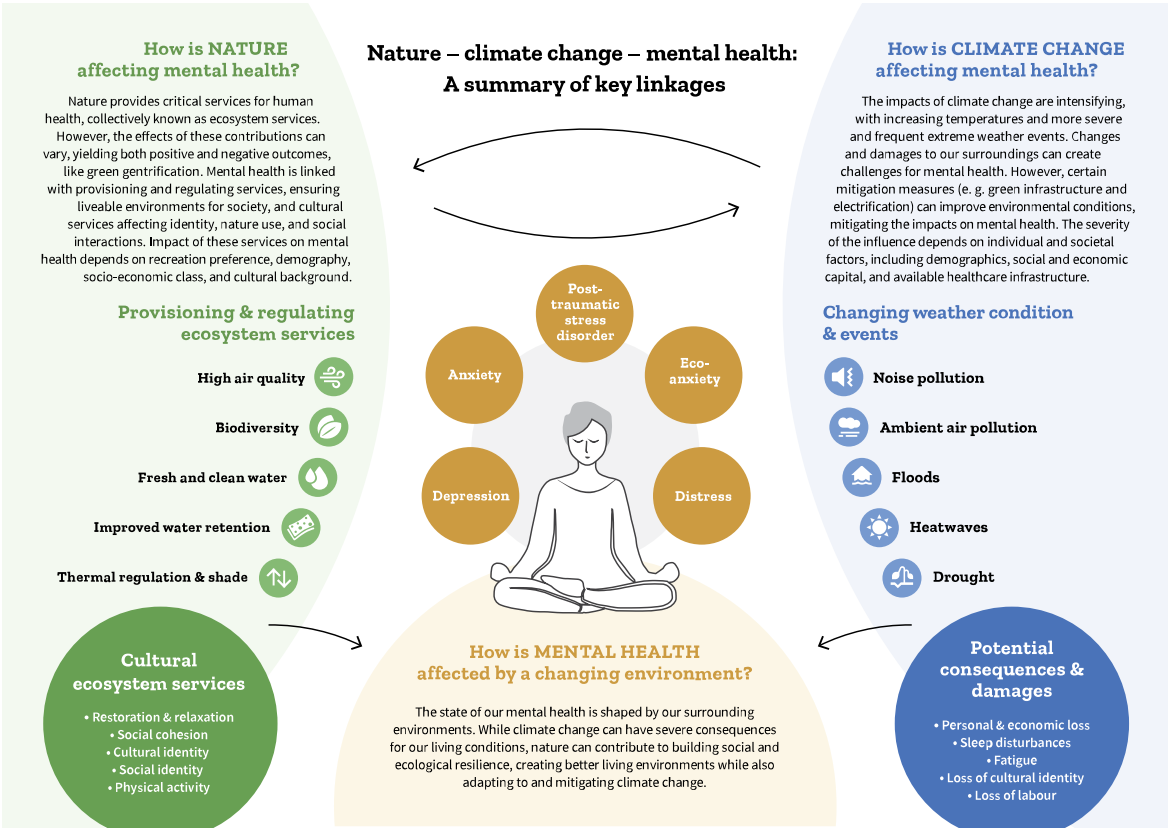

Figure 1: Graphic overview of study. © Infographic idea and design by Ecologic Institute. 2023.

1.2 Scope and definitions

This literature review targets literature published both before, during, and after the covid-19 pandemic (2015-2022). The keyword lists were developed aiming to frame different aspects of mental health in relation to important characteristics of surrounding environments that are associated to climate change and nature-based solutions. The review explores (1) how mental health is affected by the effects of a changing climate in Europe, and (2) how green spaces and nature-based solutions can play a role in reducing and treating those negative effects. In order to answer these research questions, the literature review pursues two steps:

(i) identify frequent mental health ailments arising as a result of the impacts of climate change;

(ii) explore how green space and nature-based solutions can serve as both a preventative measure to lesson/avoid the impacts of climate change on mental health and as a treatment to help recover from the mental health impacts;

Beyond this, knowledge from the literature review is used to discuss environmental justice and how perceived impacts of climate change and nature differs within a society and between demographic groups. Finally, the main research gaps and opportunities are outlined. A comprehensive Methodology section, including limitations and uncertainties, can be found in Annex I and II, respectively.

1.2.1 Definitions of key concepts

Mental health and well-being: 'Mental health is a state of mental well-being that enables people to cope with the stresses of life, realize their abilities and work well, and contribute to their community. It is an integral component of health and well-being that underpins our individual and collective abilities to make decisions, build relationship and shape the world we live in' [8].

Nature and green space: The term 'nature and green space' refers in this study to all natural or human created green and blue areas (referring to water features) that exist within a city or region. These landscapes can range from highly modified and managed environments such as grass-covered parks to more natural landscapes, such as urban forests.

Nature-based solutions: On the Fifth session of the United Nations Environment Assembly (UNEA-5) [2], resolution 5 defined Nature-based Solutions as 'actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits' [3].

Ecosystem services: The perceived benefits humans receive directly and indirectly from the natural functioning of ecosystems [9,10]. Ecosystem services exists in a variety of frameworks and scopes, but generally provide an emerging foundation to study the human-nature relationship.

Urban revitalization: Urban restoration assessing social and/or economic challenges. The process of urban revitalization can, but will not necessarily, lead to gentrification of an area [11].

Equality and equity: Equality is considered to exist when all individuals and groups of a society are given equal treatment, regardless of individual needs or the outcome of this treatment. Equity would rather focus on equal outcomes for individuals, and recognizes that some disadvantageous group may have different needs for support or resources in order to obtain the same social outcomes as more advantageous groups [12,13].

2 Mental health in a changing world: Insights from the literature

The dynamic nature of mental health is strongly influenced by the surrounding environment, which is in turn affected by climate change and nature. Various factors such as local climate, geography, demographics, infrastructure, healthcare availability, and governance play a role in shaping these conditions. This relationship is further influenced by socio-economic status and social capital. As a result, determining the extent to which mental health conditions are affected by these aspects is challenging and involves complex causal relationships. In the following section, we will explore several attributes that may impact our surroundings, thereby influencing our mental health and well-being.

Existing literature highlights the mental health-climate change-nature nexus. Climate change can indirectly affect our surroundings through events like flooding, heatwaves, ambient air and noise pollution, potentially leading to conditions such as PTSD, stress, anxiety, and depression. Additionally, climate change has directly contributed to the emergence of eco-anxiety, a fear or distress related to environmental concerns. On the other hand, nature, in its various forms, can influence mental health through stress relief, restoration, therapy, and community and social

development [14,15]. Moreover, nature's role in regulating climate and temperature may help mitigate the adverse effects of heatwaves and floods on societal well-being. Thus, mental health, climate change, and nature are intricately interconnected elements that warrant comprehensive examination.

2.1 Climate change and mental health

Key messages

- Climate change affects our surroundings through unpredictable and often extreme weather events, as well as through a general change in local climate. These changes threaten several existing aspects of society, such as the health care system, urban living and well-being, agriculture, and food production.
- Society is facing increasingly frequent and severe threats from floods, heatwaves, ambient air pollution, and noise, which could lead to challenges such as PTSD and emotional distress. A more indirect consequence of climate change on mental health is eco-anxiety, which is becoming increasingly frequent for several demographic groups.
- Demography and socio-economic status are important for how severe the consequences of climate change will be for mental health. There is a strong correlation between the impairment of social and economic conditions and mental health challenges.

Climate change will affect humans' living environments to varying degrees, depending on geography, local climate, socio-economic and demographic structures, and available health infrastructure. The ecological and environmental consequences can range from mild to extreme, through events such as floods, heatwaves, and drought, or more permanent changes in environmental conditions such as ambient air pollution and noise, or changes in precipitation patterns or temperature. Mental health challenges related to these events and environmental changes could be heat distress, stress and depression related to changing and unpredictable working conditions (e.g. for farmers and other agricultural workers), or PTDS from experiencing a trauma [16]. The development (or absence of development) of psychological challenges is highly dependent on the existing structures of an individual's surroundings and society in general.

Floods can have severe impacts on economic, environmental, and social structures. Possible consequences of flooding events, depending on the severity of the flood and the societal resilience, are death, damage of private and public property, spreading of diseases, and impairment of water and sanitation systems. Floods could cause serious consequences for mental health and well-being through increased levels of distress and the development of PTDS [17]. Displacement and economic loss have shown to increase the severity of mental health challenges, while strong local communities and social capital could decrease the negative impact [17,18].

A variety of mental health challenges can be experienced after a flooding event. Some could experience mental distress and anxiety when fearing for something similar happening in the future, for example by experiencing heavy rainfall. Other reactions could be flashbacks, nightmares, and sleeplessness [18]. Reported mental health challenges are often negatively correlated with household income [18], indicating that economic instability makes people more vulnerable for developing mental health challenges. The same accounts for the severity of the

flooding event. The strongest correlation is found between mental health challenges and relocation needs [17], again showing that personal loss would have a large impact on mental state. Warnings and precautions may lead to milder symptoms, suggesting that people are willing to contribute to resilience measures to decrease flood risk in society [19], through for example nature-based solutions [14]. Usually after a flooding event, people experience not only one, but a combination of different mental health challenges (e.g., anxiety and sleeplessness), that will vary in severeness and temporal scale. Social resilience and a strong community has been shown to have a large positive impact, especially immediately after and the time following the event, while lack of support from state or municipality could have a negative impact on psychological outcomes [17].

Heatwaves can have serious impacts on social and environmental structures. The economic consequences could be more indirect [20], triggering for example an increased pressure on the health care system and unpredictable conditions in the agricultural sector. Mental health challenges are valid for all socio-economic and demographic groups, with elderly (+65 years) being the group usually of highest risk [21]. However, social groups usually considered at highest risk of health challenges due to heatwaves could be those who are exposed the least, and vice versa [22], which indicates that all population groups can be considered at risk. In some locations, the impacts from heatwaves is unevenly distributed across socio-economic groups, for example striking more severely in high-density areas with a lower amount of green spaces and vegetation [15,23]. As for floods, preventative work is often well received by the public, and exposure to heatwaves could increase the support for green adaptation policies [24].

The mental health challenges experienced from heatwaves highly depend on demographic group and socio-economic status. Frequently reported impacts from heat stress are lethargy, difficulty sleeping, trouble concentrating, and headaches [22], which are all conditions that could impair the daily level of well-being. Lethargy is most frequently reported by elderly, while trouble with concentrating and headache is more often reported by students. At the same time, adolescents, young adults, and students could be the groups with the highest exposure level to heatwaves [22]. With increasing severity of heatwaves globally, it might be important to analyze the related risks across all demographic groups [22,25], and not just the ‘classical risk groups’, such as elderly or people of poor health.

Ambient air pollution and noise pollution caused by polluting industries, such as mining, traffic, construction, and shipping, can cause psychological impacts including increased levels of stress and mental fatigue. Climate change and high levels of ambient air and noise pollution share a complex relationship as they are both driven by human activities and environmental factors. The burning of fossil fuels for energy and transportation releases greenhouse gases, which has a warming effect due to trapped heat in the atmosphere [26]. As temperature rise, air pollution worsens causing increased ground-level ozone formation and particulate matter, posing health risks to humans. Additionally, climate change creates drier and hotter conditions, contributing to more frequent and intense wildfires, releasing harmful smoke and pollutants. Urbanization and transportation activities further add to air and noise pollution, affecting human health and ecosystems. Environmental impacts with additional impact on human health, could be impaired conditions for pollinators and plant biodiversity, that are highly affected by both air pollution and noise [27]. Consequences for mental health is often a larger challenge in more deprived neighborhoods and for groups of lower socio-economic status [28]. The perception of safety is also an important aspect in many urban areas, and unsafe living conditions could be a problem in many places where air pollution and noise are also challenges. The same accounts for garbage, creating unhealthy living conditions and impairing the feeling of well-being for many [28]. Furthermore, it is not necessarily city life itself causing psychological stress and other challenges, and it is shown that city connectedness and urban stimulation also contributes to

mental health [28], indicating the complexity and challenges related to urban planning and the diversity between urban areas [23,29,30].

Eco-anxiety is the perceived distress caused by climate change, and the fear of severe impairment in future living conditions and well-being for subsequent generations [31]. The most reported feeling in relation to climate change is frustration, rather than depression [32]. This could be a trigger to higher levels of climate action, instead of for example helplessness and paralyze. The emerging prevalence of eco-anxiety is something that is more commonly reported by children and young adults. It could also be an emerging challenge for some indigenous communities, such as Innuits in Greenland or Sámi in the Nordic countries, that are often dependent on nature both commercially and culturally and with potential strong emotional bonds to scarce nature areas [33]. Other groups of potential risk are those who are dependent on predictable weather conditions for labor, such as farmers or other employees of agricultural practices. Drought, heavy precipitation or other unpredictable weather events could impair the general well-being of farmers by creating economic and socially unstable living conditions [34,35]. Further contributing to eco-anxiety could be concerns about individual carbon footprints [36], making climate change an individual, and not an institutional and systematic problem.

Case study: United Kingdom winter floods (2013-2014)

Studies from the UK shows that the health consequences of flooding events are not only physical, but also mental, with possible long-term effects and damages. Studies exploring the experiences of the victims of the 2013-2014 UK winter floods indicates that mental health challenges are highly dependent on social capital and community relations (Walker-Springett et al. 2017). Furthermore, the victims who were forced to displacement reported higher psychological damage and long-term effects than those who were not displaced. Commonly, people who have experiences or is in risk of experiencing extreme events such as floods are more in favour of adaptation measures and green infrastructure to promote resilience against severe damages (Carter et al. 2015; Lamond & Everett 2019)

References: [17,23,30]

2.1.1 Regional comparisons

Specific impacts of climate change can vary across regions. Europe is experiencing various consequences of climate change, including heatwaves, extreme weather events, sea-level rise, and changing precipitation patterns. These impacts can lead to increased stress, anxiety, and trauma among affected populations. In other parts of the world, such as low-lying coastal areas or regions prone to droughts and floods, the mental health effects may differ due to the specific climate-related challenges faced by those regions. The effect of climate change and the needs for effective disaster risk reduction should be understood within the context of cultural processes [37].

Socio-economic factors play a significant role in shaping the mental health impacts of climate change. Europe generally has a higher level of socio-economic development, access to healthcare, and social support systems compared to many other regions. These factors can influence the vulnerability and resilience of individuals and communities in coping with climate-related mental health challenges. In less developed regions with limited resources and infrastructure, the mental health effects may be more severe due to the additional stressors associated with climate change impacts [38].

Europe has been active in implementing policies and adaptation measures to address climate change and its associated mental health impacts, and recently introduced a comprehensive

approach to mental health [39]. The EU has recognized the importance of mental health in climate action and has integrated mental health considerations into climate change policies and strategies. Other regions may have varying levels of policy frameworks and adaptation measures in place, which can affect the availability of resources, funding, and support systems for mental health in the context of climate change.

The level of research and data availability on the effects of climate change on mental health can vary between Europe and other regions. Europe, with its well-established research infrastructure, may have more extensive studies and data on the mental health impacts of climate change. In contrast, other regions may have limited research and data foundation, which can hinder the understanding and response to climate change-related mental health challenges.

2.2 Nature and mental health

Key messages

- Nature can provide physical and psychological shelter from extreme weather and climatic changes and contribute to building both ecological and social resilience to climate change, e.g. through climatic regulation and water retention.
- Nature provides a variety of ecosystem services, i.e. the perceived benefits humans receive directly and indirectly from the natural functioning of ecosystems. Examples are recreation and leisure, sense of place and attachment, spaces for community development and activities, sense of wonder, and ecotherapy.
- Nature could serve to relieve stress, contribute to higher levels of recreation, and is being used for such purposes in therapeutic settings.
- The perception of nature and recreational preferences is demographically and socio-economically conditioned. Access and exposure to nature is often not fairly and equally distributed.

Nature shapes the cultural, social, and biological environments of human beings. Mental health is strongly linked to one's surroundings, with psychological well-being being highly affected by access to and quality of nature. The literature suggests that the function of natural areas are dependent on their form and quality, with mental health being most often linked to parks, urban and peri-urban forests, natural forests, street tree canopy, gardens, and coastal areas [5,40,41]. Blue spaces can also make positive contributions to mental health and well-being [42–44], with impacts varying based on their quality and accessibility [45,46]. Such green and blue spaces can promote physical, cultural, and social activity and thereby affect mental health. However, recreation preferences and opportunities vary across demographic and socio-economic groups and affect the impacts of nature on mental health.

Ecosystem services, or cultural ecosystem services, are the perceived benefits humans receive directly and indirectly from the natural functioning of ecosystems [9,10]. These benefits can be seen as the social and cultural advantages humans gain from nature. A variety of ecosystem services could be provided by nature, such as recreation and tourism, sense of place, authentic wilderness, education value, cultural heritage and diversity, social relations, spiritual value, inspiration and aesthetic value [9]. The benefits of these ecosystem services could have a large impact on mental health and well-being of inhabitants in urban and rural areas of Europe [47].

Biological attributes of nature can directly impact human bodies, influencing physical health, and subsequently, mental health and well-being. Spending time in green spaces can reduce stress levels, lower blood pressure, and enhance cardiovascular health [48,49]. Trees and vegetation filter air pollutants by improving air quality and reducing respiratory issues. Engaging with nature can boost serotonin levels, fostering happiness and well-being [50]. Urban parks and forests can contribute to decreasing the negative effects of urban heat stress by providing shade and shelter [15,25]. Green spaces can absorb a lower amount of solar radiation, compared to for example brick roads or asphalt [51]. Trees and vegetation on ground, as well as regulated urban blue spaces, contributes to increased evapotranspiration and humidity, regulating thermal conditions and water retention, possibly building resilience to severe damages from floods or heavy precipitation [52,53]. Thus, with the increasing risks from climate change on climatic conditions in several European cities, these attributes of nearby nature are of high importance for why people would seek or promote nature and green spaces.

Biodiversity and species richness play a crucial role in our connection with nature [54], offering diverse and enriching sensory experiences that includes songbirds, colours, and scents [55]. While the impact of biodiversity on our mental health is not fully understood, some interesting findings have emerged. For instance, studies have examined the mere presence of biodiversity, demonstrated through experiments with aquariums containing or lacking fish. The results showed that being exposed to an aquarium with fish led to a lower heart rate compared to an aquarium without fish, indicating a potential positive effect of biodiversity on human stress levels [49]. Interestingly, the level of biodiversity itself may not be the sole determinant of its impact. Research suggests that the presence of biodiversity alone holds significance. Moreover, when given a choice, people generally prefer the presence of songbirds and high species richness over a large number of the same bird species [56,57]. Investigating these preferences can be more challenging unless participants are immersed in natural environments. Several studies have explored the potential benefits of activities like forest, park, and coastal walks. As a result, bird and nature-based therapies are increasingly being used in various countries as a form of treatment [58].

Stress levels have proven to be directly affected by one's surroundings. Exposure to nature could be stress revealing simply because of the lack of stressful stimuli and not because of the nature attributes themselves [28]. Comparing a walk in a busy street with a walk in a forest area shows decreased activity in amygdala [48], that is the area of the brain processing fear signals. Nature could have calming and relaxing effects in a therapeutic situation, improving the conditions for mental health and well-being [58]. Studies conducted in early stages and during the COVID-19 pandemic shows that nature and green spaces can play an extra important role when unusual life circumstances are affecting mental and physical health, on both social and recreational levels [59]. Furthermore, green spaces could play a more prominent role for the mental health and well-being of citizens in places where a pandemic hits harder and lock-downs are more severe [60] and for citizens in high-risk groups (such as elderly or people with underlying health conditions) [61]. However, the study of nature's effect on urban citizens during a pandemic must take into account different demographic structures, as not necessarily all groups of society enjoys the benefits of nature [62], as well as unusual circumstances observed during a pandemic.

Physical or creative activity often cause stronger experiences and mental health benefits from exposure to nature [53,63]. Physical activity of inhabitants could be triggered by nearby green spaces and lead to improved and increase in physical activity, which subsequently can have benefits for mental health. However, it can be challenging to determine whether it is the physical activity or exposure to nature, or a combination of the two, with a positive impact on mental health [64,65]. A general finding is that improved well-being is associated with being

close to nature while the brain is being stimulated [66]. Gardening can have recreational, restorative, and stress relieving effects on mental health and well-being [54,67,68]. This accounts for both allotment and domestic gardening, where allotment gardeners usually are socio-economically less privileged than domestic gardeners. Furthermore, differences are seen between residential gardening and allotment gardening, as allotment gardening provides also a social dimension, and additionally being available for a larger part of society and includes a broader specter of different demographic groups [54].

Demography, socio-economic structures, and culture will impact the effect of nature on mental health [69,70]. People seek nature of different reasons, such as pleasure, stress/anxiety release, recreation, social gathering, physical activity, etc. Social activity is an important aspect for many, usually spanning across demographic groups and cultures [53]. In this relation, it is important to discuss the difference between fair and equal distribution of or access to nature and green space. That is, the presence of nature does not mean that its accessible and meets the recreational preferences of everyone. For example, recreational preferences can differ between age groups and neighbourhoods. Younger people tend to prefer more urban environments, that are also located closer to other urban facilities. Furthermore, people often choose to live according to their recreational preferences, though this is also impacted by socio-economic status [69]. Other factors of importance for perceived emotional well-being and restoration benefits are local identity, history, and culture [71]. For instance, different ethnic groups within a society might define green space quality differently and have different perceived benefits from nature [72]. As such, a tendency of urban development is often that people of lower socio-economic status settle at the far outskirts of urban areas, possibly closer to nature but further away from other social and urban infrastructure [73].

Nature connectedness, personal perceptions and preferences, and previous experiences will impact the reasons to visit and the following perceived benefits or disadvantages [70]. Studies report that people with stronger emotional bonds to and knowledge about nature could also gain stronger positive experiences from nature exposure [74]. For example, biodiversity and species richness could be more important for mental health of people with eco-centric and nature-relatedness traits [40,75]. Furthermore, there are several reasons for why people would choose not to visit nature or decide that the available nature is not accessible for them. People of physical disabilities or elderly may have the opinion that some nature spaces are dangerous or not properly designed for their needs. Others might have the experience that nature areas are not safe, often having the feeling of being exposed or insecure when visiting nature areas. Some places, forests specifically was preferred for improved well-being during the pandemic [76]. This could also stem from the possible difference in perception of natural and semi-natural green space [77].

The mental and physical health of children, adolescents, and young adults could be extra vulnerable to climate change [78] and accessible and available public green space for children might be crucial in the process of reducing health inequalities [79]. Access of nature could play an important role in the development of pro-social behaviour and cognitive functioning, as well as having a stress-reducing effect [80,81]. Private gardens also play an important role but are less common in low-income households and studies from Barcelona shows larger and greener schoolyards typically are found in wealthier districts [82]. Also students could benefit from campus green space, having recreational, social, and relaxational benefits and improving well-being and everyday life in a campus setting [83].

The proximity of residences to green spaces is crucial for making nature accessible and available [84]. The 3-30-300 rule [80,85] proposes that every citizen should see at least three trees from their home, have 30% tree canopy cover in their neighbourhood, and be within 300 meters of the nearest green space. However, many European cities do not meet these requirements [86], potentially leading to insufficient exposure to urban green space for citizens [73,87]. Access to green spaces does not necessarily guarantee utilization, and integrating green space planning with social equity considerations is vital to create inclusive and sustainable cities where nature benefits all residents [69].

Case study: The relationship between nature and mental health in Oslo, Norway

Urban nature and green spaces, as well as forest areas near the city has shown to have a significant impact on the mental health of the inhabitants of Oslo, Norway (Berglihn and Gómez-Baggethun 2021). During the outbreak of COVID-19 the use of urban green infrastructure for recreation and physical activity increased significantly, especially amongst teenagers (Venter et al. 2021). However, the perceptions of recreation and preferences for activities in nature are highly dependent on demographics and cultural background. Daily recreation is possible for most inhabitants in the Oslo area, but lower accessibility is associated primarily with minority groups and low-income households (Suárez et al. 2020).

References: [47,62,69]

2.2.1 Regional comparisons

Access to nature may be limited in many urbanized European areas. In contrast, some parts of the world, particularly rural or less densely populated regions, may have more abundant and easily accessible natural environments. These differences in access to nature can influence the frequency and intensity of the mental health benefits derived from nature [84,90].

Many European countries have implemented policies and developed infrastructure to support the integration of green spaces and nature-based solutions into urban planning and healthcare systems [91]. This includes the creation and maintenance of parks, gardens, and other green areas. Furthermore, socio-economic factors, such as income level and education, can influence the access and utilization of green spaces and nature-based solutions. European countries with higher levels of socio-economic development often have better resources and infrastructure to support the integration of nature into mental health practices. On the other hand, socio-economic disparities can impact the availability and utilization of green spaces and nature-based solutions. In some regions across the world, limited resources and infrastructure may hinder the widespread implementation of nature-based solutions for mental health.

It is important to note that while these comparisons highlight some general differences between Europe and the rest of the world, there is significant diversity within each region. Different countries and local contexts within Europe and the rest of the world may have unique approaches and outcomes in relation to the effects of green spaces and nature-based solutions on mental health.

3 Research gaps

3.1 Climate change and mental health

The impacts of climate change on mental health can vary significantly across regions and communities [20]. There is a need for more localized research to assess the specific health risks and vulnerabilities of different populations. This includes considering geographical, socio-economic, and cultural factors that influence exposure and susceptibility to climate-related health risks. Furthermore, there is a need to understand the most effective strategies and interventions for adapting to climate change and building resilience in the health sector [23,25,78]. This includes identifying and evaluating adaptive measures in healthcare infrastructure, public health systems, and community resilience programs to mitigate the adverse health effects of climate change.

Effective communication and public awareness play a vital role in addressing climate change-related mental health risks. Research is needed to better understand how to effectively communicate complex climate-health information to different audiences, enhance public awareness, and promote behaviour changes that support both climate resilience and health.

3.2 Nature and mental health

Details regarding the dose, frequency, and duration of exposure to nature and the respective impacts on mental health remain unclear within the existing research. The effect of exposure is personally determined and dependent on demographic and socio-economic structures. Factors such as age, gender, and cultural background may influence how individuals perceive and respond to nature. This information could be important to guide recommendations and policymaking for incorporating nature into healthcare and urban planning. Low-income groups could greatly benefit from public parks and urban green spaces [88], and it is essential to understand the needs of all levels of society in in order to enhance local identity and ownership and to reduce the risk of gentrification [89].

Longitudinal studies investigating the long-term impact of nature exposure on health outcomes are necessary to understand the sustained benefits and potential preventative effect of regular nature engagement. Furthermore, research is needed to explore the practical aspects of implementing nature-based interventions in various settings, such as healthcare facilities, schools, and urban environments. Understanding the scalability, feasibility, and cost-effectiveness of such interventions is crucial for their widespread adoption.

4 Reflections and opportunities for future action

Future research needs and opportunities

- Longitudinal studies
- Funding
- Transdisciplinary research and multifunctionality of nature-based solutions
- Bottom-up research and policy initiatives
- Policy analysis
- Nature and mental health during and after a pandemic

Longitudinal studies are often not an option when designing research due to practical financial constraints. These studies usually provide valuable insights into the long-term effects of variables like nature or climate on mental health and can be particularly useful in investigating complex causal relationships. Examining the impact of nature and climate change on mental health can provide crucial information for policy makers, urban planners and decision-makers, and local up to national governments. Nature is considered a multifunctional solution that benefits both ecological and social conditions, making it highly relevant for the sustainable development of society. Moreover, analysing long-term effects is important in an environmental justice perspective, as the effect of green space and nature-based solutions on mental health often benefits other groups than those in target [73]. Recognizing the differences within a society is important also to create diversity within policy-making groups, as the perceived benefits vary considerably across the population affected by these policies [92,93].

Lack of funding is one of the main limitations for the implementation, maintenance, and development of nature-based solutions. It can hinder implementation and efforts to create and maintain green spaces, parks, urban forests, and other green elements that could contribute to environmental sustainability and human well-being. Furthermore, it can restrict the incorporation of green design features in urban development projects, such as green building techniques and energy efficient infrastructure. Moreover, absence of funding can hinder research and development initiatives focused on multi-functional and innovative nature-based solutions, such as longitudinal studies. This would further restrict the ability to adapt and respond to emerging environmental and health-related challenges. Lack of funding can also have implications for education and knowledge distribution and will generally create limitations for all future urban planning.

Multifunctionality and diversity of green spaces, parks, and urban and peri-urban forests is important to create a wide range of potential users [24,53,69,94,95]. The emotional well-being derived from these spaces encompasses various functions, with availability, accessibility, and quality playing pivotal roles. Planning for multifunctionality should consider diverse socio-economic and demographic characteristics to ensure inclusivity for all citizens. Increasing the quality and quantity of green spaces can also serve as a cost-effective approach to improve overall well-being [63]. Nature-based solutions that enhance disaster risk resilience and raise awareness about their advantages can foster greater acceptance of green adaptations and strengthen local communities [17]. Furthermore, multifunctionality in terms of multisensory

aesthetics of exposure to green spaces is important in a therapeutic perspective [56,96]. Moreover, multifunctionality and transdisciplinary research assessing the relation between social conditions, ecosystem restoration [97] and nature-based solutions is important to explore as the measures benefiting social conditions not necessarily benefits ecological conditions [98].

Nature-based solutions are important contributions in green urban development, and their effectiveness is intricately tied to the social context. Evidence [19,24] highlights the need for urban planners to consider diverse recreational preferences of a broad spectrum of society when implementing such solutions and encourage **bottom-up approaches**, which are initiated and led by members of the community. One compelling reason for this inclusive approach is to prevent potential negative repercussions, such as green gentrification [73]. If nature-based solutions are primarily directed towards neighborhoods or areas that are already economically advantaged, it can exacerbate existing inequalities. The result might be an influx of wealthier residents, driving up property values, displacing low-income communities, and eroding the unique character of these areas. Furthermore, it is evident that nature-based solutions and urban greening projects can disproportionally benefit individuals with economic wealth and power [23]. Recognizing and accounting for the social context in urban planning is crucial for successful implementation of nature-based solutions in urban development.

Numerous studies emphasize the significance of **involving local communities** and considering citizen opinions when planning and managing nature-based solutions in urban areas [60,94]. This aligns with the concept of multifunctionality in nature-based solutions and has the potential to enhance public awareness, knowledge, and engagement in supporting nature within urban planning. In an environmental justice perspective, local inclusion can make the city more accessible for all its citizens [76]. Moreover, when addressing disaster risk resilience, adaptation, and urban planning, it is essential to involve different socio-economic groups and consider their habits, qualitative risk perceptions, and potential solutions [22]. Taking a broader perspective that encompasses bottom-up approaches and analyses the interplay between aesthetic spaces and social spaces, as well as how governments conduct urban planning, can contribute to determining whether desired outcomes are achieved [73]. Moreover, it can strengthen the knowledge base for various types of cities, such as exploring the adaptability of existing models and frameworks in hyperdense cities and cities with ultra-low density [80]. Urban greening projects could potentially be coupled with urban revitalization projects or integrated urban justice assessments as a measure to avoid green gentrification [73,99].

Policy analysis plays a crucial role in evaluating and enhancing the utilization of nature-based solutions within the context of both national and international frameworks. These analyses encompass a thorough examination of the effectiveness of these solutions, shedding light on their impact on various levels [100,101]. In addition, comprehensive policy analyses delve into the identification of exemplary practices that have yielded positive outcomes in the realm of nature-based solutions [102]. This involves highlighting instances where the integration of nature into health policies and health into environmental policies, has been successful. Such instances serve as benchmarks that others can follow, fostering a knowledge-sharing environment among policymakers and stakeholders. Thus, policymakers can develop strategies that not only harness the mental and physical health benefits of nature but also effectively tackle the multifaceted challenges posed by climate change.

Perceptions of nature and green spaces may have undergone significant changes during the COVID-19 pandemic [77]. It has become evident that public (green) spaces hold great importance for people, and many individuals have sought solace in nature during lock-down and restrictions. The planning and recognition of urban green spaces as a means to enhance mental health well-being is increasingly crucial, particularly considering the **risks of future global pandemics** and high urban density [59,76]. The integration of nature-based solutions is an

emerging trend with large potentials across numerous European countries [103], and their importance in promoting health may be even more pronounced due to the global COVID-19 pandemic. Existing literature tend to focus on specific demographic, typically those considered vulnerable, such as elderly or individual with underlying health conditions. However, groups usually considered of low-risk may often be the ones of highest exposure, highlighting the importance of studying risks across all demographic groups [22].

5 Concluding remarks

Climate change poses significant challenges to our natural and urban environments and has profound implications for human mental health and well-being. Unpredictable and extreme weather events, together with the overall shift in local climate, threaten societal structures and living environments. Floods, heatwaves, air pollution, and noise present immediate threats that can lead to conditions like PTSD and emotional distress. Eco-anxiety is also an emerging health challenge among various demographic groups.

It is crucial to recognize that the severity of climate change impacts on mental health and well-being is influenced by demographic factors and socio-economic status. The impairment of social and economic conditions correlates strongly with mental health challenges. Vulnerable populations face greater risks and difficulties in coping with the mental health consequences of climate change.

Nature-based solutions offer promising avenues to build ecological and social resilience to climate change. Nature, with its biological attributes, can provide physical and psychological shelter from extreme weather events and contribute to climatic regulation and water retention. Additionally, nature offers various ecosystem services that directly and indirectly benefit humans, through for example recreation, education, social connections, and inspiration.

Nature has the potential to serve as a stress-reliever, promoting recreation and restoration, and is increasingly being utilized in therapeutic settings. However, it is important to acknowledge that access and exposure to nature are often unequally distributed, influenced by demographic and socio-economic factors. Efforts should be made to ensure equitable access to nature's benefits and address the disparities in recreational preferences and opportunities.

In addressing the mental health impacts of climate change, integrating nature-based solutions into adaptation and mitigation strategies becomes imperative. By prioritizing nature as a resource for resilience and well-being, we can harness its potential to alleviate the mental health burdens associated with climate change. This requires comprehensive policies, interventions, and initiatives that promote equitable access to nature and maximize its therapeutic potential for diverse populations.

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6 Annex I. Methodology: Literature review

This review explores (1) how mental health is affected by the effects of a changing climate in Europe, and (2) how nature, green spaces, and nature-based solutions can play a role in reducing and treating those negative effects. In order to answer this research question, this study pursues two steps:

(i) identify the most frequent mental health ailments arising as a result of the impacts of climate change;
(ii) explore how green space and nature-based solutions can serve as both a preventative measure to lesson/avoid the impacts of climate change on mental health and as a treatment to help recover from the mental health impacts;

The time horizon for the explored literature was set to 2015-2022, using the ScienceDirect/Elsevier database. Only open access literature was reviewed, and literature was limited to research articles and reviews. Keyword lists 1 and 2 were defined for the systematic literature search, where all keywords from list 1 were coupled with the keywords from list 2.

- Keyword list 1: Mental health, well-being, human
- Keyword list 2: Biodiversity, nature, restoration, climate change, ecosystem, recreation, disaster, wildfire, flood, heatwave, drought

The initial literature search was followed by a filtration process that included title and abstract review, duplicate removals, and a final full paper review, which resulted in the final literature collection that was used to produce this study. The following selection criteria were defined for the collection process: the literature must directly address mental health AND 1) nature as a form of treatment of mental health challenges OR 2) the effect of nature on mental health OR 3) the impacts of climate change on mental health (e.g., changing weather, extreme weather events, etc.). Furthermore, the main review is focused on Europe, but is supplemented with and compared to literature from outside of Europe.

About 400 papers were identified, which were filtered down to 240 papers based on a review of their abstracts. The final selection of reviewed papers includes 93 (39%) papers addressing one or selected European countries, regions, or cities, which are the ones used for the main analysis and discussion. 78 (33%) papers focusing only on countries, regions, or cities outside of Europe, and 29 (27%) are global studies or not addressing a specific region. The majority of cover the relationship between nature and health, rather than the relationship between climate change and health, and some papers covers both relationships. The results show an increase in publications of about 200% between 2015 and 2022, and about 140% from 2019 to 2022.

7 Annex II. Limitations and uncertainties

A main challenge when exploring the relation between mental health, climate change, and nature is to determine causal relationships. Mental health is influenced by a variety of factors, and identifying a direct cause-and-effect relationship becomes difficult when multiple variables are involved. Furthermore, human behaviour and mental health is influenced by individual differences, personal experiences, and social and cultural contexts. These factors introduce variability and complexity, making it challenging to establish universal causal relationships.

The COVID-19 pandemic likely resulted in shifts in people's mental states, which can have influenced their experiences and connection to nature. Therefore, studies examining the relationship between nature experiences and mental health during the pandemic might be influenced by biases when exploring the broader impact of nature on well-being. Considering our study period from 2015 up until 2022, with the initial outbreak of COVID-19 occurring towards the end of 2019, a considerable portion of the literature may have been affected by the pandemic and its effect on global mental health and everyday behaviors. Moreover, variations in lockdown measures could have further contributed to differences in people's appreciation of nature and outdoor spaces in general.

Several studies selected for this review are self-reporting studies which usually bring forth different types of bias. Partly because of financial limitations, these studies are also often limited in size. Self-reporting studies will in many cases rely on voluntary participation from groups that are easily accessible and recruitable, such as university students. This would further lead to a biased sample that does not accurately represent the broader population. Many of the studies are also structured experimentally, and participating in them could trigger certain types of behaviors that differ from those of a natural setting.

Due to limited resources this review does not cover all available literature within the topic of climate change, nature, and mental health. This could result in a bias from the included research and gaps in knowledge and limited perspectives on the topic, potentially overlooking important findings and viewpoints. Furthermore, it increases the risk of making inaccurate conclusions.

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