Sand and Dust Storms Risk Assessment in Asia and the Pacific

ESCAP

APDIM
Asian and Pacific Centre for the Development of Disaster Information Management

The shaded areas of the map indicate ESCAP members and associate members.*

The Economic and Social Commission for Asia and the Pacific (ESCAP) is the most inclusive intergovernmental platform in the Asia-Pacific region. The Commission promotes cooperation among its 53 member States and 9 associate members in pursuit of solutions to sustainable development challenges. ESCAP is one of the five regional commissions of the United Nations.

The ESCAP secretariat supports inclusive, resilient and sustainable development in the region by generating action-oriented knowledge, and by providing technical assistance and capacity-building services in support of national development objectives, regional agreements and the implementation of the 2030 Agenda for Sustainable Development.

* The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Sand and Dust Storms Risk Assessment in Asia and the Pacific

Front cover photo:

Dust storm in Mildura, Victoria, Australia, photo taken by Robert Klarich on 7 May 2019. Photo Submitted to APDIM Call for Photography 2021: Living with Sand and Dust Storms

Back cover design:

The letter D shuttered cubes are part of the APDIM logo and are meant to evoke the destruction brought about by disasters and the impact on development. The back cover picks up the graphic theme of APDIM's logo and amplifies it in the context of dust storms, indicating the sectors covered by the assessment of this report. The back cover was designed by Armin Farahani.

Foreword

The achievement of the 2030 Agenda for Sustainable Development, including reaching the targets of the Sendai Framework for Disaster Risk Reduction 2015-2030, are significantly under threat by the risk posed by sand and dust storms as a transboundary meteorological hazard. In the past few years, sand and dust storms have taken a high toll in terms of socio-economic damage and loss in the areas exposed to this hazard, underscoring the need to take prompt action to address the challenges associated with them. The Asian and Pacific Centre for the Development of Disaster Information Management (APDIM), a regional institution of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), as a member of the United Nations Coalition on Combatting Sand and Dust Storms works with other Coalition partners and member States to promote North-South, South-South and triangular cooperation to combat the negative socio-economic impact of sand and dust storms as mandated through General Assembly and the ESCAP Commission resolutions.

Following repeated requests made by member States to gain a better understanding of the negative impact of sand and dust storms, APDIM undertook to understand the severe multidimensional impact of sand and dust storms, including the deterioration of human health, well-being and urban health, and the potentially adverse impact on clean energy production, transport, agriculture and environment sectors, the result is this report: Sand and Dust Storms Risk Assessment in Asia and the Pacific.

The report's analysis - first of its kind for geographic and sectoral scope - shows that the health of millions of people in South and South-West Asia is affected by sand and dust storms as are thousands of hectares of agricultural lands in Central Asia and thousands of hectares of glaciers in Himalaya and Tibetan mountains. The report also illustrates how food security, energy production, agriculture, water stress and flood regimes are all directly and indirectly impacted by sand and dust storms. It is critical that, based on the evidence produced in this report, we mobilize regional coordinated action for combating the transboundary impact of this hazard.

The *Sand and Dust Storms Risk Assessment in Asia and the Pacific* report specifically makes the case that there is an urgent need for countries in the region to consider joint action towards a deeper understanding of the socio-economic impact of sand and dust storms; a coordinated monitoring and early warning system, with an impact-based focus, to timely forecast sand and dust storms and enable targeted measures to minimize exposure and reduce risks and coordinated actions in most at-risk and exposed geographical areas to mitigate the risks.

This assessment by APDIM would have not been possible without the collaboration of member States and partners who actively contributed to the research and the analysis. I hope their contribution will be brought even more to fruition as this report becomes the evidence base to guide the development of concerted action at regional level to combat the negative impact of this hazard.

Armida Salsiah Alisjahbana

Under-Secretary-General of the United Nations and
Executive Secretary of United Nations Economic and
Social Commission for Asia and the Pacific

Executive Summary

Sand and dust storms occur frequently in deserts and semi-deserts when strong winds detach small particles from dry soils with little or no vegetation cover. The Asia-Pacific region is the world's second largest in terms of mineral dust emissions, with four main sand and dust storm corridors: (i) East and North-East Asia; (ii) South and South-West Asia; (iii) Central Asia; and (iv) the Pacific subregions. These corridors contain numerous sand and dust storm hotspots.

Sand and dust storms are important for the functioning of ecosystems, but they also pose risks to society and the environment, directly threatening the achievement of 11 of the 17 Sustainable Development Goals. The impacts occur not only where these atmospheric events originate but also in places downwind far from the source areas, frequently across international boundaries.

This report assesses the risk of sand and dust storms separately for each sector analysed – agriculture, energy, environment, aviation, human health, and cities – using a quantitative method with a transboundary approach at a regional scale. Risk is measured as a function of the hazard posed by sand and dust storms, vulnerability (exposure and sensitivity), and resilience. For all sectors, the dust hazard is assessed on an annual basis using data from the Modern-Era RetrospectiveAnalysis for Research and Applications, Version 2 (MERRA-2), a reanalysis dataset that combines observational and modelled climatological conditions. Exposure, sensitivity, and resilience are each characterised using appropriate datasets, where data are available separately for each sector.

The findings of this risk assessment indicate that more than 500m people in India are exposed to medium and high levels of poor air quality due to sand and dust storms, along with 173m people in Pakistan, 62m in the Islamic Republic of Iran and 40m in China. In proportional terms, more than 80 per cent of the entire populations of Turkmenistan, Pakistan, Uzbekistan, Tajikistan and the Islamic Republic of Iran are exposed to medium and high levels of poor air quality due to sand and dust storms.

In the energy sector, sand and dust storms have a considerable impact on the generation of electricity by solar power plants which, measured in economic terms, is greater than USD107m a year in India, and exceeds USD46m and USD37m a year in China and Pakistan. The risk to electricity generation posed by sand and dust storms is likely to become greater as governments strive to ensure access to affordable, reliable, sustainable and modern energy for all (SDG 7).

In the aviation sector, the exposure of aircraft engines to dust particles is a considerable risk on flight paths traversing southwestern and central parts of Asia. Flights to and from airports on the Arabian Peninsula, Pakistan, India, and China are most affected. The risk of a flight delay, diversion and cancellation due to low visibility caused by sand and dust in the atmosphere at ground level is greatest at airports in Central Asia, southern parts of the Islamic Republic of Iran, the border area between Pakistan and India, and northern parts of China.

Large areas of farmland are affected by dust deposition in Turkmenistan (71% of the cropland area), Pakistan (49%) and Uzbekistan (44%). Much of this dust is characterised by a high salt content, which typically makes the dust toxic to plants. This reduces yields, representing a significant threat to the production of irrigated cotton and other crops.

Very high dust deposition occurs in the Himalaya-Hindu Kush Mountain range and the Tibetan Plateau, the so-called Third Pole which provides fresh water to more than 1.3 billion people in Asia. The deposition of dust on glaciers induces a warming effect, increasing the melting of ice, with direct and indirect impacts on society through numerous issues, including food security, energy production, agriculture, water stress and flood regimes.

Cities in southwestern parts of Asia have the highest exposure to sand and dust storms, which make a significant contribution to poor air quality in Karachi, Lahore, and Delhi, where nearly 60 million people experienced more than 170 dusty days a year in 2019. The situation is much worse for 6 million residents of eight cities across the region (three in China, two in the Islamic Republic of Iran, two in Pakistan, and one in Uzbekistan) who breathed air with unhealthy concentrations of particulate matter every day for at least ten months in 2019.

The risk of impacts from sand and dust storms is projected to increase in the 2030s due to more extreme drought conditions in parts of Western Australia, south-eastern Turkey, the Islamic Republic of Iran and Afghanistan, while sources in Kazakhstan, northern China, Mongolia and the Ganges basin in India face a lower risk of drought and hence probably less risk from sand and dust storms. The risk in south-eastern Turkey, the Islamic Republic of Iran and Afghanistan is even more likely to materialise given that this area is also projected to experience extremely high levels of water stress in 2030. Managing the risks associated with sand and dust storms may also become necessary in places not previously recognised as source areas for such phenomena due to more extreme droughts projected in parts of northern and southern Thailand, south-eastern China, northern Malaysia and southeasternmost Australia.

This risk assessment report demonstrates that the cumulative effects of sand and dust storms on society are significant, not least because sand and dust storms are more frequent than most other types of natural hazards. Their impacts are complex, they are very widespread, and they represent an important emerging issue for policymakers. However, our understanding of how sand and dust storms interact with society and the environment is still undermined by considerable uncertainties.

A lack of data presented one of the most prominent challenges throughout the process of conducting this risk assessment. Several types of sand and dust storm hazard are poorly accounted for, and in-depth risk assessments for sand and dust storm events across multiple sectors at national and local levels are needed. At the international level, coordinated multi-country transboundary studies of individual dust storm events are required to fully understand their multiple impacts. The lack of data is particularly acute in the case of economic analysis. This situation has prompted ESCAP-APDIM to advocate for sand and dust storm issues to be mainstreamed into disaster risk reduction strategies and become fully integrated into multi-hazard management plans for disaster risk reduction at all levels and across all sectors.

Given the frequent transboundary impact of sand and dust storms, there is a strong case for the design and implementation of well-coordinated actions at national, regional and interregional levels. The analysis in this report highlights critical areas for countries in the region to consider joint action towards:

- A deeper understanding of the socio-economic impacts of sand and dust storms;
- A coordinated monitoring and early warning system, with an impact-based focus, to timely forecast sand and dust storms and enable targeted measures to minimize exposure and reduce risks;
- Coordinated actions in most at-risk and exposed geographical areas with a view to mitigating the risks.

This report is the first attempt to assess and analyse the risks posed to society and the environment by sand and dust storms in such a large-scale geographical area. It is the product of collaboration, active support and contributions from other UN entities and subsidiary bodies of ESCAP, national agencies, research institutions and universities all over the world.

Acknowledgements

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The Report and the Analysis:

The risk assessment was conducted, and this report was prepared under the direction of Letizia Rossano, Director of APDIM. The coordinator of the assessment and production of the report was Amin Shamseddini, Programme Officer, APDIM.

The core team of authors were Amin Shamseddini, Programme Officer and Ava Bahrami, Public Information Officer, APDIM and Nicholas Middleton, Oxford University, UK.

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The Methodology

The methodology for this assessment was initially discussed during an expert meeting co-convened by the Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) and World Meteorological Organization (WMO) in Geneva on 30-31 October 2019. The workshop discussed various methodologies for sand and dust storms risk assessment including probabilistic and deterministic methods. Participants of the workshop were Sara Basart, Barcelona Supercomputing Centre; Sahar Safaei Director and Principal Consultant at Sage on Earth Consulting Ltd; Alexander Baklanov and Jose Camacho, World Meteorological Organization; Utchang Kang, United Nations Convention to Combat Desertification; and Hossein Fadaei, United Nations Environment Management Group; Yoshiya Touge, Tohoku University, Japan; Gabriel Bernal, Risk Nexus Initiative; Nicholas Middleton, Oxford University, Letizia Rossano, Director of APDIM, Amin Shamseddini, Programme Officer, APDIM. The methodology was subsequently discussed and further refined at the Steering Committee meeting of the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) and its Regional Nodes (Pan American, North Africa, Europe and Middle East (NAMEE) and Asian Nodes) organized by the China Meteorological Agency in November 2019 in Hangzhou, China.

Partnership with WMO and the Sand and Dust Storm Warning Advisory System (SDS-WAS)

The Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) is grateful to the World Meteorological Organization for having given access to the network of scientists and meteorological agencies who form part of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) and who, in turn, made available their knowledge and experience in sand and dust storms observation, modelling and risk analysis to the benefit of this report. Please also refer to Box 5-3: The Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) of the World Meteorological Organization (WMO).

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Explanatory Notes

Analyses in the Sand and Dust Storms Risk Assessment in Asia and the Pacific are based on data and information available up to 18 April 2020.

The Asia-Pacific region, unless otherwise specified, refers to the group of ESCAP members and associate members that are within the Asia and the Pacific geographic region. Groupings of countries and territories/areas referred to in the present edition of the Report are defined as follows:

ESCAP region: Afghanistan; American Samoa; Armenia; Australia; Azerbaijan; Bangladesh; Bhutan; Brunei Darussalam; Cambodia; China; Cook Islands; Democratic People's Republic of Korea (the); Fiji; France; French Polynesia; Georgia; Guam; Hong Kong, China; India; Indonesia; Iran (the Islamic Republic of); Japan; Kazakhstan; Kiribati; Kyrgyzstan; Lao People's Democratic Republic (the); Macao, China; Malaysia; Maldives; Marshall Islands (the); Micronesia (the Federated States of); Mongolia; Myanmar; Nauru; Nepal; Netherlands (the); New Caledonia; New Zealand; Niue; Northern Mariana Islands; Pakistan; Palau; Papua New Guinea; Philippines (the); Republic of Korea (the); Russian Federation (the); Samoa; Singapore; Solomon Islands; Sri Lanka; Tajikistan; Thailand; Timor-Leste; Tonga; Turkey; Turkmenistan; Tuvalu; United Kingdom of Great Britain and Northern Ireland (the); United States of America (the); Uzbekistan; Vanuatu; and Viet Nam.

East and North-East Asia: China; Democratic People's Republic of Korea; Hong Kong, China; Japan; Macao, China; Mongolia and Republic of Korea.

North and Central Asia: Armenia; Azerbaijan; Georgia; Kazakhstan; Kyrgyzstan; Russian Federation; Tajikistan; Turkmenistan and Uzbekistan.

Pacific: American Samoa; Australia; Cook Islands; Fiji; French Polynesia; Guam; Kiribati; Marshall Islands; Micronesia (the Federated States of); Nauru; New Caledonia; New Zealand; Niue; Northern Marina Islands; Palau; Papua New Guinea; Samoa; Solomon Islands; Tonga; Tuvalu and Vanuatu.

South and South-West Asia: Afghanistan; Bangladesh; Bhutan; India; Iran (the Islamic Republic of); Maldives; Nepal; Pakistan; Sri Lanka and Turkey.

South-East Asia: Brunei Darussalam; Cambodia; Indonesia; Lao People's Democratic Republic; Malaysia; Myanmar; Philippines; Singapore; Thailand; Timor-Leste and Viet Nam.

Developing ESCAP region: ESCAP region excluding Australia; Japan and New Zealand

Developed ESCAP region: Australia; Japan and New Zealand

Countries with Special Needs

Least Developed Countries: Afghanistan; Bangladesh; Bhutan; Cambodia; Kiribati; Lao People's Democratic Republic; Myanmar; Nepal; Solomon Islands; Timor-Leste; Tuvalu and Vanuatu. Samoa was part of the least developed countries prior to its graduation in 2014.

Landlocked Developing Countries: Afghanistan; Armenia; Azerbaijan; Bhutan; Kazakhstan; Kyrgyzstan; Lao People's Democratic Republic; Mongolia; Nepal; Tajikistan; Turkmenistan and Uzbekistan.

Small Island Developing States: American Samoa; Cook Islands; Fiji; French Polynesia; Kiribati; Maldives; Marshall Islands; Micronesia (the Federated States of); Nauru; New Caledonia; Niue; Northern Mariana Islands; Palau; Papua New Guam; Guinea; Samoa; Singapore; Solomon Islands; Timor-Leste; Tonga; Tuvalu and Vanuatu.

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In the tables, two dots (..) indicate that data are not available or are not separately reported; a dash (–) indicates that the amount is nil or negligible, and a blank indicates that the item is not applicable.

In dates, a hyphen (-) is used to signify the full period involved, including the beginning and end years, and a stroke (/) indicates a crop year, fiscal year or plan year.

Acronyms and Abbreviations

ADRC	Asian Disaster Reduction Center
APDIM	Asian and Pacific Centre for the Development of Disaster Information Management
CAT	In the aviation sector, CAT is the acronym of three main categories of approach and landing
CMA	China Meteorological Administration
COP	United Nations Climate Change Conference, Conference of the Parties
CSOs	Civil Society Organizations
DESA	United Nations Department of Economic and Social Affairs
DOE	Department of Environment, Iran (the Islamic Republic of)
DRR	Disaster Risk Reduction
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
ESCWA	United Nations Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization of the United Nations
GA	United Nations General Assembly
GAR	Global Assessment Report on Disaster Risk Reduction
GDP	Gross Domestic Product
GIC-AIT	Geo-informatics Center of Asian Institute of Technology
GIS	Geographic Information System
GLCNMO	Global Land Cover by National Mapping Organization
GSI	Geospatial Information Authority of Japan
IATA	International Air Transport Association
ICT	Information Communications Technology
ILS	Instrument Landing System
INFORM	Index for Risk Management
INGOs	International Non-Governmental Organizations
IPCC	Intergovernmental Panel on Climate Change
IRIMO	Islamic Republic of Iran Meteorological Organization

ISCGM	International Steering Committee for Global Mapping
kWh	Kilowatt-hour
M	Million
MODIS	Moderate Resolution Imaging Spectroradiometer
MERRA	Modern-Era Retrospective analysis for Research and Applications
MW	Mega Watt
NAMEE	North Africa, Europe and, Middle East Regional Node of WMO SDS-WAS
NASA	National Aeronautics and Space Administration, United States of America (the)
NCC	National Cartographic Center, Iran (the Islamic Republic of)
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric, United States of America (the)
PM	Particles with an aerodynamic diameter <10 µm (PM_{10}) and <2.5 µm ($PM_{2.5}$)
PV	Solar Photo Voltaic
SDGs	Sustainable Development Goals
SDS	Sand and Dust Storms
SDS-WAS	Sand and Dust Storms Warning Advisory and Assessment System
SEDAC	Socioeconomic Data and Applications Center
SHDI	Sub-National Human Development Index
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNS	United Nations Secretariat
WHO	World Health Organization
WMO	World Meteorological Organization

Chapter 1.

Sand and Dust Storms in Asia and the Pacific

Sand and Dust Storms Impact on Sustainable Development

As a meteorological phenomenon, sand and dust storms derive mainly from arid and semi-arid areas and are spread across large parts of the study region. Major events can transport dust over great distances so that their impacts occur not only in the areas where they originate but also in communities far from the source areas, frequently across international boundaries.

Sand and dust storms **directly affect 11 of the 17 SDGs:**

- Ending poverty in all forms (SDG 1)
- Ending hunger (SDG 2)
- Good health and well-being (SDG 3)
- Safe water and sanitation (SDG 6)
- Affordable and clean energy (SDG 7)
- Decent work and economic growth (SDG 8)
- Industry innovation and infrastructure (SDG 9)
- Sustainable cities and communities (SDG 11)
- Climate action (SDG 13)
- Life below water (SDG 14)
- Life on land (SDG 15)

Infographic 1-1: The impact of sand and dust storms on Sustainable Development Goals (SDGs)

Sand and dust storms can adversely impact **poverty** in a community in numerous ways, not least because sand and dust storms often represent a form of dryland degradation or desertification. Sand and dust storms have a negative impact on food security by intensifying the damages to the livelihood and food security of millions of small farmers and pastoralists, as well as by damaging agricultural infrastructure, directly impacting production. This, in turn, becomes a major limitation to the second sustainable development goal **to end hunger** by 2030.

Achieving good **health and well-being** in communities can also be adversely impacted. Sand and dust storms represent a risk factor for chronic diseases such as lung cancer and acute lower respiratory infections, cardiovascular and respiratory diseases which result in premature death (UNEP, WMO, & UNCCD, 2016). The condition of people with diseases such as bronchitis, eye infections, skin irritations, meningococcal meningitis, valley fever and diseases associated with toxic algal blooms is also impacted over time.

An increase in the level of sand and dust in the **environment and water resources** will adversely affect water quality. In the long term, this will lead to difficulties in providing **safe and affordable drinking water** for all. Moreover, the economic growth of a community might be affected by sand and dust storms. They can severely damage crops, fill irrigation canals, trigger power blackouts and result in other damage.

Power, water, road and other **important infrastructure** failures might occur as a result of sand and dust storms which can interrupt the provision of vital and critical services for the community. All these impacts can affect the sustainability and resilience of infrastructure and small and big businesses. Sand and dust storms can severely impact **cities and other communities**, hampering their efforts to become **inclusive, safe, resilient** and sustainable.

Climate change and changes in temperature and precipitation levels are modifying sand and dust storm hazard levels and increasing the associated risks. Due to changes in climate conditions, many **drylands** are becoming drier and consequently more prone to wind erosion and sand and dust storms.

Life below water and **on land** are directly and indirectly affected by sand and dust storms in both a positive and negative way. Sand and dust deposition in coastal areas adversely affect coral reef ecosystems and life below water. The resilience of communities on land is undermined by many of the risks associated with sand and dust storms.

Sand and dust storms also threaten the means of implementation and revitalization of the global partnership for sustainable development because of the extensive and intensive socio-economic losses they can trigger.

The Intergovernmental Mandate for Sand and Dust Storms

In recent years, a number of resolutions have been adopted requesting the ESCAP Secretariat to support and facilitate disaster risk assessment to strengthen regional cooperation mechanisms as well as to combat the negative impact of sand and dust storms.

In June 2015, ESCAP Commission requested the Executive Secretary to strengthen disaster risk modelling, assessment, mapping, monitoring and multi-hazard early warning systems of common and transboundary disasters. Subsequently, the General Assembly at its seventieth session, also in 2015, addressing multidimensional hazards, "emphasized the relevance of the efforts and cooperation of Member States at regional and international levels to control and reduce the negative impacts of sand and dust storms on human settlements in vulnerable regions". The General Assembly also "stressed the need for cooperation at global and regional levels with a view to preventing and managing sand and dust storms through the development of early warning systems and the sharing of climate and weather information to forecast sand and dust storms and affirming that resilient action to combat sand and dust storms requires a better understanding of the severe multidimensional impacts of sand and dust storms, including the deterioration of the health, well-being and livelihood of people, increased desertification and land degradation, deforestation, loss of biodiversity and land productivity, and their impact on sustainable economic growth" A/RES/70/195.

Furthermore, the General Assembly through the adoption of A/RES/74/226, "encouraged regional, subregional and interregional organizations and processes to continue to share best practices, experiences and technical expertise in combating sand and dust storms to address the root causes and impacts of sand and dust storms, including through improved implementation of sustainable land management practices, and to promote regional cooperation in this matter to reduce the risks and impact of future sand and dust storms and to provide affected countries with capacity-building and technical support from the relevant United Nations organizations"

The Asian and Pacific Centre for the Development of Disaster Information Management (APDIM), as a subsidiary body of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), supports regional cooperation mechanisms for slow-onset disasters including sand and dust storms – involving member countries from West, South West and Central Asia and key partners including the United Nations Environment Programme (UNEP), United Nations Convention to Combat Desertification (UNCCD), World Meteorological Organisation (WMO), United Nations Development Programme (UNDP) and other related members of the UN Coalition on Combating Sand and Dust Storms.[1] A list of related resolutions is provided in Annex.

The Tehran Ministerial Declaration of the International Conference on Combating Sand and Dust Storms: Challenges and Practical Solutions organized in July 2017 by the Ministry of Foreign Affairs and Department of Environment of the Government of the Islamic Republic of Iran in collaboration with UNEP, UNDP, United Nations Department of Economic and Social Affairs (UN DESA), and ESCAP highlights the consensus reached on regional and sub-regional cooperation on combating sand and dust storms through sharing knowledge, lessons learnt, best practices, and monitoring data and forecasting information; exchanging technical knowledge; strengthening national, regional and global level cooperation among relevant organizations and institutes; enhancing public awareness on sand and dust storms and its impacts; strengthening research activities for effective monitoring, impact-based assessment and forecasting and early warning mechanisms for sand and dust storms. The Declaration also recognised the role of the Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) and that of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) of the World Meteorological Organization, to develop human and institutional capacity through strengthened regional cooperation in disaster information management (APDIM & ESCAP, 2018). For example, in June 2019, the Eighteenth World Meteorological Congress approved Resolution 19 (Cg-18) on enhancing cooperation for monitoring and forecasting sand and dust storms. Congress noted the progress with the implementation

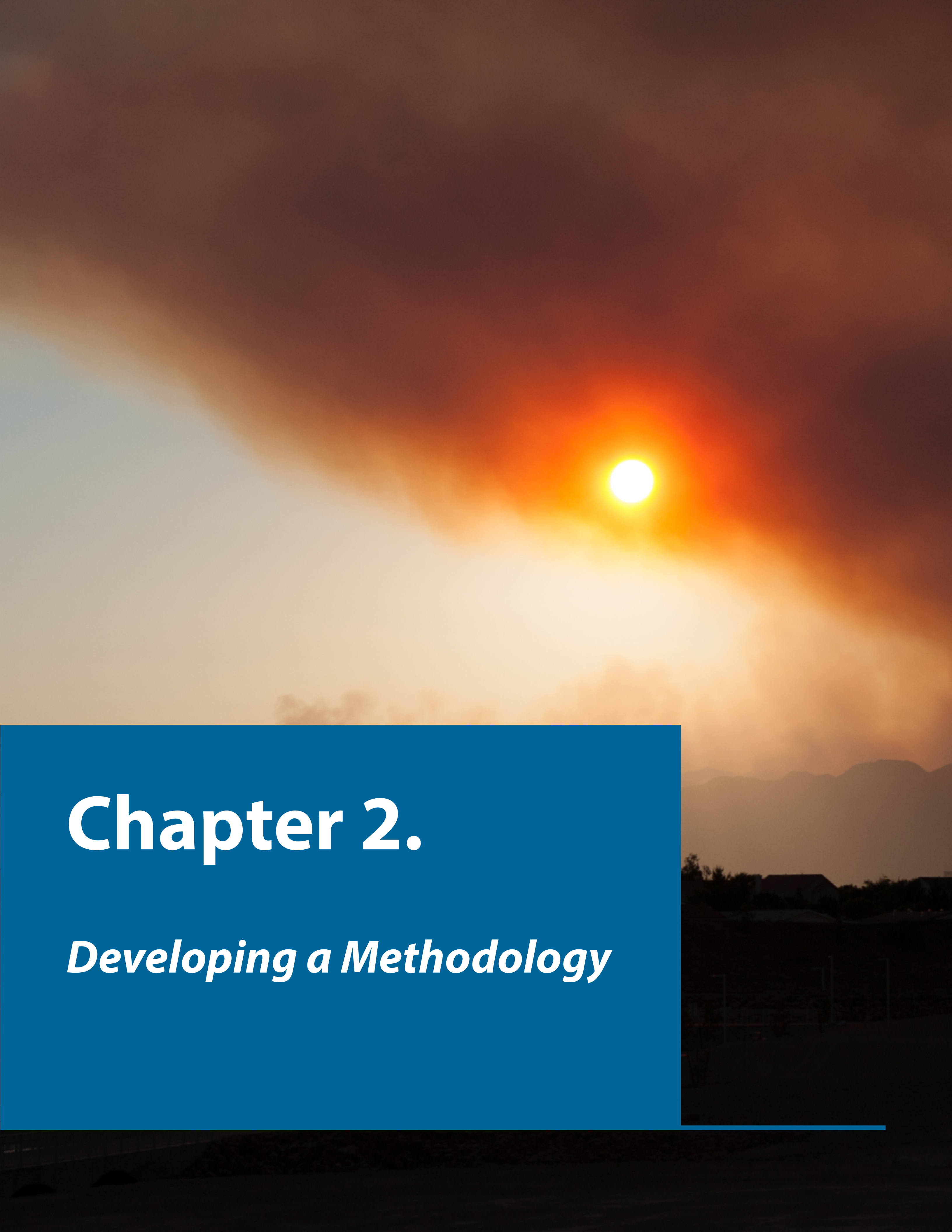
1. United Nations, General Assembly, seventy-fourth session, A/RES/74/226 welcomed the creation of the United Nations Coalition on Combating Sand and Dust Storms, which aims, inter alia, to promote and coordinate a collaborative United Nations system response to the growing issue of sand and dust storms on a local, regional and global scale, ensuring that unified and coherent action is taken, and to facilitate the capacity-building of Member States, raise their awareness and enhance their preparedness and response to sand and dust storms in critical regions.

of the SDS-WAS and suggested Member Countries promote international cooperation to combat sand and dust storms through the exchange of knowledge, experiences, best practices and by launching training courses, and to enhance capacity building and technical assistance for monitoring and forecasting sand and dust storms and to support the implementation of national, regional, and global action plans of affected countries (World Meteorological Organization, 2019).

In line with this mandate, in 2018, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) published a report entitled Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action. The report offers perspectives to enhance the science-based understanding of sand and dust storms among policymakers and supports the development of adaptation and mitigation policies at the regional and national levels. It also presents an in-depth diagnosis of sand and dust storm events using terrestrial and satellite observations, and analyses potential drivers, as well as pointing to the risk in problem areas and identifying gaps in information, cooperation, and policy capacity.

The report highlights the vulnerability countries share across wide expanses of the Asia-Pacific region and underlines the need to address sand and dust storms through a multi-hazard risk assessment and alert system for slow-onset disasters.

Dust storm hits refugees arriving at Dadaab, Photo taken on 15 August 2011,
Photo credit: Jo Harrison, Oxfam International, Source: Flickr



Chapter 2.

Developing a Methodology

To act upon the recommendation to develop an assessment of the medium- and long-term projected impact of SDS in the Asia-Pacific region, APDIM and the World Meteorological Organization convened a technical workshop in Geneva in October 2019 bringing together experts to discuss and identify a viable methodology. The participants were selected to cover three broad fields of expertise: (i) land use issues (land degradation, desertification, and water resource management); (ii) climate and weather-related issues, and (iii) socio-economic vulnerability/exposure.

The workshop discussed various possible methodologies including probabilistic and deterministic methods. Based on the needs and data availability, experts recommended using historical records of sand and dust storms as a hazard layer. The methodology was further discussed in November 2019 at the WMO Global Steering Committee Meeting of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) where China and Japan Meteorological Agencies offered to prepare and share their data on sand and dust storm forecasts re-analysis to facilitate APDIM's regional risk assessment work and offered to collaborate in the risk assessment.

This assessment employs the risk concept from Disaster Risk Reduction and the concept of vulnerability from Climate Change Adaptation to achieve a more granular overview of the impact of this phenomenon. To assess the risk, indicators, and layers for each of the components of risk for each sector were selected. Due to the lack of available data or literature, for some of the sectors, the assessment was limited only to assessing the exposure.

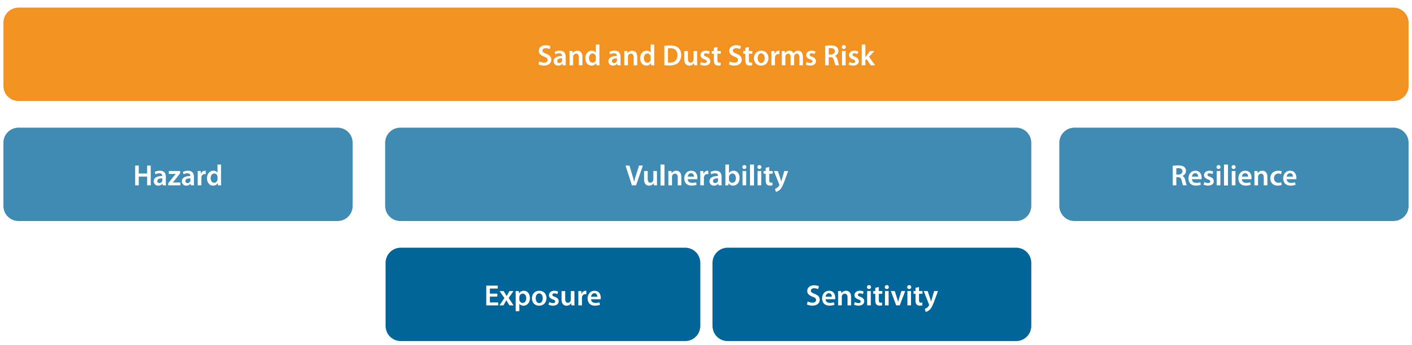
At an early stage in this risk assessment, APDIM evaluated the evidence for the risks posed by sand and dust storms to all aspects of society, economy, and environment. This evaluation involved an appraisal of our knowledge and understanding of impacts as well as the availability of relevant data. As a result, this study assesses the risk of sand and dust storms to the following sectors: human health, energy, aviation, agriculture, environment, and cities. It does not, however, assess risks to other sectors known to be affected because of significant gaps in available data and deficiencies in knowledge and understanding. Sectors that are not assessed for these reasons include information and communications technology (ICT), road and maritime transport, extractive industries such as oil and gas, and the manufacturing industry.

Part of the required data was gathered by APDIM from the subsidiary bodies of ESCAP including Information and Communication Technology and Disaster Risk Reduction, Statistics, Transport and Energy Divisions. Other required data were gathered from the Food and Agriculture Organization of the United Nations (FAO), and the International Air Transport Association (IATA). The sand and dust storms reanalysis data were gathered from the Japan Meteorological Agency and the second Modern-Era Retrospective analysis for Research and Applications (MERRA-2) reanalysis dataset of NASA.

The Conceptual Framework for Risk Assessment

Assessing risk involves an understanding of the hazard in question, in this case, sand and dust storms, along with an appreciation of whatever is at risk, whether it be people, assets or some aspect of the physical environment. How a system is potentially affected by a hazard – the risk it faces – depends on the vulnerability of the system and its resilience. In turn, vulnerability is a function of exposure and sensitivity (Figure 2-1).

Figure 2-1: Conceptual framework of the sand and dust storms risk assessment



Many of these concepts can be defined in more than one way. The terms 'risk' and 'vulnerability' are fundamental in various disciplines such as disaster management, geography, poverty and development, livelihood and food security, sustainability science, and climate change impacts and adaptation. See for example the approaches taken in disaster risk reduction and climate change adaptation (Gain, Giupponi, & Renaud, 2012). In disaster risk reduction studies, vulnerability is considered as a physical and environmental input for the quantification of risk.[2] Some climate change adaptation research considers vulnerability as an output deriving from social conditions and processes such as adaptation or maladaptation (Gain & Giupponi, 2015).

This assessment applies an integrated approach to the **concept of risk** considering the concepts of exposure, sensitivity, and resilience according to the climate change adaptation research stream, and the concept of hazard is extracted from the disaster risk reduction approach.

Sand and dust storms have been categorized among meteorological and hydrological **hazards** in the Hazard Definition and Classification Review of UNDRR 2020. Sand and dust are also among the predefined hazards in the Sendai Framework Monitor (UNDRR, 2020). Sand and dust storms are transboundary in nature with widespread impacts at the sub-regional/regional scale. Such impacts can often be classified as disasters, which are defined in the General Assembly report A/71/644 on disaster risk reduction terminology, as serious disruptions of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

2. According to UNDRR terminology, vulnerability defined as: "The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards." (UNDRR, UNDRR terminology on disaster risk reduction, 2017)

Measuring Risk

Sand and dust storms comprise particles detached by a strong wind from dry soil (a source area) and carried in the atmosphere, sometimes affecting a large area before being deposited elsewhere.

The risk of sand and dust storms is assessed in this report using a quantitative method with a transboundary approach at a regional scale: it is measured as a function of **hazard** (sand and dust storms), **vulnerability** (exposure and sensitivity), and **resilience** (see Figure 2-1). Putting this conceptual framework into practice is not, however, as straightforward as it sounds and in order to account for the different impacts of sand and dust storms in different sectors, risk has been assessed separately for each sector: agriculture, energy, environment, aviation, human health, and cities.

In each case, separate decisions have been made on what parameters to take into account and are detailed in the relevant sections in Chapter 3 of this report.

Table 2-1: Summary of hazard data used for each sector

Sector	Hazard data
Human Health	The average number of dusty days (with dust concentration PM_{10} higher than 50 µg/m^3) (2019)
Energy (Solar powerplants)	Average dust deposition (µg/m^2) (2019)
Transport (Aviation, Visibility)	The average number of hours per year with visibility less than 1000m due to atmospheric dust concentration (PM_{10})
Transport (Aviation, Erosion)	Average atmospheric dust concentration (PM_{10}) in cruise elevation (2019)
Agriculture	Average dust deposition (µg/m^2) (2019)
Environment (Glaciers)	Average dust deposition (µg/m^2) (2019)
Cities	The average number of dusty days (atmospheric dust concentration (PM_{10}) higher than 50 µg/m^3)

Massive sandstorm rolling into Yazd province, Islamic Republic of Iran, Photo taken on 16 April 2018,
Photo credit: Matthias Schmidt, Reuters, Source: Mashregh News

Data for Risk Assessment

Hazard: For the hazard layer in all sectors, the data used is from the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) (Global Modelling and Assimilation Office- NASA, 2020). MERRA-2 is a reanalysis dataset that combines observational and modelled climatological conditions to simulate changes in weather patterns. It assimilates space-based observations of aerosols and represents their interactions with other physical processes in the climate system (Buchard, et al., 2017), and has been used successfully for studies of dust events.[3] (Jing, Zhang, Chen, & Xu, 2017)[4] (Mukkavilli, et al., 2019). Temporally, the data coverage is from 1980 onward, with a time interval of one hour. MERRA-2 data is used to define the hazard in different ways, depending on the sector in question, as shown in Table 2-1. Note that for all sectors, the dust hazard is assessed on an annual basis. Sand and dust storms typically vary seasonally in frequency and magnitude, but seasonal variations were beyond the scope of this report.

Vulnerability: The Open-ended Intergovernmental Expert Working Group on indicators and terminology relating to disaster risk reduction defines vulnerability in its report to the General Assembly (A/71/644) as the conditions determined by physical, social, economic, and environmental factors or processes which increase

3. Jing et al., using the MERRA-2 Reanalysis, were quantitatively estimated the dust budget of a severe dust event in East Asia that occurred from April 28 till May 3, 2011.
4. In the study by Mukkavilli et al. (2019), atmospheric total and dust aerosol optical depth (AOD) from various reanalysis datasets were analysed over Australia. The analysis showed that MERRA-2 total AOD had a much higher correlation against AeroSpan/AERONET total AOD than ECMWF/MACC. While both ECMWF/MACC and MERRA-2 provided dust estimates during normal conditions and extreme events, the MERRA-2 seems to be more sensitive with higher dust estimates during extreme events.

Table 2-2: Summary of exposed elements and source of data for each sector

Sector	Exposed element/layer	Data source
Human Health	Population	NASA Socioeconomic Data and Applications Center (SEDAC) (NASA, 2020)
Energy (Solar powerplants)	Solar powerplants' location and capacity	Asia Pacific Energy Portal, ESCAP, Energy Division (ESCAP & APEF, Asia Pacific Energy Portal, 2020)
Transport (Aviation, Visibility)	Airports' location	The OPS Group, World Airports Database (OPS Group, 2019)
Transport (Aviation, Erosion)	Flight paths	OpenFlights.org, Airport, Airline and Route data (OpenFlights, 2019)
Agriculture	Agricultural land cover map, including Cropland and Paddy field	GLCNMO[5]
Environment (Glaciers)	Land cover map, Glaciers	GLCNMO
Cities	Population of Urban Agglomerations with 300,000 inhabitants or more in 2018 (2020 Population)	UN-DESA (DESA, 2020)

the susceptibility of an individual, a community, assets, or systems to the impacts of hazards. In the current study, vulnerability is intended as the potential of being exposed to sand and dust storms as a hazard and the sensitivity of the different sectors in facing the hazard.

Exposure: Exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (A/71/644). Exposure is therefore the portion of the sector in question that is exposed to sand and dust storms. Exposure is generated by overlaying the sand and dust storms hazard map onto a vulnerable sector map to determine what portion of the sector concerned is exposed to sand and dust storms. The dataset used for each sector assessed is shown in Table 2-2.

Sensitivity: Sensitivity is considered as the degree to which a sector (or parts of it) is affected by sand and dust particles. The nature of the sector determines what factors need to be measured, but for this parameter, there is a lack of appropriate data in most sectors Table 2-3.

Resilience: The Open-Ended Intergovernmental Expert Working Group on indicators and terminology relating to disaster risk reduction defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform,

5. Land Cover (GLCNMO) Global version data were developed by the secretariat of ISCGM in collaboration with Geospatial Information Authority of Japan (GSI), Chiba University, and NGIAs of respective countries and regions. The data were prepared by using MODIS data with remote sensing technology. https://globalmaps.github.io/glcnmo.html#:~:text=The%20Global%20Land%20Cover%20by,on%20LCCS%20developed%20by%20FAO.

Table 2-3: Summary of sensitivity data used for each sector

Sector	Sensitivity data
Human Health	Age (under 14 and above 65 got higher value), sub-national Human Development Index (SHDI)
Energy (Solar powerplants)	Sensitivity is considered equal for all solar power plants
Transport (Aviation, Visibility)	Sensitivity is considered equal for all aircraft types
Transport (Aviation, Erosion)	Sensitivity is considered equal for all values of passengers and goods, and alternative transport options
Agriculture	Sensitivity is considered equal for all crop types and growth stages
Environment (Glaciers)	Sensitivity is considered equal for all glaciers
Cities	Sensitivity is considered equal for all cities

and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Resilience in this study is the ability to cope and overcome the negative impacts of sand and dust storms, as well as the capability to build back better. In the short term, this ability is considered as the coping capacity; in the long term, it is considered as adaptive capacity (UN, Report of the open-ended Intergovernmental Expert Working Group on indicators and terminology relating to disaster risk reduction, A/71/644, 2016).

For human health, resilience is considered as the public and private expenditure per capita for each country. The level of resilience in the transportation sector (aviation) is measured based on the level of navigation equipment technology advancement at each airport. Modern and advanced navigation equipment reduces the dependence level on visibility.

The indicators to measure the resilience of each sector, some of which are also characterised by a lack of appropriate data, are summarized in Table 2-4.

Risk Analysis Application

Decision-makers and authorities can apply risk assessment in their operational, tactical, and long-term decisions on all timescales to practice policy, planning, intervention and programming. As illustrated in Figure

Table 2-4: Summary of resilience data used for each sector

Sector	Resilience data
Human Health	Per capita expenditure on healthcare (public and private)
Energy (Solar powerplants)	Resilience considered equal
Transport (Aviation, Visibility)	Based on 5 categories of navigational instrument
Transport (Aviation, Erosion)	Resilience considered equal
Agriculture	Resilience considered equal
Environment (Glaciers)	Resilience considered equal
Cities	Resilience considered equal

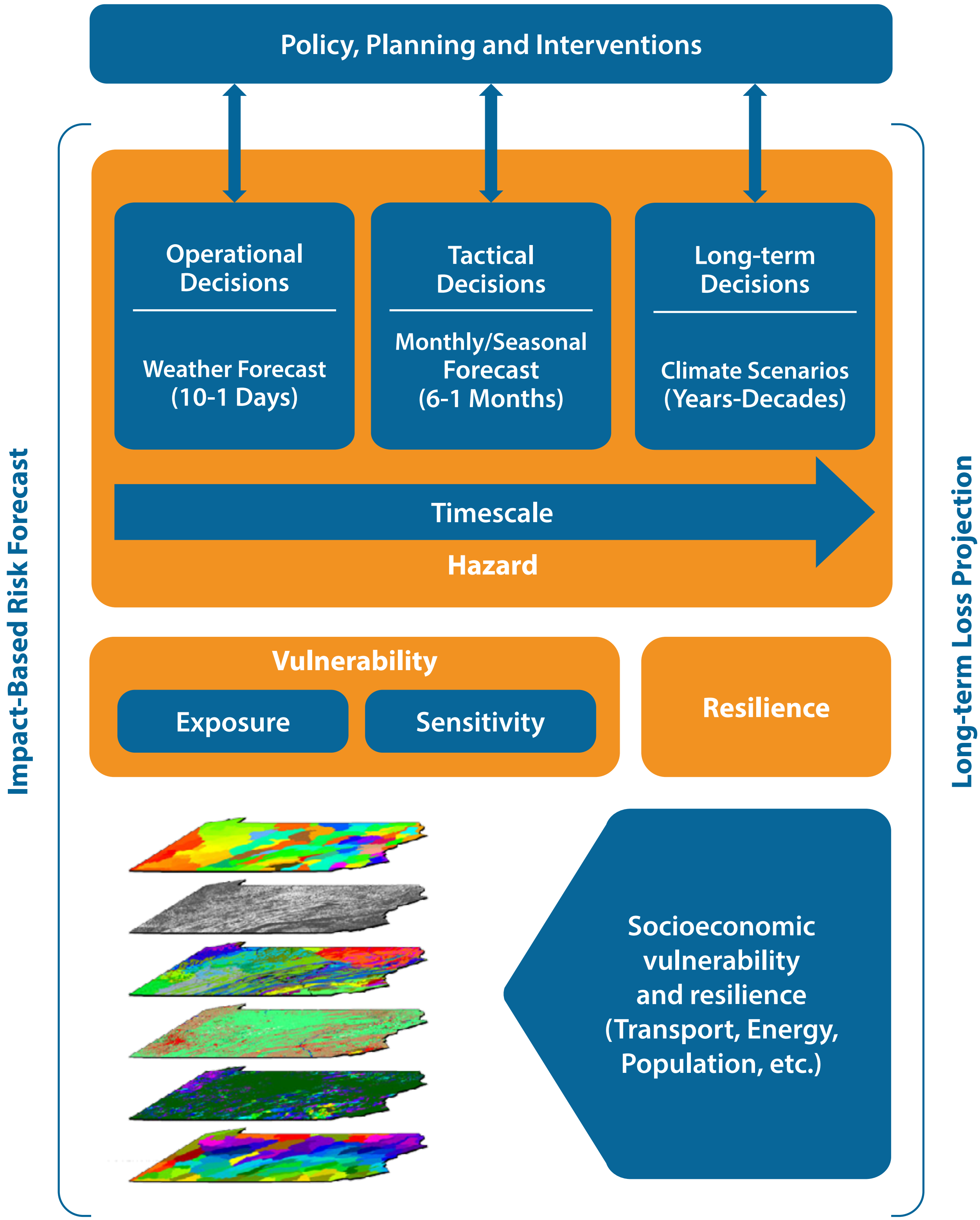
2-2, sand and dust storms risk assessment can be used for operational decision-making over periods ranging from **1-10 days**, by using a weather forecast as the hazard layer, in addition to other components of risk to develop an impact-based sand and dust storms risk forecast.

With this approach, decision-makers in addition to being aware of the meteorological event itself can also gain a clear overview of the actual impacts of sand and dust storms on various sectors. This would greatly facilitate the management of preparedness, early warning, and response phases.

Decision-makers can also incorporate monthly/seasonal forecasts over **1-6 months**. Decisions for longer timescales – **years/decades** – can employ climate scenarios. All of these approaches yield average losses due to sand and dust storms, so helping decision-makers in their long-term planning to implement disaster risk reduction strategies and risk-informed development.

Decisions at all these levels are more effective and risk-informed when founded on impact-based risk forecasting and long-term loss projection (average annual loss). All vulnerable socioeconomic sectors including agriculture, energy, environment, human health, transport (aviation) and cities are used for the purpose of sand and dust storms risk assessment.

Figure 2-2: Applications of sand and dust storms risk assessment



Chapter 3.

Risk of Sand and Dust Storms in Asia and the Pacific

Sectoral Risk Analysis

The Asia-Pacific region is the world's second largest in terms of mineral dust emissions, with four main sand and dust storm corridors: (i) East and Northeast Asia; (ii) South and South-West Asia; (iii) Central Asia; and (iv) the Pacific subregions. These corridors contain numerous hotspots including the Taklamakan Desert and Inner Mongolia in China and the Gobi Desert in Mongolia, the Sistan Basin in the south-eastern Islamic Republic of Iran and southwestern Afghanistan, southern areas of the Islamic Republic of Iran, north-western Baluchistan in Pakistan, the Thar Desert of Rajasthan in western India, the plains of Afghan Turkestan and the Registan area of Uzbekistan, the Aralkum Desert of Uzbekistan and Kazakhstan, Alice Springs, coastal Western and Central Australia (APDIM & ESCAP, 2018) (Tozer & Leys, 2013).

In Chapter 2, we outlined the impact of sand and dust storms on various sectors. The impact can be in the form of disruption or damage. Disaster damage occurs during or after the disaster in the short and long term. Damage is usually in measurable units (e.g., square meters of housing, kilometres of roads, monetary value), and describes the total or partial destruction of physical assets, the disruption of basic services and damage to sources of livelihood in the affected area (UN, A/71/644,

Table 3-1: The mechanism of the impact of sand and dust storms in various sectors

Sector	Disruption	Damage
Human Health	Short-term impact on human health	Asthma; bronchitis; emphysema; silicosis
Energy	Reduction in the efficiency of solar power plants, cost of cleaning, industries power stations	Sandblast/erosion of solar power plants, wind turbines and other energy equipment, damage to wind-generated electricity equipment
Transport - Aviation	Disruption to services for goods and passengers	Aircraft engine damage due to erosion; loss due to flight cancellation and delay
Agriculture	Solar radiation reduction; crops growth	Irrigation canal blockage; reduction in soil quality; soil loss (source area); decline in water quality; damage to agricultural equipment; damage to agricultural crop grows
Environment	Solar radiation changes	Glacier melt with impacts on water availability

2016). Disruption is disordering in providing services. In transport, for example, this can occur through flight cancellation and road blockage; disorder in the health sector might be a disruption in hospital functioning. The mechanisms of disruption and damage in sectors assessed in this report are shown in Table 3-1. However, it is not possible to assess the risk for disruption and damage in all cases. For the aviation and health sectors of this report, the risk is calculated. The remaining sectors face limitations (lack of understanding and required data), so the exposure analysis is presented considering the mechanism of damage. Further details of the risk and exposure assessment for each sector is presented.

Human Health

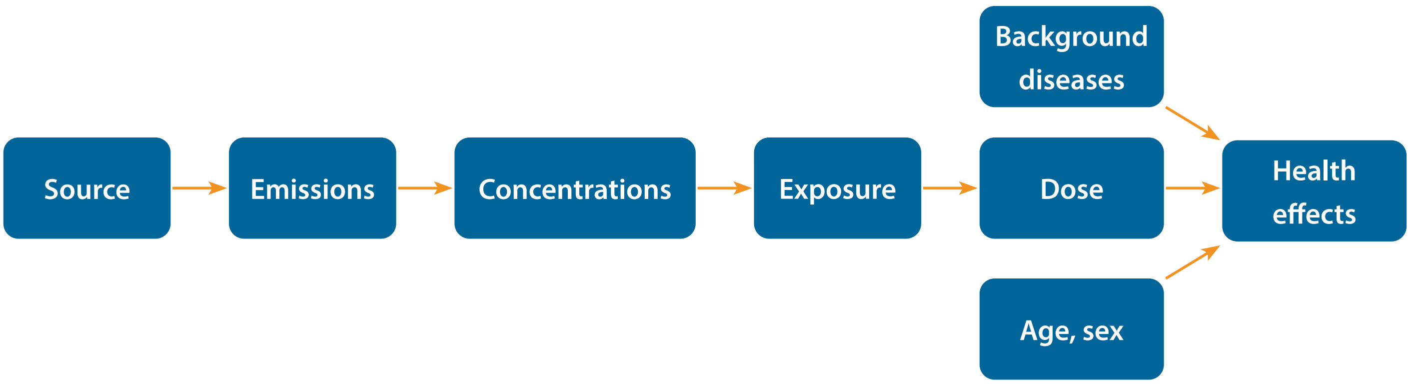
Mineral dust suspended in the atmosphere is associated with morbidity and mortality and can affect human health because of its physical, chemical, and biological properties. Exposure can result in conjunctivitis and dermatological problems, while inhalation can cause respiratory illnesses such as silicosis (otherwise known as desert lung syndrome) and act as a trigger for many others, including asthma, bronchitis, emphysema, and chronic obstructive pulmonary disease (Goudie, 2014).

Sand and dust storms can negatively impact the Air Quality Index (AQI). Karagulian et al. analysed

Central Beijing during heavy dust storm. Photo taken on 15 March 2021,
Photo credit: Simon Song, Source: South China Morning Post

Infographic 3-1: The impact of sand and dust storms on human health

Figure 3-1: Conceptualization of the environmental pathway continuum from source to human health effects. Adapted from (World Health Organization , 2005)



severe dust storms and their impact on air quality conditions using WRF-Chem modelling, satellite imagery, and ground observations which demonstrate that $PM_{2.5}$ and PM_{10} dust particles contributed to reaching the maximum AQI value during the peak time of the dust event (Karagulian, et al., 2019).

Conceptualization of the environmental pathway continuum from source to human health effects is illustrated in Figure 3-1. Human exposure occurs "when a person comes into contact with a pollutant of a certain concentration during a certain period of time" (Rivas, et al., 2016). The dose is the volume of sand and dust particles inhaled, and its health effects are also varying according to other factors including age, sex, and other ailments

Table 3-2: Threshold of the human health sector (WHO air pollution guidelines)

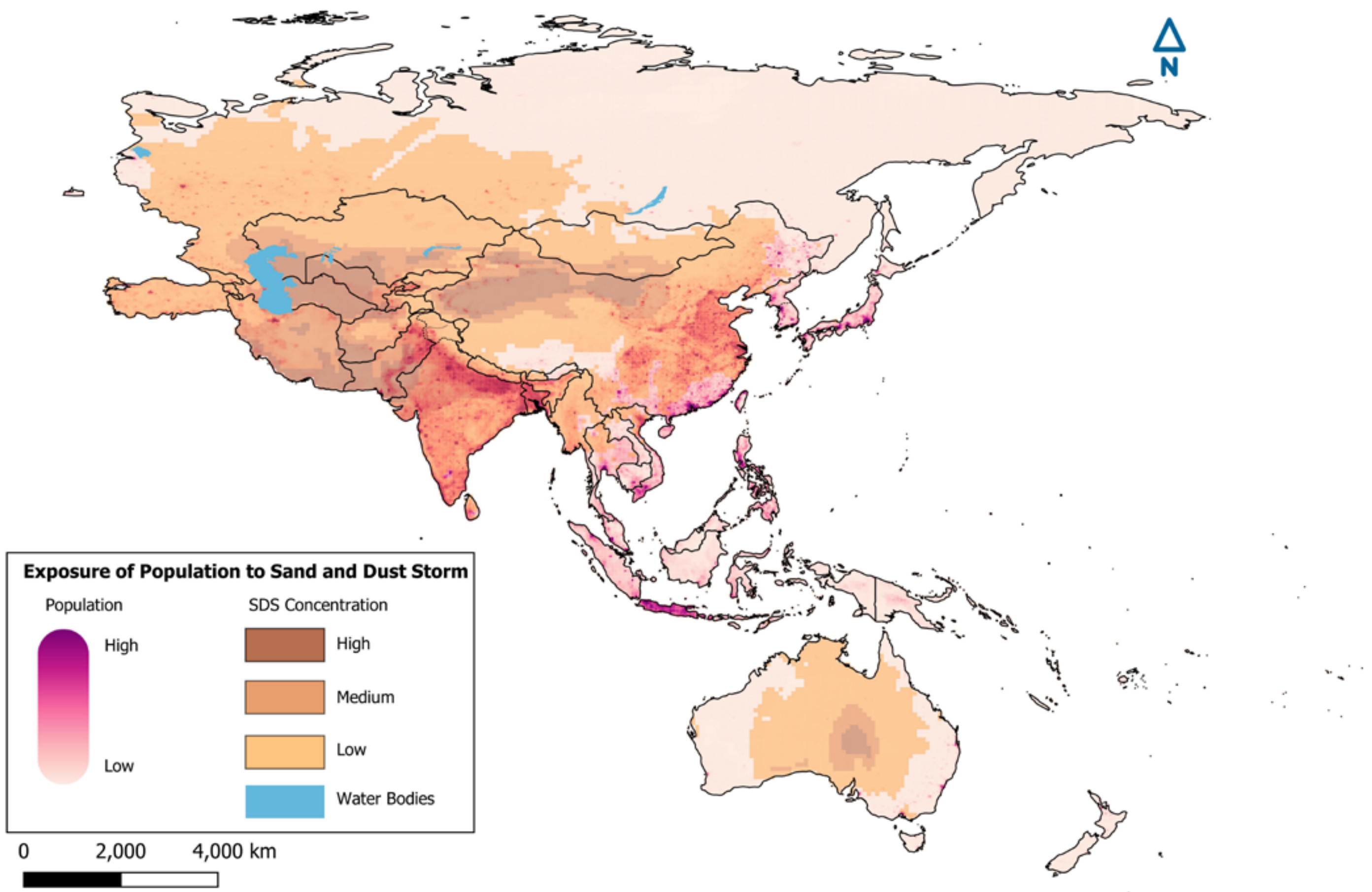
Guideline levels for each pollutant (µg/m³):		
$PM_{2.5}$	1 year	10
	24 h (99th percentile)	25
PM_{10}	1 year	20
	24 h (99th percentile)	50

The hazard map for the risk of sand and dust storms to the human health sector, based on inhalation as the primary exposure pathway, is generated according to WHO's Air Quality Guideline, 2005. Once inhaled, the size of the dust particle is the main determinant of where it comes to rest in the respiratory tract. A distinction is typically made between particles less than 10 microns in diameter (PM_{10}), which can enter the lungs, and those with a diameter of less than 2.5 microns ($PM_{2.5}$), which can reach deeper into the lung tissue. The atmospheric concentration of dust that can meaningfully affect human health is shown in Table 3-2. This study uses daily atmospheric concentration data for PM_{10}.

In the health sector, the sensitivity of the population depends on various factors including age, and people with pre-existing health conditions. In this study, sensitivity is assessed based on two factors: population under 14 years old and above 65 years, and the sub-national Human Development Index (SHDI). Resilience, in this case, is assessed using the per capita rate of public and private expenditure on healthcare.

For the health sector, the hazard map is based on the number of days on which the average atmospheric dust concentration exceeds the WHO guideline of 50 μg/m³ for PM_{10}.[6] High atmospheric concentrations of dust are prevalent in three main areas: Central Asian countries of Kazakhstan, Uzbekistan and Turkmenistan; northern China; and in a swathe of southwest Asia from southern coastal parts of the Islamic Republic of Iran through southern Afghanistan and southern Pakistan into north-western India Figure 3-2.

Figure 3-2: Exposure of population to atmospheric dust

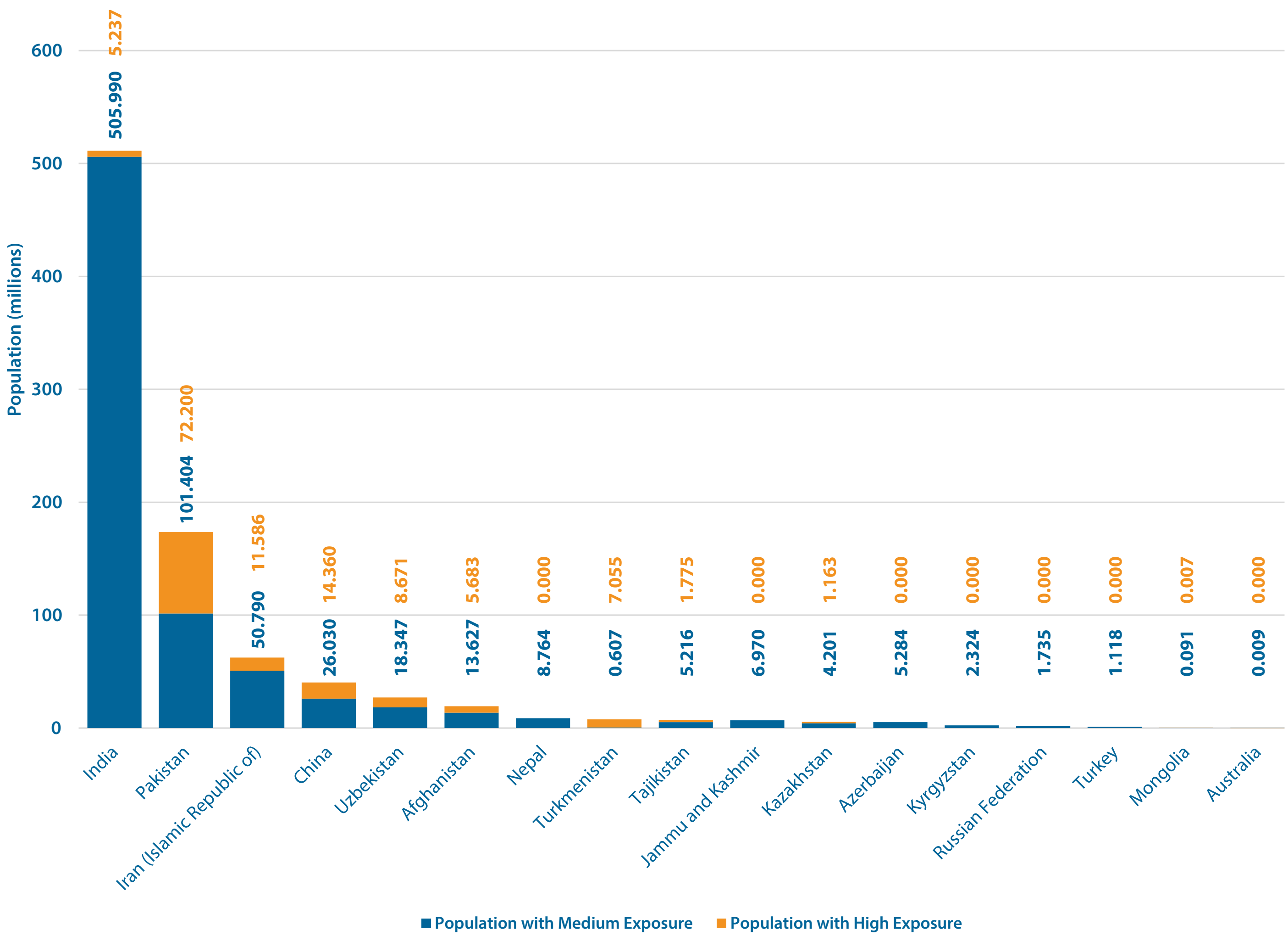


Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) Population from NASA Socioeconomic Data and Applications Center (SEDAC).

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

6. Hazard map was generated based on the 2019 data of MERRA-2 (dust concentration). The values of pixels are the number of days that level of dust concentration is higher than 50 μg/m³

Figure 3-3: The number of people with medium and high exposure to sand and dust storms

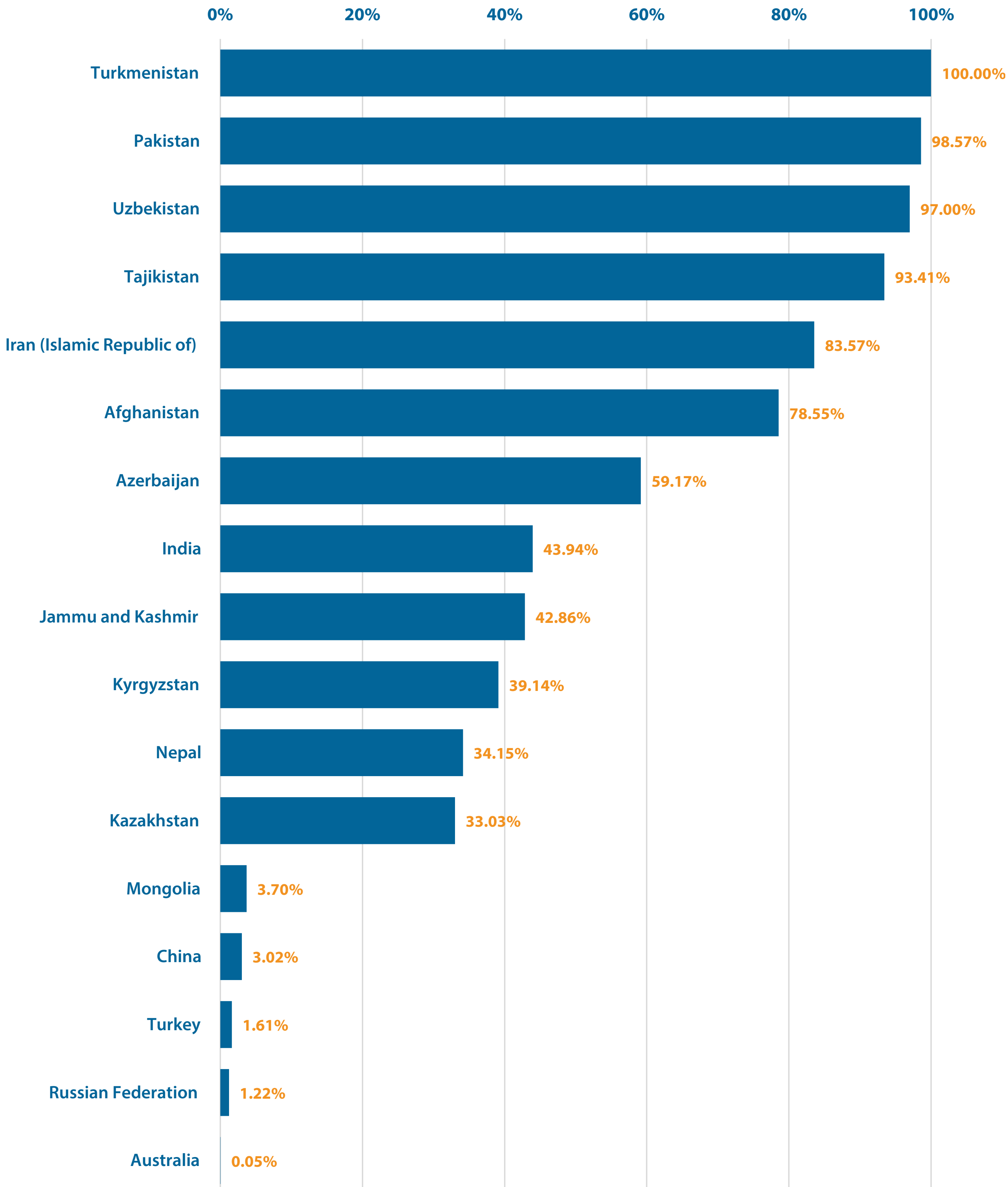


In absolute terms, Figure 3-3 shows that India has by far the largest population exposed to medium and high[7] levels of poor air quality due to sand and dust storms (some 511m people), followed by Pakistan (173m), Iran (62m) and China (40m).

However, the perspective changes when the numbers of people are shown in proportional terms. Figure 3-4 indicates that Turkmenistan, Pakistan, Uzbekistan and Tajikistan have the highest proportions of their total population exposed, in all cases more than 90 per cent. The Islamic Republic of Iran and Afghanistan both have about 80 per cent of their populations exposed to poor air quality due to sand and dust storms.

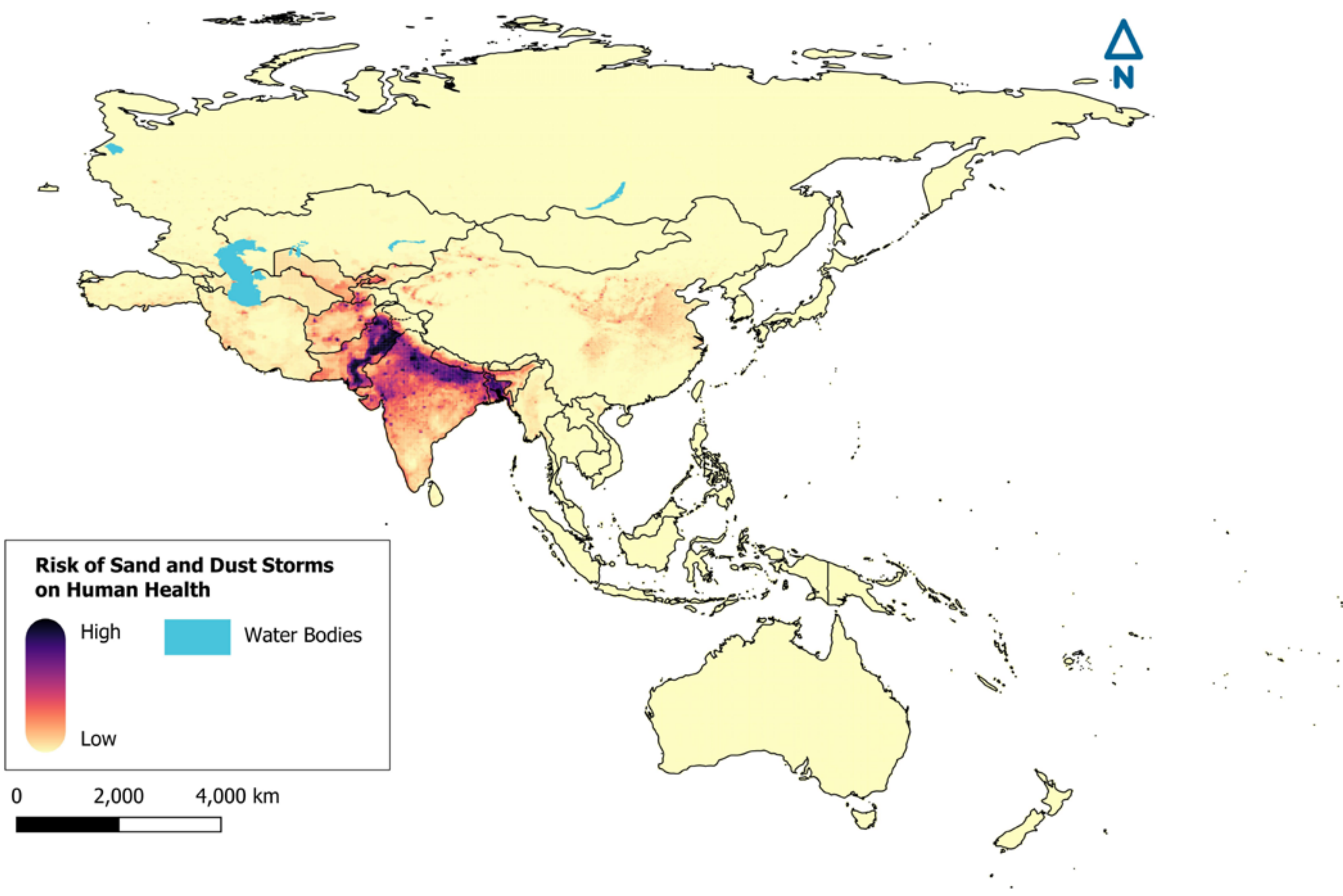
7. **Medium** is when the number of days that dust concentration near the ground is higher than 50 µg/m³ being between 81–238 days, and **high** is when the number of days that the dust concentration is higher than 50 µg/m³ being between 238–365 days.

Figure 3-4: Percentage of population in medium and high exposure to total population in Asian and Pacific countries



The map of overall risk to human health (Figure 3-5) indicates the largest concentrations of high risk are in the provinces of Punjab and Sindh in Pakistan and along the Ganges plain in northern India. The areas of relatively high risk in Bangladesh may initially seem surprising given the low exposure, but reflects the relatively high population density, high sensitivity (a relatively low SHDI) and low resilience (relatively low spending on healthcare).

Figure 3-5: Risk of sand and dust storms on human health (annual)

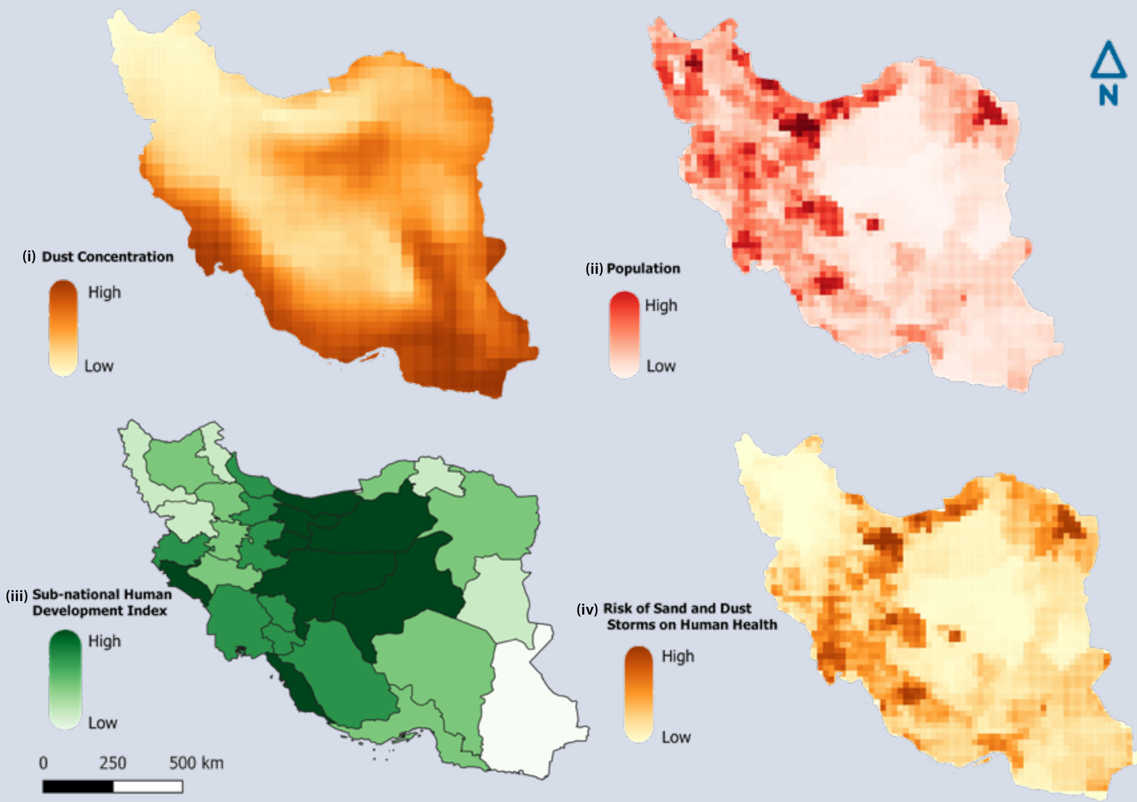


Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) Population from NASA Socioeconomic Data and Applications Center (SEDAC), (iii) Sub-national Human Development Index (SHDI) from UNDP, (iv) Public and private per capita expenditure on health care from INFORM Risk Index.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Box 3-1: Risk of sand and dust storms to human health in the Islamic Republic of Iran in July 2019

Analysis of health sector data for the entire Asia-Pacific region over time scales of years inevitably masks details that become evident at smaller time and space scales. This box is designed to highlight the risks associated with sand and dust storms at a smaller spatial scale (a single country) and smaller temporal scale (a single month), taking as an example July – typically a dusty month in the Islamic Republic of Iran – in 2019. The maps show (i) hazard (the number of days when dust concentration exceeds 50 μg/m^3), (ii) exposure (the population in each pixel), (iii) sensitivity (value of sub-national Human Development Index in province level), and the aggregation of these factors in (iv) an overall risk map.[8] Broad swathes of the country in the south, southeast, east and northeast are exposed to high dust hazards, but the population is largely concentrated in the north and northwest parts of the country. SHDI values are highest in the central part of Iran. The overall risk to health, based on the combination of all these layers, is highest in the southwest, northeast, central and southern parts of the Islamic Republic of Iran.



Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) Population from NASA Socioeconomic Data and Applications Center (SEDAC), (iii) Sub-national Human Development Index (SHDI) from UNDP.

Disclaimer: The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Note: Second level of admin for Sub-national Human Development Index.

8. Note that resilience (public and private expenditure in the health sector) in this case is a single national value and therefore not shown in the map.

Urban (Health)

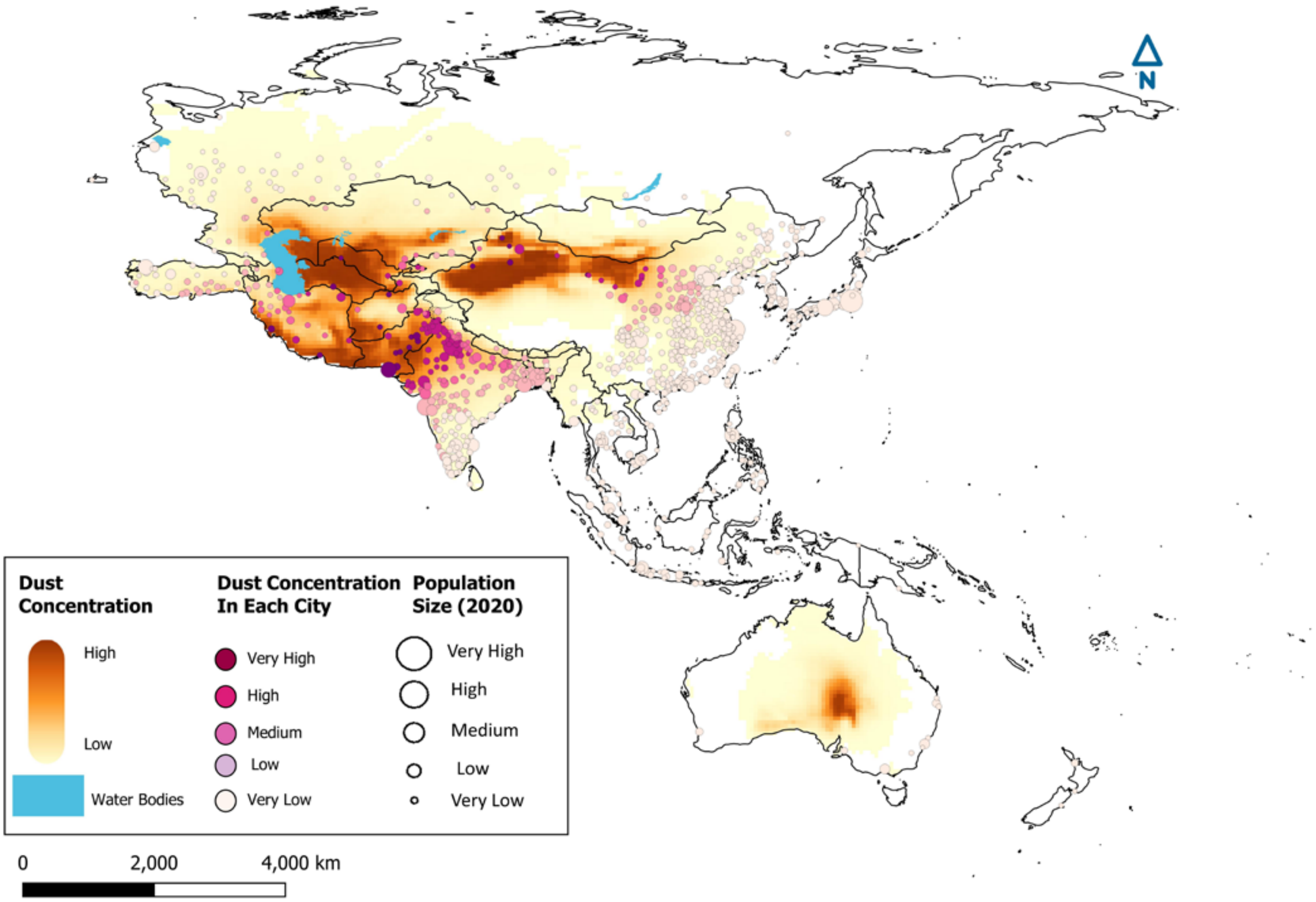
Rapid urbanization has occurred in many parts of Asia and the Pacific region, but particularly high rates have been experienced in the east and northeast, southeast, and south and southwest Asia subregions compared to other sub-regions (ESCAP, 2013). Sand and dust storms can affect cities in numerous ways, interrupting urban life and impacting people's lives across several sectors, including their health and education as well as transport, manufacturing, and construction (Ai & Polenske, 2008). Dust deposition in households and commercial buildings also typically results in considerable cleaning costs (Miri, Ahmadi, Ekhtesasi, Panjehkeh, & Ghanbari, 2009) (Tozer & Leys, 2013).

This chapter analyses available data in cities in Asia and the Pacific with a population higher than 300,000 with a focus on the health impact on their residents, considering the urban population size and the level of atmospheric dust exposure, using MERRA-2 data for daily 2019 PM_{10} concentrations higher than 50 µg/m^3 (the WHO's acceptable 24-hour mean atmospheric concentration) as illustrated in Figure 3-6.[9] This shows that cities in parts

Ferris wheel and lamps in Sydney hit by a red dust storm, Photo taken on 23 September 2009, Photo credit: Ian Sanderson, Source: Flickr

9. Sand and dust storms vary largely depending on meteorology. In this assessment due to limited resources only one year of daily data (2019) was considered. To have a more accurate understanding, long-term average is suggested.

Figure 3-6: Dust exposure in cities with a population higher than 300,000



Source: Produced by APDIM, Data: (i) Dust concentration from MERRA 2 Reanalysis, (ii) Cities population from UN DESA.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

of southwestern Asia, Central Asia, and North-Western China have the highest exposure to sand and dust storms.

Another representation of the large number of cities where residents are exposed to many days of poor air quality is shown in Figure 3-8. Of course, not all of the small particles in PM_{10} concentrations come from sand and dust storms, and air quality in some of the larger cities, in particular, is likely to be affected by other sources of particulate matter, such as pollution from motor vehicles, industry and vegetation burning (Grover & Chaudhry, 2019). Nevertheless, all of the worst affected cities shown in Table 3-3 are located in drylands, a clear indicator that sand and dust storms represent a significant cause of their poor air quality.

The 6 million people living in these eight cities breathe air that exceeds acceptable levels for PM_{10} every day for at least ten months a year on average. Sand and dust storms are also likely to make a significant contribution to the poor air quality in the three megacities (urban agglomerations with over 10 million inhabitants) with more than 170 dusty days a year: Karachi, Lahore and Delhi, home to nearly 60 million people.

Table 3-3: Cities with more than 300 days of poor air quality due to sand and dust

City (Country)	2020 Population	Number of dusty days* in 2019
Kelamayi (China)	457,000	355
Nukus (Uzbekistan)	338,000	342
Kuerle (China)	761,000	321
Ahvaz (Islamic Republic of Iran)	1,244,000	320
Bandar Abbas (Islamic Republic of Iran)	607,000	318
Akesu (China)	413,000	311
Sukkur (Pakistan)	534,000	310
Hyderabad (Pakistan)	1,850,000	301

*Days with dust concentration higher than 50 μg/m^3

It is worth noting that very little research has been conducted on air quality and sand and dust storms in the eight cities in Table 3-3, with the notable exception of Ahvaz (Maleki, Sorooshian, Goudarzi, Nikfal, & Baneshi, 2016) (Geravandi, De Marco, Ghomeishi, Goudarzi, & Mohammadi, 2017). Similarly, little is known about the links between sand and dust storms and human health in Karachi, Lahore and Delhi.

There is, however, a large and growing body of research that has examined links between mineral dust and a range of infections and diseases. Numerous studies demonstrate associations between exposure to high atmospheric dust concentrations and increases in mortality and hospital visits and admissions due to respiratory and cardiovascular diseases such as bronchitis, asthma, emphysema, and chronic obstructive pulmonary disease (Zhang, et al., 2016) (Hashizume, et al., 2020) (Querol, et al., 2019) (Grover & Chaudhry, 2019).

Particularly interesting is the fact that most of these studies have been conducted in urban areas located great distances from sand and dust storm source areas, including cities in the Republic of Korea (Lee, Kim, Honda, Lim, & Yi, 2013), Japan (Kanatani, et al., 2010), Taiwan, Province of China (Liu, Liao, Kuo, & Kuo, 2017) and New Zealand (Cowie, Lawson, & Kim, 2010). As Figure 3-6 shows, these cities experience very low dust concentrations relative to cities in arid and semi-arid regions.

Since associations between atmospheric dust and human health have been established many hundreds of kilometres from sand and dust storm source areas, due to long-distance transport of sand and dust, it is highly likely that adverse human health outcomes are considerably greater in cities located within the drylands of the Asia-Pacific region.

The urban areas shown in Table 3-3 are the worst-affected, but there are many other dryland cities with high and very high dust exposure, as shown in Figure 3-8 and Figure 3-7.

Virtually all of these cities have received very little attention from researchers examining links between health and atmospheric dust. This is a deficiency that should be addressed. All in all, the lack of relevant studies in dryland cities suggests that the human health impacts of exposure to sand and dust storms have been greatly under-rated.

Figure 3-7: Big cities (population more than 5 million) with the highest number of days that the amount of dust exceeds 50µg/m³ annually

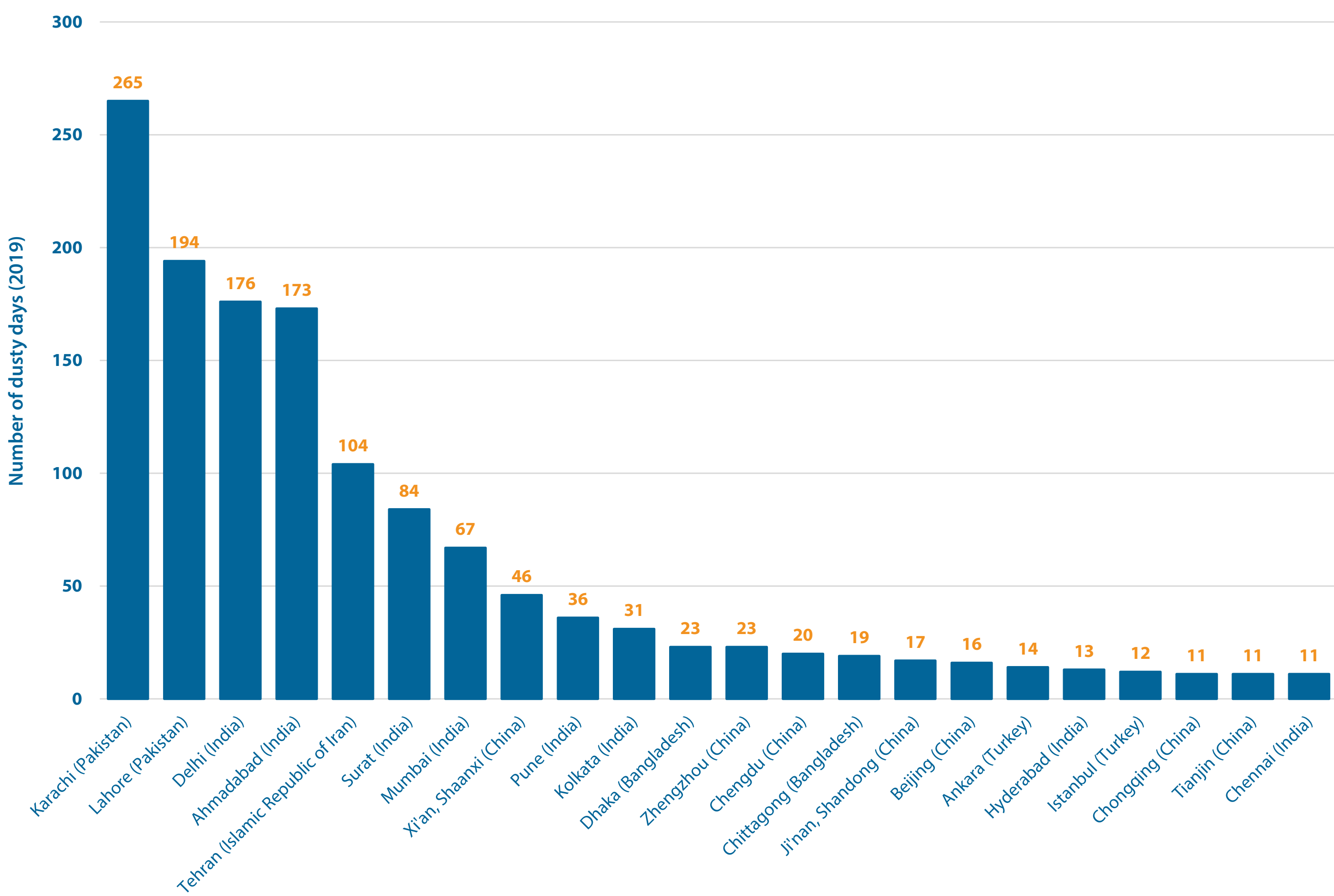
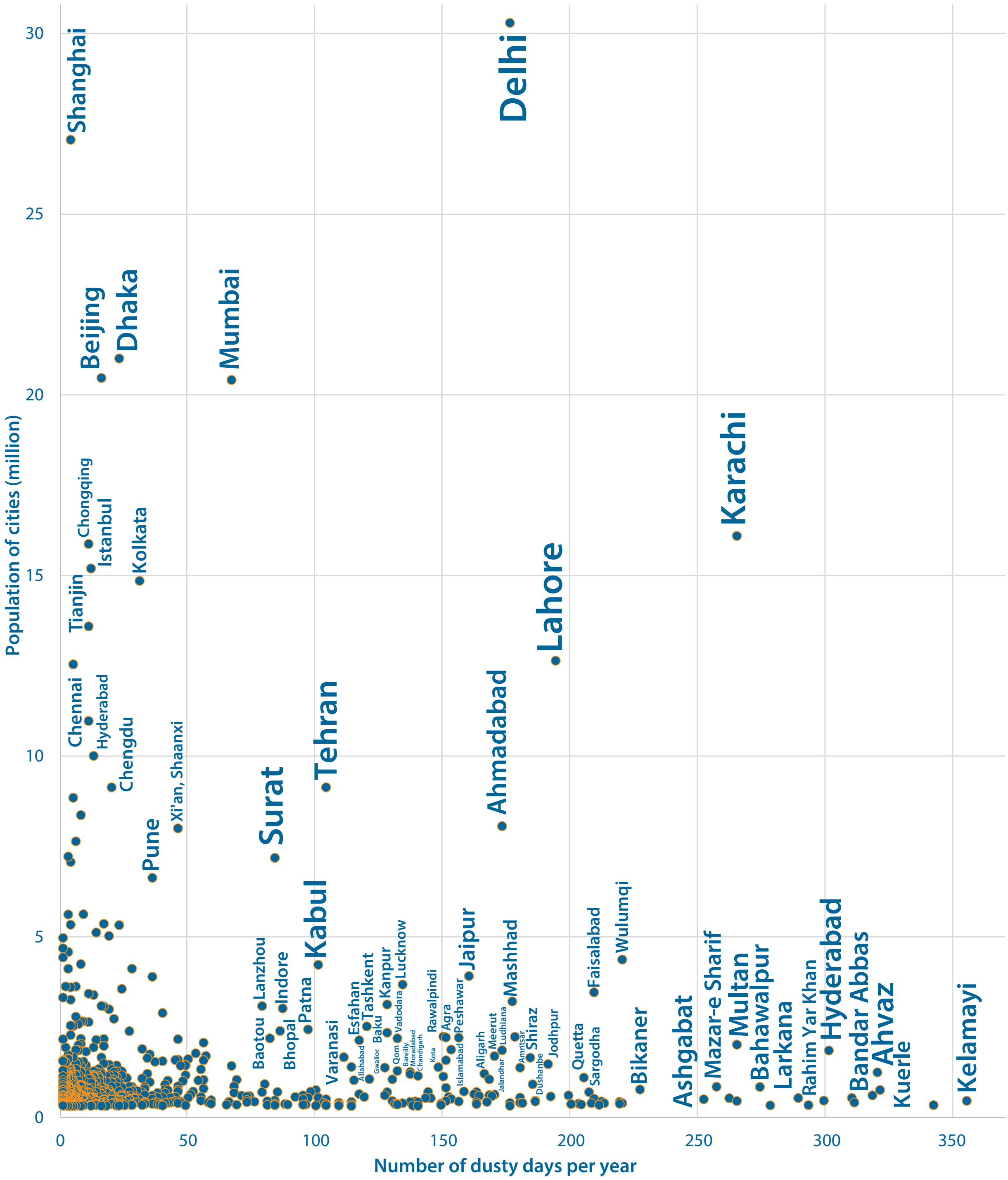
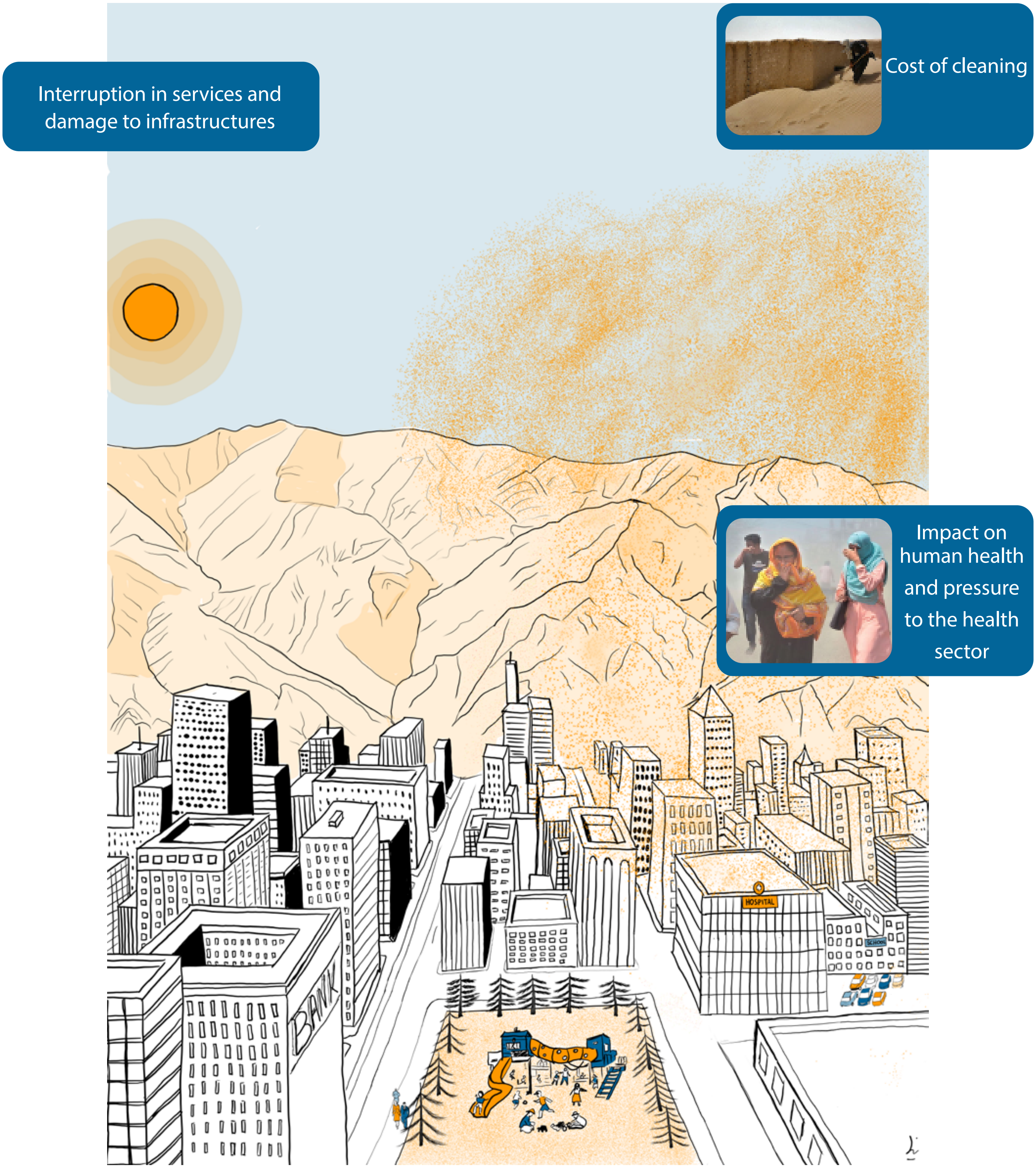


Figure 3-8: Cities by population and the number of days on which dust exposure exceeds 50 µg/m³ annually[10]



10. This graph shows the number of days with dust concentrations higher than 50 µg/m³ in cities with a population higher than 300,000. The number of days and the city population are normalised from 0 to 1 value and aggregated; a total of 708 cities that experienced at least one dusty day (in 2019) were considered for this analysis. The cities name with the highest aggregated values are indicated in the graph.

Infographic 3-2: The impact of sand and dust storms on urban environment



Box 3-2: March 2021 sand and dust storm in north and northeast of Asia *

On 14 March 2021, a sand and dust storm hit the north and eastern parts of Asia for a few days. It begun in the Eastern Gobi Desert steppe and subsequently spread to the entire Mongolian Plateau South, the Loess Plateau, the North China Plain and the Korean Peninsula. It was caused by the strong northwest winds coming in from Mongolia, as a result of hot and dry conditions.

Beijing and cities in the Mongolian Plateau regularly experience sand and dust storms in March and April, partially due to their proximity to the Gobi Desert.

Initial assessment of the National Emergency Management Agency of Mongolia reported 10 people (1 minor and 9 adults) had died due to the storm, and 1.6 million livestock were reported missing. Furthermore, 69 buildings including office buildings and houses were severely damaged.

In three cities in the Chinese region of Inner Mongolia, schools were closed, and the public transport system was temporarily halted. Flights out of Hohhot, Inner Mongolia’s capital, were grounded. This storm was the strongest experienced in Ningxia in 19 years.

The sandstorm was the biggest to hit China in a

Dust storm blankets Beijing, causing hazardous air quality, Photo taken on 15 March 2021, Source: Greenpeace East Asia decade, causing pollution levels in some districts to rise to 160 times the recommended limit. It affected 12 provinces in China, including the Chinese capital Beijing which was hit by the storm on March 15, 2021.

Visibility in Beijing was lowered to less than 300 meters. Over 400 flights at the city's main airports – Capital Airport and Daxing Airport – were cancelled, a fifth of all flights and more than the typical number for Asian dust storms. Visibility at the Beijing Daxing airport had dropped to 400–800 metres. PM_{10} levels reached over 8,100 micrograms per cubic metre in six central districts. Schools cancelled outdoor events, and people with respiratory diseases, as well as children and elder residents, were advised to stay indoors.

On 16 March, the sandstorm reached the western Republic of Korea. The Korea Meteorological Administration forecasted "very bad" PM_{10} levels – over 151 micrograms per cubic meter – in the Seoul Capital Area and on Jeju Island, as well as the provinces of Chungcheong and Jeolla.

Houses in Dundgovi province before the wind, Photo taken on 14 March 2021, Source: Mongolia Red Cross

* Sources: https://en.wikipedia.org/wiki/2021_East_Asia_sandstorm
https://reliefweb.int/report/mongolia/mongolia-sandstorm-emergency-plan-action-epoa-dref-operation-n-mdrmn014

Energy

The energy sector is made up of several components, principally generating stations, electrical substations, transmission lines, and distribution lines. Sand and dust storms can interfere with energy infrastructure, adversely affecting electricity transmission lines and causing power outages. They can also damage equipment, hindering its operation, and impose cleaning expenses. Dust particles can also damage energy infrastructures due to erosion, particularly on wind power plant's leading edge. Law and Koutsos show that the energy losses associated with leading-edge erosion (LEE) due to solid airborne particles and rain on an operational wind farm are causing the average annual energy production to drop by 1.8 to 4.9 per cent due to medium to high levels of erosion (Law & Koutsos, 2020).

The mechanism of damage and loss of the energy sector due to sand and dust particles are complicated and there are significant gaps in the data and literature, particularly when it comes to large scale studies. This current assessment focuses in particular on assessing the risk of sand and dust storms to all types of the solar power plant, by estimating the reduction in energy production caused by dust deposition (Sarver, Al-Qaraghuli, & Kazmerski, 2013).[11] This choice was made in consideration of the higher impact sand and dust storms have on solar energy production as compared to the relatively smaller impact on other energy production sectors, the impact on which would not have been possible to analyse at a regional scale with the data currently available.

The exposure of solar power plants to sand and dust storms is assessed using data on the location and capacity of plants and it is assumed that plants are cleaned on a monthly basis. All solar power plants are also considered to have equal sensitivity values.

Actual energy production is calculated based on the nominal capacity of each plant. For the assessments, the dust dry deposition data (Figure 3-9) are converted to a reduction in potential energy produced and overlayed with the data on the location and capacity of the powerplants. Dust dry deposition data are extracted from the MERRA-2 Reanalysis dataset.

These values were calculated based on the radiation reduction due to dust deposition only. It is calculated based on the nominal capacity, adjusted by 30 per cent, and the average level of dust deposition in each solar powerplant. The 30 per cent adjustment was made to account for the other factors that impact energy capacity production including cloudy days, latitude, pollution, etc. The value gap between nominal and actual capacity is considered to be between 18 to 30 per cent. Due to the lack of more specific data on operating conditions for each powerplant, for the analysis, we assumed in our calculations that all solar powerplants are installed horizontally and are cleaned once a month.[12]

Factors this assessment did not take into consideration include the effect of precipitation leading to wet dust deposition, and the reduction of energy production due to absorption or scattering of solar radiation by the dust particles while in the atmosphere. The long-term impact of dust on power generation efficiency, via the chemistry of dust particles that may degrade solar power plants and possible damage to solar panels due to erosion are also excluded.

The resilience of the energy sector is evaluated by calculating the ratio of solar to other sources of electricity in each country, a measure that indicates the relative

11. Any permanent efficiency reduction due to dust erosion of solar photovoltaic (PV) panels is not considered. The energy reduction is calculated with the assumption that solar power panels are installed horizontally, although most solar PV panels are angled towards the sun.
12. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b

Infographic 3-3: The impact of sand and dust storms on energy production

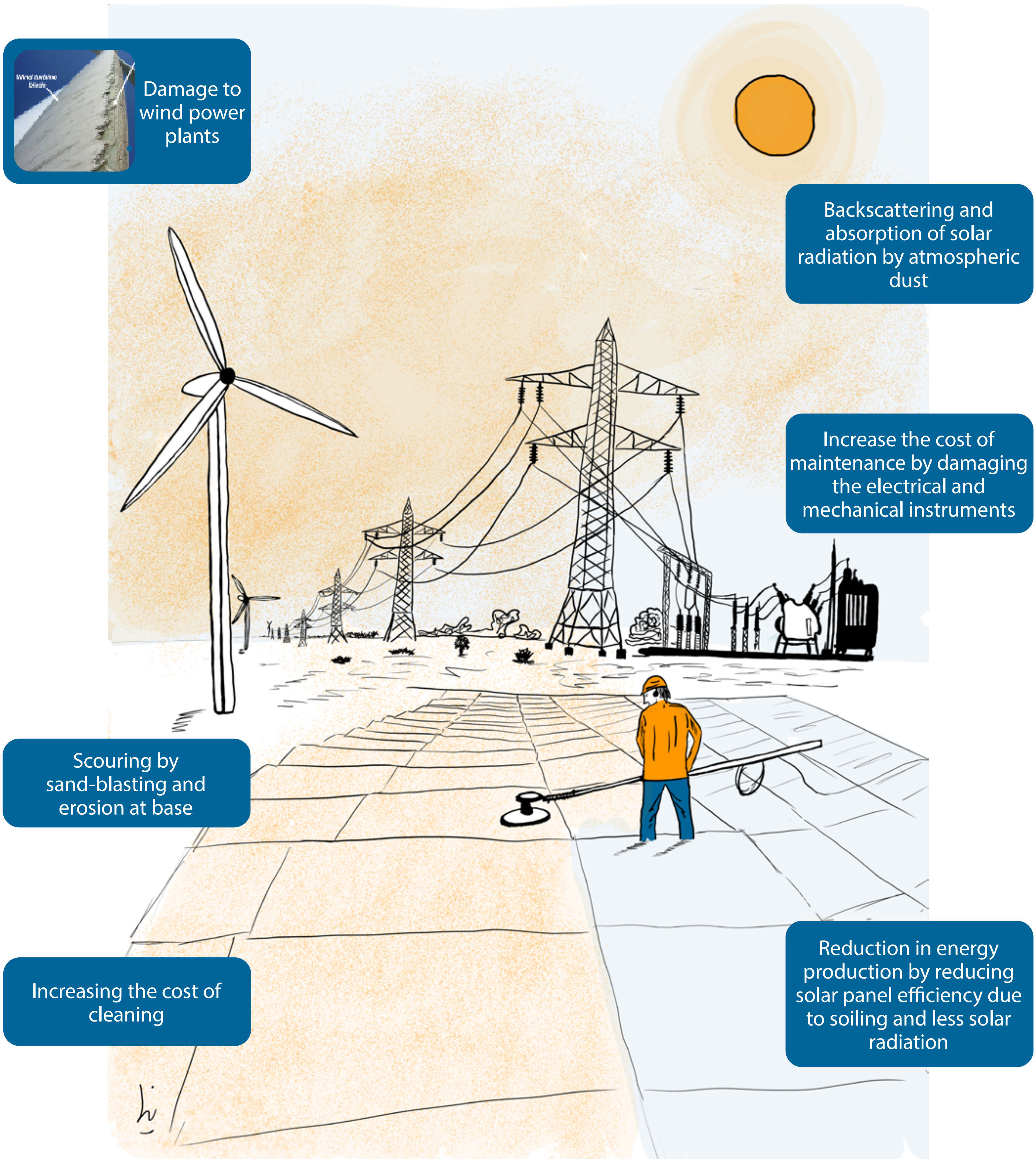
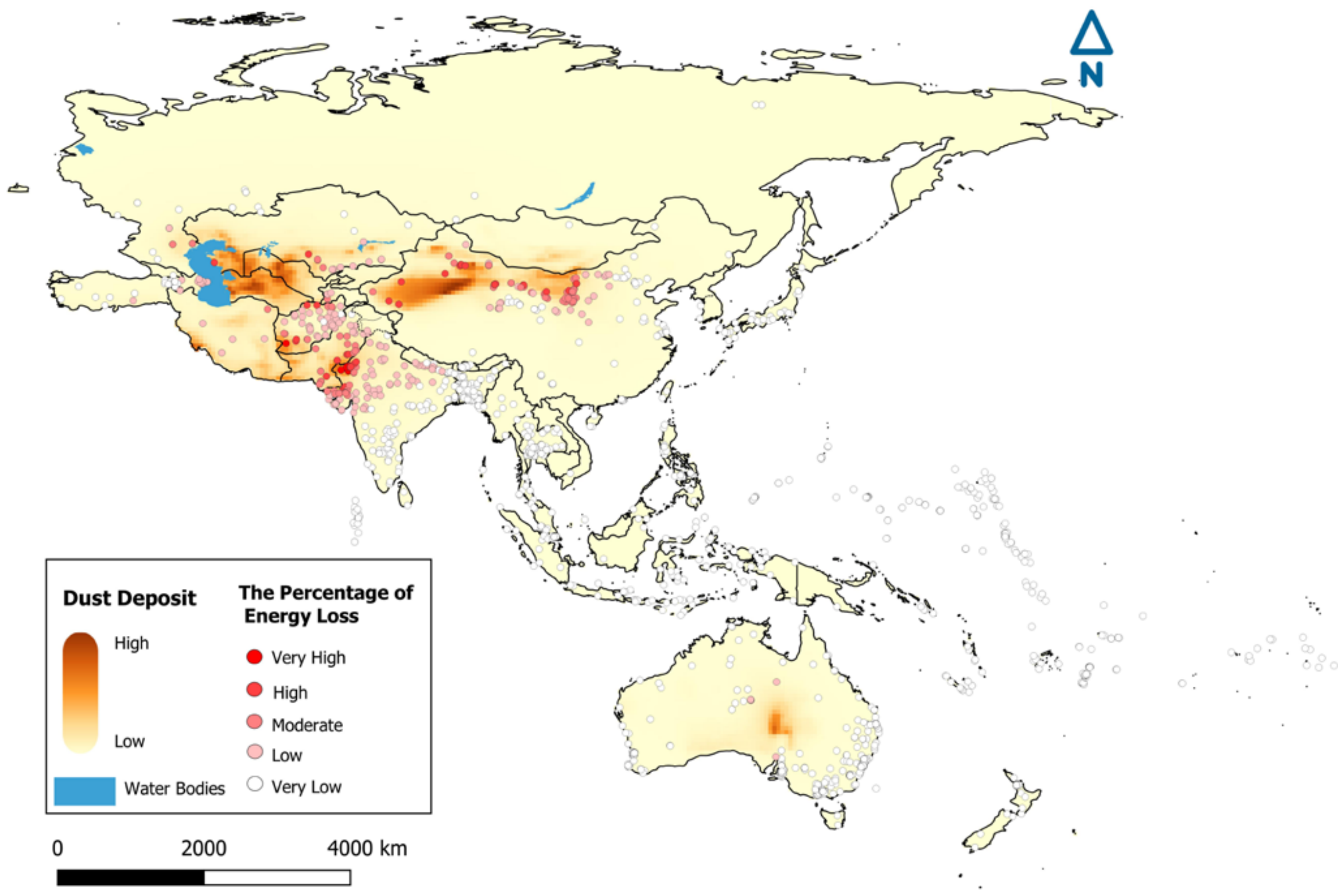


Figure 3-9: The exposure of solar powerplant (circles in the map) to dust (average dust deposit) and the percentage of average energy loss due to dust deposition



Source: Produced by APDIM, Data: (i) Dust deposition from MERRA-2 Reanalysis, (ii) Solar power plant capacity and location from Asia-Pacific Energy Portal, ESCAP.

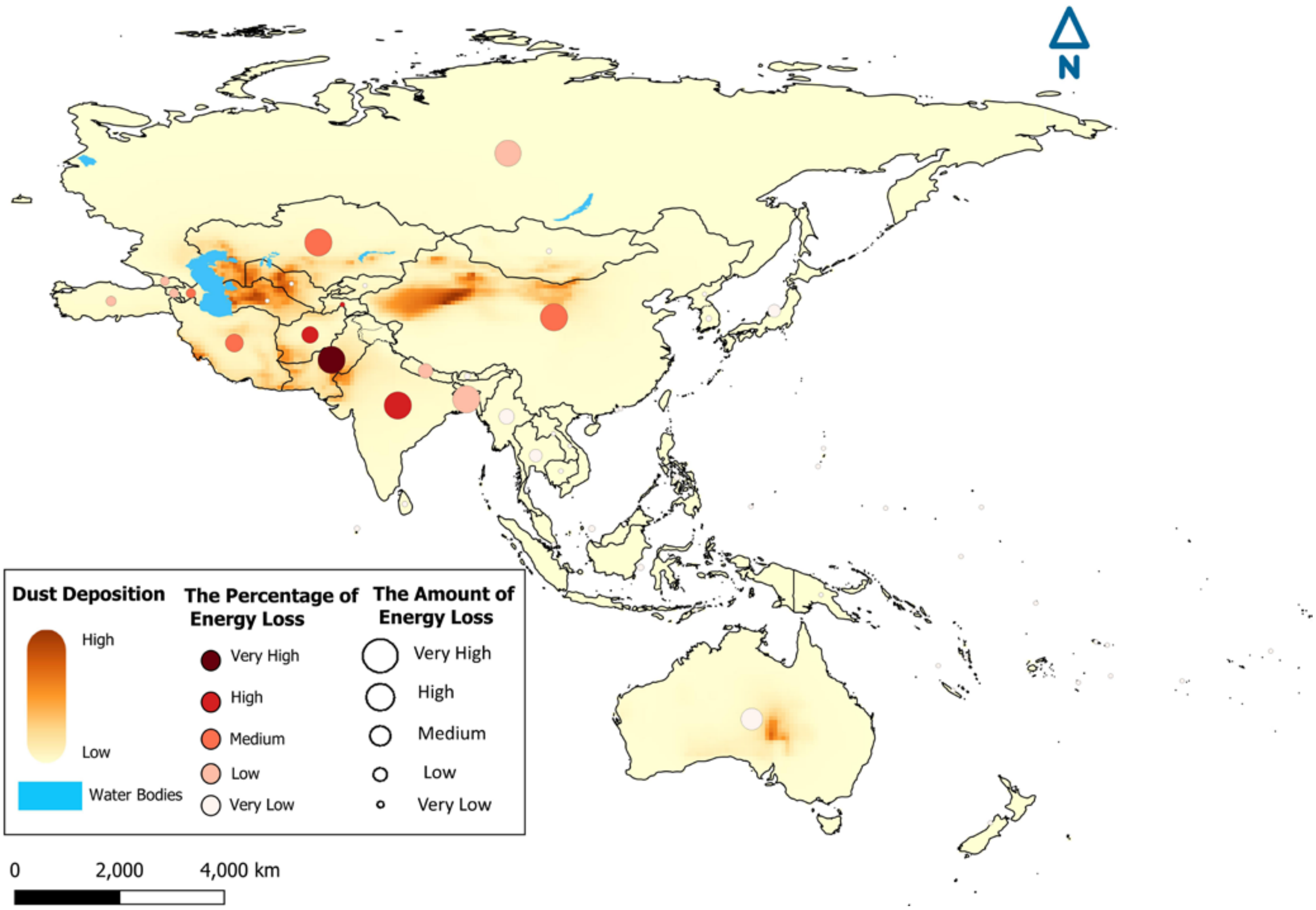
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

dependency of a country on solar energy production.

Figure 3-9 shows the location of solar power plants (circles on the map) overlaid with a MERRA-2 dust deposition map. Power plants that have the greatest energy losses are located in Afghanistan, Pakistan, northern India, northern China, Armenia, southern Kazakhstan and the Islamic Republic of Iran. The aggregation of energy loss in Asia-Pacific countries is illustrated in Figure 3-10. It shows that Pakistan has the highest percentage of energy loss due to sand and dust deposition, a loss that is also high in absolute terms. After Pakistan, the highest energy losses (kWh) experienced in the region occur in Kazakhstan, China, India and Bangladesh, followed by the Russian Federation, Australia, the Islamic Republic of Iran and Afghanistan.

India, China, and Pakistan stand to have the highest amount of energy loss due to sand and dust storms in the region by the values of 1584, 679- and 555-Gigawatt hour electricity, respectively. In economic terms, the loss of energy produced by solar power plants is nonetheless

Figure 3-10: The amount of energy loss and percentage of energy loss in energy production of the solar powerplant in Asia-Pacific countries



Source: Produced by APDIM, Data: (i) Dust deposition from MERRA-2 Reanalysis, (ii) Solar power plant capacity and location from Asia-Pacific Energy Portal, ESCAP.

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considerable, as shown in Figure3-8. These losses are greater than USD107m in India per year and exceed USD46m and USD37m in China and Pakistan.

As a proportion of national electricity production, solar provides relatively small amounts in all countries of the region, but investment in solar power is increasing in line with government action contributing to SDG 7, affordable and clean energy. As Figure 3-12 shows, energy production by solar power plants has grown rapidly in recent years, and this growth is expected to continue. The impediment posed by sand and dust storms to electricity generation by solar power plants is therefore likely to become magnified, hindering progress towards the achievement of SDG 7.

The highest levels of energy poverty in the Asia Pacific are in South Asia, Southeast Asia, and the Pacific. In absolute terms, the countries in the Asia-Pacific region with the largest electricity access deficit are India, Bangladesh, Pakistan, Indonesia, and Myanmar (ESCAP, 2017) of these, India, Bangladesh and Pakistan currently have a large level of energy loss due to sand and dust storms. Solar is an attractive option in these countries, particularly in remote rural areas where smaller facilities can generate electricity locally without the need for transmission lines. Dryland areas receive high levels of solar radiation, but this advantage could be undermined by the hazards associated with sand and dust storms, if not adequately addressed in the planning and early investment phases.

Figure 3-11: Energy loss due to dust deposition in solar power plant (GWh)

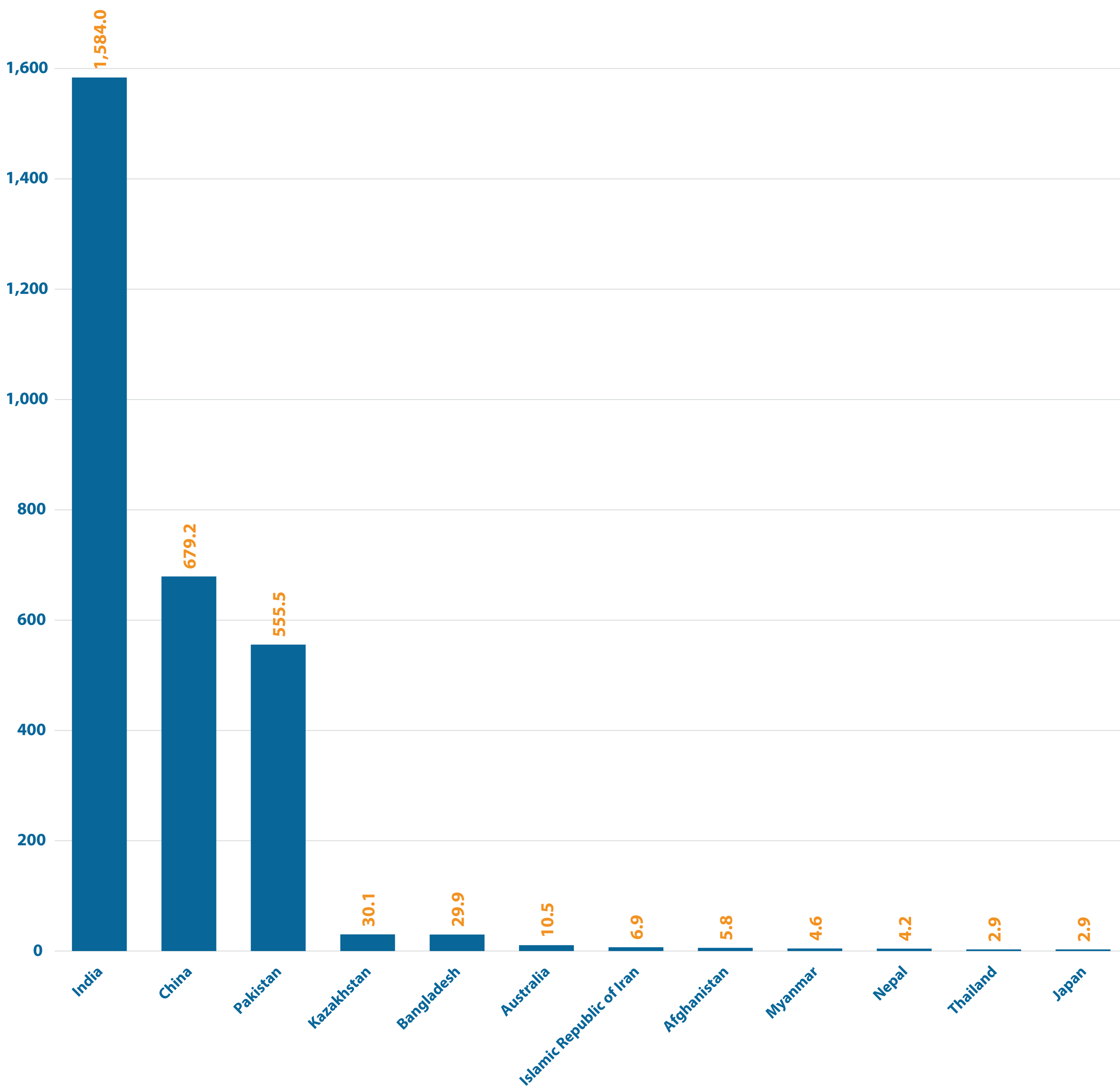


Figure 3-12: Changes in the production of energy from solar power plants, from 2000 to 2017

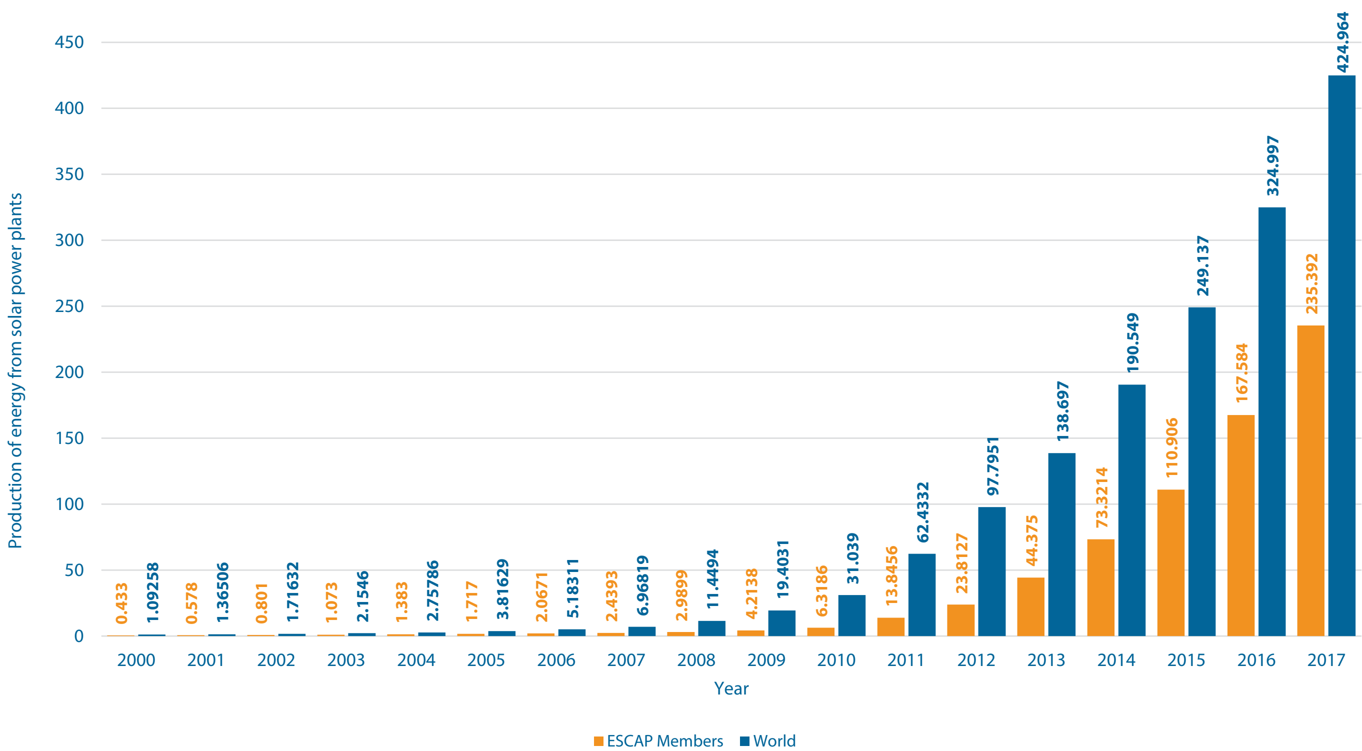
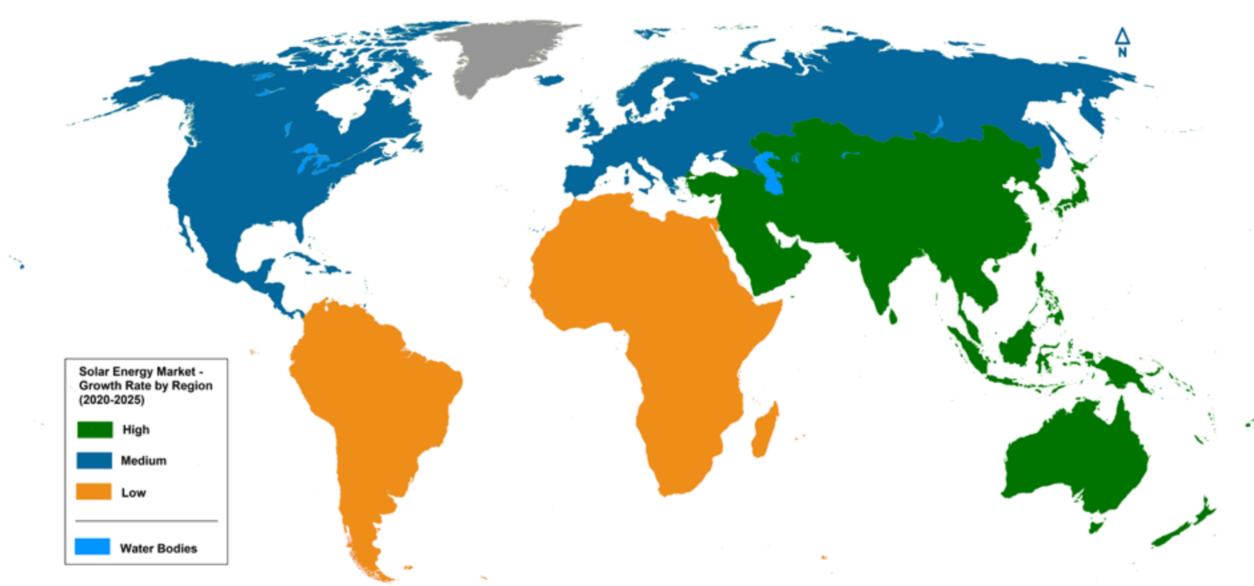


Figure 3-13: Solar energy market - growth rate by region, 2020-2025 (Mordor Intelligence, 2020)



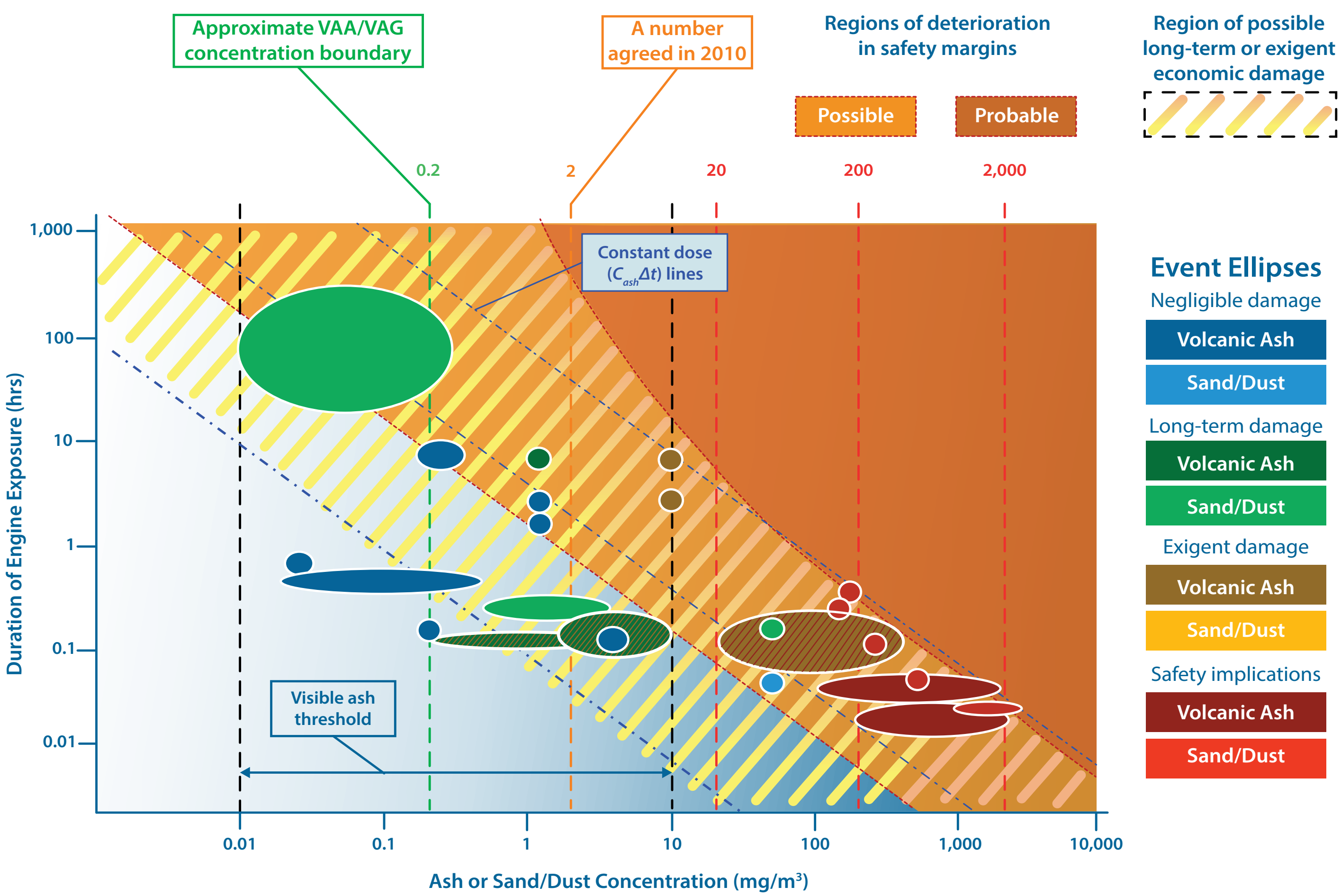
Source: Produced by APDIM, Data: Mordor intelligence 2020.
Disclaimer: The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Transport – Aviation

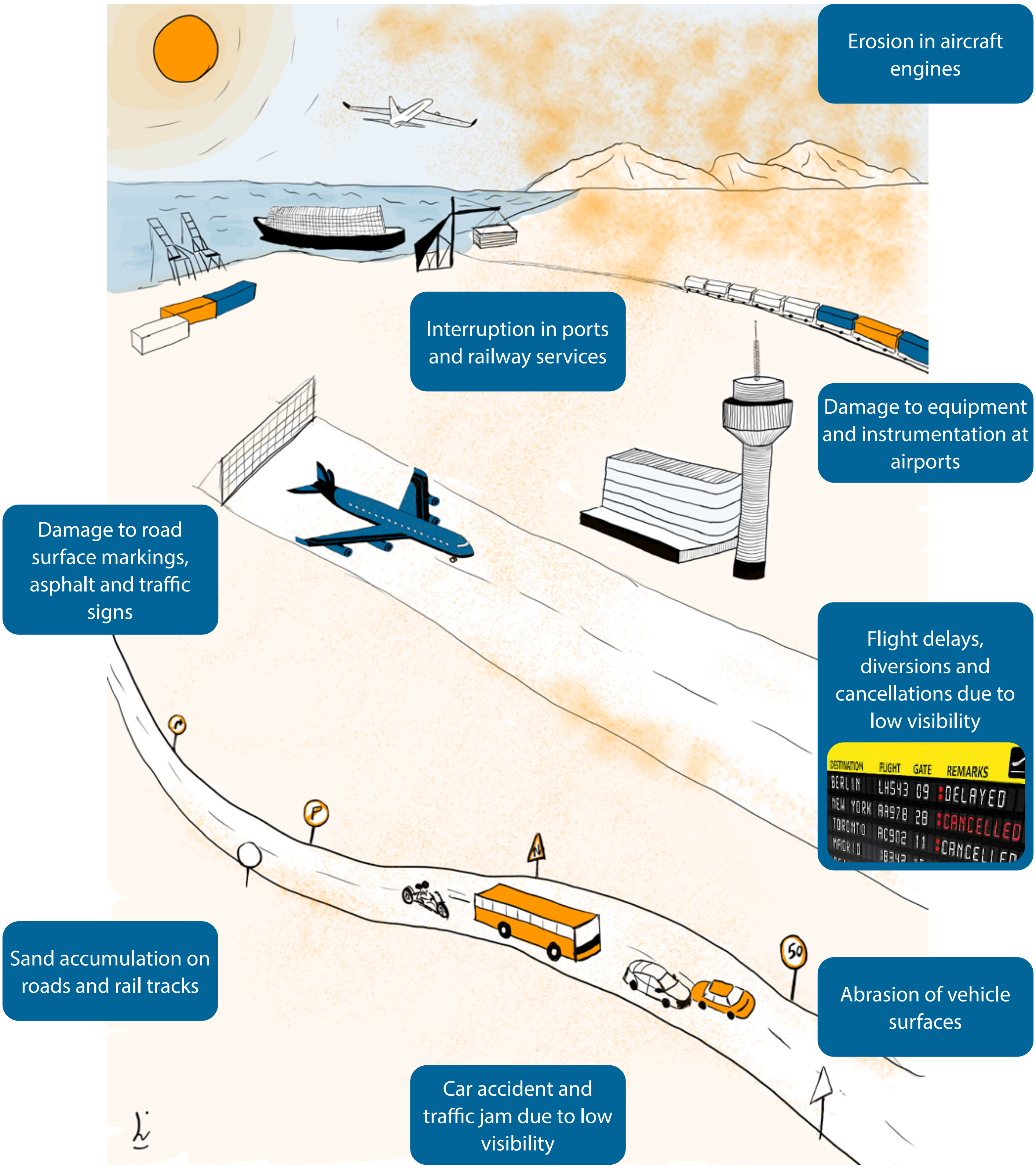
Sand and dust storms impact the aviation sector in two main ways. Firstly, by causing flight delays, diversions, or cancellations due to lack of visibility (AlKheder & AlKandari, 2020). Secondly, dust particles have an erosive effect when ingested by the engines of aircraft (Bojdo, Filippone, Parkes, & Clarkson, 2020).

Flight interruption due to poor visibility is assessed using the average hourly ground-level visibility at airports, data for which (location, altitude) are from OPS Group database. To calculate the interruption in flights due to lack of visibility, this report uses the methodology proposed by the Impact Assessment on Aviation and Solar Energy of the DustClim project, the European Research Area for Climate Services (Votsis A. , et al., 2020). The exposure of aircraft engines to dust particles is analysed using data on the duration and density of sand and dust particles at the cruise elevation of flight pathways, data on which is from the OpenFlights database. The thresholds are illustrated in Figure 3-14.

Figure 3-14: The threshold of exposure by the duration of engine exposure and dust concentration (Votsis A. , et al., 2020)



Infographic 3-4: The impact of sand and dust storms on transport



Sensitivity, where visibility reduction is concerned, depends on the services each airport provides, including the number of passengers and goods and the availability of alternative means of transport. Since this data is not publicly accessible, the sensitivity of this component is valued equally for all airports. Engine sensitivity is highly dependent on the type of aircraft and the characteristics of dust particles, but a lack of relevant literature and available data means that this study did not take these differences into account and valued all flights equally.

The resilience of the aviation sector depends on a number of factors. The erosion of engines due to sand and dust particles depends on the engine type. The resilience value for interruption due to lack of visibility depends on the type of airport and aircraft which are categorized from CAT I to CAT III depending on the level of visibility that the system can handle. For example, at the airports with CAT I standards no visibility is required for flight and the CAT III class require visibility for flights (Votsis A. , et al., 2020). Therefore, the value of 1 to 5 is assigned to the visibility of airports.[13]

Dust storm over the Luxor airport, Eygpt, when temperature rises and mist reduces visibility.
Photo taken on 4 May 2009, Photo credit: Guillén Pérez, Source: Flickr

13. The definition and scoring of resilience are listed below:
Highest: The airport uses an instrument landing system (ILS) approach; the airport operates with Slot 2/3; one or more of the four nearest alternative airports have ILS approach.
High: The airport has ILS approach; one or more of the four nearest alternative airports have ILS approach.
Moderate-high: The airport does not have ILS approach, but the first nearest alternative airport has ILS approach.
Moderate-low: The airport does not have ILS approach; its first nearest alternative airport does not have ILS; the second to fourth nearest alternative airports have ILS approach.
Low: Neither the airport nor the four nearest alternative airports have ILS approach.
Lowest: Neither the airport nor the four nearest alternative airports have ILS approach; the airport services exclusively unscheduled flights.

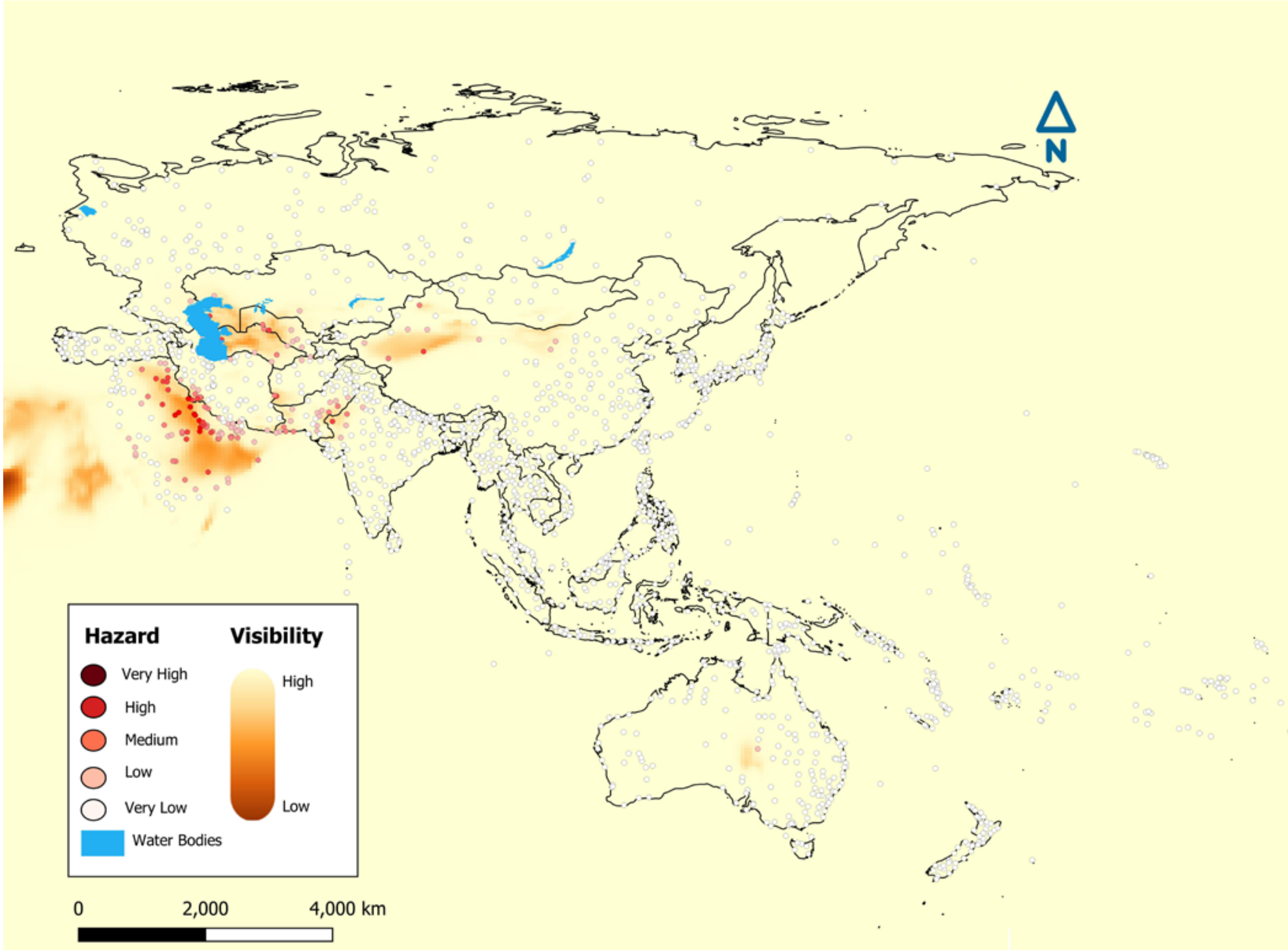
The Risk of Flight Delay and Cancellation due to Low Visibility

Figure 3-15 shows the location of airports in Asia and the Pacific and the level of visibility at airports that are impacted by dust storms (average total hours that visibility drops to below 1000m in a year).

The map indicates that the lowest visibility due to sand and dust storms is experienced at airports in Central Asia, those close to the border between India and Pakistan, in southern parts of the Islamic Republic of Iran, northern China, and central parts of Australia.

Figure 3-16 shows the level of resilience of airports, based on their navigation instruments. It shows that

Figure 3-15: The level of visibility in airports that impacted by dust storms (average total hours that visibility drop to below 1000m in a year)

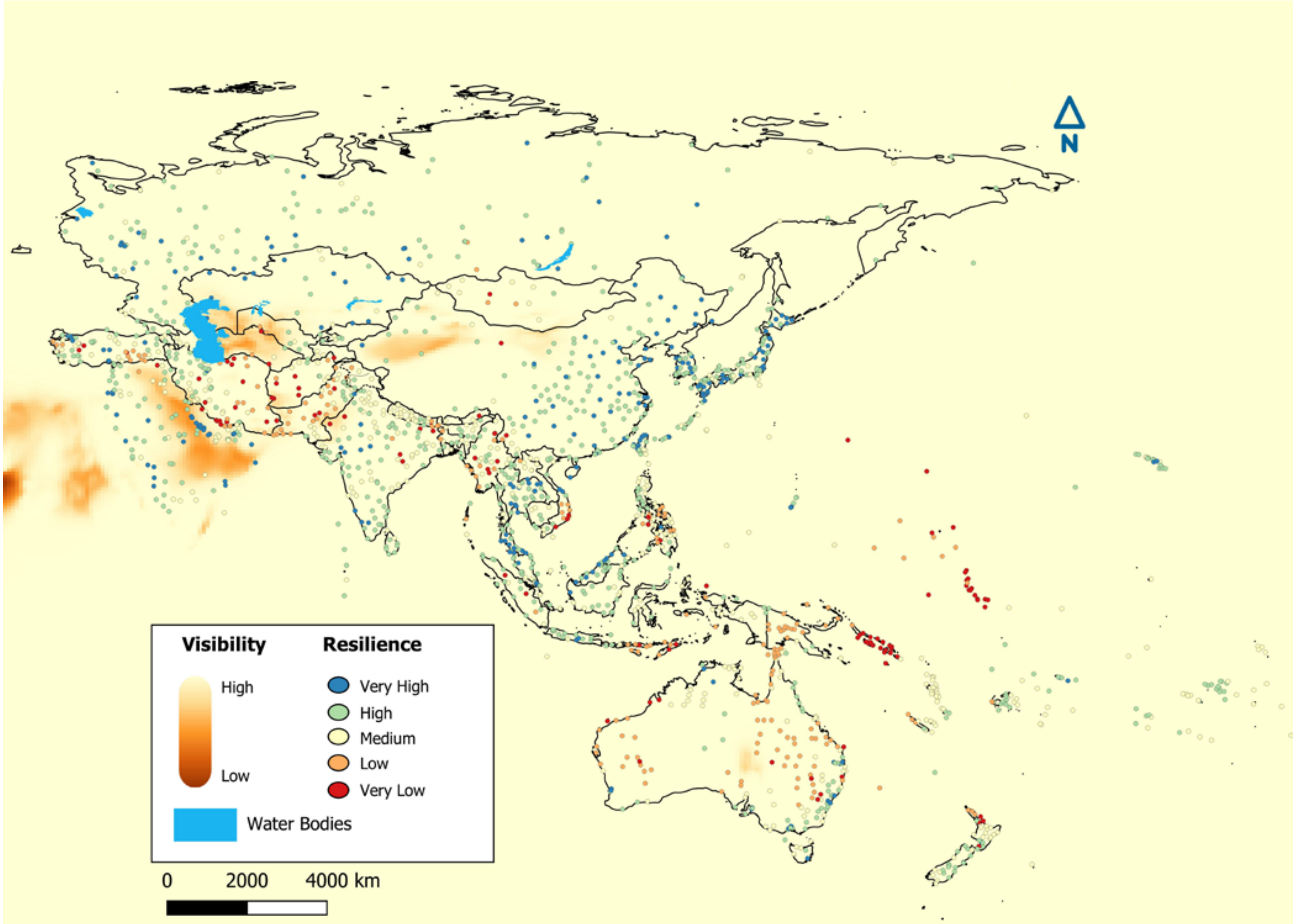


Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) Airports' location from the OPS group, World Airports Database.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

the countries in southwest Asia and the Pacific have the lowest level of resilience.

Figure 3-17 shows the risk of flight delay and cancellation due to low visibility caused by dust by effectively combining the information shown in the previous two maps. It indicates that the airports in Central Asia, southern parts of the Islamic Republic of Iran, areas close to the border between Pakistan and India, and northern parts of China have the highest risk of flight delay and cancellation due to low visibility.

Figure 3-16: The resilience of airport to low visibility classified based on navigation technology in each airport



Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) The OPS group, 'World Airports Database'.
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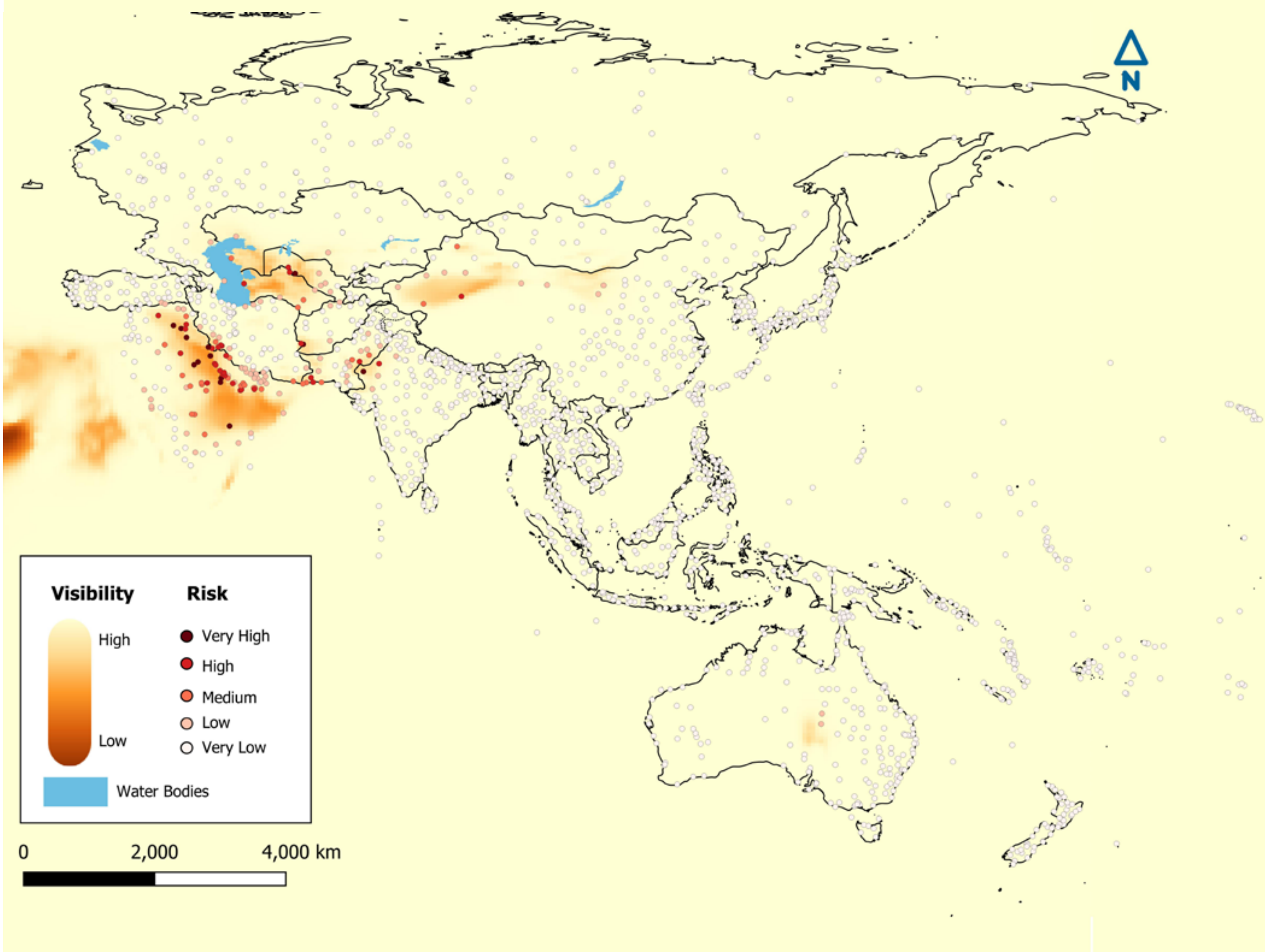
Figure 3-17: The risk of flight delay and cancellation due to low visibility caused by dust, considering dust concentration, exposure, and resilience.



Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) The OPS group, 'World Airports Database'.
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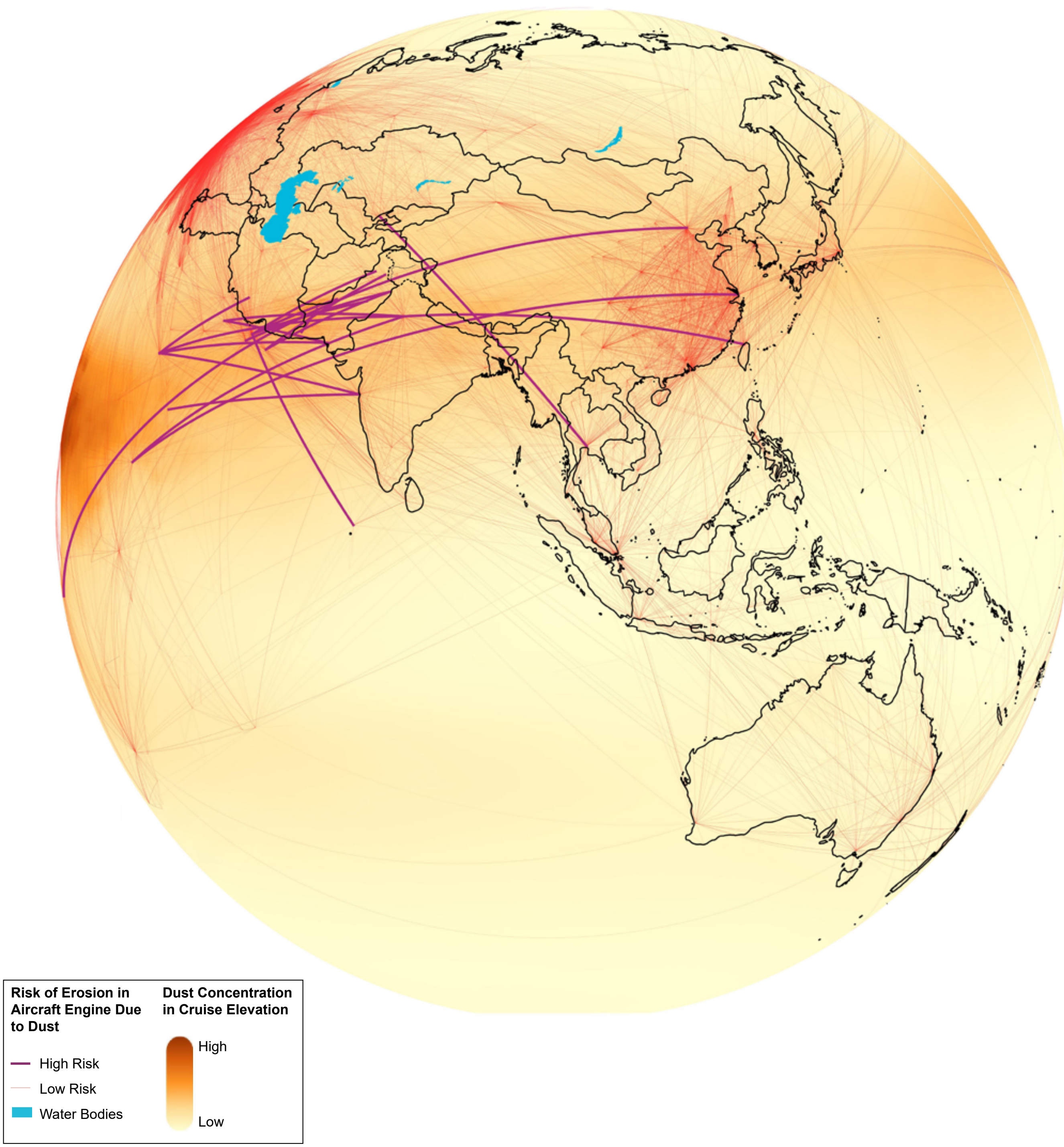
The Risk of Damage due to Engine Erosion

The flight paths on which exposure of aircraft engines to dust particles is greatest are shown in Figure 3-18. Those traversing southwestern and central parts of Asia are at the greatest risk. Flights to and from airports on the Arabian Peninsula, Pakistan, India, and China are most affected, as shown in Table 3-4.

Figure 3-18: The flight paths with the high risk of erosion in aircraft engines due to dust concentration in the cruise elevation



Source: Produced by APDIM, Data: (i) Dust concentration from MERRA-2 Reanalysis, (ii) Airport, airline and route data from OpenFlights.org.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Table 3-4: The flight paths with the highest risk of erosion to aircrafts' engines. Calculated based on the average dust concentration values along the flight paths at cruise elevation

Flight Paths From/To	
Airport Name	**Airport Name**
King Abdulaziz International Airport (Saudi Arabia)	Indira Gandhi International Airport (India)
Dubai International Airport (United Arab Emirates)	Male - International Airport (Maldives)
Quatro de Fevereiro Airport (Angola)	Beijing Capital International Airport (China)
Indira Gandhi International Airport (India)	Taiwan Taoyuan International Airport (Taipei / Taiwan)
Sharjah International Airport (United Arab Emirates)	Multan International Airport (Pakistan)
Sana'a International Airport (Yemen)	Chhatrapati Shivaji International Airport (India)
Tashkent International Airport (Uzbekistan)	Suvarnabhumi Airport (Thailand)
Addis Ababa Bole International Airport (Ethiopia)	Shanghai Pudong International Airport (China)
King Fahd International Airport (Saudi Arabia)	Indira Gandhi International Airport (India)
Sharjah International Airport (United Arab Emirates)	Quetta International Airport (Pakistan)
Turbat International Airport (Pakistan)	Dalbandin Airport (Pakistan)
Sharjah International Airport (United Arab Emirates)	Peshawar International Airport (Pakistan)
King Fahd International Airport (Saudi Arabia)	Jinnah International Airport (Pakistan)
King Abdulaziz International Airport (Saudi Arabia)	Shiraz Shahid Dastghaib International Airport (Iran)
King Abdulaziz International Airport (Saudi Arabia)	Indira Gandhi International Airport (India)
King Abdulaziz International Airport (Saudi Arabia)	Chhatrapati Shivaji International Airport (India)
King Abdulaziz International Airport (Saudi Arabia)	Jinnah International Airport (Pakistan)
Muscat International Airport (Oman)	Alama Iqbal International Airport (Pakistan)
Muscat International Airport (Oman)	Qasim Airport (Pakistan)
Abu Dhabi International Airport (United Arab Emirates)	Alama Iqbal International Airport (Pakistan)

Agriculture

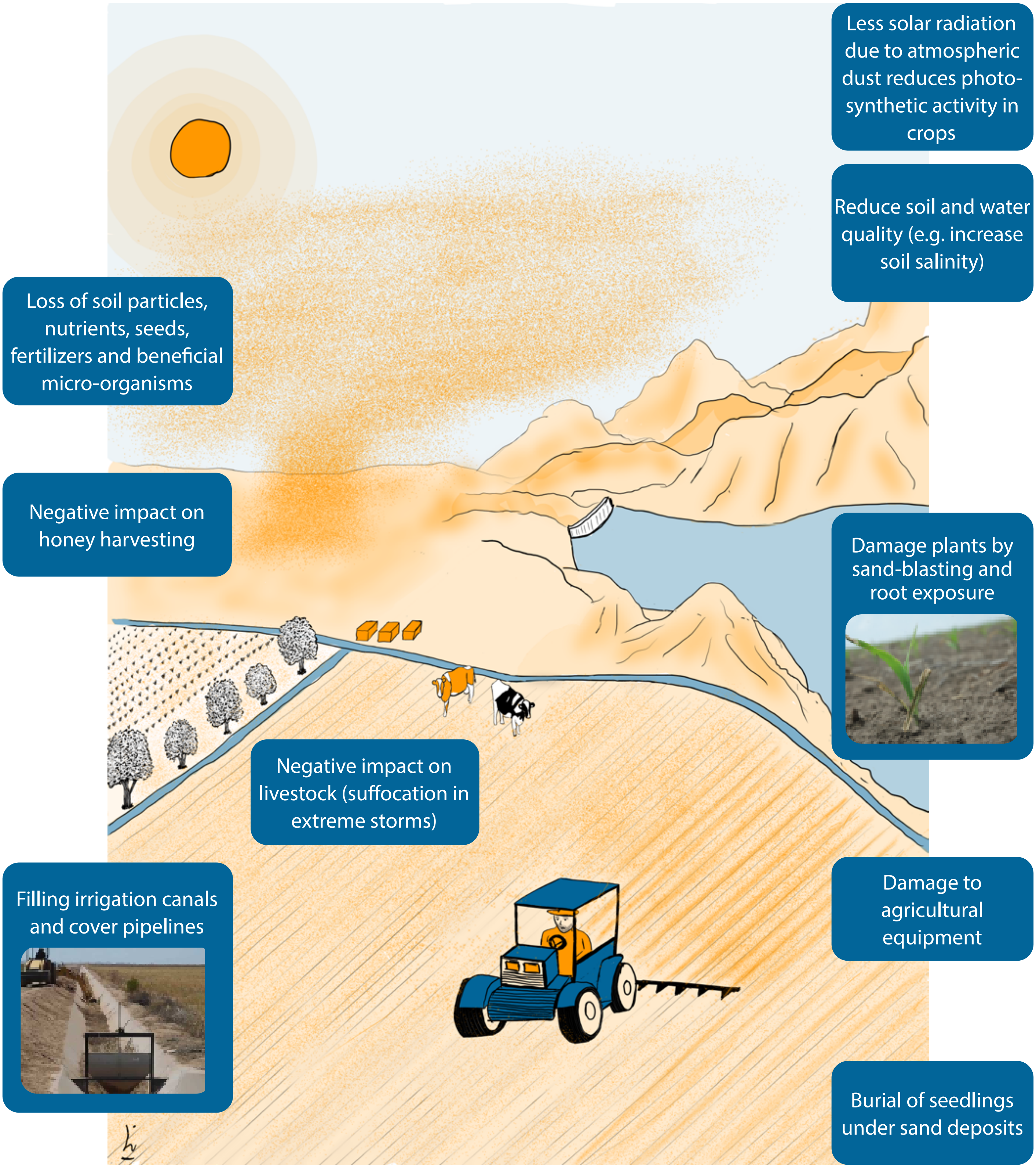
Sand and dust storms can have a direct impact on agriculture, causing the loss of crops, trees and livestock or significant decreases in their production (Stefanski & Sivakumar, 2009). Impacts occur by reducing soil quality, damaging agricultural equipment, filling irrigation canals, damaging plants and reducing solar radiation and therefore reducing production and creating delays in plant development. In places where agricultural land is a source of sand and dust storms, the loss of soil reduces its productivity by removing soil particles, nutrients, seeds, fertilizers and beneficial microorganisms. Interruption to agricultural production may impact poverty and food security, SDG 1 and 2, respectively.

In this study, the hazard posed to the agriculture sector by sand and dust storms is considered only where soil particles are deposited, using data on average dust deposition. For exposure, we used data on land cover. The type of crop and the stage of plant growth are factors that determine the degree of sensitivity in the agriculture sector due to dust deposition. However, there is a lack of literature on the sensitivity of various crops and growth stages to dust deposition, so this report does not take into account different sensitivities.

The resilience of the agriculture sector is a function of numerous factors including the percentage of Gross Domestic Product (GDP) contributed by agriculture, the percentage of the population in rural areas,

Damage to plants due to dust storms, Photo taken on 23 September 2009, Photo credit: Simone Walsh, Source: Flickr

Infographic 3-5: The impact of sand and dust storms on agriculture

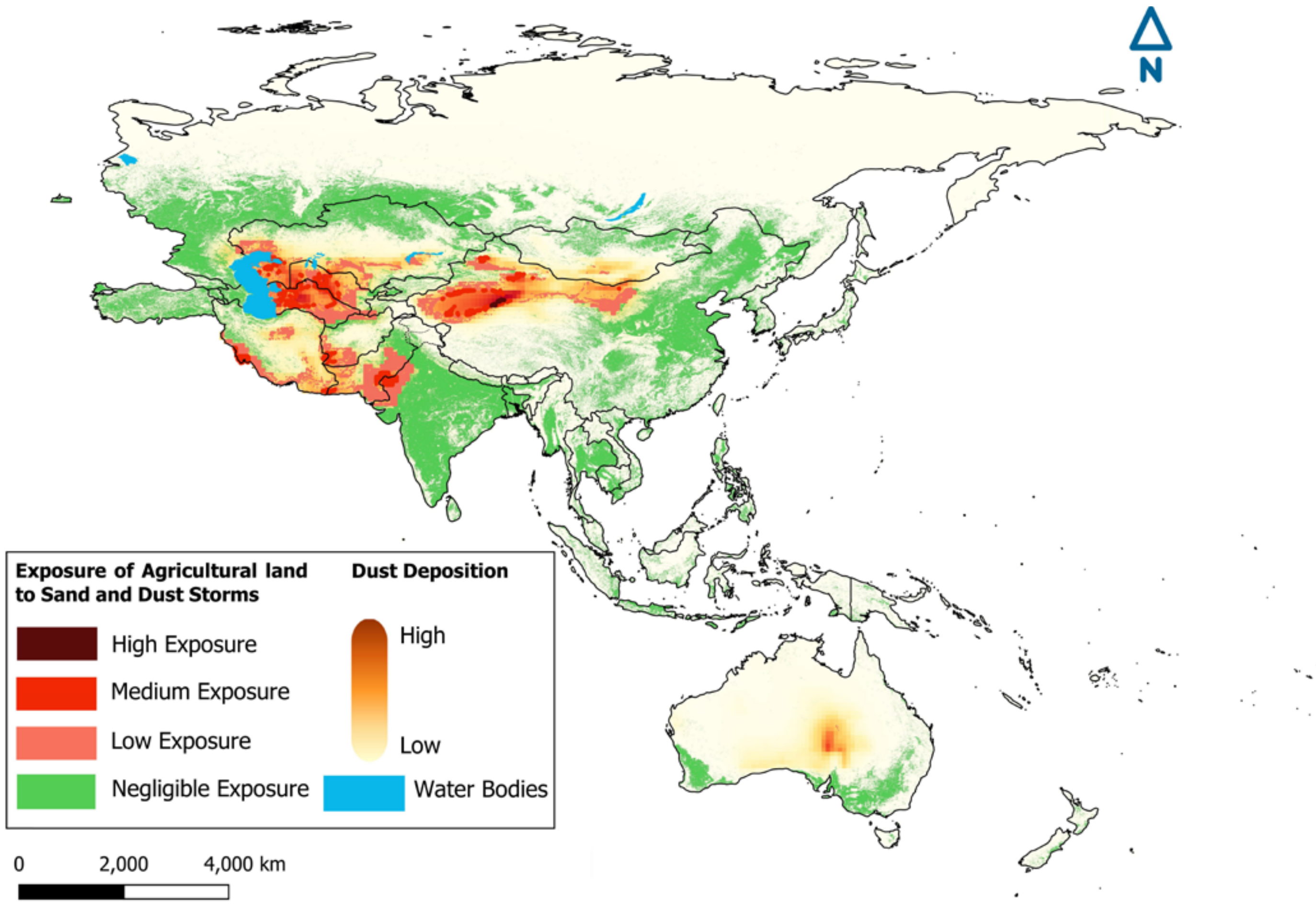


the percentage of the population with livelihoods dependent on agriculture, and the existence of risk transfer strategies such as agricultural insurance. However, this study is unable to consider resiliency in the agriculture sector due to limitations in accessible data.

Agricultural farmland (cropland and paddy field land cover classes according to Kobayashi, et al., 2017) is mapped in Figure 3-19 using the Land Cover map, Global Land Cover by National Mapping Organizations (GLCNMO), Global version data developed using MODIS Version 3 remote sensing data by the secretariat of International Steering Committee for Global Mapping (ISCGM) in collaboration with the Geospatial Information Authority of Japan (GSI), Chiba University, and National Geospatial Information Authorities (NGIAs) of respective countries and regions. This farmland map is then overlaid with a MERRA-2 dust deposition map.

Figure 3-19 indicates the highest exposure values[14] (average dust deposition on agricultural land) are on the south-eastern fringe of the Tarim Basin in China.

Figure 3-19: The exposure of agricultural land to average dust deposition (2019)



Source: Produced by APDIM, Data: (i) Dust deposition from MERRA-2 Reanalysis, (ii) Land cover from GLCNMO.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

14. **Low** is when the dust sedimentation value is between 0.4 and 1.3 g/m^2/month, **medium** is between 1.3 and 2.8 g/m^2/month, and **high** is higher than 2.8 g/m^2/month

Significant areas with medium and low exposure are located in China elsewhere around the Tarim Basin and in northern parts of the Xinjiang autonomous region, in southern parts of the Islamic Republic of Iran, southwestern Afghanistan, a region on the border of India and Pakistan, and in the Central Asian countries of Turkmenistan, Uzbekistan and Kazakhstan. The exposure of farmland in the rest of the region is negligible.

Within those countries most affected, the proportion of all agricultural land on which dust deposition occurs varies greatly, as indicated in Figure 3-19. Turkmenistan has the highest percentage of its agricultural land exposed (more than 70 per cent), and the proportion approaches half of all agricultural land in Pakistan (almost 50 per cent) and Uzbekistan (about 45 per cent). Tajikistan and Afghanistan (about 20 per cent), and the Islamic Republic of Iran (about 15 per cent) also have significant exposure of agriculture to sand and dust storms in the region. In absolute terms, the largest areas of farmland exposed to dust deposits are in Pakistan with 127,533 km^2, followed by China with 79,376 km^2 and Turkmenistan with 51,383 km^2.

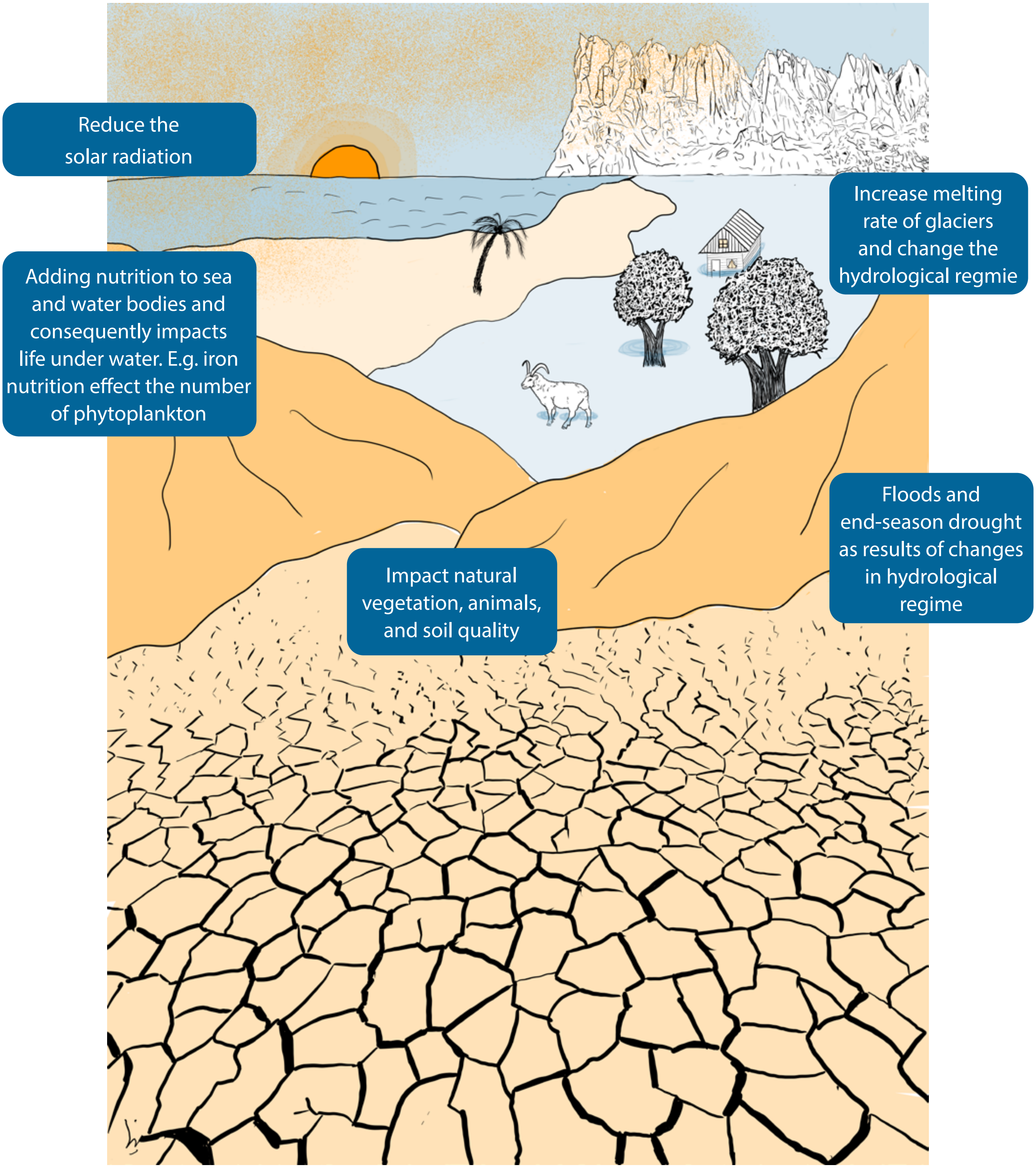
The deposition of mineral dust on farmland may be beneficial, by introducing nutrients to soils, but it can also be detrimental to crops, by reducing photosynthetic activity and hindering plant growth. Establishing the balance between these two effects is not possible with the information currently available. Nevertheless, the large areas of farmland affected by dust deposition in Turkmenistan, Pakistan and Uzbekistan are likely to result in a significant negative impact on agricultural production. Cotton is a major crop, contributing significantly to GDP and foreign exchange earnings in these three countries, and dust deposition has been associated with sizeable reductions in the yield of cotton plants (Zia-Khan, et al., 2015). In addition, many of the irrigated agricultural schemes in Turkmenistan, Pakistan and Uzbekistan have been plagued by problems of soil salinity, and deposition of dust from saline dust storms represents an additional hazard to cotton and other crops (Abuduwaili, DongWei, & GuangYang, 2010). The same issues are evident in Tajikistan, albeit on a smaller proportion of national agricultural land (Abdullaev & Sokolik, 2020). Although the dust deposition issue is less significant on the national scale in other countries, it may represent a considerable problem regionally. A case in point occurs in north-western China, where high levels of dust deposition occur on the oasis cropland surrounding the Tarim Basin in Xinjiang (Xu, et al., 2016).

Environment

There are numerous ways in which sand and dust storms can affect the physical environment, through impacts on many of its constituents, including the atmosphere, soils, vegetation, and bodies of water and ice. Such impacts inevitably, in turn, influence human society. The impacts are not all negative. The effects on natural vegetation, for example, are similar to those on the agriculture sector: including reducing solar radiation but also increasing nutrients in areas of deposition. Dust deposited on water bodies can alter their chemical characteristics, with both positive and negative outcomes. For example, dust particles that carry iron can enrich parts of the oceans, changing the phytoplankton balance, with implications for marine food webs (UNEP, 2020).

Assessing the risks posed by sand and dust storms to the environment is hampered by a lack of understanding and available data, but one critical aspect that is relatively well-understood is the impact on glaciers. The deposition of dust on glacier ice darkens the ice surface which makes the ice less reflective of solar radiation, resulting in the ice absorbing more of the sun's rays, creating a warming effect. The overall outcome is an increase in melting of ice and greater flows of water even under the same meteorological conditions (Shi, et al., 2020). In this study, data on dust deposition (2019) extracted from the MERRA-2 Reanalysis dataset is

Infographic 3-6: The impact of sand and dust storms on environment



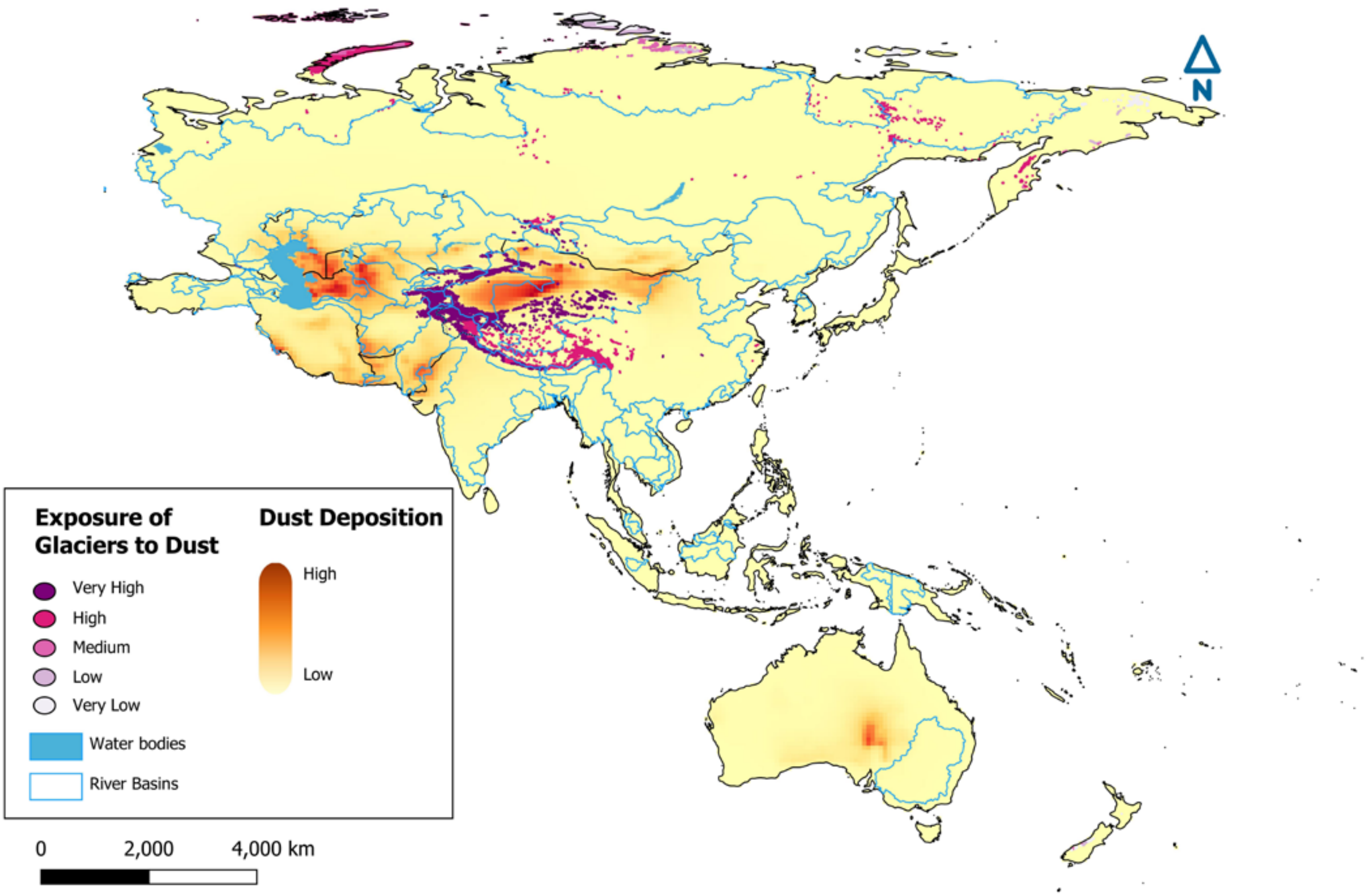
combined with glacier distribution detailed in the land cover map (GLCNMO). The sensitivity and resilience of all glaciers are valued equally.

Figure 3-20 shows the glaciers in Asia and the Pacific and their exposure to sand and dust storms, as represented by the MERRA-2 dust deposition data. The most noticeable feature of this map is the large expanse of glacier ice exposed to high and very high dust deposition in the Himalaya-Hindu Kush Mountain range and the Tibetan Plateau, an area widely known as the Third Pole because its ice fields contain the largest reserve of our planet's freshwater outside the polar regions. A very high deposition is also notable on the glaciers of the Tian Shan mountains and the Pamirs.

The Third Pole is the source of ten major river systems that provide irrigation and drinking water, as well as generating electricity, for over 1.3 billion people in Asia – nearly 20% of the world's population. The area of glaciers exposed to dust deposition in the main river basins is shown in Figure 3-21, which indicates that the flow of water in the Indus, Tarim, Ganges-Bramaputra and the Amu Darya are particularly affected. The availability of water and the seasonality of flow in rivers originating in the Third Pole is changing in response to dynamic aspects of the physical environment, particularly climate change. Dust deposition is another vital component of change to these essential sources of water (Hu, Kang, Li, Li, & Sillanpää, 2020), with direct and indirect impacts on numerous aspects of society, including food security, energy production, agriculture, water stress and flood regimes.

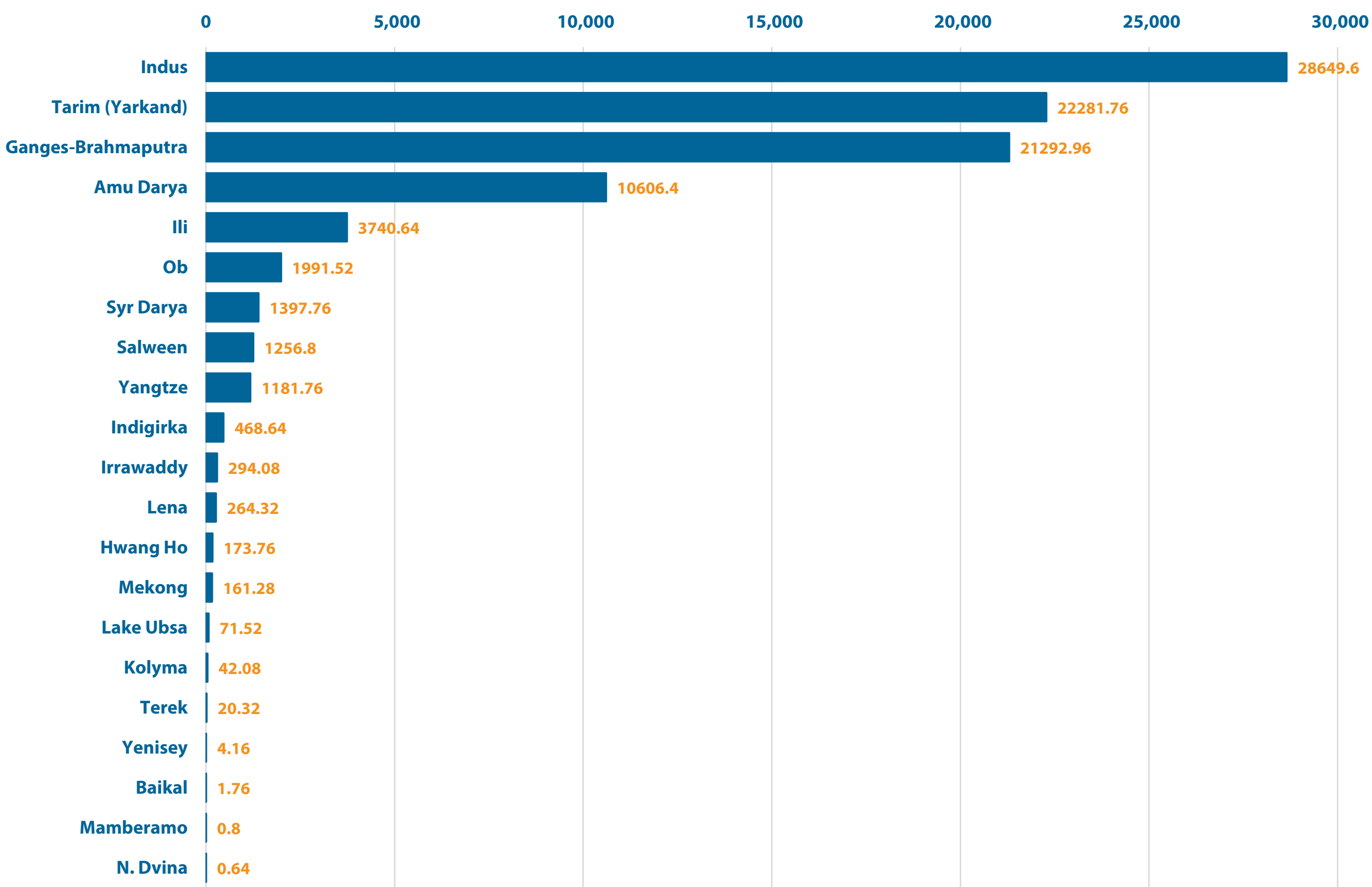
Dust storm that swept through most of Eastern Australia, Photo taken on 23 September 2009,
Photo credit: Michael Dawes, Source: Flickr

Figure 3-20: The exposure of glacier to the different levels of dust deposition



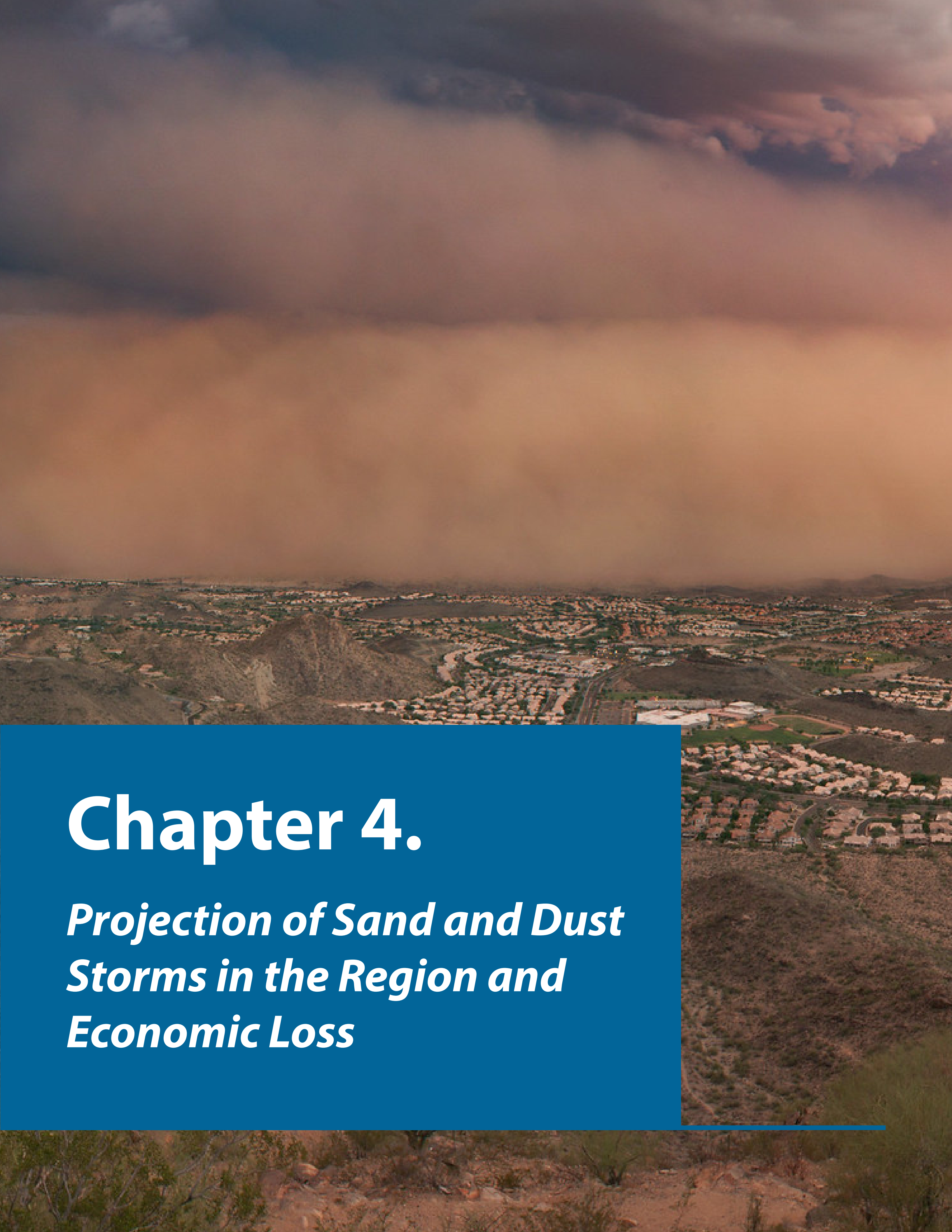
Source: Produced by APDIM, Data: (i) Dust deposition from MERRA-2 Reanalysis, (ii) Land cover from GLCNMO.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Figure 3-21: The area of glaciers exposed to dust deposition in the main basins of Asia and the Pacific (km²)



Box 3-3: Melting of major glaciers in the Third Pole

The Himalayan and Tibetan glaciers, among the largest bodies of ice and freshwater resource outside the polar ice caps, face a significant threat of accelerated meltdown in the coming decades due to climate variability and change. The rate of retreat of these glaciers and changes in their dynamics is highly variable across the Himalayan range. These large freshwater sources are critical to human activities for food production, human consumption and a whole host of other applications, especially over the Indo-Gangetic plains. They are also situated in a geo-politically sensitive area surrounded by China, India, Pakistan, Nepal and Bhutan where more than a billion people depend on them. The major rivers of the Asian continent such as the Ganga (also known as the Ganges), Brahmaputra, Indus, Yamuna, and Sutlej, originate and pass through these regions and they have greater importance due to their multi-use downstream: hydropower, agriculture, aquaculture, flood control, and as a freshwater resource. Recent studies over the Himalayan glaciers using ground-based and space-based observations, and computer models indicate a long-term trend of climate variability and change that may accelerate the melting of the Himalayan glaciers (Prasad A. K., 2011).



Chapter 4.

Projection of Sand and Dust Storms in the Region and Economic Loss

Projected Sand and Dust Storm Trends

The frequency and intensity of sand and dust storms vary seasonally, because of droughts, and over longer timescales. In recent times, increases in rainfall, soil moisture and vegetation have resulted in a reduction of dust-raising in some parts of Asia (Jin & Wang, 2018) (Fan, et al., 2014) projects designed to combat wind erosion with soil conservation measures have also played a part in this connection (Tan & Li, 2015). Increases in wind erosion and associated dust storms have, however, been recorded in parts of Lower Mesopotamia and adjacent regions (Ghasem, Shamsipour, Miri, & Safarrad, 2012), and parts of northeast Asia (Kim, 2008).

Climate change projections indicate that the global area of drylands is likely to expand (Huang, Yu, Guan, Wang, & Guo, 2016) and the risk of drought is also expected to increase (Dai, 2013), both trends that would lead to higher levels of sand and dust storm activity. Assessing future risk of impacts from sand and dust storms in the region requires a broad range of information reflecting possible changes in hazard, vulnerability and resilience. Likely drivers of such dynamism include climate change and socio-economic change. Sand and dust storms are controlled by climate, so any alteration to surface winds and/or the magnitude, timing and distribution of precipitation will affect where and when sand and dust may be eroded from the soil. Climate also directly affects vegetation cover, another control on wind erosion, but vegetation is similarly affected by human activities, such as agricultural practices and water management schemes. Other socio-economic factors may result in modifications to water consumption, for example, or land cover change, both of which may have secondary effects on sand and dust storms. The development of infrastructure, for instance, results in a change to the elements of the socio-economic system that are exposed to sand and dust storms. Changes to any of these variables can result in modifications to geographical patterns but also to variation in the timing and seasonality of sand and dust storm risk.

This report looks at the future risk of impacts from sand and dust storms in the region by encapsulating possible trends in these complex systems in two separate parameters: drought and water stress. Drought is depicted by the Palmer Drought Severity Index, a commonly employed climatic measure that uses temperature and precipitation data to estimate relative dryness (Dai, 2011). Water stress reflects societies' use of water. It measures the ratio of all water withdrawals (for domestic, industrial, agricultural, and non-consumptive use) to the surface and groundwater supplies available (Gassert, 2019). Both parameters have a direct link to sand and dust storm occurrence.

Projections for drought and water stress are combined with the best available regional scale map of sand and dust storm sources derived from satellite data of atmospheric dust. This study of source areas (Ginoux, Prospero, Gill, Hsu, & & Zhao, 2012) was conducted at a global scale, which is why some of the sources named in Box A in Figure 4-1 are outside the ESCAP region. Other sources are grouped in Boxes B, C and D as an approximate indicator of regions.

The projection for drought in 2030-39 is shown in Figure 4-2. On the map, areas that are green or blue are unusually wet and therefore likely to be at lower risk of drought, while those coloured red and purple are unusually dry and could face more extreme drought conditions. Looking at the drought index with the sand and dust storm sources, it immediately becomes apparent that sources in Kazakhstan, northern China, Mongolia and the Ganges basin in India face a lower risk of drought and can, therefore, be expected to be less at risk from sand and dust storms.

In Australia, changes to the likelihood of drought are minor in most of the sand and dust storm source areas except the North West Cape and the Darling Front Range, which could face more extreme drought and hence greater risk from sand and dust storms. The situation is more serious in southwest Asia, where sand and dust storm sources in south-eastern Turkey, Iran and Afghanistan could face much more extreme drought conditions and risks from sand and dust storms.

The projection for water stress in 2030, shown in Figure 4-3, indicates that almost everywhere in the region is expected to experience some level of increased water scarcity. This map also indicates that extremely high-water stress is projected for a larger number of existing sand and dust storm source areas. These are Victorian Big Desert and Riverina in south-eastern Australia, some of the sources in northern China, northern India, Pakistan, and parts of source areas in Kazakhstan, Turkmenistan, and Uzbekistan. The areas of greatest concern are in south-eastern Turkey, Iran, and Afghanistan where extremely high-water stress is projected in addition to much more extreme drought conditions. In combination, these projected conditions strongly indicate considerably higher sand and dust storm risk.

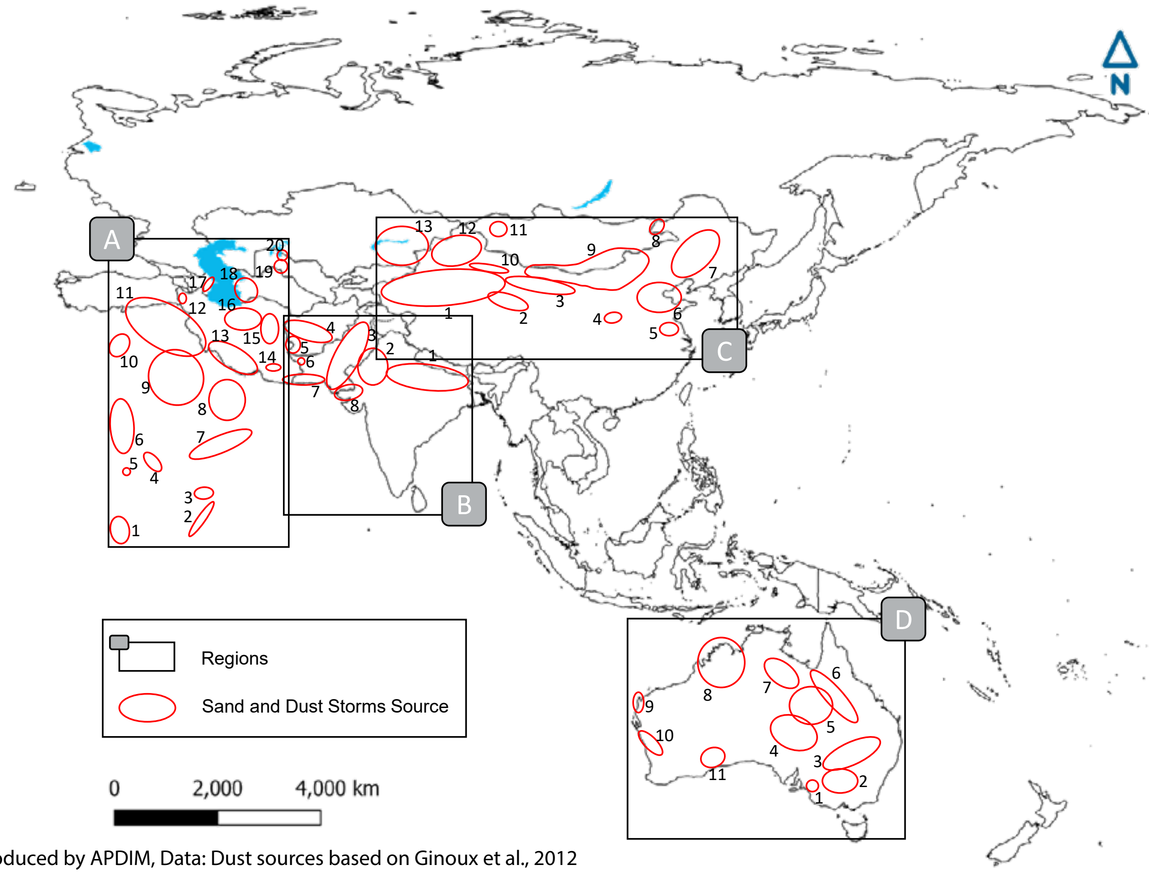
It is worth reiterating that the focus here is on projected changes to conditions in existing sand and dust storm source areas. However, sand and dust storms can occur in almost any environment if conditions are favourable.

The projection in Figure 4-2, presented by Dai (2011), indicates more extreme droughts may occur in parts of northern and southern Thailand, south-Eastern China, northern Malaysia, and south-eastern Australia and hence these regions could experience such favourable conditions.

These projections suggest that disaster risk managers should monitor the occurrence of drought in these parts of the Asia-Pacific region and keep in mind the possibility of facing new sand and dust storm hazards in these areas.

Taj Mahal in a dust storm from Agra Fort, India, Photo taken on 25 March 2009, Photo credit: Tristan Clarke, Source: Flickr

Figure 4-1: Sand and dust storm source areas



Source: Produced by APDIM, Data: Dust sources based on Ginoux et al., 2012

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

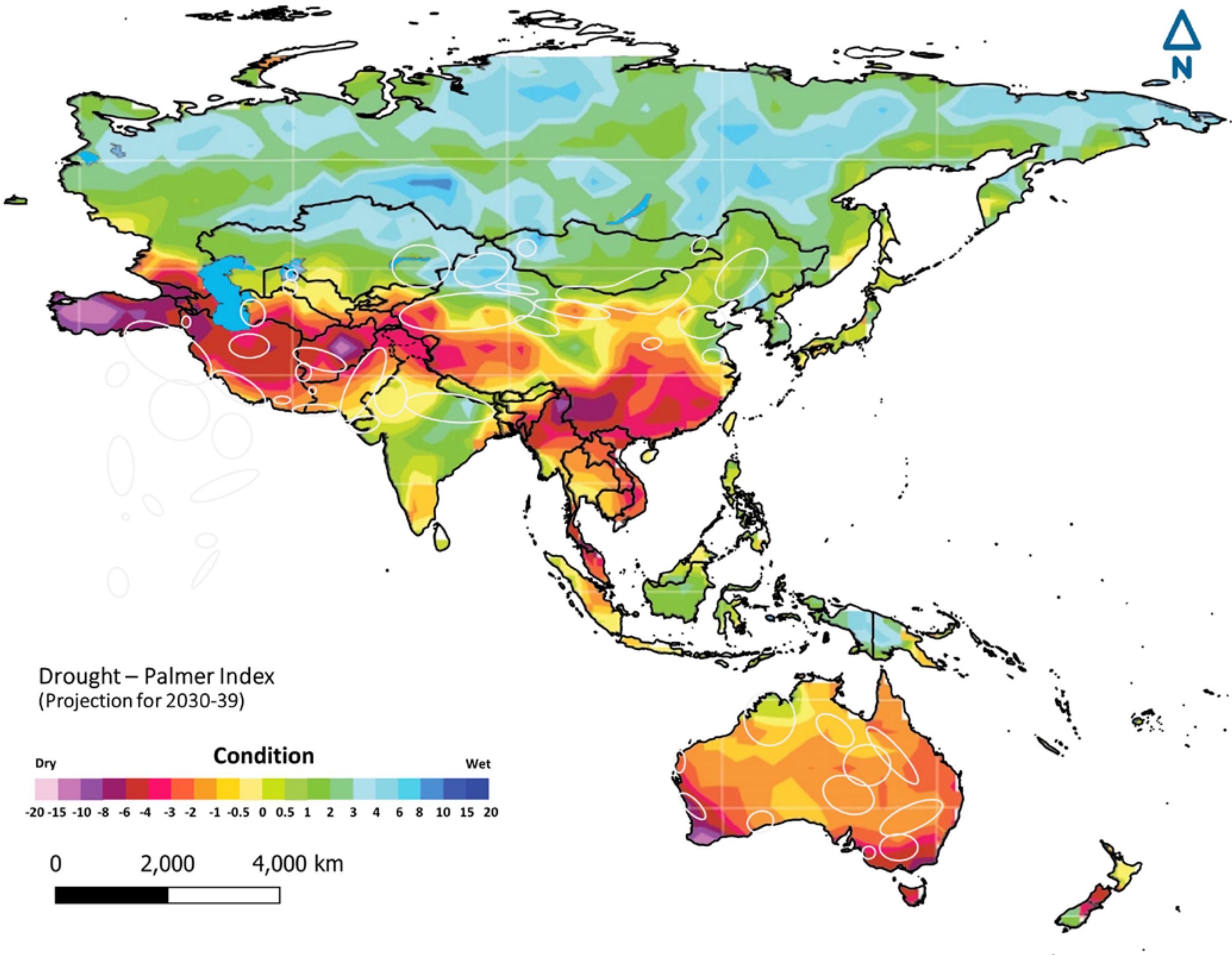
Box A: 1, Chalbi Desert of Kenya; 2, coastal desert of Somalia; 3, Nogal Valley of Somalia; 4, Danakil Desert of Ethiopia; 5, Lake Tana of Ethiopia; 6, northeast Sudan; 7, Hadramawt region; 8, Empty Quarter; 9, highlands of Saudi Arabia; 10, Jordan River Basin of Jordan; 11, Mesopotamia; 12, Urumia Lake of Iran; 13, coastal desert of Iran; 14, Hamun-i-Mashkel; 15, Dasht-e Lut Desert of Iran; 16, Dasht-e Kavir Desert of Iran; 17, Qobustan in Azerbaijan; 18, Atrek delta of Turkmenistan; 19, Turan plain of Uzbekistan; and 20, Aral Sea.

Box B: 1, Ganges basin in India; 2, the desert of Rajasthan in India; 3, Indus basin of Pakistan; 4, the southern drainage basin of the Hindu Kush in Afghanistan; 5, ephemeral lakes around the city of Zabol; 6, Hamun-i-Mashkel of Pakistan; 7, Makran coast of Pakistan; and 8, Rann of Kutch in India.

Box C: 1, Tarim Pendi; 2, Qaidam Pendi; 3, Hexi Corridor in Gansu Province; 4, Tongguan county; 5, Hongze and Gaoyou Lakes of eastern China; 6, North China Plains; 7, Horqin sandy land; 8, Hulun Buir plain; 9, Inner Mongolia deserts; 10, Turpan Pendi; 11, Great Lakes depression in Mongolia; 12, Junggar Pendi; and 13, Balkhash-Alakol depression.

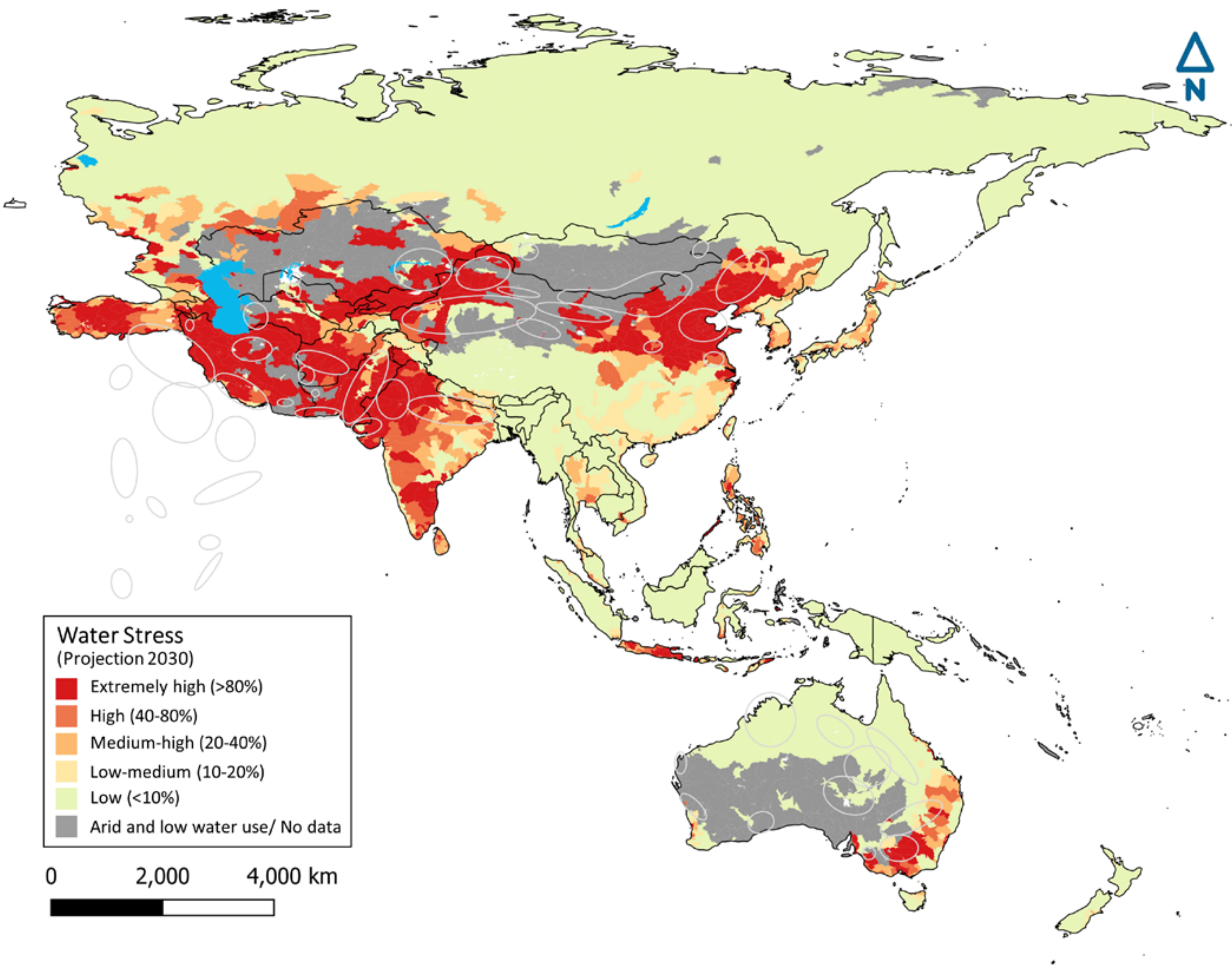
Box D: 1, Victorian Big Desert; 2, Riverina; 3, Barwon-Darling Basin; 4, Lake Eyre Basin; 5, Simpson Desert; 6, lee side of Great Dividing Range; 7, Barkly Tableland; 8, Kimberley Plateau; 9, North West Cape; 10, Darling Front Range; and 11, Nullarbor Plain.

Figure 4-2: Drought projection for 2030-39 (Palmer Index)



Source: Produced by APDIM, Data: (i) Drought projection from Dai, 2011, (ii) Dust sources based on Ginoux et al., 2012
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Figure 4-3: Water stress (Projection 2030)



Source: Produced by APDIM, Data: Water stress projection from World Resources Institute.
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Assessing and Projecting Economic Losses due to Sand and Dust Storms

An economic analysis of loss due to risks is a powerful tool to support decision-making on strategies to reduce those risks. However, there have been very few attempts to assess in economic terms the damage associated with sand and dust storm hazards. A thorough review of the literature highlights specific analyses in this regard from Australia, China, the Islamic Republic of Iran, and the Republic of Korea. These studies focus on a variety of sectors, some assessing the impact of single events, others focusing on annual loss. The lack of consistency about what data are collected and how they are analysed makes comparisons between studies difficult. For example, the reported economic loss in the aviation sector caused by one severe sand and dust storm event in Australia (Tozer & Leys, 2013) was based on the cost of airline diversions, while a similar analysis for a whole year in the Republic of Korea (Jeong, 2008) also included losses due to cancellations, from the decrease in sales, landing charges and car parking charges.

Three studies that assessed the economic damage incurred on **roads in the transport sector** all assessed different aspects, albeit with some similarities. An assessment conducted in China reported road accidents. Assessments from Australia and the Islamic Republic of Iran reported expenditure on road maintenance but the study from the Islamic Republic of Iran also included the cost of damage to road signs and asphalt surfaces. Only one study, from China, reported the interruption to the rail network, resulting in blockage or delays to 37 freight trains.

Studies from China and the Islamic Republic of Iran also reported on the economic damage to the agriculture sector. The variables accounted for included the accumulation of sand in irrigation canals and wells.

In the **health sector**, studies from Australia, the Islamic Republic of Iran and the Republic of Korea all report the annual cost of treatment for asthma and respiratory system diseases, while the study from the Republic of Korea also covers annual treatment costs for cardiovascular, otorhinolaryngological (ear, nose and throat) and ophthalmological (eye) diseases (Jeong, 2008). A study from China reports demand-driven effects and supply-constrained effects caused by yellow dust storms in Beijing in 2000.

For the **energy sector**, the annual cost of cleaning power transformers, additional repair and maintenance costs, and expenses associated with cleaning up were reported in studies from Australia and the Islamic Republic of Iran. One study in China included costs due to the destruction of electrical infrastructure. The study from the Islamic Republic of Iran also estimated the costs associated with power failures caused by sand and dust storms, calculating the value of electricity not consumed (so-called 'undistributed energy') by industry, services, commercial and residential sectors during electricity blackouts.

Based on the literature review, besides the above-mentioned reported data, sand and dust storms also result in millions of socio-economic losses among the whole population due to a decrease in amenity, increase in disease, stores and school closure or delay in the opening, evacuation, repairing buildings, cleaning up and washing homes, cars, clothes, etc. as well as repairing electrical equipment and water consumption.

While scattered research and data all point in the direction of recurrent and significant economic losses across several sectors, a comprehensive picture of the overall economic impact of sand and dust storms at the regional level is still not easily drawn. Importantly, there is a complete absence of economic impact studies in numerous dryland countries where sand and dust storms are a well-known characteristic of climate. Agriculture is one key sector where the economic losses due to sand and dust storms are both poorly understood and very rarely quantified, despite the finding of this study that the impacts are widespread. Human health is another sector that is affected across large swathes of the Asia-Pacific region, yet there have been very few attempts to assess in economic terms the adverse health effects associated with sand and dust storms.

The sections below present a brief recap of available post-disaster damage and loss assessment.

Agriculture

On 5th May 1993 in northwest China, sand and dust storms destroyed more than 373,000 hectares of cultivated land and 16,300 hectares of orchards and gardens. The storm eroded an average of 10 cm from the surface soil in most areas, more than 50 cm in some areas and more than 1,000 km of irrigation canals were buried by sand accumulation (UNCCD, 2001)

During the period 2000-2004 in one region of the Islamic Republic of Iran, sand and dust storms resulted in reduced crop production and the accumulation of sand on agricultural land and in wells. The total cost of damage to farmers in the region was calculated to be USD 48.3 million over the five years (Pahlavanravi, Miri, Ahmadi, & Ekhtesasi, 2011)

Energy

In one state of Australia, the cost of cleaning power transformers after sand and dust storms were reported to be USD 162,500 annually. (Williams & Young, 1999)

Total costs of damage to electrical installations, including cleaning and repairs, in the Sistan region of the Islamic Republic of Iran over the period 2000-2004 was nearly USD 650,000. With an additional cost due to blackouts of almost USD 50,000 over the same period, the total cost to power supplies came to USD 0.69m over the five years. (Pahlavanravi, Miri, Ahmadi, & Ekhtesasi, 2011)

Human Health

The high prevalence of respiratory problems such as asthma in sand and dust storm-prone areas may cause considerable economic losses in the human health sector, although dust is just one of numerous factors that might influence the development and expression of respiratory allergic diseases such as asthma. Associations have been demonstrated between atmospheric dust exposure and various human health outcomes, as noted in Chapter 3 but causation is more difficult to establish. The distinction is important for estimates of economic damage and loss. A study in the state of South Australia (Williams & Young, 1999), which estimated direct market values, concluded that the annual cost of the off-site impacts of wind erosion in the state was USD 2m. However, the inclusion of health-related costs – in this case stemming largely from the annual cost of asthma in South Australia – increased the sum to USD 15m per year.[15]

15. A more recent study of the impacts of a dust storm in Australia in February 2019 "estimated to cause four premature deaths, 161 respiratory disease hospitalization and seven cardiovascular disease hospitalization based on model prediction of $PM_{2.5}$ concentration, the Relative Risk (RR) from published epidemiological studies and the 2016 distribution of population in NSW with the assumption that all is exposed equally to the predicted ambient pollutant at the location." (Aragnou et al. 2021)

Box 4-1: A perfect (sand) storm - the butterfly effect and the impact of sand and dust storms on transportation and global trade*

On March 12, 2021, the ship Ever Given left Malaysia carrying more than 20,000 containers destined for the Netherlands. Eleven days later, due to low visibility caused by a sandstorm in the Suez Canal area, the giant container ship ran aground. The Ever Given blocked this key artery of international trade to all traffic for almost a week, affecting more than 369 cargo ships.

The consequences of this dust storm were enormous: disrupting the global supply chain at a time when most economies were just starting to recover from the Covid-19 pandemic.

It has been estimated that the blockage created a loss of billions of dollars. Whenever the canal is blocked, the only alternative route is a long detour via the Cape of Good Hope, involving around 15 days of additional travel time. This incident delayed deliveries in many parts of the world, increased the global oil price, and affected ships carrying perishable goods including livestock and food. Even after the ship was re-floated and the canal unblocked, the pressure was transferred to port services and railway systems.

Events such as the Suez Canal blockage, triggered by dust storms, illustrate how even a moderate and local scale hazard can become a very high-risk event with enormous impact on the global scale due to very high sensitivity and lack of resilience.

The blockage resulted in a cascading effect, expanding from one point in the supply chain to impact trade globally, with huge economic consequences, the effect of which went beyond the transport sector to energy and food security.

* Sources: (The Weather Company, 2021), (Hincks, 2021), (Jones Jr., 2021)
https://en.wikipedia.org/wiki/Suez_Canal
https://www.nytimes.com/2021/03/28/world/middleeast/syria-fuel-suez-canal.html

Chapter 5.

Findings and Policy Implications

This report is the first assessment of its kind analysing the risks posed to society and the environment by sand and dust storms in such a large-scale geographical area. It reflects a considerable degree of collaboration with other UN entities and subsidiary bodies of ESCAP, national agencies, research institutions and universities all over the world. The work conducted for this assessment involved expert consultations with scientists, active support and contributions in the fields of data supply, processing, analysis, interpretation and mapping.

Taking into account measures of hazard, vulnerability and resilience illustrate some surprising findings. The overall risk to human health via poor air quality affected by sand and dust storms, for example, is highest not in those areas where atmospheric dust concentrations are at a maximum but in parts of Pakistan and northern India where dust levels, though still elevated, are more modest.

This is due in large part to the combination of high population densities and moderate atmospheric dust levels in these areas. Nevertheless, the scale of the health threat is illustrated in certain dryland cities in Asia where residents breathe air that exceeds acceptable levels for PM_{10}, largely due to sand and dust storms, every day for at least ten months a year. The nature of impacts in the solar energy sector is also notable and widespread in many countries, and likely to become even more of an issue as the transition towards renewables accelerates.

This risk assessment has also highlighted significant gaps in available data and some important areas where knowledge and understanding are inadequate. For these reasons, some aspects of society, economy and environment are known to be affected by sand and dust storms could not be assessed in this report. These data and knowledge gaps warrant further investigation and should be addressed as a matter of urgency.

Risk Assessment Findings

More than 500m people in India are exposed to medium and high levels of poor air quality due to sand and dust storms, along with 173m people in Pakistan, 62m in the Islamic Republic of Iran and 40m in China. In proportional terms, more than 80 per cent of the entire populations of Turkmenistan, Pakistan, Uzbekistan, Tajikistan, and the Islamic Republic of Iran are exposed to medium and high levels of poor air quality due to sand and dust storms. Nevertheless, the overall risk to human health is greatest where relatively high dust concentrations occur in areas with high densities of the human population and relatively low resilience when measured by expenditure on healthcare. This combination is most prominent in the provinces of Punjab and Sindh in Pakistan and along the Ganges plain in northern India.

In the energy sector, sand and dust storms have a considerable impact on the generation of electricity by solar power plants which, measured in economic terms, is greater than USD107m in India per year and exceed USD46m and USD37m in China and Pakistan. Growth in energy produced by solar power plants has been very rapid in recent years, a trend that is expected to continue as governments strive to ensure access to affordable, reliable, sustainable, and modern energy for all (SDG 7), so the hazards to electricity generation posed by sand and dust storms is likely to become greater, hindering progress towards achievement of SDG 7.

In the aviation sector, the exposure of aircraft engines to dust particles is a considerable risk on flight paths traversing southwestern and central parts of Asia and flights to and from airports on the Arabian Peninsula, Pakistan, India and China are most affected. The risk of flight delays, diversions, and cancellations due to low visibility caused by sand and dust in the atmosphere at ground level is greatest at airports in Central Asia, southern parts of the Islamic Republic of Iran, the border area between Pakistan and India, and northern parts of China. Flights diverted for this reason may have to land at an airport in a neighbouring country, another example of the transboundary effects of sand and dust storms (Box 5-1).

Large areas of farmland are affected by dust deposition in Turkmenistan (71% of the cropland area), Pakistan (49%) and Uzbekistan (44%). Much of this dust is characterised by a high salt content, which typically makes the dust toxic to plants. This reduces yields, representing a significant threat to the production of irrigated cotton and other crops. The same issue is evident in Tajikistan, although on a smaller proportion (21%) of national agricultural land. Dust deposition is less significant at the national scale in other countries in the region but may represent a considerable problem more locally, as in north-western China, where high levels of dust deposition occur on oasis cropland surrounding the Tarim Basin in the Xinjiang autonomous region.

Very high dust deposition occurs in the Himalaya-Hindu Kush Mountain range and the Tibetan Plateau, the so-called Third Pole which provides fresh water to more than 1.3 billion people in Asia. The deposition of dust on glaciers induces a warming effect, increasing the melting of ice. Along with the effects of climate change, dust deposition is a vital component of change to these essential sources of water, with direct and indirect impacts on society through numerous issues, including food security, energy production, agriculture, water stress and flood regimes.

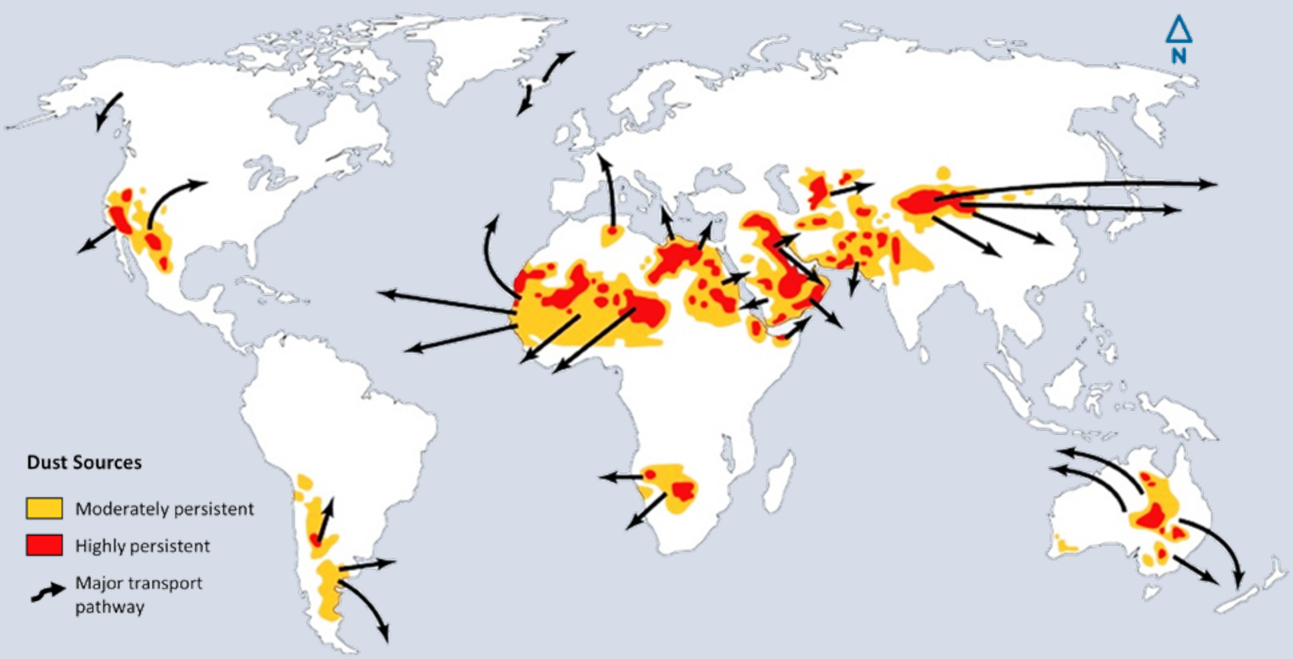
Example of dust deposit on snow-covered areas. Photo published on 4 August 2015, Photo credit and Source: NASA Goddard Space Flight Center, Source: GSFC/NASA

Box 5-1: Transboundary effects of sand and dust storms

Soil particles raised in sand and dust storms are frequently carried great distances in the wind. Major pathways are shown in the map transport dust across international boundaries and out over the oceans. These long-distance transport events involve large amounts of fine-grained material and are visible on satellite imagery. Dust from sources in China and Mongolia, and occasionally from Central Asia, reach the Korean Peninsula and Japan and even the west coast of North America. Australian dust can reach New Zealand and Antarctica. Note also that in these cases dust has impacts far beyond the boundaries of the world's drylands.

Parts of the Asia-Pacific region also receive dust from elsewhere, so that dust storms in the Arabian Peninsula, for example, impact air quality in Iran, Pakistan, and India. On occasion, intense periods of sand and dust storm activity impact multiple countries, as in May 2018 when a series of fierce dust storms caused considerable disruption across parts of Kazakhstan, Uzbekistan, Turkmenistan, the Islamic Republic of Iran, Afghanistan, Pakistan and northern India (Sarkar, Chauhan, Kumar, & Singh, 2019) (Oguz, 2020). The indirect effects of such events can also become transboundary, as when flights prevented from landing at an airport in one country are diverted to land in another country.

Figure 5-1: Global sources of sand and dust storms and major long-range transport pathways



Source: Based on Muhs, Prospero, Baddock, & Gill, 2014.

Disclaimer: The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Cities in southwestern parts of Asia have the highest exposure to sand and dust storms, which make a significant contribution to poor air quality in Karachi, Lahore, and Delhi, where nearly 60 million people experienced more than 170 dusty days a year in 2019. The situation is much worse for 6 million residents of eight cities across the region (three in China, two in the Islamic Republic of Iran, two in Pakistan, and one in Uzbekistan) who breathed air that exceeded acceptable levels for PM_{10} every day for at least ten months in 2019.

The risk of impacts from sand and dust storms is projected to increase in the 2030s due to more extreme drought conditions in parts of Western Australia, South-Eastern Turkey, the Islamic Republic of Iran, and Afghanistan, while sources in Kazakhstan, northern China, Mongolia and the Ganges basin in India face a lower risk of drought and hence probably less risk from sand and dust storms. The risk in South-Eastern Turkey, the Islamic Republic of Iran and Afghanistan is even more likely to materialise given that this area is also projected to experience extremely high-water stress in 2030.

Managing the risks associated with sand and dust storms may also become necessary in areas not previously recognised as source areas for such phenomena. This might be the case if projections of more extreme droughts prove to be accurate in parts of northern and southern Thailand, South-Eastern China, northern Malaysia and southeasternmost Australia.

Sand and Dust Storms Risk Management

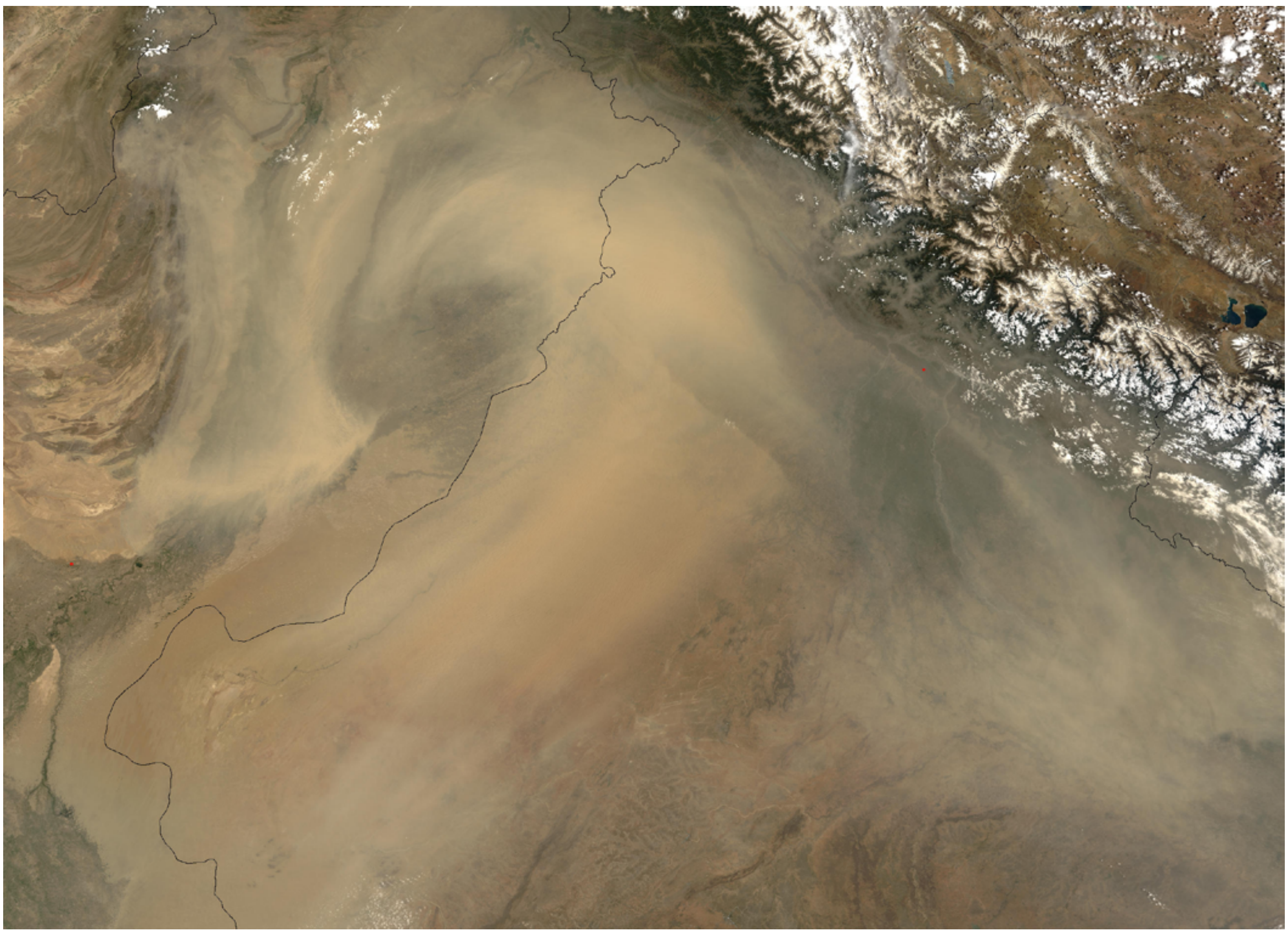
Policy measures designed to mitigate sand and dust storm hazards for disaster risk reduction can be divided logically into those that aim to prevent wind erosion occurring in source areas and those designed to manage the adverse impacts of small particles in the atmosphere and on deposition. Effective control of sand and dust storm hazards should adopt an integrated multi-scale and multi-functional approach and can comprise both technical solutions and behavioural approaches, depending on the local context concerned. Deciding what strategy to adopt, or indeed whether to adopt one at all, should theoretically be supported by cost-benefit analysis, but the scarcity of economic analyses of sand and dust storm disasters is a serious impediment in this respect. Nevertheless, identification of appropriate risk reduction measures should be preceded by national and regional assessments of vulnerability, risk, and capacity, and by linking these to climate change scenarios.

Successful management of sand and dust sources depends initially on knowing where those sources are located. The sand and dust storm source areas in Asia and the Pacific are relatively well known at the scale shown in Figure 4-1 but many of these areas are very large and more detailed information is needed at higher spatial resolution. In some of the source areas that are better known, for example, most sand and dust storms occur in small, very active hotspots (Zhang, Tsunekawa, & Tsubo, 2015). Another critical element to understand in source areas is the relative importance of human activities, such as unsustainable land or water management, in generating sand and dust storms.

There are numerous technical approaches to environmental management designed to mitigate sand and dust storms at source (Middleton & Kang, 2017) that include elements of sustainable land management, integrated landscape management and integrated water management. However, deciding which approach to adopt depends on a good appreciation of the relative roles of climatic variables and human activities as drivers of wind erosion. When deciding which of a range of measures might be introduced, a useful distinction can be made between techniques designed to minimize actual risk in the short-term (e.g. cultivation practices such as minimum tillage) from those that minimize potential risk over the long term (e.g. planting windbreak) (Riksen, Brouwer, & De Graaff, 2003).

However, preventing emissions of sand and dust at the source is not always possible. In these situations, a range of monitoring, forecasting, and early warning measures can be implemented to mitigate the numerous effects of mineral dust. Operational dust forecasts have been developed at a number of centers around the world as part of the World Meteorological Organization's Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). SDS-WAS enhances the ability of countries to deliver timely, quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities.

There is an SDS-WAS Regional Center for Asia, coordinated and hosted by the China Meteorological Administration, and a Regional Node for West Asia has been proposed. SDS-WAS forecasts are better used in some parts of Asia and the Pacific than others and



Thick clouds of desert dust were blowing over Pakistan (left) and India (right)
at the foothills of the Himalaya Mountains, Photo taken on 9 June 2003,
Photo credit: Jacques Descloitres, MODIS Rapid Response Team at NASA GSFC, Source: NASA GSFC

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much work is needed to develop these forecasts to make them more sector-specific. The findings of this report indicate the need for impact-based forecasting in the agriculture, energy, environment, transport, urban and health sectors. Such sector-specific forecasts would significantly improve countries' abilities to ensure targeted and timely measures can be put in place to minimize the negative impact of dust storms.

Some lessons on sand and dust storm risk management can be learned from the experience of the Seoul Metropolitan Government, which issues dust forecasts in weather reports, on the internet, and through emergency broadcasts. Seoul is more than 1000 km from the nearest dust source, but yellow haze (Hwang sa in Korean) created by mineral dust blown from sources in China and Mongolia is a common seasonal occurrence. Seoul Metropolitan Government has a guide on its website (Seoul Metropolitan Government, 2021) advising on what to do before, during, and after a Hwang sa event, and issues alert when a mean hourly PM_{10} concentration of greater than 800 µg/m^3 is expected to last more than two hours. Alerts of desert dust events are a simple and effective way of reducing hospital admissions and harmful impacts on human health by prompting behavioural changes that lower exposure (Merrifield, Schindeler, Jalaludin, & Smith, 2013).

An example of the effectiveness comes from the dust storm that hit Sydney, Australia on 23 September 2009. As reported in Tozer et al. (2013) "Alert SMS and emails were sent to subscribers to the health-alert system advising of a high pollution-level event. Alerts were sent from 02.00 to 09.00 hours on the morning of the storm (S. Quigley, pers comm.), thus those at risk could make. individual decisions" the result was "there was no significant increase in emergency room visits or hospital admissions in the week of the Red Dawn event when compared with 2008 or 2010."

The very large number of cities where residents are exposed to many days of poor air quality (see Figure 3-8) indicates the huge potential health benefits that could be achieved by introducing alerts of desert dust events. However, such alerts would need to be tailored to circumstances prevailing in specific national settings. Appropriate dust concentration thresholds would need to be established and suitable media for communication agreed.

Details of possible impact-based forecasting in the agriculture, energy, environment, and transport sectors also need to be established. Sector-specific forecasts and risk management will also benefit from more integrated research across sectors to understand the economic cost of disasters.

Looking Ahead: Suggested Next Steps for Coordinated Regional Action on Sand and Dust Storms

This risk assessment has highlighted a range of sectors that are ripe for further study. Several types of sand and dust storm hazard are poorly accounted for. These include many of the effects of dust deposition on different crop types and other forms of food production such as apiculture and pastoralism. Another area where more research is needed is on the impacts on agriculture in sand and dust storm source regions, where damage occurs primarily due to the loss of soil, nutrients, seeds and fertilizer involved in a wind erosion event. Cropland and rangeland are land use that commonly becomes dust sources, either through mismanagement and/or when drought occurs. There is a clear need for a comprehensive assessment of the geography of such sources in the Asia-Pacific region, and for the impacts to be catalogued and quantified.

The risk of human health impacts is assessed in this report, but the method used does not distinguish between short- and long-term effects, nor does it capture

Workers are waiting for the steam train in dust storm, China Rail SY at Baiyin,
Photo taken on 29 February 2008, Photo credit: Smoky Shin, Source: Flickr

all health effects. Some cannot be assessed simply by using data on atmospheric dust concentration because the dust is associated with the transmission of certain infectious diseases (e.g., meningitis, Kawasaki disease). The same situation applies to a range of animal and plant diseases that can be transmitted in atmospheric dust.

More information is needed on the microorganisms carried in desert dust events and other determinants of the dynamics of these infectious diseases, as well as the precise nature of their relationship to atmospheric dust.

Perhaps most importantly, the large majority of existing studies into the links between atmospheric dust and human health have been conducted far from sources of sand and dust storms. This report demonstrates clearly that dust concentrations are much higher and exceed health guidelines for many more days in sand and dust storm source areas, yet health studies in drylands are few and far between. This imbalance in the geography of investigations requires urgent attention.

Another adverse health effect of sand and dust storms that deserves greater consideration is the risk of injuries and death from transport accidents, which can occur due to reduced visibility on roads particularly. Indeed, many of the risks associated with sand and dust storms on roads and rail lines, such as the deposition and accumulation of sand, cannot be quantified adequately at the geographical scale adopted in this report because the impacts are very localized.

This issue of geographical scale also has wider importance. There is a general need for in-depth risk assessments for sand and dust storm events across multiple sectors at national and local levels. Similarly, at the international level, coordinated multi-country transboundary studies of individual dust storm events are required to fully understand their multiple impacts.

Certain aspects of other sectors assessed in this report also warrant greater attention. These include the impacts of sand and dust storms on agricultural infrastructure (e.g., irrigation canals), and infrastructure in the energy sector (e.g., transmission lines, forms of electricity generation other than solar). Other hazards associated with mineral dust that should be assessed include the impacts on information and communication technology, and water quality, both surface water and groundwater.

A lack of data presented one of the most prominent challenges throughout the process of conducting this sand and dust storms risk assessment. This limitation is particularly acute in the case of economic analysis, including estimates of average annual loss. For all forms of hazard associated with sand and dust storms, there are very few post-damage economic assessments of impact (under 20 in Asia and the Pacific), and those studies that have been conducted lack consistency in data collection methods and analysis. Partly this is because sand and dust storms do not feature prominently in the disasters' literature (Middleton, Tozer, & Tozer, 2019), despite the hazards to society they represent. This report presents a clear view of the numerous ways in which sand and dust storms can and do impact socio-economic systems. The case for filling these data gaps is therefore indisputable.

A better understanding of the impacts associated with sand and dust storms has prompted ESCAP-APDIM to advocate for sand and dust storm issues to be mainstreamed into disaster risk reduction strategies and become fully integrated into multi-hazard management plans for disaster risk reduction at all levels and across all sectors, this is especially relevant for national disaster risk reduction plans as envisaged under Target E of the Sendai Framework.

There is a lack of systematic data gathering and reporting the negative impact of sand and dust storm in the region and Member States reporting to the Sendai Framework Monitoring have not reported so far on sand and dust storms. To facilitate a closer integration of sand and dust storms into disaster risk reduction plans and policies, ESCAP-APDIM has developed guidelines to support countries should they choose to set up nationally defined and customized targets and indicators specifically related to sand and dust storms within the Sendai Framework Monitoring System, in order to gather much-needed additional data on their impacts (Box 5-2).

The data collected by countries as part of their disaster risk management will feed into policy interventions at the national and international levels. Given the frequent transboundary impact of sand and dust storms, a strong case can be made for the design and implementation of well-coordinated actions at national, regional, and interregional levels.

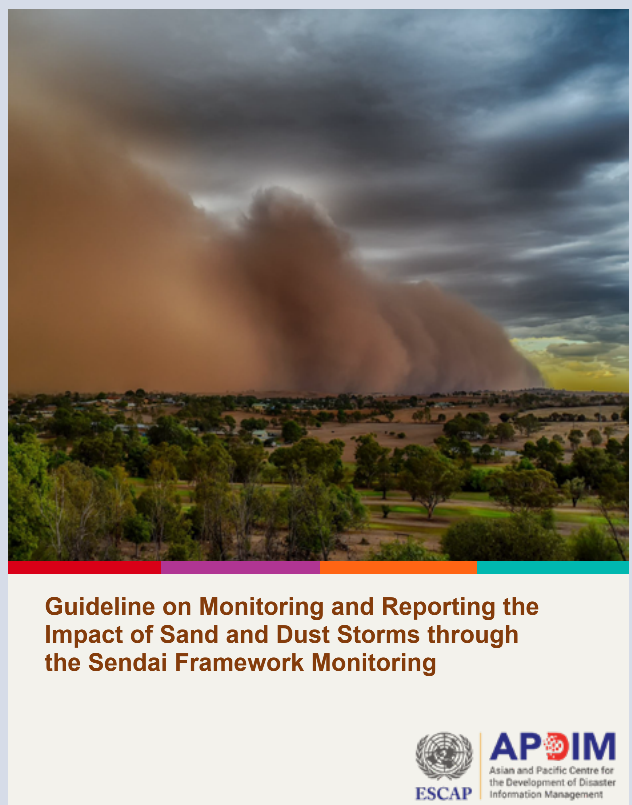
Box 5-2: Reporting sand and dust storms through the Sendai Framework Monitoring for Disaster Risk Reduction 2015-2030

While the occurrence of sand and dust storms can be scientifically determined, this report highlights the fact that quantifying their impact on society, environment and economy is more difficult. Partly this is due to the lack of relevant data and the absence of a disaster-impact database that records and systematically quantifies sand and dust storm activity and impacts. As this report indicates, there are few studies available on the post damage and loss assessment of sand and dust storms, and those that are available use a range of different methodologies.

To collect these data in a systematic manner and to improve the average annual loss estimation, APDIM has developed a guideline on monitoring and reporting the impacts of sand and dust storms using the Sendai Framework Monitoring tool. APDIM encourages Member States to report sand and dust storm losses and supports countries to build their capacity to do so. Ultimately, the Guideline should contribute to enhancing capacities of Member States to collect, collate, understand, and use data for the monitoring and reporting of the negative impacts of sand and dust storms through the Sendai Monitor; and to building an evidence base on the negative impacts of sand and dust storms using the Sendai Framework Monitoring process for policy and decision-making.

The target audience of the Guideline includes government officials working on sand and dust storms and the monitoring of the Sendai Framework in Asia and the Pacific. The Guideline may also provide useful inputs for implementing partners in the region, including the United Nations System (UNS), the Red Cross Movement, INGOs, Civil Society Organizations (CSOs), academia, donors and other actors supporting data collection and monitoring and reporting of the impacts of sand and dust storms.

While the Guideline focuses specifically on the Asia-Pacific region, it can be used by all countries affected by sand and dust storms who wish to report their impact through the Sendai Framework Monitoring.



To download, visit the APDIM website:
https://apdim.unescap.org/knowledge-hub/guideline-monitoring-and-reporting-impact-sand-and-dust-storms-through-sendai

The cumulative effects of sand and dust storms on society are significant, not least because sand and dust storms are more frequent than most other types of natural hazards. Their impacts are complex and very widespread and represent an important emerging issue for policymakers.

The lack of data and thorough understanding of the socio-economic impacts of the phenomenon present significant challenges to decision-makers, who often lack sufficient information on which to base policy. There is therefore a need for researchers to measure and understand the impacts of sand and dust storms on specific sectors and discrete segments of affected populations, including in densely populated cities.

The health effects, in particular, are highlighted in this report, effects that take on greater significance in the context of the COVID-19 pandemic. Experts engaged in the science-policy interface of disaster risk management, public health and climate change will play a key role in guiding decision-makers toward a safer, healthier, and more sustainable future as they steer a course through the challenges of the post-COVID-19 era.

The analysis in this report highlights the urgent need for countries in the region to consider joint action towards:

- A deeper understanding of the socio-economic impacts of sand and dust storms;
- A coordinated monitoring and early warning system, with an impact-based focus, to timely forecast sand and dust storms and enable targeted measures to minimize exposure and reduce risks;
- Coordinated actions in most at-risk and exposed geographical areas with a view to mitigating the risks

In the following section, a few specific suggestions are made under each of these joint action recommendations.

Deeper Understanding

There is a need to obtain detailed information at a high spatial resolution on the location of sand and dust storm source areas, estimate the soil loss and catalogue the relative importance of human activities in generating sand and dust storms in those areas. In this way, unsustainable land and water management can be superseded by sustainable equivalents.

There is a need to obtain and analyse more in-depth sensitivity and resilience data for most of the sectors assessed in this report. In the agriculture sector, data on the sensitivity of various plants and growth stages to both erosion and deposition need to be obtained and studied. In the energy sector, more detailed information on the types of solar powerplants and their installation need to be considered in order to have a more accurate estimation of energy loss. In the aviation sector, the sensitivity of various aircraft to erosion by dust needs to be considered. In information and communication technology (ICT), the sensitivity of various wireless technologies to dust particles and their chemistry needs to be studied.

There is a need for economic analyses of sand and dust storm disasters and calculations of average annual loss (AAL) using standardised methodologies for data collection and analysis. These analyses are required for all sectors in this report, but agriculture and human health should be regarded as priority sectors.

There is a need for a deeper understanding of certain aspects of sectors that are covered in this report. One important hazard to agriculture from sand and dust storms occurs in poorly managed agricultural areas that are subject to wind erosion, yet our appreciation of this issue is inadequate. In the human health sector, there is a critical need for studies into the links between atmospheric dust and health to be conducted in drylands.

There is a need for a deeper understanding of sectors not covered in this report. These include the risks associated with sand and dust storms on roads and rail lines, ICT, and on water quality, both surface water and groundwater. For instance, the railway system in Northwest China experiences serious delays as a result of sand and dust storms, however, the scope of this assessment did not allow for an in-depth review of this particular sector.

There is a need for further elaboration on the effect of climate change on sand and dust storm hazards in order to have a better understanding of the projection of sand and dust storm impacts as well as the trend of this phenomenon. Some of the risks may be reduced with climate change, in regions projected to experience a lower risk of drought for example, but others are likely to be enhanced, as in regions facing more extreme drought conditions. Other aspects of future climate, such as changes to wind speeds, heat waves and the seasonality of precipitation will also affect sand and dust storms. It is important to quantify these risks and identify regions that may become more susceptible to the risks in order to plan for appropriate risk management.

Sector-specific transboundary studies should be conducted in:

- Central Asia to obtain a clearer understanding of the impact of sand and dust storms in the agriculture and human health sectors;
- Southwest Asia to obtain a clearer understanding of the impact of sand and dust storms in the solar energy sector;
- Northeast Asia to obtain a clearer understanding of the impact of sand and dust storms in the human health sector;
- Third Pole countries (Afghanistan, Bangladesh, Bhutan, China, India, Nepal, Pakistan, and Tajikistan) to obtain a clearer understanding of the impact of sand and dust storms on water supply.

Impact-Based Monitoring and Early Warning

The current forecasting system provides sand and dust storm forecasts as the 'hazard' component of 'risk'. Translating hazard forecasting into required concrete actions for disaster risk reduction and management will be a time-consuming process that needs additional socioeconomic information on other components of risk, vulnerability and resilience.

Impact-based forecasting fills the gaps between forecasted hazards and response by estimating the damages that the forecasted hazard might cause in future, prior to their occurrence. Impact-based forecasts can be used by policymakers and actors in the planning, response, and recovery phases of the disaster risk reduction cycle.

This study has a sectoral risk assessment approach that can be used as the foundation of impact-based forecasts. However, to do so, the hazard layer needs to be replaced by a model-generated short-term forecast. This report highlights significant vulnerabilities and exposure especially in human health particularly in South Asia, in the aviation sector in the southwest and Central Asia, and the energy sector in the South, Southwest, and North-eastern Asia.

The transboundary nature of sand and dust storms which results in transboundary risk prompts us to plan and implement countermeasures with a transboundary approach. A regional/subregional impact-based forecast along with regional cooperation and action can significantly reduce the negative impact of sand and dust storms particularly in the human health, aviation, and energy sectors. This impact-based forecast can also reduce secondary risks, for example, flood and end-season droughts which might occur if glaciers in the same basin are exposed to sand and dust storms, particularly in the Himalayas-Hindu Kush Mountain range and the Tibetan Plateau.

Box 5-3: The Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) of the World Meteorological Organization (WMO)

The establishment of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) of the World Meteorological Organization (WMO) was proposed in 2006. In 2007, the 14th World Meteorological Congress endorsed the launching of the SDS-WAS project with its mission to enhance the ability of WMO Members to deliver timely and quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities.

The establishment of two of the SDS-WAS regional centres in China and Spain in support of the corresponding SDS-WAS nodes was welcomed in June 2008 at the 60th Executive Council of WMO (EC-LXI, 2008).

The major objective of SDS-WAS is to enhance the ability of countries to deliver timely, quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities.

The SDS-WAS project is realised under the WMO World Weather Research (WWRP) and Global Atmosphere Watch (GAW) Programmes and coordinated by the Steering Committee supported by the WMO Secretariat, (WMO, WWRP Report- No. 2015-5, 2015).

The WMO SDS-WAS, which is a global federation of partners organized around regional nodes, integrates research and user communities (e.g., health, climate, energy, transport, aeronautical, and agricultural users). Presently, there are three regional nodes:

- The Northern Africa-Middle East-Europe (NAMEE) Node (with its centre hosted by Spain in Barcelona);

- The Asian Node (with its Centre hosted by China in Beijing); and,

- The Pan-American Node (hosted by Barbados and the USA), coordinated globally by the SDS-WAS Steering Committee. And yet another node may be established for Western Asia.

The main objective of the SDS-WAS regional centres is to facilitate user access, particularly for national meteorological and hydrological services, to observational, assessment and forecast products, as well as to contribute to the enhancement of ca-pacity-building.

Through their various research activities information exchange through the corresponding web, portals are performed (WMO, GAW Report-No. 254, WWRP 2020-4, 2020). A federated approach allows flexibility, growth and evolution of activities while preserving the autonomy of individual institutions.

In addition to short-term (up to 1 week) impact-based forecast and assessments of SDS events (Figure 5-2), SDS-WAS is also providing annual and multi-year simulations and reanalysis on the global and regional level of SDS load for analysis of SDS long-term trends, risk assessments and mitigations (Figure 5-3).

Figure 5-2: Scheme of SDS-WAS regional center's impact-based SDS forecasting and early warning *

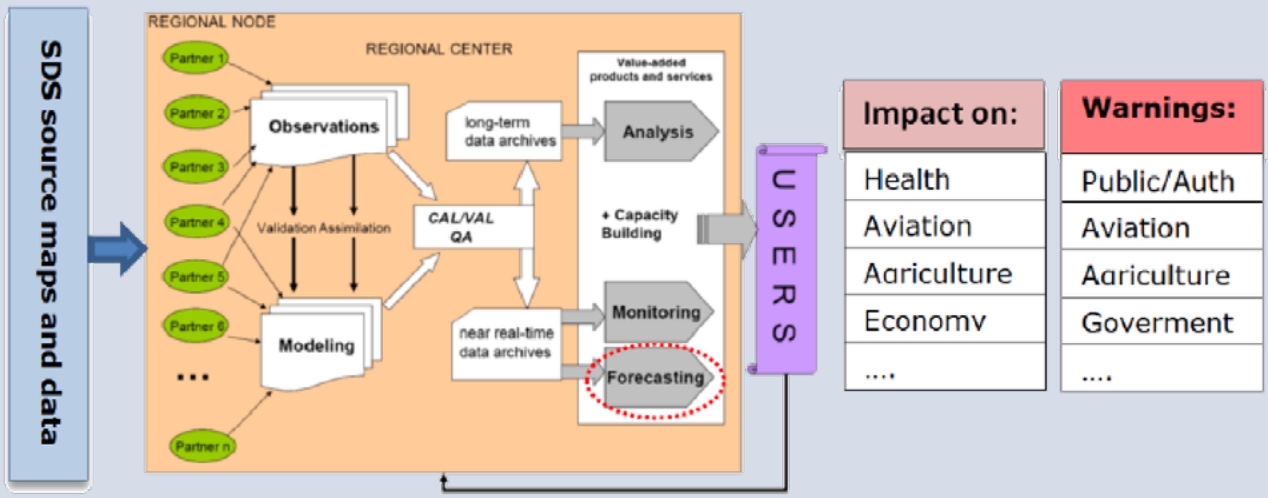
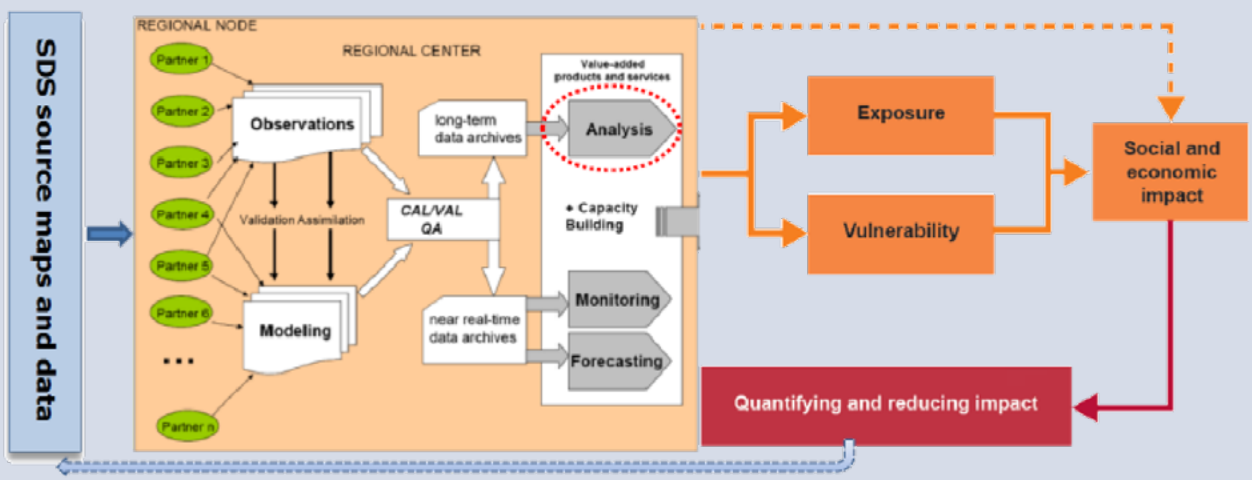


Figure 5-3: Scheme of SDS-WAS regional center's long-term SDS impact assessments **



* Source: https://public.wmo.int/en

** Source: https://public.wmo.int/en ; https://public.wmo.int/en/our-mandate/focus-areas/environment/SDS

General Assembly resolution 70/195 acknowledged the role of the UN system in promoting international cooperation to combat sand and dust storms.

Also, the Tehran Ministerial Declaration on Combating Sand and Dust Storms recognized the role of APDIM in developing human and institutional capacities in disaster information management.

Furthermore, ADPIM's first Governing Council suggested that APDIM can serve as a repository for a geospatial database on sand and dust storms in the ESCAP subregions.

Moreover, ESCAP, in the seventy-first session dated 2nd June 2015, requested the Executive Secretary to guide actions at the regional level through agreed regional and subregional strategies and mechanisms to strengthen disaster risk modelling, assessment, mapping, monitoring and multi-hazard early warning systems of common and transboundary disasters.

APDIM, as the subsidiary body of ESCAP which specializes in developing disaster information management, with the support of other UN entities, particularly WMO, and ESCAP divisions, is well placed to take this request forward and make this impact-based forecast a reality, in order to support the Member States to reduce the negative impact of sand and dust storms to various sectors.

The WMO SDS-WAS Regional Centers for Asia (hosted by CMA, Beijing, China) and for Northern Africa, Middle East and Europe (NAMEE, hosted by AEMET and BSC, Barcelona, Spain) lead the development and implementation in the regions of a comprehensive system for mineral dust observation and forecast, with special emphasis on extreme sand and dust events for early warning and impact-based forecasts (see Box 5-3 and WMO, 2015, 2020).

Coordinated Risk Management, Adaptation, and Mitigation

This report helps to address the priority of the Sendai Framework for Disaster Risk Reduction, which is to understand disaster risk. Understanding the risk of sand and dust storms to various sectors in the region is the foundation for strengthening disaster risk governance to manage disaster risk. It also helps to identify the sectors and geographical areas with the highest priority for investment in order to increase resilience and enhance disaster preparedness for effective response through inter-regional, regional, national and local action plans, so effectively promoting risk-informed development planning.

The transboundary nature of sand and dust storms requires regional action and inter-regional collaboration. This is why APDIM is working closely with ESCWA to geographically widen its understanding of the risk and apply it in the regional plan of action, and to help the Member States collaborate in more concrete ways. In this regard, APDIM is also contributing to the Central Asia DRR Strategy to ensure the risk of sand and dust storms is well understood and the required actions are considered.

Coordinated actions can include data sharing among source and impact regions, as well as coordination among countries that share risks in various sectors. Coordinated action can help to develop an effective action plan and develop a regional strategy on the actions needed for risk reduction, mitigation and prevention strategies in source and impact areas.

Today many forms of infrastructure are interlinked so that impacts on a sector in one area could subsequently impact other areas which might not be directly exposed to sand and dust storms. For instance, the transport and energy sectors are highly connected throughout the region and subregions, which means effects in one area can damage other areas by transferring goods and services, or by trading in energy.

Risk-informed development is another area in which coordinated action can be beneficial. Considering the risk of disasters in infrastructure development plans at national and regional scales helps the region as a whole to avoid unnecessary disaster costs.

This report highlights the subregions and sectors with shared risks and proposes coordinated actions to reduce those risks. Countries in subregions with sectors of common interest are:

South and South-West Asia (particularly India and Pakistan) where there is a very high risk of sand and dust storms impacting human health. Developing an impact-based forecast system to provide warnings in these countries can significantly reduce the exposure of people in the subregion, so reducing the risks they face.

South and Southwest Asia, and East and North-East Asia (particularly China, India and Pakistan) where impacts on the generation of electricity by solar power plants entail national economic costs > USD100m a year. Coordinated action among these countries can improve understanding of the risks to solar electricity generation. Associated deeper understanding is also needed in countries with considerable rural populations generating solar electricity off-grid (e.g., China, India, Mongolia).

East and North-East Asia, North and Central Asia, and South and South-West Asia (particularly Afghanistan, China, India, Islamic Republic of Iran, Pakistan, Turkmenistan and Uzbekistan) where dust is a common hazard to aviation. Coordinated action among these countries can improve understanding of the risks to airports and aircraft.

South and South-West Asia, and North and Central Asia (particularly Pakistan, Turkmenistan and Uzbekistan) where large farmland areas are affected by the deposition of dust with high salt content. Coordinated action among these countries can improve understanding of the risks to the production of irrigated cotton and other crops.

Third Pole countries of **South and South-West Asia, East and North-East Asia, and North and Central Asia** (Afghanistan, Bangladesh, Bhutan, China, India, Nepal, Pakistan and Tajikistan) where dust on glaciers affects water supply in adjacent lowland areas. Coordinated action among these countries can help to reduce the negative impact of secondary disasters including drought and floods.

East and North-East Asia, North and Central Asia, and South and South-West Asia cities with high exposure to poor air quality due to sand and dust storms. Developing an impact-based forecast system to provide warnings in these numerous cities, through UNDRR's Making Cities Resilient 2030 (MCR2030) initiative, can significantly reduce the exposure of urban residents, so reducing the risks they face.

Annex

UN Resolutions Related to Sand and Dust Storms, Regional Cooperation and Disaster Risk Assessment

Resolution adopted by ESCAP Commisssion on the establishment of APDIM, E/ESCAP/RES/71/11, 2015:

Date: 2 June 2015

Description:

- Providing Information support and analytical works on hazard, vulnerability, exposure and risk assessment at the regional/subregional levels is among APDIM products and services.
- APDIM is to apply a multi-hazard approach in its planning and activities with a focus on earthquakes, tsunamis, floods, cyclones/typhoons and drought as the main hazards of the region.
- The main objective of the Center is to reduce risks, losses and damages resulting from natural hazards by developing the capacities and capabilities of the countries and organizations in the region and strengthening regional cooperation on information sharing and management of disaster risk reduction. The Center would also commence its functions and programmes with a focus on the more vulnerable subregions of Asia and the Pacific.

Keywords: Risk Assessment, APDIM, Asia-Pacific

Resolution adopted by ESCAP Commisssion on implementation of the Sendai Framework 2015-2013, E/ESCAP/RES/71/12, 2015

Date: 2 June 2015

Description:

- Requested the Executive Secretary to guide actions at the regional level through agreed regional and subregional strategies and mechanisms to strengthen disaster risk modelling, assessment, mapping, monitoring and multi-hazard early warning systems of common and transboundary disasters.

Keywords: SDS, Regional Cooperation, Risk Assessment, Disaster Risk

Resolution adopted by the General Assembly on Combating sand and dust storms, A/RES/70/195, 2016:

Date: 6 February 2016

Description:

- Recalled the Sendai Declaration and the Sendai Framework for Disaster Risk Reduction 2015–2030, adopted at the Third United Nations World Conference on Disaster Risk Reduction and endorsed by the General Assembly in its resolution 69/283 of 3 June 2015, and recognized that one of the priorities for action of the Framework is an understanding of disaster risk for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters, which continue to undermine efforts to achieve sustainable development.
- Acknowledged that, based on the notion of hazards as defined in the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters, 1 addressing multidimensional hazards, including those posed by SDS, contributes towards the achievement of goals, targets and priorities for action set out in the Sendai Framework for Disaster Risk Reduction 2015–2030.
- Emphasized the relevance of the efforts and cooperation of Member States at regional and international levels to control and reduce the negative impacts of SDS on human settlements in vulnerable regions.
- Stressed the need for cooperation at global and regional levels with a view to preventing and managing SDS through the development of early warning systems and the sharing of climate and weather information to forecast SDS, and affirming that resilient action to combat SDS requires a better understanding of the severe multidimensional impacts of SDS, including the deterioration of the health, well-being and livelihood of people, increased desertification and land degradation, deforestation, loss of biodiversity and land productivity, and their impact on sustainable economic growth.
- Recognized that SDS, and the unsustainable land management practices, among other factors, that can cause or exacerbate these phenomena, pose a great challenge to the sustainable development of affected countries and regions, also recognized that, in the past few years, SDS have inflicted substantial socioeconomic damage on the inhabitants of the world's arid, semi-arid and dry sub-humid areas, especially in Africa and Asia, and underscores the need to treat them and to promptly undertake measures to address these challenges.
- Encouraged regional, subregional and interregional organizations and all other related organizations to continue to address this problem and contribute to the enhancement of capacity-building, the implementation of regional and subregional projects, the sharing of information, best practices and experiences and the boosting of technical cooperation in the affected countries and countries of origin, to improve the implementation of sustainable land management practices and the development of early warning systems as tools to combat SDS in accordance with their strategic plans. Also, to promote regional cooperation on this matter.

Keywords: SDS, SDG, DRR, Disaster Risk, Regional Cooperation

Resolution adopted by ESCAP Commission on Regional cooperation to combat sand and dust storms, E/ESCAP/RES/72/7, 2016:

Date: 24 May 2016

Description:

- Noted with concern that the frequency and intensity of SDS have increased in the past three decades and posed a great challenge to the sustainable development of affected countries and that they have adverse impacts on infrastructure, transport and communications and human health.
- Recognized that SDS are a challenging problem for affected countries, with transboundary impacts that are being frequently experienced in Asia and other regions with serious consequences, that require institutional and technical interventions.
- Invited Member States to enhance their cooperation towards enhancement of necessary tools, projects and mechanisms aimed at facilitating needed measures, such as forecasting the likelihood of damaging sand- and dust-related events, data collection and knowledge-sharing, setting up monitoring systems and mitigating the adverse impacts of this phenomenon on the health of people, in particular people living on frontiers and in rural areas, in collaboration with related international, regional and subregional entities, including United Nations regional commissions, within their respective mandates and expertise;
- Requests the Executive Secretary to Work through APDIM, as well as with other relevant regional organizations, utilizing a combination of existing funds and extrabudgetary contributions, to promote regional and interregional networking on SDS.

Keywords: SDS, SDG, APDIM, Regional Cooperation

Resolution adopted by the General Assembly on Combating sand and dust storms, A/RES/71/219, 2017:

Date: 3 February 2017

Description:

- Emphasized the relevance of the efforts and cooperation of Member States at regional and international levels to control and reduce the negative impacts of SDS on human settlements in vulnerable regions.
- Stressed the need for cooperation at global and regional levels with a view to managing and mitigating the effects of SDS through enhancing early warning systems and the sharing of climate and weather information to forecast SDS, and affirming that resilient action to combat SDS requires a better understanding of the severe multidimensional impacts of SDS, including the deterioration of the health, well-being and livelihood of people, increased desertification and land degradation, deforestation, loss of biodiversity and land productivity, and their impact on sustainable economic growth.
- Acknowledged the role of the United Nations system in advancing international cooperation and support to combat SDS, and invites all relevant bodies, agencies, funds and programmes of the United Nations system, and all other related organizations to integrate, in their respective cooperation frameworks, operational programmes, measures and actions aimed at combating SDS so as to address this problem and contribute to the enhancement of, inter alia, capacity-building at the national level, the implementation of regional and subregional projects, the sharing of information, best practices and experiences and the boosting of technical cooperation in affected countries and countries of origin and to promote regional cooperation in this matter in accordance with their strategic plans.

Keywords: SDS, SDG, Regional Cooperation

Resolution adopted by ESCAP on implementation of Sendai Framework for DRR 2015-2030, E/ESCAP/RES/73/7, 2017:

Date: 23 May 2017

Description:

- Requested the Executive Secretary to continue to support and facilitate multi-hazard early warning systems, impact-based forecasting and disaster risk assessment to strengthen regional cooperation mechanisms.

Keywords: Risk Assessment, Regional Cooperation

Resolution adopted by the General Assembly on combating sand and dust storms, A/RES/72/225, 2018:

Date: 25 January 2018

Description:

- Invited the Executive Director of UNEP to consider initiating an inter-agency process involving relevant entities of the United Nations system, within their respective mandates and existing resources, and taking into account United Nations resolutions and decisions, to prepare a global response to SDS, including situation analysis, a strategy and an action plan, which could result in the development of a United Nations system-wide approach to addressing SDS and which can be used as an inter-agency framework for medium- or long-term cooperation and division.
- Encouraged regional, subregional and interregional organizations and processes to continue to share best practices, experiences and technical expertise in combating SDS to address the root causes and impacts of SDS, including through improved implementation of sustainable land and management practices, and to promote regional cooperation in this matter to reduce the risks and impact of future SDS and to provide affected countries with capacity-building and technical support from the relevant United Nations organizations.
- Encouraged the relevant entities of the United Nations and donors to provide capacity-building and technical assistance for combating SDS and to support the implementation of the national, regional and global action plans of the affected countries.

- Recognized that given the shorter time frame for achieving target (e) of the Sendai Framework by 2020, the scale of action needed for the development of national and local disaster risk reduction strategies, and thus encouraged States to continue to prioritize and support the development of inclusive national and local disaster risk reduction strategies, promoting synergies with existing national policies and plans, including national climate change adaptation plans, where relevant, and to establish and strengthen national disaster loss databases, risk profiles and available capacities, as well as the conduct of risk assessments, and reaffirms the need for the enhancement of the implementation capacity and capability of developing countries.

Keywords: SDS, Regional Cooperation, Risk Assessment, SDG, DRR

Resolution adopted by the General Assembly on disaster risk reduction, A/RES/73/231, 2019:

Date: 17 January 2019

Description:

- Urged States to prioritize the establishment and strengthening of national disaster loss databases and to conduct disaster risk assessments so as to develop inclusive and multi-hazard risk assessments that consider climate change projections to support evidence-based disaster risk reduction strategies and guide risk-informed development investments by the private and public sectors.

Keywords: Disaster Risk, Risk Assessment, DRR

Resolution adopted by the General Assembly on combating sand and dust storms, A/RES/74/226, 2020"

Date: 21 January 2020

Description:

• Welcomed the creation of the United Nations Coalition on Combating Sand and Dust Storms, which aims, inter alia, to promote and coordinate a collaborative United Nations system response to the growing issue of SDS on a local, regional and global scale, ensuring that unified and coherent action is taken, and to facilitate the capacity-building of Member States, raise their awareness and enhance their preparedness and response to SDS in critical regions.

Keywords: SDS, Regional Cooperation

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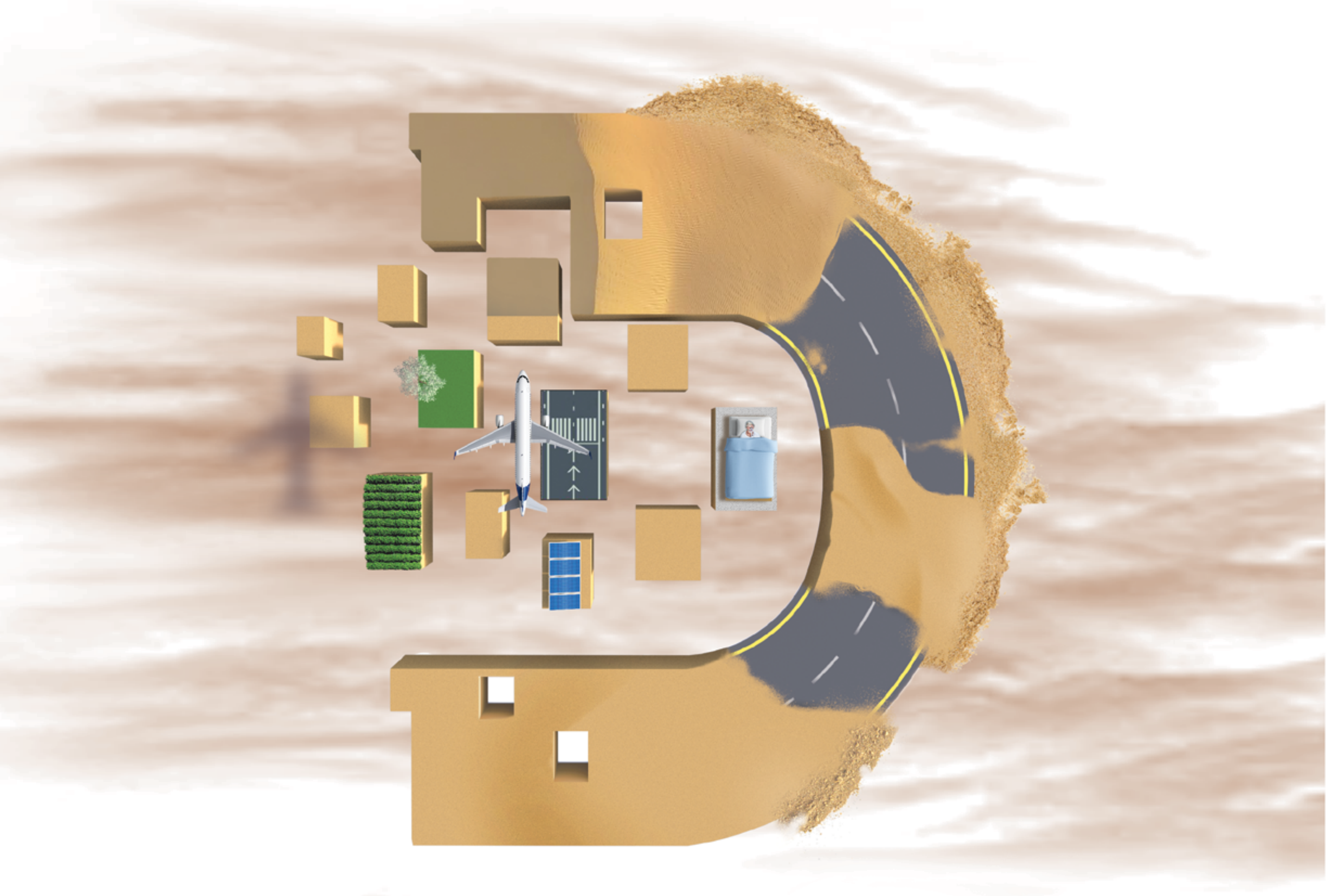

The Sand and Dust Storms Risk Assessment in Asia and the Pacific provides a long-term horizon of the risk and potential socio-economic losses associated with sand and dust storms in the region for a better understanding of the severe multidimensional impact of this hazard, including the deterioration to human health, in urban and rural settings, and its adverse impact on energy, transport, agriculture and environment sectors with a regional and transboundary perspective. The report makes the case that there is an urgent need for countries in the region to consider joint action towards a deeper understanding of the socio-economic impact of sand and dust storms; towards a coordinated monitoring and early warning system, with an impact-based focus, to timely forecast the impact of sand and dust storms and enable targeted measures to minimize exposure and reduce risks as well as towards coordinated actions in most at-risk and exposed geographical areas to mitigate the risks. This report can serve as the evidence base on which to build a coordinated plan for action at regional level.

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