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SHORT COMMUNICATION

Urbanization Trends in the 21st Century - a Driver for Negative Climate, Noise and Air Quality Impacts on Urban Population

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According to climate change, an increase in various extreme climate and weather events, such as heavy precipitation, storm weather, longer drought period, tropical cyclones, snow blizzard, and among them more frequent and severe heat waves, can be expected in coming decades (IPCC, 2021). In parallel with climate change, cities experience very intensive urbanization in the last few decades (UN, 2018), and as a result, the urban area will increase by 141 % in low-income countries, 44 % in lower-middle-income,

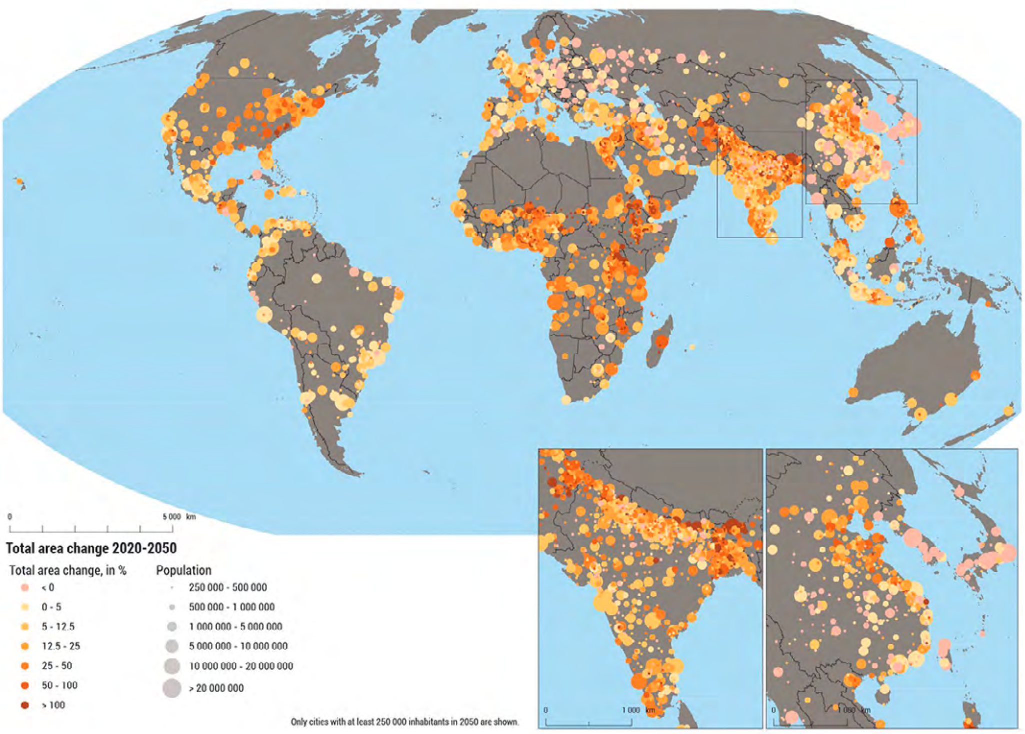

Figure 1. Projections of the urban area change (in %) and population in cities across the Globe for the period 2020-2050
Source: UN, 2022

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34 % in high-income, and by 13 % in upper-middle-income countries until 2070, compared to city land area in 2020 (UN, 2022). Consequently, more land areas and more world population (Figure 1) are under modified climate (urban climate), changed air quality conditions (such as Ozone, NOx, nanoparticles, but particularly in PM1, PM2.5 and PM10) and additional noise stress.

The combined climate and urbanization pressures on public health and the environment in cities will continue in coming decades and will increase the necessity to provide more optimal solutions to monitor and assess urban environmental risks, and to find effective ways to implement these in practice. The defined interaction process "climate change-urbanization-urban climate" where the climate conditions are recognized as an important risk factor in cities (Savić et al., 2022), in the further steps of the environmental risk adaptation, wider risk factors within cities should be considered. Therefore, the interaction process "climate change-urbanization-urban environment" should include, in addition to climate condition risks, air quality and noise risks as elements that are directly driven by current weather conditions, traffic intensity, industrial and construction activity, heating supply in winter, and urban design application, and all of that should be included in future urban environmental risk assessments.

Significant processes contributing to urban environmental risks - an overview

The latest IPCC report (IPCC, 2021) presented that global surface temperature[1] has increased by 0.99 °C from 1850–1900 to the first decades of the 21st century (2001-2020) and by 1.09 °C from 1850–1900 to the last decade period (2011–2020). It means, that the increasing temperature trend is constantly enlarging decade by decade, and in a parallel concentration of the CO_2 is constantly increasing and reached annual averages of 410 ppm. Also, datasets reveal that hot extremes (hot days, heatwaves) have become more frequent and

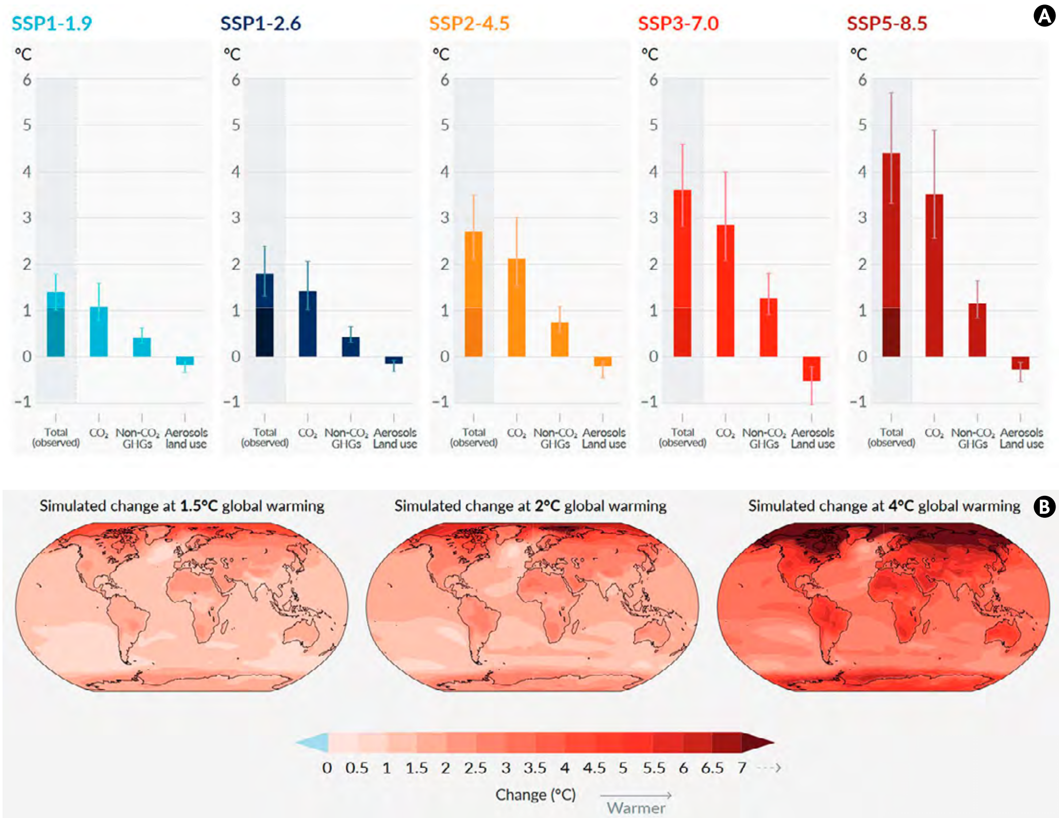

Figure 2. A) Contribution to global surface temperature increase from different GHG emissions. It is presented the change in global surface temperature in 2081-2100 relative to 1850-1900 (in °C). For this projection were used five SSP scenarios based on different CO2 and GHG emission levels (SSP1-1.9, SSP1-2.6 – very low and low, SSP2-4.5 – intermediate, SSP3-7.0, SSP5-8.5 – high and very high emissions); B) Spatial distribution of the global annual mean temperature change (°C) relative to 1850-1900, in situation if temperature rise by 1.5 °C, 2 °C or 4 °C (simulated)
Source: IPCC, 2021

[1] The term „global surface temperature" is used in reference to both global mean surface temperature and global surface air temperature throughout the IPCC report.

more intense across most land regions since the 1950s, while cold extremes (frost/ice days, cold waves) have become less frequent and less severe. Based on projections (Shared Socio-economic Pathways - SSP3-7.0 and SSP5-8.5) of high and very high CO_2 and GHG (greenhouse gas) emissions, in comparison to the average temperature from 1850-1900, the global surface temperature will be higher by 2.8 – 4.6 °C (SSP3-7.0) or by 3.3 – 5.7 °C (SSP5-8.5) until the 2100 (Figure 2A). In the same Figure (2B) are presented simulated temperature levels and spatial distribution of thermal conditions that are mostly dominant in the northern hemisphere (IPCC, 2021).

In the next five decades, in case that the global surface temperature increases by 2 °C relative to 1850-1900, the frequency of hot extreme events will increase about 15 times, and intensity will rise by about 2.5 °C. Even more, the projection shows that if the temperature changes by 4 °C, the frequency of hot extreme events will increase about 35 times, and intensity will rise by about 5.5 °C (Arias et al., 2021). Therefore, today, but also in the future, cities will experience extreme thermal conditions more often and more intense compared to non-urbanized areas (rural areas) due to the amplification of air/surface temperatures, and as result this will trigger the urban heat island (UHI) effect (Lauwaet et al., 2016). These temperature-caused effects (UHIs) are contributing to more thermal stress and increasing morbidity/mortality cases across European cities, as well as impact-

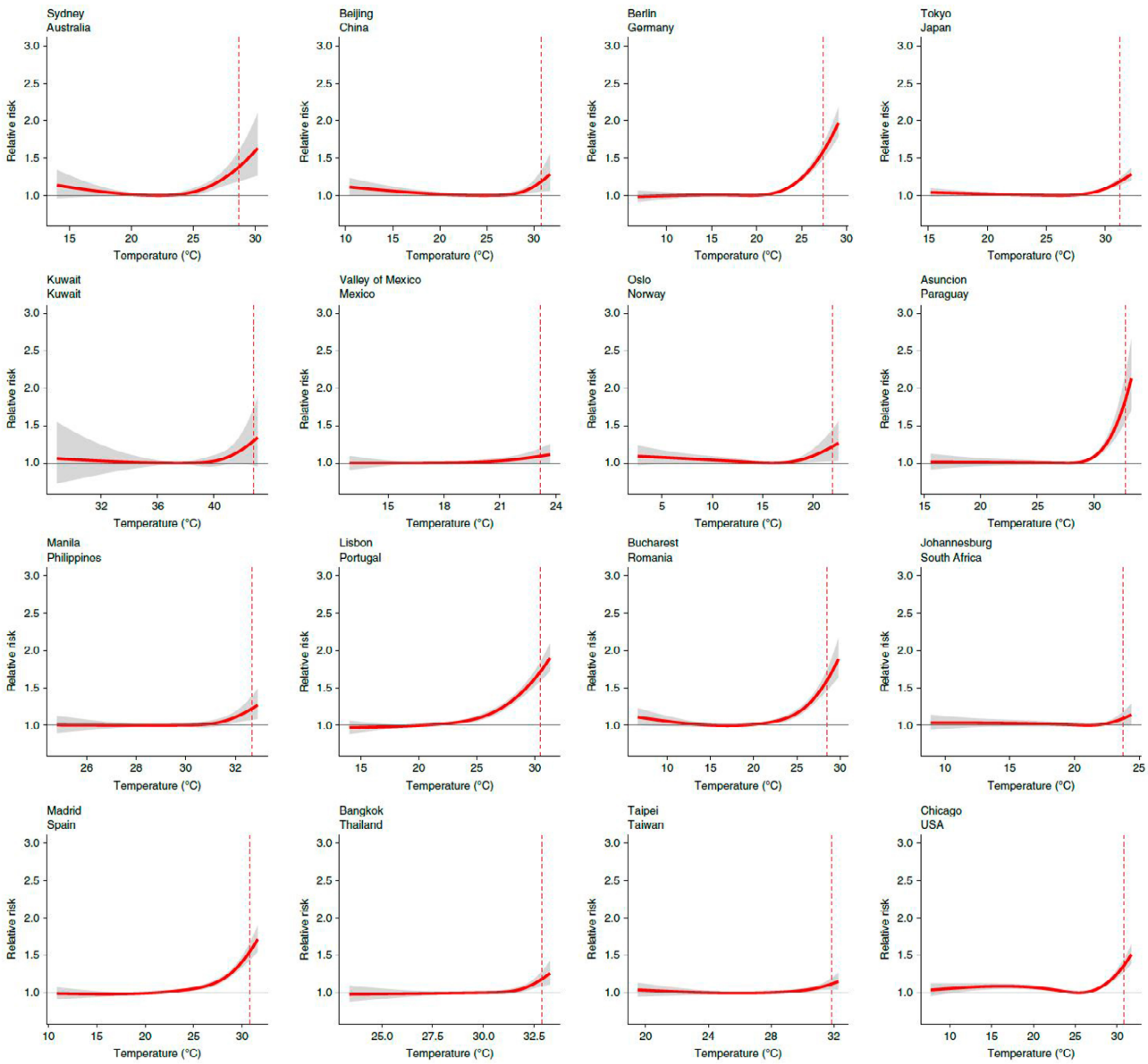

Figure 3. A) Heat-mortality relations for 16 representative cities where the functions represent the cumulative relative risk of death over a 10-days lag period for each temperature value. Exposure-response associations are estimated as best linear unbiased predictions and reported as relative risk (with 95 % CI, shaded grey) for a cumulative 10-days lag of warm-season temperature, versus the optimum temperature (temperature of minimum mortality)

Source: Vicedo-Cabrera et al., 2021

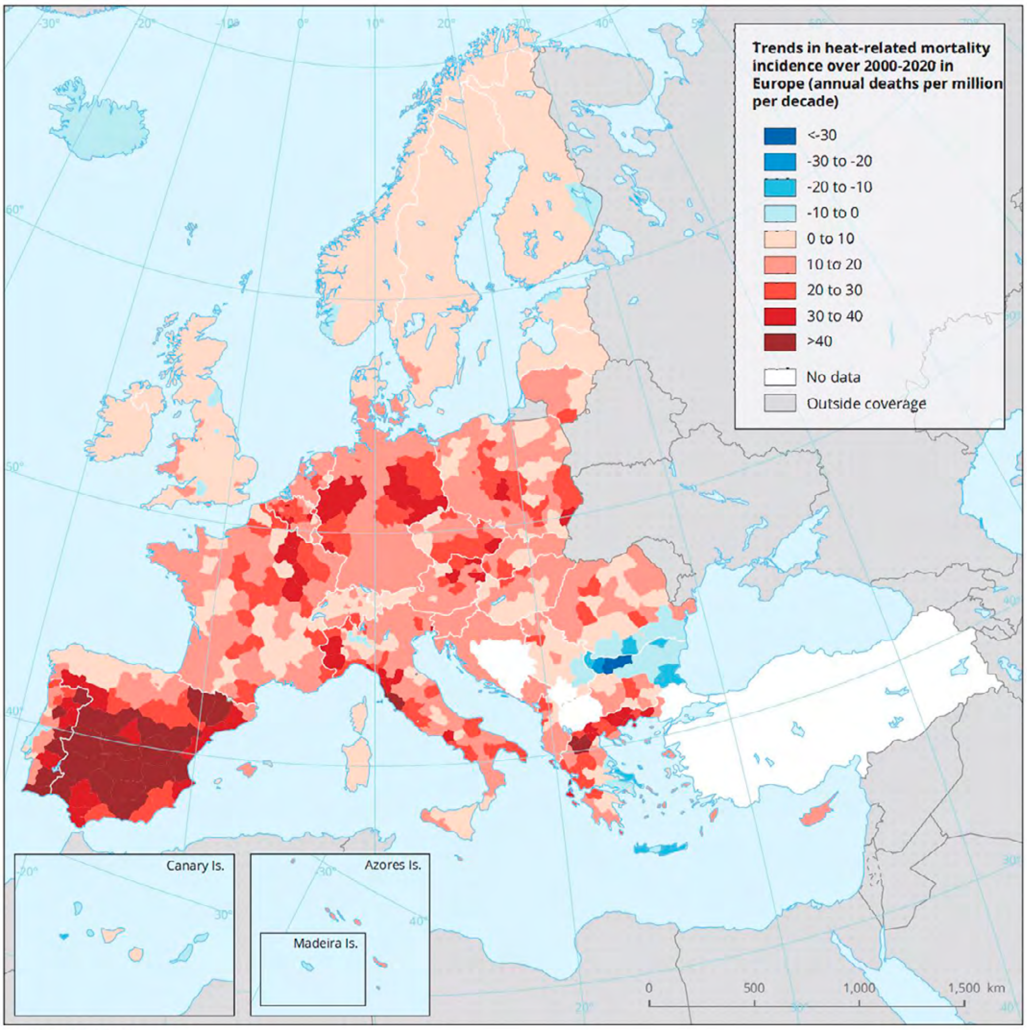

Figure 3. B) Trends in heat-related mortality incidence in the period 2000-2020 in Europe (annual deaths per million per decade). The smallest regions possible were used, depending on the spatial resolution of the mortality data in a given country, i.e., ranging from the NUTS 3 (areas with 150,000-800,000 inhabitants) to a single country
Source: van Daalen et al., 2022

ing biodiversity and economic losses (IPCC, 2022). Based on the research about the contribution of human-induced warming to the heat-related mortality in 732 locations (cities) from 43 countries over the period 1991-2018, it has been found that 37 % of warm-season heat-related deaths can be attributed to anthropogenic climate change (Vicedo-Cabrera et al., 2021). This heat-related mortality and morbidity have been increasing across Europe, particularly in southern Europe, and with a scenario of 3 °C temperature change, the projection predicts approximately 90,000 deaths of Europeans every year due to extreme heat events. Moreover, about half of hospitals and schools in European cities are in areas with strong UHI effects (higher than 2 °C), meaning that their vulnerable users and staff are exposed to high temperatures (EEA, 2022a). Figure 3 presents some general tendencies of heat risks and heat-related mortality in 16 selected cities, as well as across European regions.

According to the current report of the European Environmental Agency (EEA, 2022b), air pollution is the single largest environmental health risk in Europe, causing cardiovascular and respiratory diseases that lead to the loss of healthy years of life and, in the most serious cases, to premature deaths. For the area of Europe, it can be stated that the fine particulate matter (PM2.5 and PM10) represents a significant risk for air quality, which also confirms the goal of the European Commission to reduce the number of premature deaths caused by PM2.5 at least 55% until 2030 compared to 2005 levels. In 2020, according to the World Health Organization (WHO) standard (where the threshold is 5 $\mu g/m^3$), about 96% of the European population is exposed to a higher concentration of PM2.5 and based on the EU standard (where the threshold is 25 $\mu g/m^3$), less than 1% of the population is exposed, and this difference is a result of obvious distinct standards. Still, there are real air pollution risks based on the

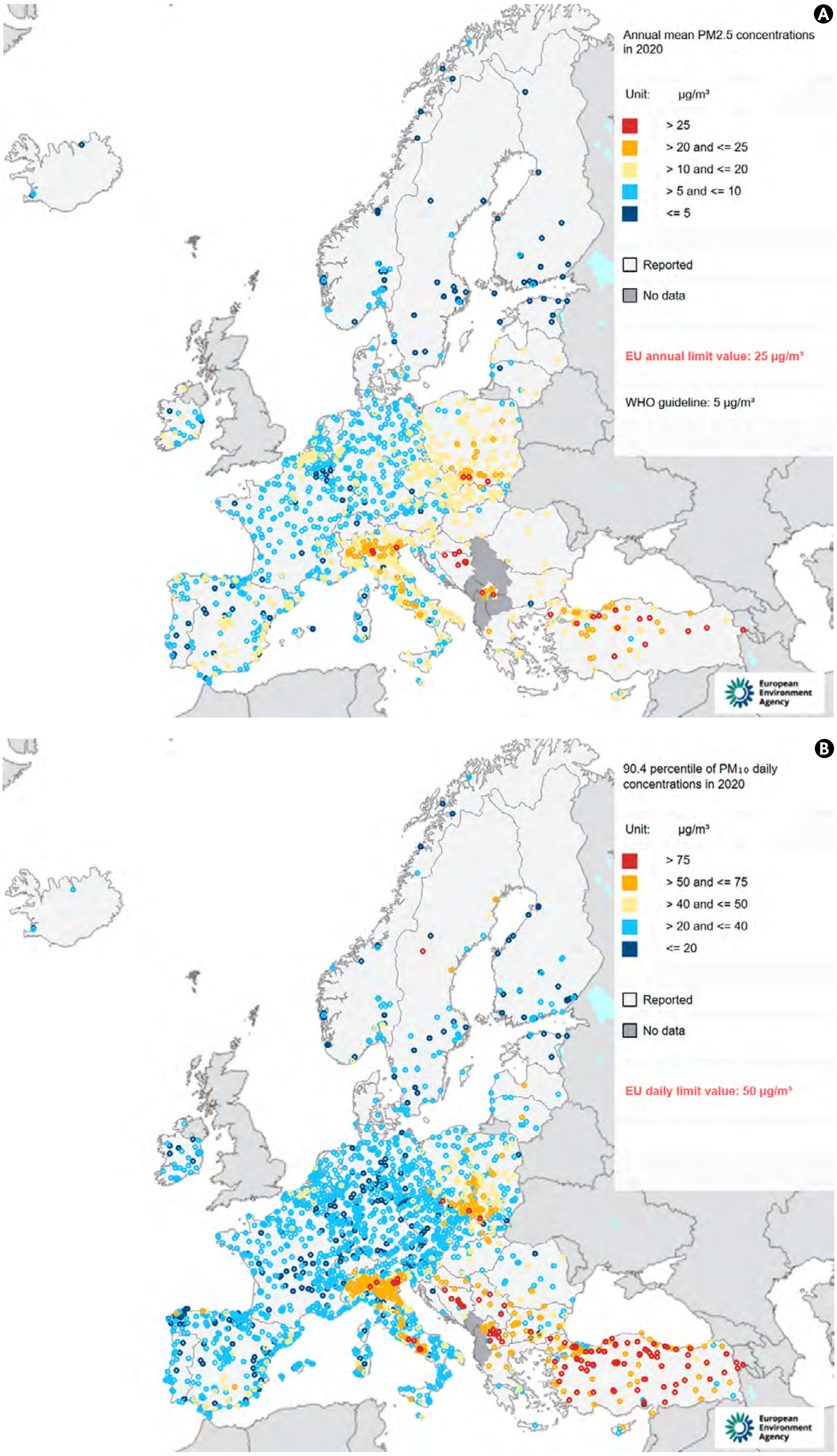

Figure 4. A) Concentration of PM2.5 in European countries for 2020 (validated data) in relation to the EU and WHO standards. Six countries reported PM2.5 concentration above the EU limit (25 $\mu g/m^3$), and only Estonia did not report PM2.5 concentration higher than the WHO standard (5 $\mu g/m^3$); B) Concentration of PM10 in European countries for 2020 (validated data) in relation to the EU and WHO standards. 20 countries reported PM10 concentration above the EU standard (50 $\mu g/m^3$), and only Iceland did not report PM10 concentration above the WHO standard (15 $\mu g/m^3$)
Source: https://www.eea.europa.eu/publications/status-of-air-quality-in-Europe-2022

fine particulate matter, particularly in some European regions, such as Central Europe, Southeast Europe and Italy, where combination of domestic heating, road traffic and some industrial branches cause higher concentrations of PM2.5 and PM10 (Figure 4) (EEA, 2022b).

The road traffic noise is one of the major environmental problems in Europe causing health and well-being issues for millions of people. It is estimated that about 113 million people are affected by long-term daytime and nighttime traffic noise levels of at least 55 dB(A). About 22 million people suffer chronic high annoyance and 6.5 million people suffer chronic high sleep disturbance. Furthermore, projections show that road traffic noise in urban areas, in the category of day-evening-nighttime – noise level at least 55 dB(A), will increase by 7.8 % in EU countries by 2030

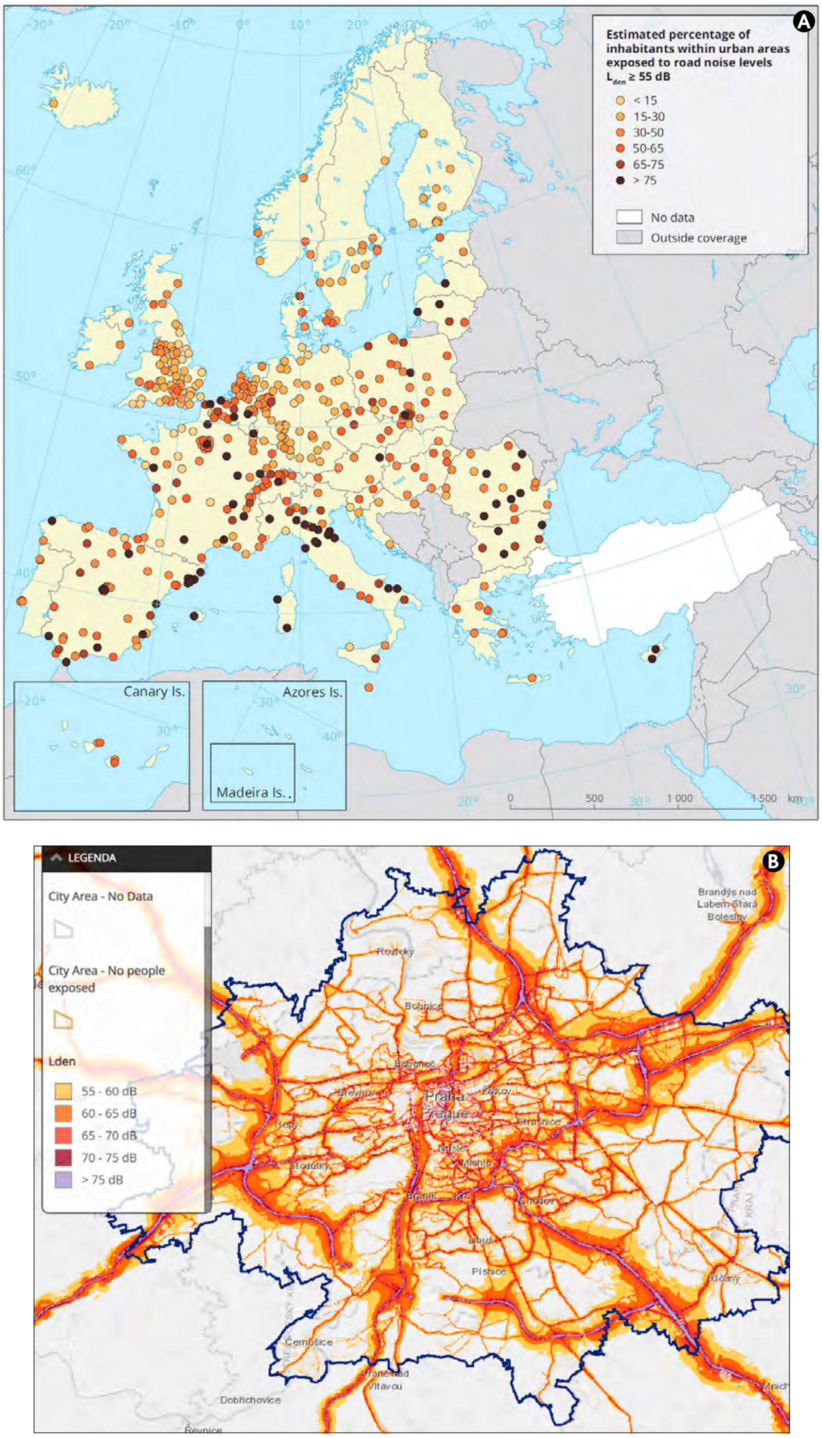

Figure 5. A) Estimated percentage of population in cities from EU and EEA (+ CH) countries that are exposed to road traffic noise levels L_{den} ≥ 55 dB in 2017; B) Urban area of Prague that is exposed to day-evening-nighttime average sound levels of L_{den} ≥ 55 dB from road traffic noise. In this exposed area of Prague lives about 876 000 inhabitants
Sources: EEA, 2020 and http://noise.eea.europa.eu

(compared to the level in 2017). Despite these problems, there are still delays in providing action plans, good quality spatial/temporal noise datasets and assessments from both urban and rural areas, and it suggests that countries have not taken serious actions to address noise pollution (EEA, 2020). More details about urban population exposed to the road traffic noise risk are presented on Figure 5.

What are the next steps

Effective urban and territorial planning by applying the New Urban Agenda and the Sustainable Development Goal - SDG 11 should be considered seriously in the urbanization policy. For example, integrating green infrastructure into the urban design will provide co-benefits for adapting to climate change, improving health or mitigating the effects of traffic by restoring and regenerating natural ecosystems in cities (UN, 2022). Furthermore, by implementing public transport and decreasing individual transport is main task for many urban challenges (spatial efficiency, noise mitigation, transport safety, GFG emissions, economic efficiency and also air quality). Implementing electric mobility has a positive influence of air quality and noise issues, however it does not bring solution to other urban problems mentioned above. For these measures and solutions to have a maximum result on the ground, it is necessary to further develop integrative and complex monitoring and assessments of environmental and social risks in cities. According to international projects and actions there are developed a few indices with various risk approaches and responses to different natural and social sectors. In Table 1 is presented more details on the concept and idea of these indices. However, based on the natural and anthropogenic processes that are occurring and will occur in the coming decades in urban areas, the creation of a "global/regional urban environmental risk index" that would simultaneously integrate the most important atmospheric effects on the environment, as which are thermal conditions (air and surface temperature), noise (dB(A)) and air quality (with focus on the fine particulate matter) (Table 1), could contribute to the creation of more effective adaptation measures and policies that will better response to further changes expected in cities during the 21st century.

Finally, we cannot think about developing new risk approaches or indices only, but we should also think about the availability of datasets and information. Hence, the FAIR (Findability, Accessibility, Interoperability, and Reusability) principle for data usability should be considered more in the future. Good examples could be more environmental observational platforms developed (COPERNICUS, OpenEO, NoisePlanet, OpenAQ, PM2.5 open data, ECMWF, etc.) that provide various spatial and temporal data across the globe. But we should focus also on platforms that gather data from specific sources, such as the Micrometeorological knowledge share platform (Micromet_KSP) that is currently developed by the COST Action project FAIRNESS[2] and will contain the datasets and metadata from urban and rural networks, which are not part of official national networks, and this kind of platforms could provide additional contributions to more detailed environmental risk assessments in cities.

Table 1. Review of the developed risk indices and possible further actions

Risk index	Risk approach	Response to sectors	Reference
European Green City Index	CO_2; Energy; Buildings; Transport; Water; Waste and land use; Air quality; Environmental governance	Environmental performance of 30 leading European cities	Economist Intelligence Unit, 2009
Global Urban Risk Index	• Natural hazards (earthquakes, landslides, floods, cyclones); • Exposure (covering people, buildings, transport infrastructure, economies, communities); • Vulnerability; • Losses (mortality, economy)	Different natural and social sectors in cities	Brecht et al., 2013
Urban heat risk index	• Location within the city; • Characteristics of the building; • Characteristics of people	• Physical; • Social; • Strategic – before hot weather; • Operational – during hot weather	ARUP, 2014

[2] More about the project: https://www.fairness-ca20108.eu/

Risk index	Risk approach	Response to sectors	Reference
"City co-benefits" by LSE Cities and C40 Cities	Health; Mobility; Buildings; Resources; Economy	- Traffic pollution; - Healthy lifestyles; - Smart transportation systems; - Flooding and building damage; - Valuing the size of the environmental goods market	Floater et al., 2016
Cities in Motion Index - CIMI	Human capital; Social cohesion; Economy; Governance; Environment; Mobility and transportation; Urban Planning; International profile; Technology	Sustainability issues and quality of life in cities	Berrone et al., 2022
Environmental Performance Index - EPI	• Environmental health (air quality, waste management, water & sanitation, heavy metals); • Climate (climate, change, mitigation); • Ecosystem vitality (biodiversity & habitat, ecosystem services, fisheries, agriculture, acid rain, water resources)	Sustainability issues on country level	Wolf et al., 2022
Further actions			
"Global/regional urban environmental risk index"	• Climate (air/surface temperature, thermal indices); • Noise pollution; • Air quality (PM2.5, PM10)	Comprehensive urban environmental issues	/

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References

Arias, P. A., Bellouin, N., Coppola, E., Jones, R. G., Krinner, G., Marotzke, J., Naik, V., Palmer, M. D., Plattner, G. K., Rogelj, J., Rojas, M., Sillmann, J., Storelvmo, T., Thorne, P. W., Trewin, B., Achuta Rao, K., Adhikary, B., Allan, R. P., Armour, K., Bala, G., Barimalala, R., Berger, S., Canadell, J. G., Cassou, C., Cherchi, A., Collins, W., Collins, W. D., Connors, S. L., Corti, S., Cruz, F., Dentener, F. J., Dereczynski, C., Di Luca, A., Diongue Niang, A., Doblas-Reyes, F. J., Dosio, A., Douville, H., Engelbrecht, F., Eyring, V., Fischer, E., Forster, P., Fox-Kemper, B., Fuglestvedt, J. S., Fyfe, J. C., Gillett, N. P., Goldfarb, L., Gorodetskaya, I., Gutierrez, J. M., Hamdi, R., Hawkins, E., Hewitt, H. T., Hope, P., Islam, A. S., Jones, C., Kaufman, D. S., Kopp, R. E., Kosaka, Y., Kossin, J., Krakovska, S., Lee, J. Y., Li, J., Mauritsen, T., Maycock, T. K., Meinshausen, M., Min, S. K., Monteiro, P. M. S., Ngo-Duc, T., Otto, F., Pinto, I., Pirani, A., Raghavan, K., Ranasinghe, R., Ruane, A. C., Ruiz, L., Sallée, J. B., Samset, B. H., Sathyendranath, S., Seneviratne, S. I., Sörensson, A. A., Szopa, S., Takayabu, I., Tréguier, A. M., van den Hurk, B., Vautard, R., von Schuckmann, K., Zaehle, S., Zhang, X. & Zickfeld, K. (2021). *Technical Summary. In Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33–144. doi:10.1017/9781009157896.002

ARUP (2014). *Reducing urban heat risk – A study on urban heat risk mapping and visualisation.* ARUP, London, pp. 54, available at: file:///C:/Users/steva/Downloads/Reducing_Urban_Heat_Risk_Full_Report.pdf

Berrone, P., Ricart, J. E., & Brito, E. (2022). *IESE Cities in Motion Index*. IESE Business School, University of Navarra, Spain, pp. 113, available at: https://media.iese.edu/research/pdfs/ST-0633-E.pdf
Brecht, H., Diehcmann, U., & Wang, H. G. (2013). A Global Urban Risk Index. *Policy Research Working Papers,* 6560, 42. https://doi.org/10.1596/1813-9450-6506
EEA (2020). *Environmental noise in Europe – 2020* (Report no. 22/2019). European Environmental Agency, Copenhagen, Denmark, pp. 100.
EEA (2022a). *Climate change as a threat to health and well-being in Europe: focus on heat and infectious diseases* (Report no. 07/2022). European Environmental Agency, Copenhagen, Denmark, pp. 68.
EEA (2022b). *Europe's air quality status 2022 - breafing.* European Environmental Agency, Copenhagen, Denmark, available at: https://www.eea.europa.eu/publications/status-of-air-quality-in-Europe-2022
Economist Intelligence Unit (2009). *European Green City Index – Assessing the environmental impact of Europe's major cities.* Siemens AG, Corporate Communications and Government Affairs, Munich, Germany, pp. 99, available at: https://assets.new.siemens.com/siemens/assets/api/uuid:fddc99e7-5907-49aa-92c4-610c0801659e/european-green-city-index.pdf
Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A., Carvalho, M., Gill, D., Bailey, T., & Huxley, R. (2016). *Co-benefits of urban climate action: A framework for cities.* LSE Cities – London School of Economics and Political Science, C40 Cities – Climate Leadership Group, pp. 86, available at: https://eprints.lse.ac.uk/68876/1/Cobenefits_Of_Urban_Climate_Action.pdf
IPCC (2021). *Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32. doi:10.1017/9781009157896.001
IPCC (2022). *Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33. doi:10.1017/9781009325844.001
Lauwaet, D., De Ridder, K., Saeed, S., Brisson, E., Chatterjee, F., van Lipzih, N. P. M., Maiheu, B., & Hooyberghs, H. (2016). Assessing the current and future urban heat island of Brussels. *Urban Climate*, 15, 1-15. http://dx.doi.org/10.1016/j.uclim.2015.11.008
Savić, S., Trbić, G., Milošević, D., Dunjić, J., Ivanišević, M., & Marković, M. (2022). Importance of assessing outdoor thermal comfort and its use in urban adaptation strategies: a case study of Banja Luka (Bosnia and Herzegovina). *Theoretical and Applied Climatology*, 150, 1425-1441. https://doi.org/10.1007/s00704-022-04237-8
UN (2018). *The speed of urbanization around the world* (Report no. 2018/1). United Nations, Department of Economic and Social Affairs, Population Division, New York, USA, available at: https://population.un.org/wup/publications/Files/WUP2018-PopFacts_2018-1.pdf
UN (2022). *World Cities Report 2022 – Envisaging the Future of Cities.* United Nations Human Settlements Programme (UN-Habitat), New York, USA, pp. 387, available at: https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf
Van Daalen, K. R., Romanello, M., Rocklov, J., Semenca, J. C., Tonne, C., Markandya, A., Dasandi, N., Jankin, S., Achebak, H., Ballester, J., Bechara, H, Callaghan, M. W., Chambers, J., Dasgupta, S., Drummond, P., Farooq, Z., Gasparyan, O., Gonzalez-Reviriego, N., Hamilton, I., Hanninen, R., Kazmierczak, A., Kendrovski, v., Kennard, H., Kiesewetter, G., Lloyd, S. J., Batista, M. L., Martinez-Urtaza, J., Mila, C., Minx, J. C., Nieuwenhuijsen, M., Palamarchuk, J., Quijal-Zamorano, M., Robinson, E. J. Z., Scamman, D., Schmoll, O., Sewe, M. O., Sjodin, H., Sofiev, M., Solaraju-Murali, B., Springmann, M., Trinanes, J., Anto, J. M., Nilsson, M., & Lowe, R. (2022). The 2022 Europe report of the *Lancet* Countdown on health and climate change: towards a climate resilient future. *Lancet Public Health*, 7, E942-E965. https://doi.org/10.1016/S2468-2667(22)00197-9
Vicedo-Cabrera, A. M., Scovronick, N., Sera, F., Roye, D., Schneider, R., Tobias, A., Astrom, C., Guo, Y., Honda, Y., Hodula, D. M., Abrutzky, R., Tong, S., de Sousa Zanotti Stagliorio Coelho, M., Nascimento Saldiva, P. H., Lavigne, E., Matus Correa, P., Valdes Ortega, N., Kan, H., Osorio, S., Kysely, J., Urban, A., Orru, H., Indermitte, E., Jaakkola, J. J. K., Ryti, N., Pascal, M., Schneider, A., Katsouyanni, K., Samoli, e., Mayvaneh, F., Entezari, A., Goodman, P., Zeka,

A., Michelozzi, P., de`Donato, F., Hashizume, H., Alahmad, B., Hutado Diaz, M., De La Cruz Valencia, C., Overcenco, A., Houthuijs, D., Ameling, C., Rao, S., Di Ruscio, F., Carrasco-Escobar, G., Seposo, X., Silva, S., Madureira, J., Holobaca, I. H., Fratianni, S., Acquaotta, F., Kim, H., Lee, W., Iniguez, C., Forsberg, B., Ragettli, M. S., Guo, Y. L. L., Chen, B. Y., Li, S., Armstrong, B., Aleman, A., Zanobetti, A., Schwartz, J., Dang, T. N., Dung, D. V., Gillett, N., Haines, A., Mangel, M., Huber, V. & Gasparrini, A. (2021). The burden of heat-related mortality attributable to recent human-induced climate change. *Nature Climate Change*, 11, 492-500. https://doi.org/10.1038/s41558-021-01058-x

Wolf, M. J., Emerson, J. W., Esty, D. C., de Sherbinin, A., & Wendling, Z. A., et al. (2022). 2022 *Environmental Performance Index*. New Haven, CT, Yale Center for Environmental Law & Policy. epi.yale.edu, available at: https://epi.yale.edu/downloads/epi2022policymakerssummary.pdf