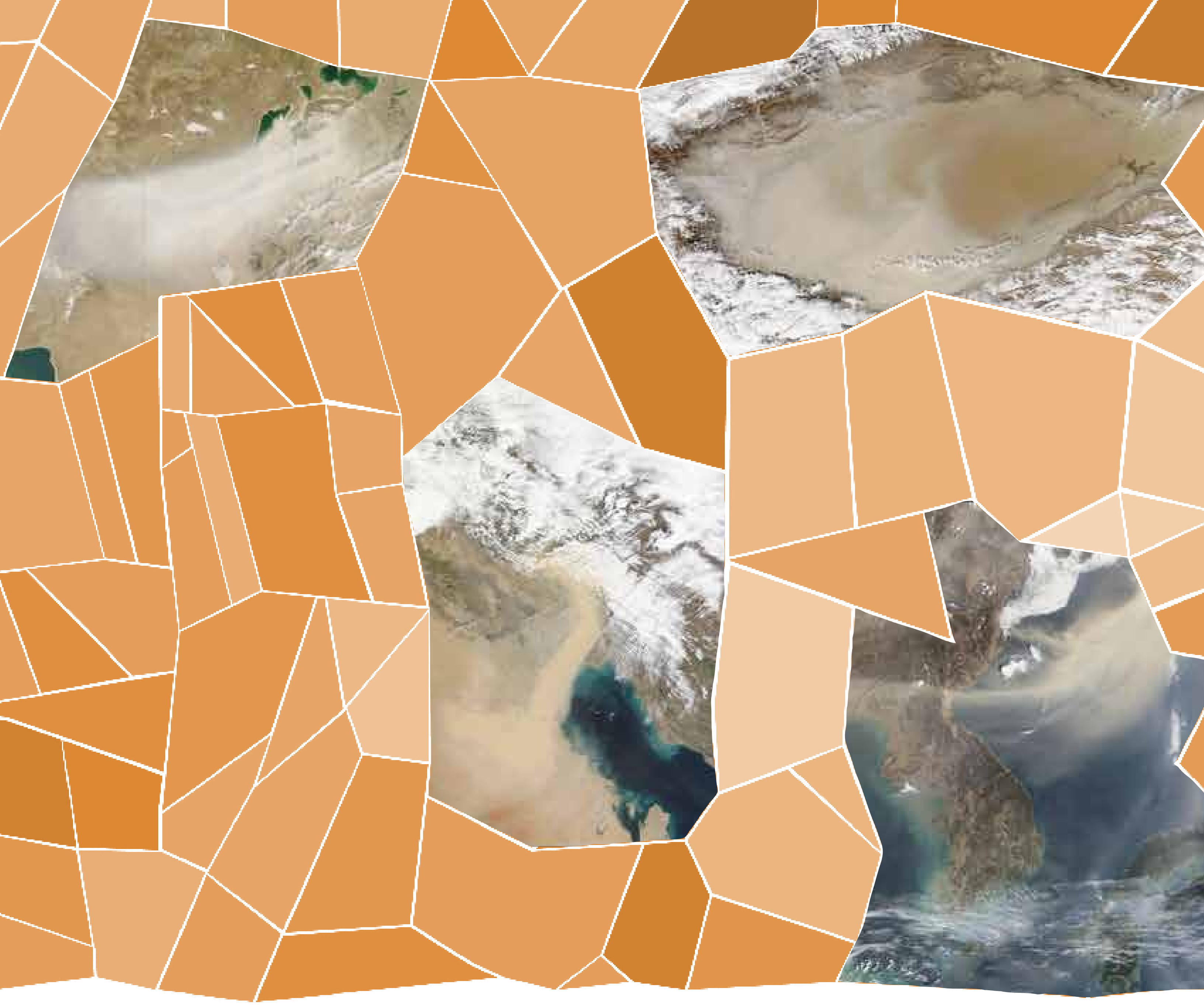

Sand and Dust Storms in Asia and the Pacific:

Opportunities for Regional Cooperation and Action

UNITED NATIONS
ESCAP
Economic and Social Commission for 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) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 Member States and 9 Associate Members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

The ESCAP office is located in Bangkok, Thailand. Please visit the ESCAP website at www.unescap.org for further information.

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Sand and Dust Storms in Asia and the Pacific:
Opportunities for Regional Cooperation and Action

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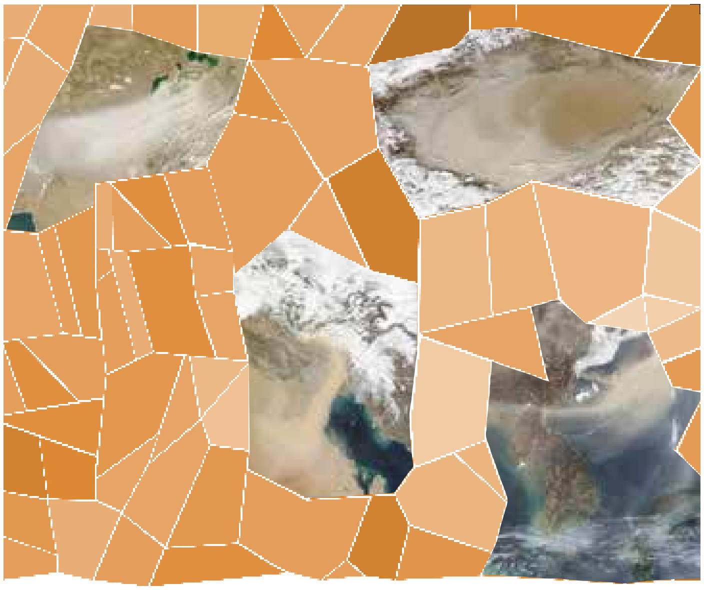

About the cover

The polygon represents drought and desertification as key drivers of sand and dust storms. Earth observation satellite captures the source and impacted regions of sand and dust storms in Asia and the Pacific.

FOREWORD

There is growing alarm over the increasing frequency and intensity of sand and dust storms and their negative repercussions on the economic, social and environmental dimensions of sustainable development in arid and semi-arid regions.

This is a global phenomenon, stretching from the Sahara Desert and the Middle East to the Great Indian Desert and the mid-latitude deserts of Central Asia, China and Mongolia. Dry-land areas cover over 40 per cent of the Earth's land surface and include some of the most fragile ecosystems, highly susceptible to the impacts of climate change. A sizable portion of the impacted area lies in the Asia-Pacific region.

This report-*Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action*-offers perspectives to enhance the science-based understanding of the phenomenon among policymakers. It supports the development of adaptation and mitigation policies at the regional and national levels. The Report presents an in-depth diagnosis of sand and dust storm events using earth-observation satellite images. It analyses potential drivers, points to the risk in problem areas and identifies gaps in information, cooperation and policy capacity.

The report highlights the vulnerability countries share across wide expanses of the Asia-Pacific due to the nature of these storms. They can blow for thousands of kilometres across national borders. The geospatial nature of the storms necessitates information sharing and dialogue to arrive at risk-informed and climate sensitive policy interventions. Considering the borderless nature of these disasters, multi-country coordinated policy actions are imperative. Such policies are already making positive impacts in some countries. In China, an ecological restoration programme from 2001 to 2013 reduced the risk of sand and dust storms by up to 15 per cent in the North China Plain. In Mongolia, customized drought monitoring tools developed through cooperation under ESCAP's drought monitoring mechanism have increased timely risk-mitigating actions.

The report underlines the need to address sand and dust storms through a multi-hazard risk assessment and alert system for slow-onset disasters. In accordance with the guidance received from the Governing Council of ESCAP's Asia-Pacific Centre for Development of Disaster Information Management, this system will be developed and supported by a network of experts, with an initial focus on the sand and dust storm belts of South-West and Central Asia before gradually expanding farther afield. The ultimate aim is to achieve regional cooperation and partnerships that observe, predict, mitigate and cope with the increasingly costly impacts on societal well-being from sand and dust storms.

Shamshad Akhtar

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

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The core team of authors was led by Sanjay Srivastava, Chief, Disaster Risk Reduction Section, IDD, and comprised Amin Shamseddini, Michelle Kathryn Blade, Kareff Rafisura, Madhurima Sarkar-Swaisgood, Syed Ahmed, Sung Eun Kim and Ingrid Dispert.

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EXECUTIVE SUMMARY

Sand and dust storms present a formidable challenge to sustainable development, particularly in arid and semi-arid regions. Globally, more than 150 countries are affected directly by such storms, with 45 countries classified as sand and dust storm source areas. Approximately 2 billion tonnes of dust are emitted into the atmosphere each year, with the Asia-Pacific region contributing 27 per cent of those emissions. The impacts are large scale and affect a range of Sustainable Development Goals (SDGs) related to human health, productivity, agriculture and infrastructure (transport). Reducing the harmful impacts of sand and dust storms will be an important component for the success of multiple SDGs.

Most sand and dust storms originate in arid, semi-arid and dry sub-humid areas. Their impacts, however, are frequently felt far beyond those dry lands due to the propensity of dust to be transported over long distances. The risk belts that comprise source and impacted regions stretch from the tropical and subtropical deserts of the Sahara through the Middle East to the Great Indian Desert and the mid-latitude deserts of Central Asia, China and Mongolia. With such wide transboundary impacts, managing the sand and dust storm risks requires both global and regional cooperation.

This report, ***Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action***, promotes greater scientific assessment and science-based policymaking that leads to regional action. The key points of the report include:

Risk of sand and dust storms in the Asia-Pacific region

Worldwide, more than 2 billion tonnes of dust are emitted every year. The Asia-Pacific region is the second-largest in terms of dust emissions, contributing more than half a billion tonnes per year. Impacted areas are disproportionately large and include East, North-East, South, South-West and Central Asia and the Pacific. Because of their unique origin, geographical coverage and cross-sector links, sand and dust storms are characterized as extensive and intensive risks, both of which cause severe short- as well as long-term impacts and can affect progress towards many of the SDGs. In terms of economic impact, sand and dust storm events cost up to an estimated $5.6 billion annually in the Asia-Pacific region. While East and North-East Asia are better prepared to address the shared vulnerability to sand and dust storms, South, South-West and Central Asia are increasingly exposed and vulnerable.

Of particular concern is how these sand and dust storms can negatively affect the progress to be made or already made on at least eleven 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), 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) and partnerships for the goals (SDG 17).

Drivers of the risk

The drivers of sand and dust storms encompass land degradation, desertification and climate change, exacerbated by unsustainable land and water use, extreme wind events, greater aridity in some areas and more frequent and severe drought with extended duration. Droughts, typically associated with vegetation decline and drier soil, frequently result in greater sand and dust storm activity. The regional climate variables, such as higher air temperature, less precipitation and stronger winds, help drive the formation of dust storms. Natural sources, such as topographic depressions in arid regions (mainly dry ancient lake beds with little vegetation cover), contribute 75 per cent of the current global dust emissions. Anthropogenic sources, such as land use changes, agriculture, water diversion and deforestation, contribute up to the remaining 25 per cent.

Changing climate conditions are exacerbating the risk of sand and dust storm. The 2030 climate scenarios show an alarming geographical shift in drought risk and other slow-onset disasters. In South Asia, there is a westward shift, while in South-East Asia the shift is eastwards. Sand and dust storms, along with drought, land degradation, desertification and wind erosion, are expanding in South-West Asia and present new formidable challenges to sustainable development. In the specific contexts of South, South-West and Central Asia, the likely influence of climate change on future sand and dust storms is quite significant. Future levels or incidence of temperature, precipitation, evaporation, drought and humidity are expected to mostly increase in South, South-West and Central Asia. Wind speed is expected to increase mostly in South and South-West Asia. Soil moisture is expected to decrease in all three regions. As temperatures and drought occurrence increase, reduced soil moisture will greatly contribute towards increasing the intensity and frequency of sand and dust storms in all three regions.

This climate shift is resulting in areas where climate change-related sand and dust storms coincide with a high concentration of vulnerable, poor or marginalized people. As these hotspots expand, socioeconomic inequalities will widen over larger geographical areas. In the Islamic Republic of Iran, for example, the Sistan Basin has a high level of poverty and multiple episodes of sand and dust storms. These storms exacerbate the poverty and endanger the livelihoods of those who have the least means to cope.

The need for science, policy and action

Combating sand and dust storms in source and impact areas requires science-based national, regional and international cooperation and partnerships to observe, predict, mitigate and cope with the adverse effects of sand and dust storms. A periodic scientific assessment of the transboundary multi-hazard risks related to sand and dust storms help policymakers understand and diagnose their complexity and the dynamics needed to support policy actions. For example, according to various mapping exercises, the co-existence of drought, desertification, land degradation and sand and dust storms is explicit in certain pockets of arid and semi-arid subregions. The Earth-observation satellite-based Normalized Difference Vegetation Index and the Aerosol Index are used to understand the geography of those four slow-onset disasters and to identify potential risk hotspots as well as real-time risk assessment and monitoring. Time-series analysis of Earth-observation data helps in understanding the risk accumulation that leads to sand and dust storms. Analysis of Earth-observation data from 1998 to 2014 of the hypersaline Lake Urmia in the north-western area of the Islamic Republic of Iran, for instance, revealed a 90 per cent loss of surface area, which resulted in desertification, sand dunes and, consequently, sand and dust storms. A science-based understanding of the storm dynamics across the source and impacted areas is the key enabler for policy action.

It is important to analyse the cause-and-effect relationships of the sand and dust storm components to develop appropriate and science-based policy actions. Such analysis would identify drought, land degradation (wind erosion), desertification and the potential for sand and dust storms, as well as changes in vegetation cover and condition, land-use and land-cover status and changes in agricultural productivity. In addition to satellite image analyses, land surface-based observations capture these indicators. The Earth-observation satellite-based Normalized Difference Dust Index for determining visibility (which is an indicator of sand and dust storms) is a good tool for monitoring and for impact assessments.

Interventions at sand and dust sources and impacted regions need to be scientifically analysed, based on monitorable indicators. For example, sand and dust storm sources in China are thousands of kilometres away from the impacted regions. But data from those affected areas led to policy interventions that reflect the geospatial link between the source and impacted regions and have had positive impact on both adaptation as well as mitigation aspects. An ecological restoration programme, for instance, has reduced the frequency of sand and dust storms by 5 per cent to 15 per cent in the North China Plain. Quite often, sand and dust storm sources and impacted regions are transboundary in nature, which thus requires dialogue and cooperation among the affected countries to generate appropriate policy interventions.

Gaps in information and knowledge

Combating sand and dust storms requires accelerated action and relevant capacity in multiple-hazard risk reduction for both adaptation and mitigation. But first there is urgent need to overcome the gaps in information and knowledge by connecting science, policy and actions.

Information-Although there have been several assessments of desert dust sources using data from satellite-borne sensors and terrestrial meteorological stations, significant gaps remain in the information supply chain at the local, national and regional levels. Information on sand and dust storms is mostly sparse or incomplete and dispersed. The information is often generic and not actionable in terms of sand and dust storm adaptation and mitigation. The scale of sand and dust storm risk information is vast and varies from the regional to national to local levels. And not enough assessments have been undertaken on the impact of such storms at the national and transboundary levels.

Cooperation-There is a need to deepen cooperation between countries that are sand and dust storm sources (hotspots) and the affected areas at the regional as well as interregional levels to bring about synergy and coherence of all adaptation and mitigation initiatives.

Capacity-Managing sand and dust storm risk requires substantial capacity for risk reduction, adaptation and mitigation action. The capacity of countries exposed to sand and dust storms, particularly in South and South-West Asia as well as in North and Central Asia, needs to be enhanced substantially and guided by well-informed risk-sensitive plans of action.

Regional cooperation

A regional cooperation mechanism could tackle the gaps and thus more aggressively combat sand and dust storms. This mechanism would align with the Sendai Framework for Disaster Risk Reduction 2015–2030 and Regional Road Map for Implementing the 2030 Agenda for Sustainable Development in Asia and the Pacific. It would entail regular scientific assessments of the multi-hazard and transboundary nature of these storms. Such a mechanism could also facilitate risk governance through a regional platform of stakeholders, promote resilience by way of adaptation and mitigation measures and help strengthen response preparedness with a better understanding of the impacts. The ESCAP programme to strengthen regional cooperation for disaster risk reduction and resilience provides the foundation for this work. The regional cooperation mechanism that ESCAP is working to establish, based on the ESCAP resolution 72/7, offers a platform for regular dialogue and collective action among experts and other stakeholders to reinforce adaptation and mitigation responses to sand and dust storms.

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Analyses in ***Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action*** are based on data and information available to the end of 2017.

The Asia-Pacific region, unless otherwise specified, refers to the group of ESCAP members and associate members that are within that geographic boundary. Groupings of countries and territories and areas referred to in 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; Fiji; French Polynesia; Georgia; Guam; Hong Kong, China; India; Indonesia; Islamic Republic of Iran; Japan; Kazakhstan; Kiribati; Kyrgyzstan; Lao People's Democratic Republic; Macao, China; Malaysia; Maldives; Marshall Islands; Federated States of Micronesia; Mongolia; Myanmar; Nauru; Nepal; New Caledonia; New Zealand; Niue; Northern Mariana Islands; Pakistan; Palau; Papua New Guinea; Philippines; Republic of Korea; Russian Federation; Samoa; Singapore; Solomon Islands; Sri Lanka; Tajikistan; Thailand; Timor-Leste; Tonga; Turkey; Turkmenistan; Tuvalu; 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; Federated States of Micronesia; 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; Islamic Republic of Iran; 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:** Cook Islands; Fiji; Kiribati; Maldives; Marshall Islands; Federated States of Micronesia; Nauru; Niue; Palau; Papua New Guinea; Samoa; Solomon Islands; Timor-Leste; Tonga; Tuvalu; and Vanuatu

ECONOMIC CLASSIFICATIONS AND GROUPINGS

The classification of countries into income groups is from the World Bank. The World Bank divides countries according to their 2015 gross national income per capita, calculated using the World Bank Atlas method. Group classifications are: low income ($1,025 or less per capita), lower-middle income ($1,026- $4,035 per capita), upper-middle income ($4,036-$12,475 per capita) and high income ($12,476 or more per capita).

- **Low-income economies:** Afghanistan; Democratic People's Republic of Korea; Nepal.
- **Lower middle-income economies:** Armenia; Bangladesh; Bhutan; Cambodia; India; Indonesia; Kiribati; Kyrgyzstan; Lao People's Democratic Republic; Federated States of Micronesia; Mongolia; Myanmar; Pakistan; Papua New Guinea; Philippines; Samoa; Solomon Islands; Sri Lanka; Tajikistan; Timor-Leste; Tonga, Uzbekistan; Vanuatu; and Viet Nam
- **Upper-middle-income economies:** American Samoa; Azerbaijan; China; Fiji; Georgia; Iran (Islamic Republic of); Kazakhstan; Malaysia; Maldives; Marshall Islands; Palau; Russian Federation; Thailand; Turkey; Turkmenistan; and Tuvalu

- **High-income economies:** Australia; Brunei Darussalam; French Polynesia; Guam; Hong Kong, China; Japan; Macao, China; Nauru; New Caledonia; New Zealand; Northern Mariana Islands; Republic of Korea; and Singapore

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References to dollars ($) are to United States dollars, unless otherwise stated.

The term “billion” signifies a thousand million. The term “trillion” signifies a million million.

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, an en dash (–) 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.

ABBREVIATIONS

APDIM	Asian and Pacific Centre for the Development of Disaster Information Management
APDRN	Asia-Pacific Disaster Resilience Network
AUD	Australian dollars
BTD	brightness temperature difference
CUACE/Dust	Chinese Unified Atmospheric Chemistry Environment for Dust
DPSIR	driving forces, pressures, states, impacts and responses framework
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
IPCC	Intergovernmental Panel on Climate Change
MODIS	Moderate Resolution Imaging Spectroradiometer
Mt	megatonnes
NASA	National Aeronautics and Space Administration
NDDI	Normalized Difference Dust Index
NDVI	Normalized Difference Vegetation Index
PMC	particulate matter and mass concentration
RCP	representative concentration pathways
SDGs	Sustainable Development Goals
SDS	sand and dust storms
SDS-WAS	Sand and Dust Storms Warning Advisory and Assessment System
SRES	Special Report on Emissions Scenarios
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
WCRP-CMIP3	World Climate Research Programme's Coupled Model Intercomparison Project phase 3
WMO	World Meteorological Organization


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1

SAND AND DUST STORMS: A TRANSBOUNDARY HAZARD

1. SAND AND DUST STORMS: A TRANSBOUNDARY HAZARD

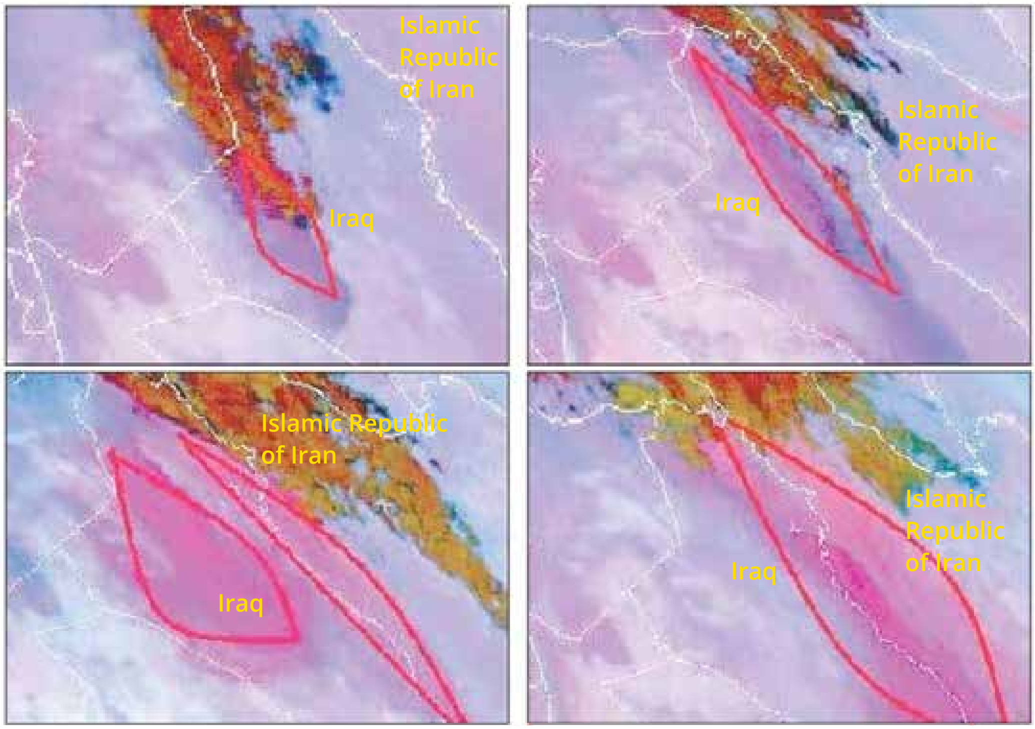
A sand and dust storm is a meteorological phenomenon, mostly originating in arid and semi-arid regions. Each year, more than an estimated 2 billion tonnes of arid soil moves great distances through the Earth's atmosphere in these storms (Perkins, 2001), with adverse impacts on human health, the environment and economies.

Sand and dust storms occur when strong, turbulent winds combine with exposed loose soil on dry earth surfaces–conditions that are common in arid and semi-arid regions. Most global dust emissions derive from natural sources, such as hyper-arid regions, topographic depressions in arid areas and dry ancient lake beds with little vegetation cover. Due to the wind-erodible nature of their surface material, exacerbated by dry conditions and limited vegetation, inland drainage basins in arid areas dominate the range of typical dust sources (UNEP, WMO and UNCCD, 2016).

Dust generally originates from a small geographical area before spreading to cover vast and transboundary regions. Figure 1.2 highlights the formation, expansion and movement of sand and dust storms. When sand and dust storms spread out from their source, they tend to hover close to the ground surface and thus do not travel too far. However, fine dust particles may be lifted kilometres high into the atmosphere, where strong winds transport them long distances, even across continents. At such heights, dust particles can fly thousands of kilometres–depending on their size and wind speed, passing beyond political as well as hydrological boundaries. The duration of sand and dust storm events varies, from a few hours to several days. Their intensity is commonly manifested in terms of the atmospheric concentration of particles and the resultant reduction in visibility.

Figure 1.1

Origin and expansion of a sand and dust storm beyond national boundary – from Iraq into the Islamic Republic of Iran on 15–17 June 2016



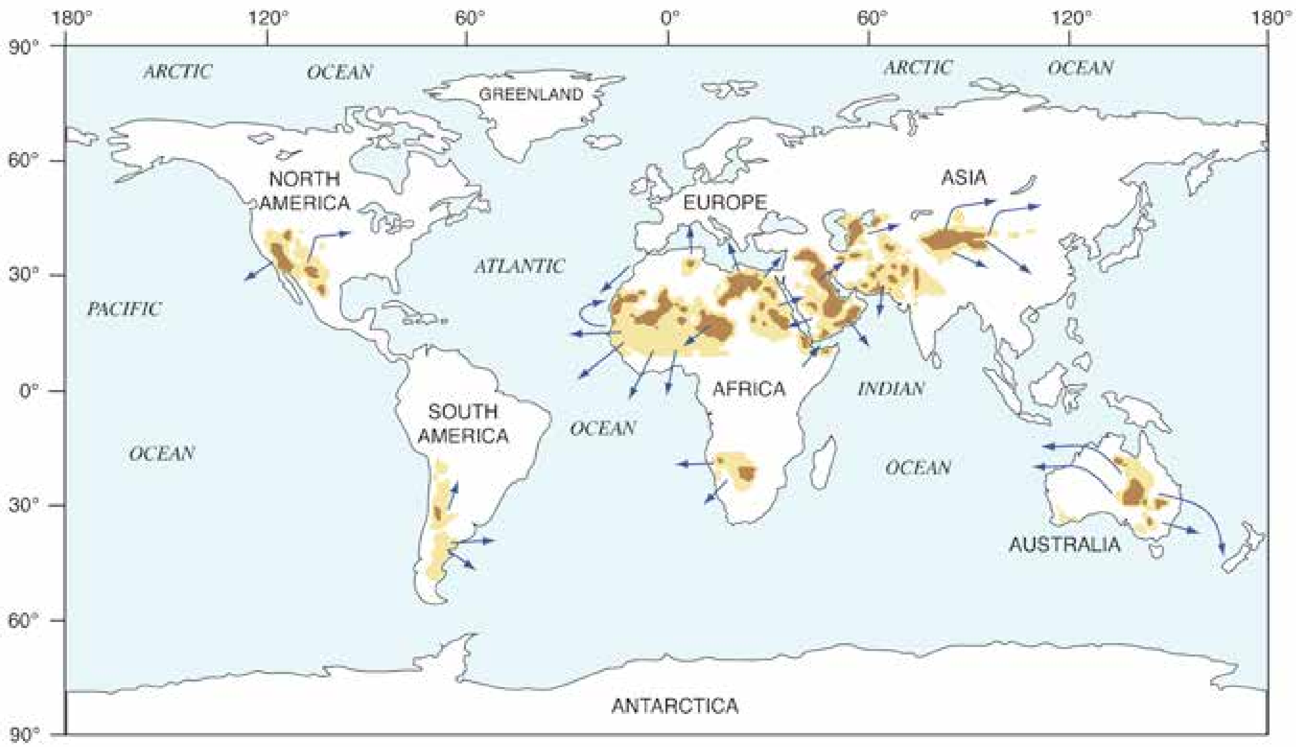
Source: Iran (newspaper), 30 June 2016.

Global and regional dimensions

Globally, the two most important dust source areas are in the Sahara Desert: the Bodélé depression in Chad and an area in the south-western region that encompasses Mali, Mauritania and Algeria. In addition, the Arabian Peninsula, Central Asia, desert basins in China and in central and south-eastern Australia, the Mojave Desert, the Sonoran Desert, the Chihuahuan Desert, the Great Plains region of western North America and the Pampas and Patagonian regions of southern South America (see figure 1.2) have been major dust sources over the past two decades (Muhs and others, 2014).

Figure 1.2

Map of global dust sources and typical dust transport pathways

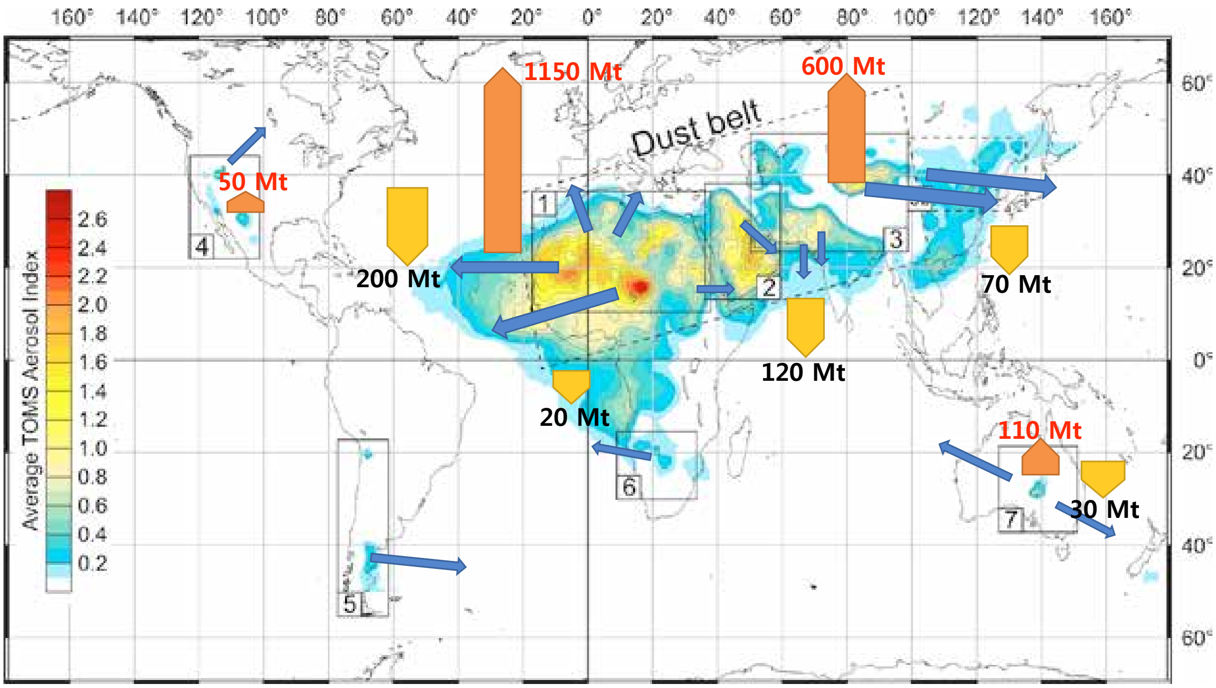


Source: Muhs and others, 2014.

Figure 1.3 depicts both, the global dust transport pathways and the pattern of dust emissions from numerous sources of wind-blown surface material. The main routes of desert dust transport (light blue arrows) and location of the major dust sources are: (i) Sahara Desert; (ii) Arabian Peninsula; (iii) Asia; (iv) North America; (v) South America; and (vi) Southern Africa. The orange arrows indicate dust emissions from different regions, in megatonnes (Mt), and the blue arrows indicate deposition to the oceans (also in Mt). The dust belts include North and East Asia, South and South-West Asia and Central Asia (Middleton and Kang, 2017).

Figure 1.3

Main routes of desert transport and locations of major dust sources, based on the daily measured Total Ozone Mapping Spectrometer Aerosol Index values, 1979–2011



Abbreviations: TOMS = Total Ozone Mapping Spectrometer Aerosol; Mt = megatonnes.
Source: Middleton and Kang, 2017; modified from Varga, 2012; Shao and others, 2011.

A total of 151 countries (77 per cent of all parties to the United Nations Convention to Combat Desertification) are generally affected directly by sand and dust storms. Of them, 45 countries (23 per cent of all parties) are classified as sand and dust storm source areas, 44 countries (22 per cent of all parties) are sand and dust storm deposition areas, and 62 countries (32 per cent of all parties) are affected by wind erosion. Most of the countries classified as source areas (38 of 45 countries, or 84 per cent of the source-area parties) are in Africa and Asia (see figures 1.3 and 1.4) (Middleton and Kang, 2017).

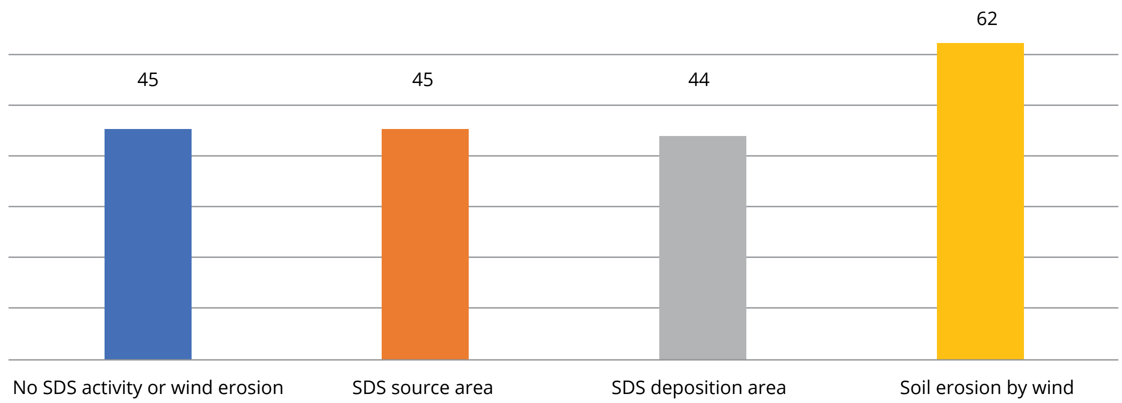
Subregional hotspots in Asia and the Pacific

Sand and dust storms commonly occur in the Middle East, northern China, South-West Asia and Australia (Tsolmon and others, 2008), with the Asia-Pacific region contributing 26.8 per cent to global dust emissions as of 2012 (see figure 1.5).

Of the more than 2 billion tonnes of dust emitted into the global atmosphere every year, the Sahara Desert in North Africa is the largest contributor, at approximately 1.43 billion tonnes as of 2012. The Asia-Pacific region is the second-largest dust emitter, at slightly more than half a billion tonnes per year (Akhlaq, Sheltami and Mouftah, 2012).

Figure 1.4

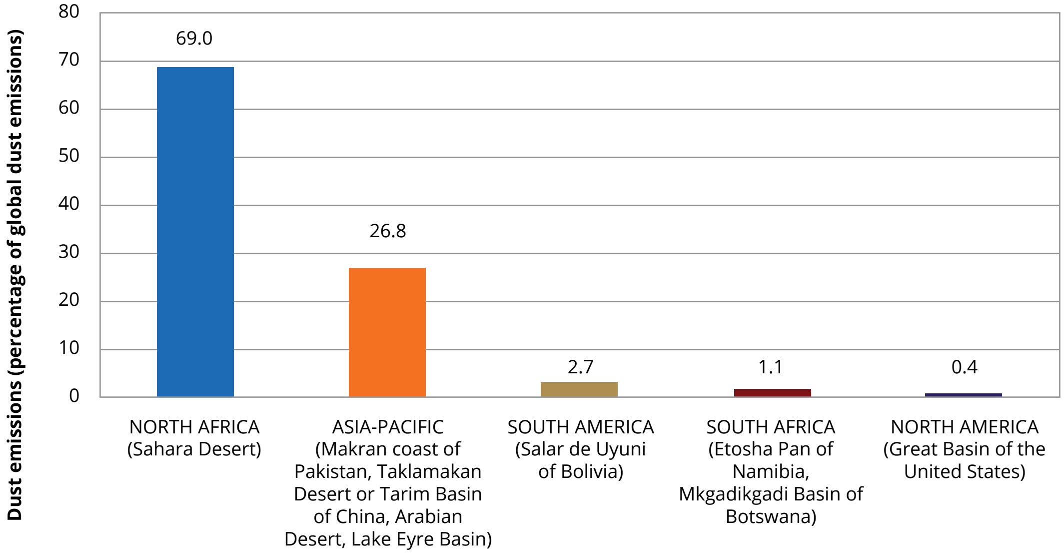
Number of countries party to the United Nations Convention to Combat Desertification affected by sand and dust storms



Abbreviation: SDS=sand and dust storm.
Source: Middleton and Kang, 2017.
Note: There were 196 countries party to the Convention to Combat Desertification as of January 2017.

Figure 1.5

Percentage of global sand and dust emissions, by region



Source: Akhlaq, Sheltami and Mouftah, 2012.

Sand and dust storm hotspots in Asia and the Pacific are found in four subregions: (i) East and North-East Asia; (ii) South and South-West Asia; (iii) Central Asia; and (iv) the Pacific.

East and North-East Asia

Sand and dust storms constitute a phenomenal environmental concern in the East and North-East Asia subregion. Originating principally in arid areas of Inner Mongolia in China and the Gobi Desert in Mongolia (as well as increasingly from north-eastern China), windborne dust particles are carried eastward to affect not only China but also the Korean Peninsula and Japan (Jung, 2016).

Figure 1.6

True-colour image of a sand and dust storm over the Taklimakan Desert on 5 March 2018, taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the NASA Aqua satellite

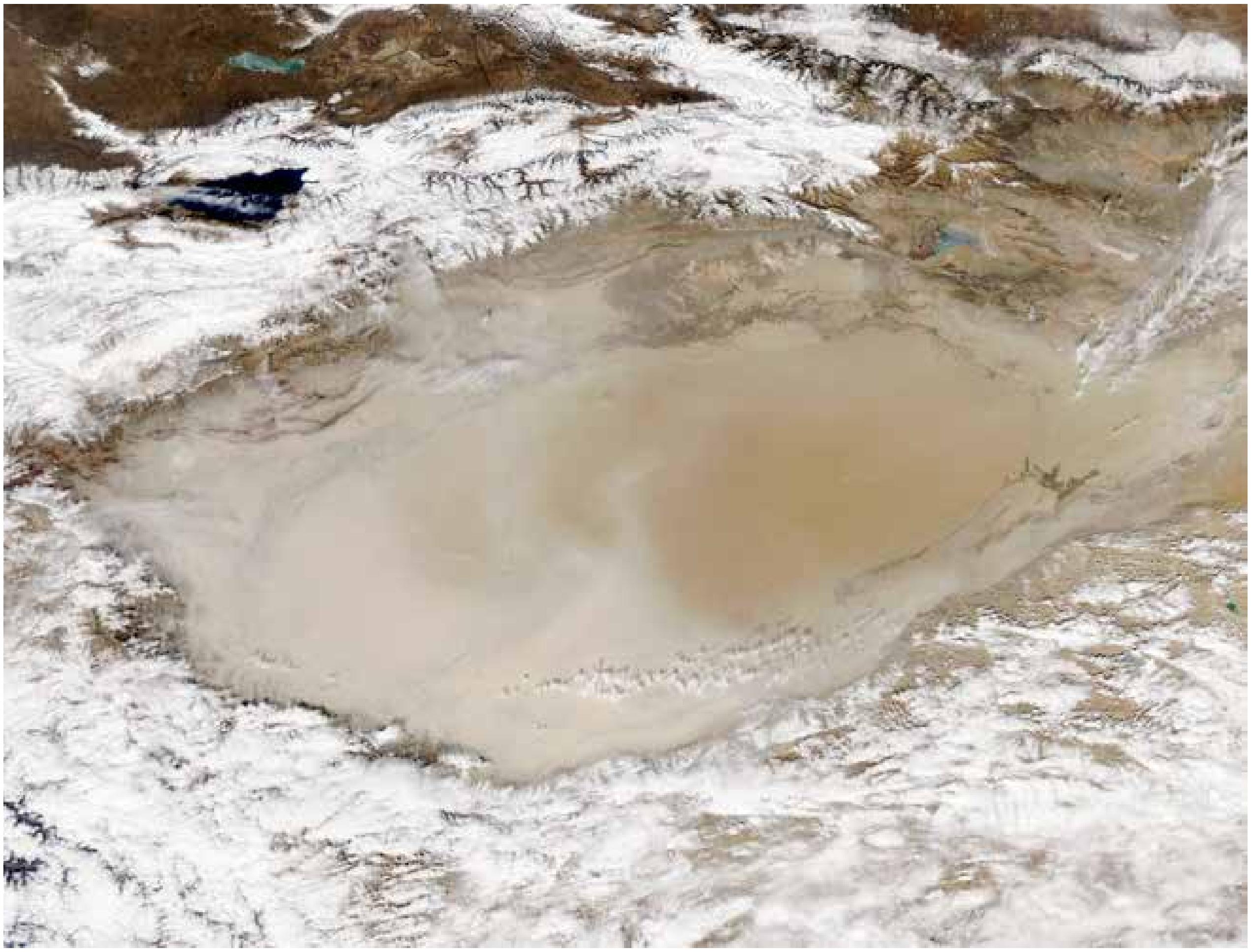


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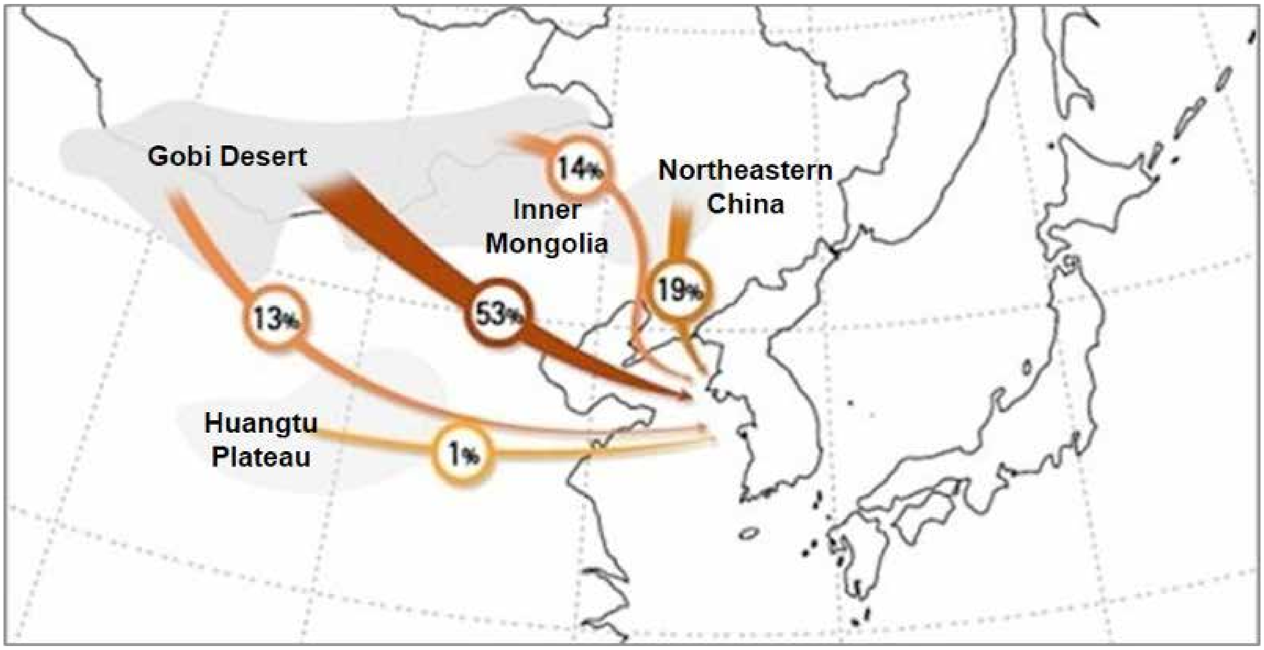
Figure 1.7

NASA Aqua MODIS satellite-captured natural-colour image of dust from the Gobi Desert blowing across China to the Yellow Sea on 1 May 2011

© NASA image courtesy Jeff Schmaltz, MODIS Rapid Response Team at NASA/Goddard Space Flight Center

Figure 1.8

Origins of sand and dust storms and routes in East and North-East Asia, 2002–2011



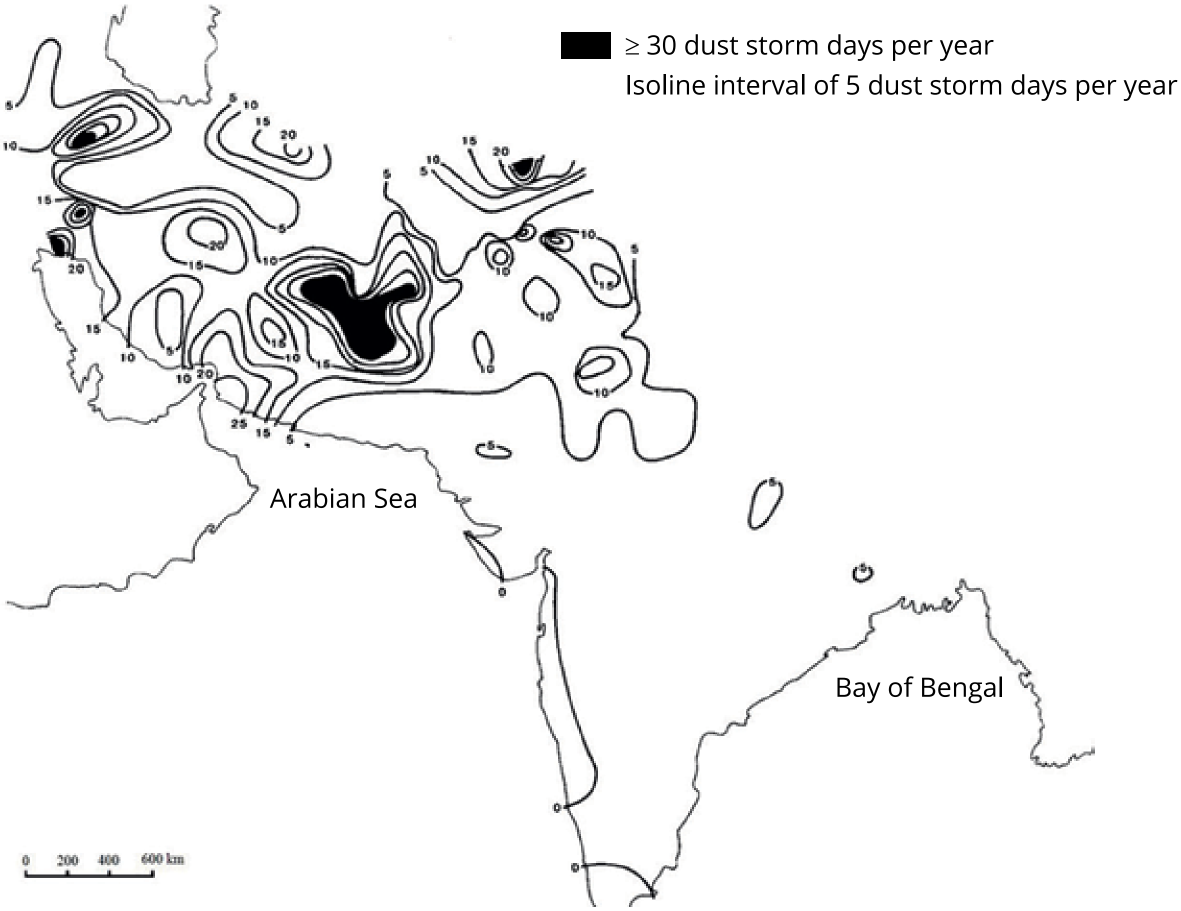
Source: Jung, 2016.

South and South-West Asia

Sand and dust storms also severely affect the South and South-West Asia subregion. There are many storm sources from within the subregion as well as hotspot sources in western Asia and northern Africa that eventually make their way to this area.

Figure 1.9

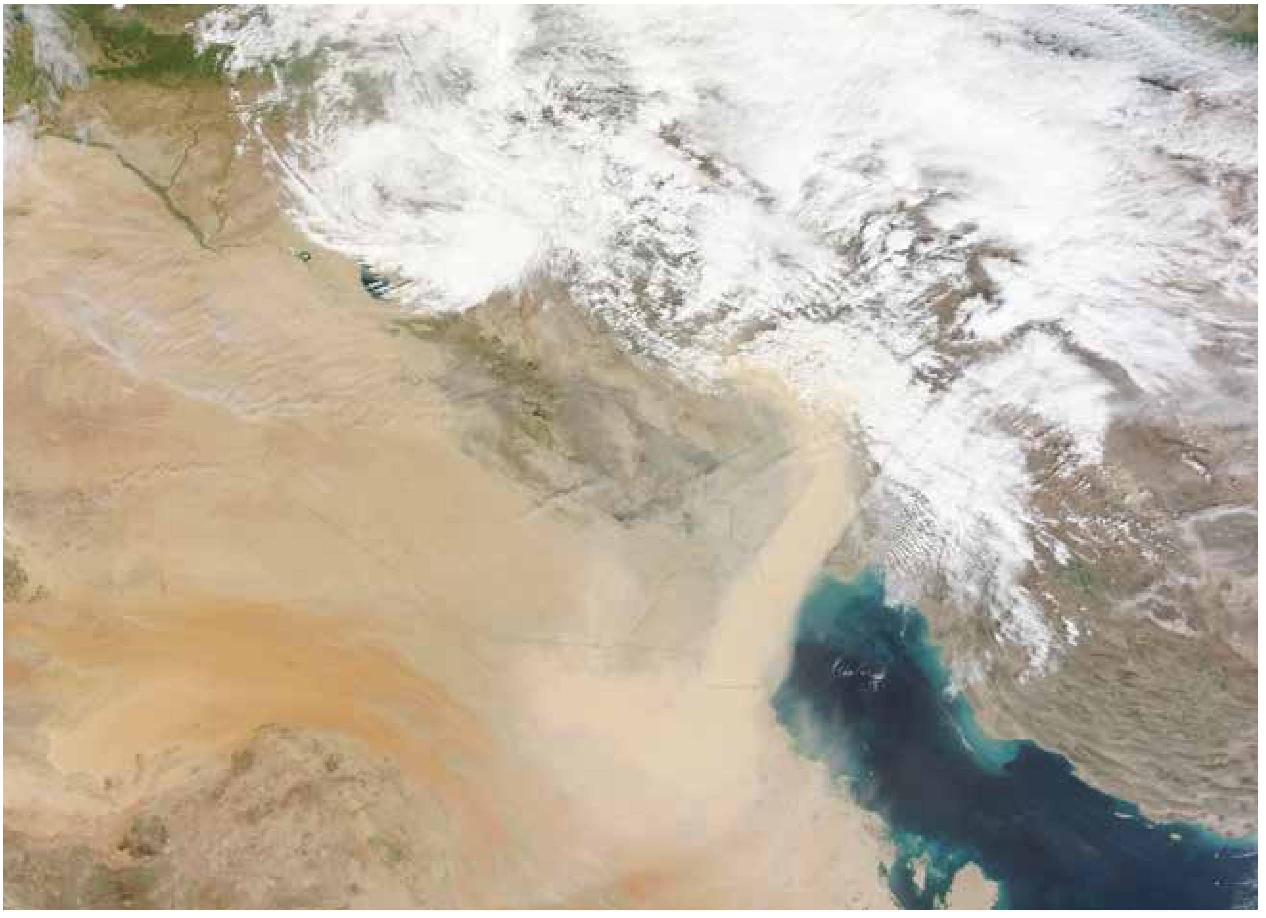
Distribution of dust storms (visibility less than 1,000 metres) in South and South-West Asia



Source: Middleton, 1986.

Figure 1.10

Dust extends from Saudi Arabia to the Islamic Republic of Iran on 4 March 2010



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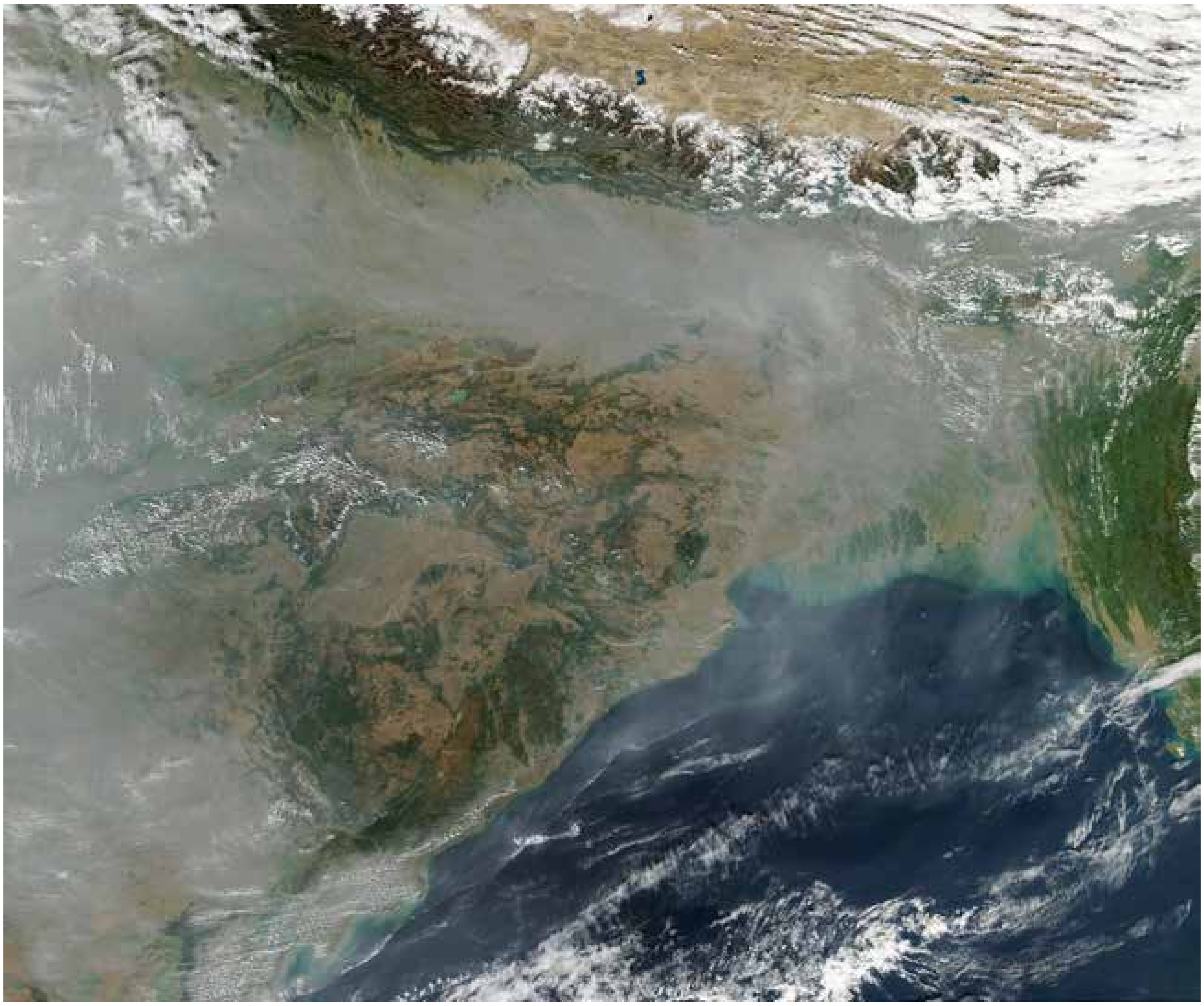
Sand and dust storms also are common in all parts of South and South-West Asia. The greater dust storm frequencies occur in the Sistan Basin in south-eastern Islamic Republic of Iran and south-western Afghanistan, areas of south-eastern Islamic Republic of Iran, north-western Baluchistan in Pakistan, the Thar Desert of Rajasthan in western India, the plains of Afghan Turkestan and the Registan area of Uzbekistan. Dust from these areas is transported north to Central Asia, south over the Arabian Sea and east over South-East Asia (Middleton, 1986).

Figure 1.11

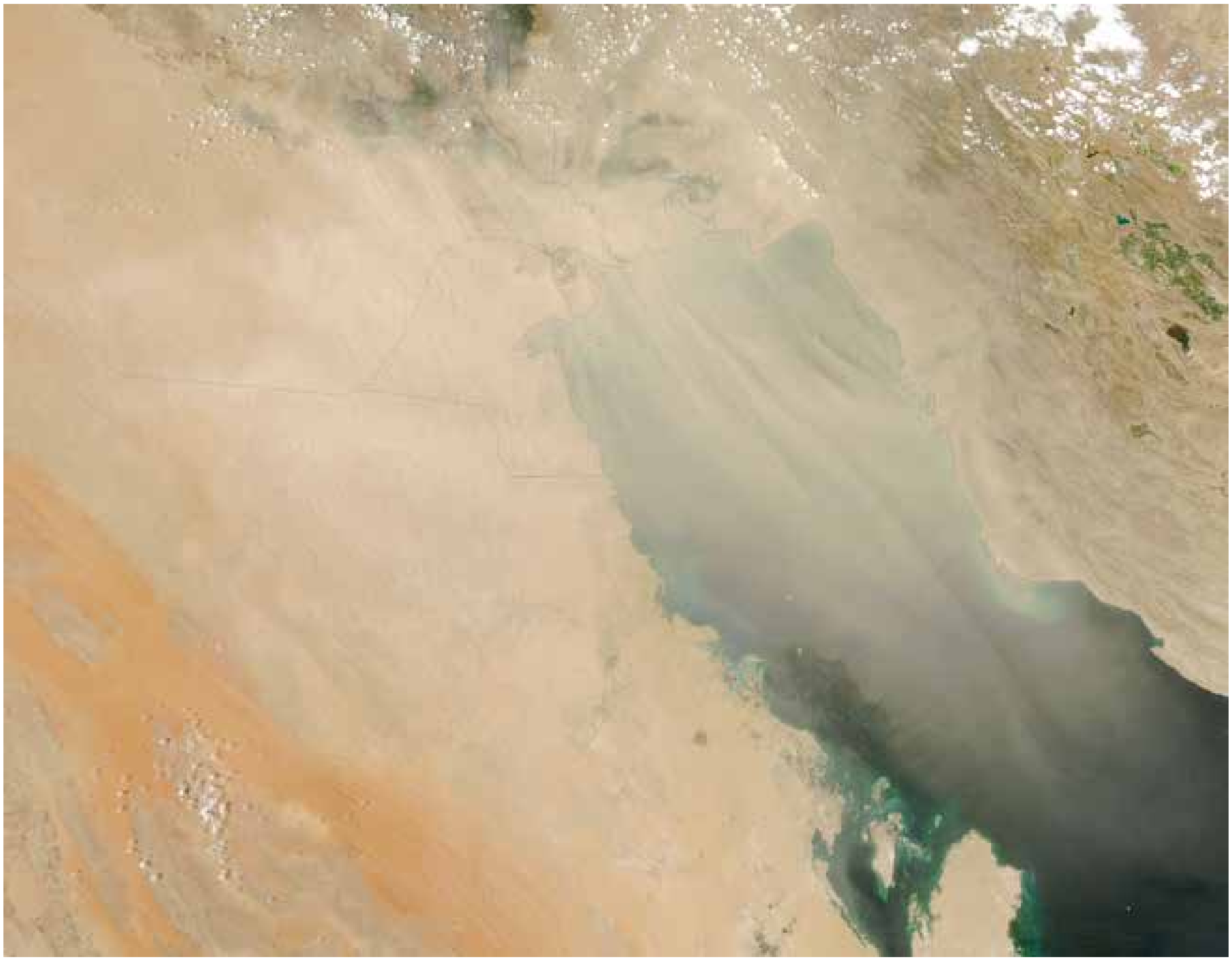
NASA Aqua MODIS satellite-captured true-colour image of haze hugging the southern face of the Himalayas on 14 December 2009



© NASA Earth Observatory image courtesy MODIS Rapid Response Team, Goddard Space Flight Center

Figure 1.12

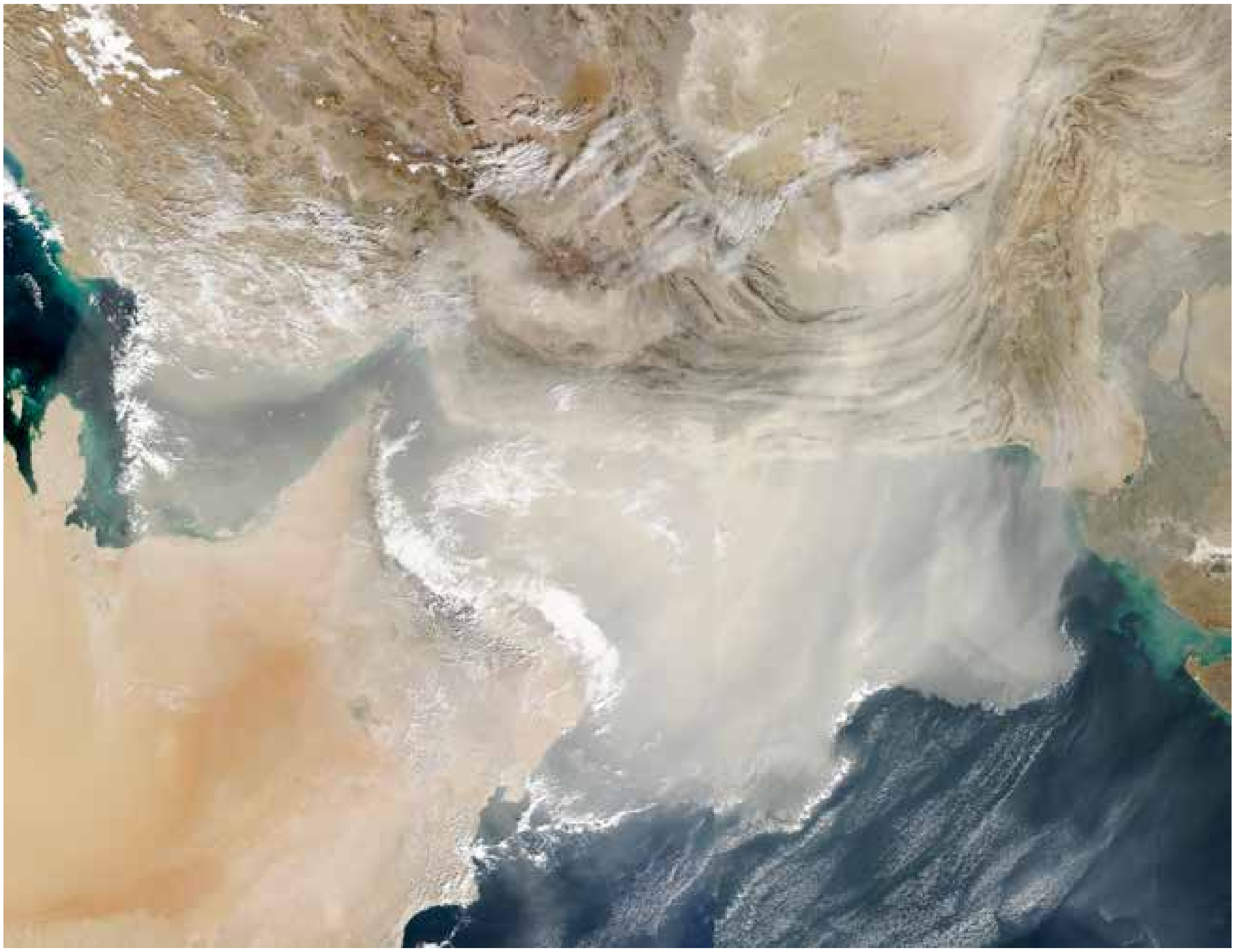
Sand and dust storms passing through the Persian Gulf on 18 May 2007



©NASA image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA/Goddard Space Flight Center

Figure 1.13

Terra and Aqua MODIS satellite-captured true-colour composite image of a storm blowing large quantities of dust outward over the Persian Gulf and the Arabian Sea on 13 December 2003



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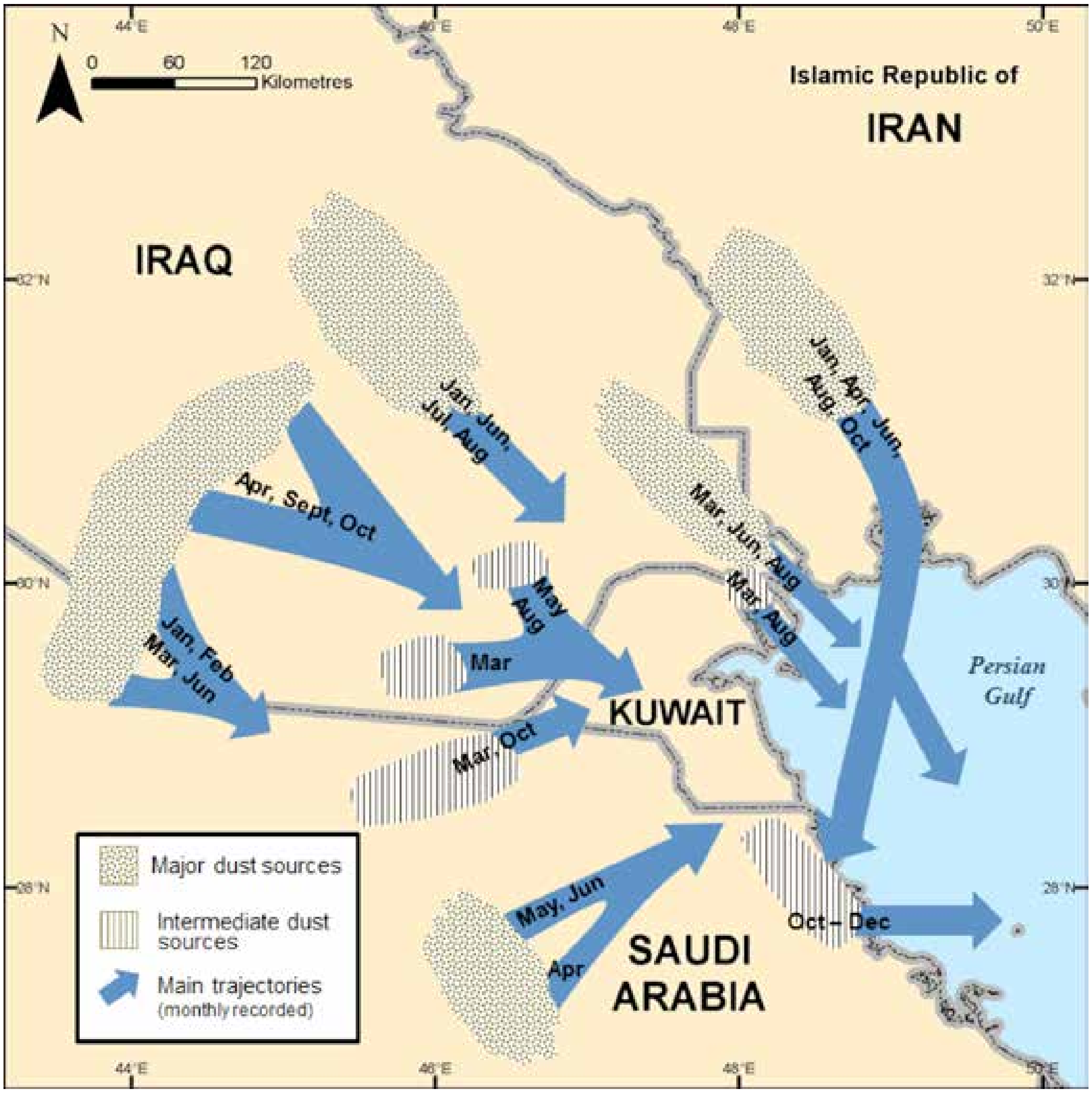
The probability of sand and dust storms varies throughout the year, depending on the environmental conditions. Figure 1.14 illustrates the temporal and spatial distribution of dust sources in a portion of South-West Asia, near the Persian Gulf.

Figure 1.14

Seasonal origin of dust sources in the Islamic Republic of Iran, Iraq and Saudi Arabia



Source: Al-Dousari and others, 2012.

Central Asia

Central Asia experiences a high frequency of dust and salt storms. The subregion is characterized by the presence of vast areas of sandy and solonchak[1] deserts of natural and anthropogenic origin. Enhanced anthropogenic activity in the Aral Sea Basin contributed to bringing about the Aral environmental crisis.[2] As a result, the powerful basis of aeolian processes[3] was formed, which favoured the development of salt and dust removal from the dried-up bottom of the Aral Sea and distribution of salt and dust over significant parts of the Aral Sea Basin.

Atmospheric precipitation (seasonal distribution, amount and type) influences seasonality significantly and contributes to the frequency of dust storms in Central Asia. Much of the dust has a high salt concentration (UNCCD, 2001).

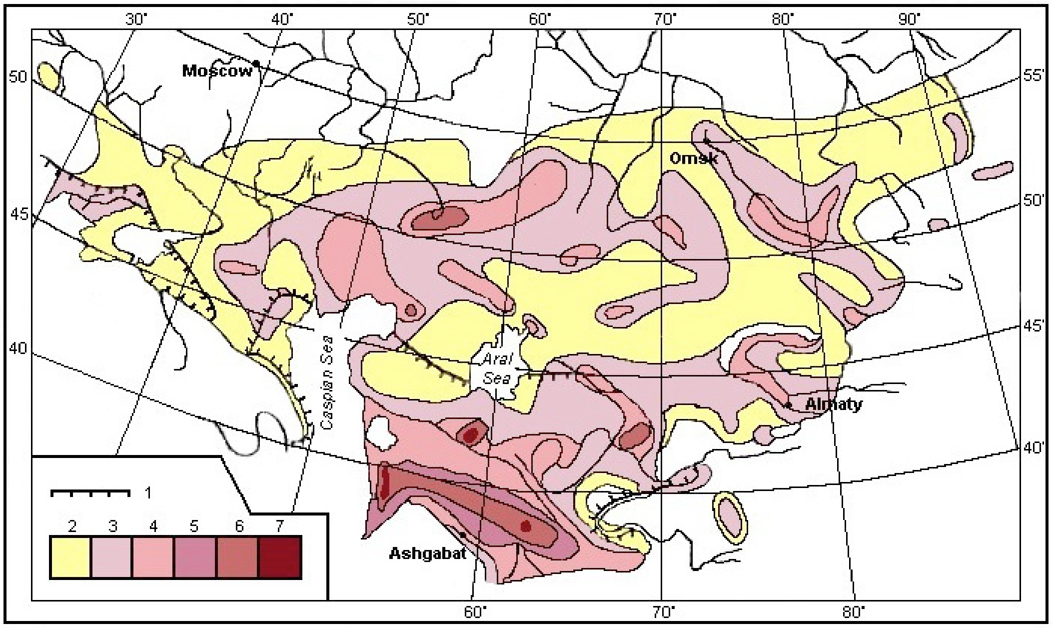
1 Solonchak deserts are characterized by their high salt concentration, expressed by the electrical conductivity of the saturation extract that exceeds 15 deciSiemens per meter (dS/m) (or > 8 dS/m when the pH is ≥ 8.5). The presence of salt crystals and hydromorphic features are indicators of solonchak. The dominant soil processes involved in solonchak formation are salt accumulation and the development of hydromorphic features (FAO and ITPS, 2015).

2 The Aral Sea was once the fourth-largest inland body of water on Earth, with a surface area of 66,000 square kilometres. In 1960, the mean water level was 53.4 metres and contained 1,090 cubic kilometres of water (Glantz, 1999). The destruction of the sea and its ecosystems constitutes one of the greatest human-induced environmental disasters in history. The ecological catastrophe has been associated with a sharp decline in the health status of the human population in the region. The environmental deterioration is expected to continue, and the health outlook is similarly grim. There is a requirement for immediate health-related assistance from the international community (Whish-Wilson, 2002).

3 Aeolian processes are related to wind activity that erodes, transports and deposits sediments.

Figure 1.15

Spatial distribution of annual average dust storm frequency in Central Asia, 2001



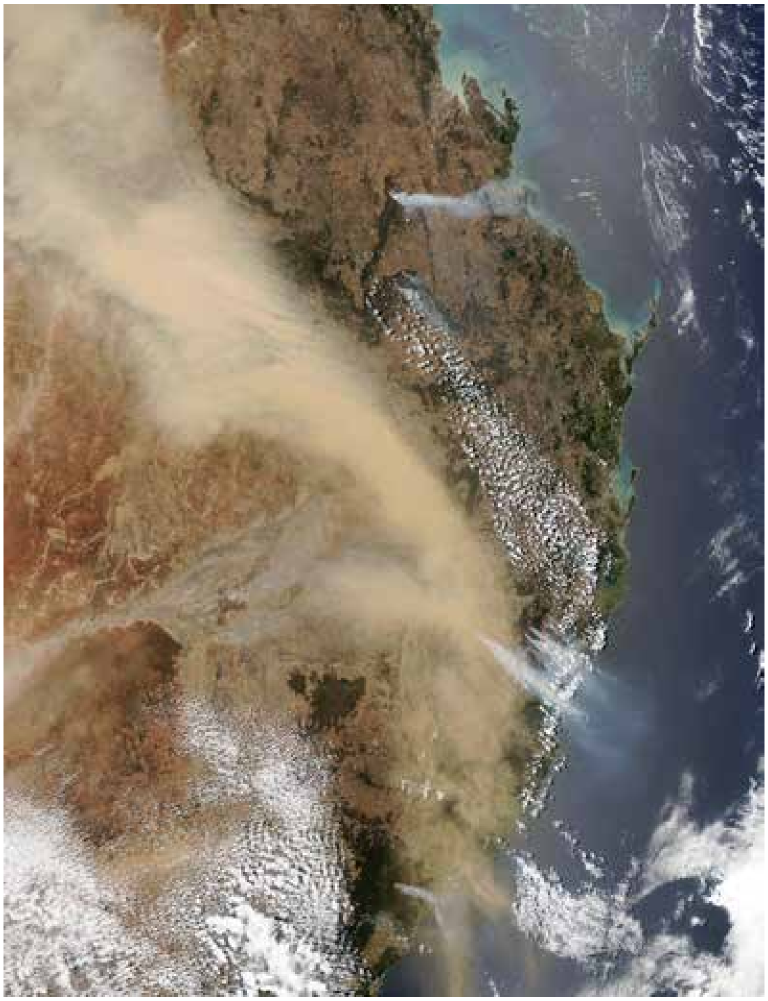
Source: UNCCD, 2001.

Pacific

Australia is the largest contributor of dust within the southern hemisphere. Southern Africa and the Americas contribute significantly smaller quantities of dust into the global atmosphere (Bullard and Livingstone, 2009). The highest frequency of dust storms on record occurred in the centre of Australia, where there was an average of 10.8 events per year at Alice Springs and a maximum of 65 events per year in coastal Western Australia (McTainsh and Pitblado, 1987; Middleton, 1984). The dust plumes produced by dust storms in those areas of Australia generally travel far beyond the continent, to the south-east over New Zealand into the Southern Ocean and to the north-west over the Indian Ocean (see figure 1.16) (Boyd and others, 2004; Ekstrom, McTainsh and Chappell, 2004; McGowan and others, 2000; Knight, McTainsh and Simpson, 1995; Raupach, McTainsh and Leys, 1994; McTainsh, 1989).

Figure 1.16

Terra MODIS satellite-captured view of a large dust storm (centre) blowing across eastern Australia on 23 October 2002



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2

CLIMATE CHANGE AND SAND AND DUST STORMS

2. CLIMATE CHANGE AND SAND AND DUST STORMS

The changing climate is a well-documented global threat. The Earth's average temperature for 2017 was 1.1°C above pre-industrial-era temperatures and about 0.46°C above the 1981–2010 long-term average of 14.3°C (WMO, 2018). The past three years (2015, 2016 and 2017) were the warmest on record (WMO, 2018).

Climate change is having significant impact on the increased intensity and frequency of sand and dust storms, which are affected by climatic variables: wind speed, wind direction, air temperature, precipitation and evaporation. With changing climate and its impact on the environment, economies and people's health, it is imperative to understand the changing relationship between climate change and future intensity and frequency of sand and dust storms regionally and locally.

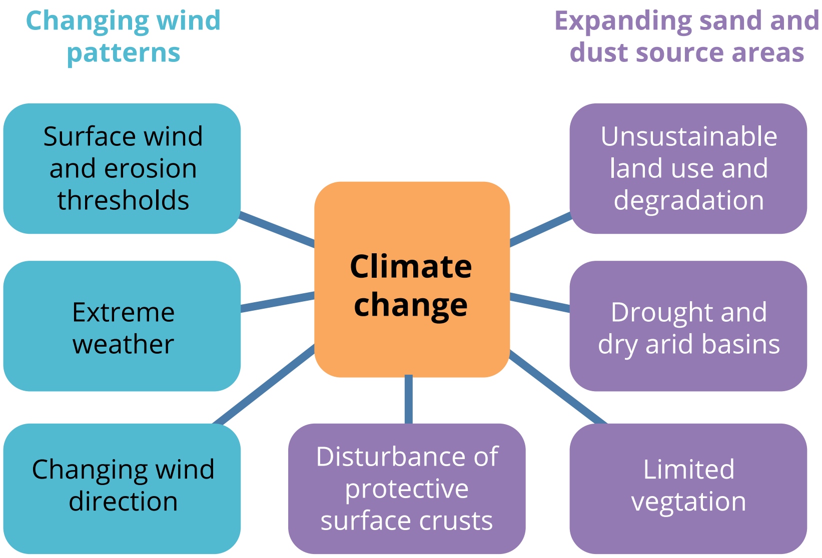
Assessment reports from the Intergovernmental Panel on Climate Change (IPCC) warn that atmospheric dust is one of the most uncertain factors contributing to the effects of aerosols on global climate processes (Boucher and others, 2013). There is intense international interest in Asian dust storms because of their impact on regional and global climate conditions and the potential to impair human health and welfare (Zhao, 2004). Sand and dust storms exacerbate desertification, drought and soil salinity while reducing water supplies, obstructing renewable energy sources, blocking sunlight to coral reefs and spawning toxic algal blooms. Natural sources, such as topographic depressions in arid regions (mainly dry ancient lake beds with little vegetation cover), contribute 75 per cent of current global dust emissions. Anthropogenic sources, such as land-use changes, agriculture, water diversion and deforestation, contribute up to the remaining 25 per cent (UNEP, WMO and UNCCD, 2016).

Drivers of sand and dust storms

There are two primary climate change-related drivers of sand and dust storms: (i) changing wind patterns and (ii) expanding sand and dust source areas (see figure 2.1). Changing wind patterns is distinguished by three categories: (i) fraction of surface winds exceeding the erosion threshold as defined by local surface properties, (ii) greater occurrence of extreme weather events and (iii) changing wind direction. Expanding sand and dust source areas is distinguished by four categories: (i) increased frequency of drought and dry arid basins; (ii) limited vegetation; (iii) unsustainable land use and degradation; and (iv) disturbance of protective surface crusts.

Figure 2.1

Drivers of sand and dust storms and their link to climate change

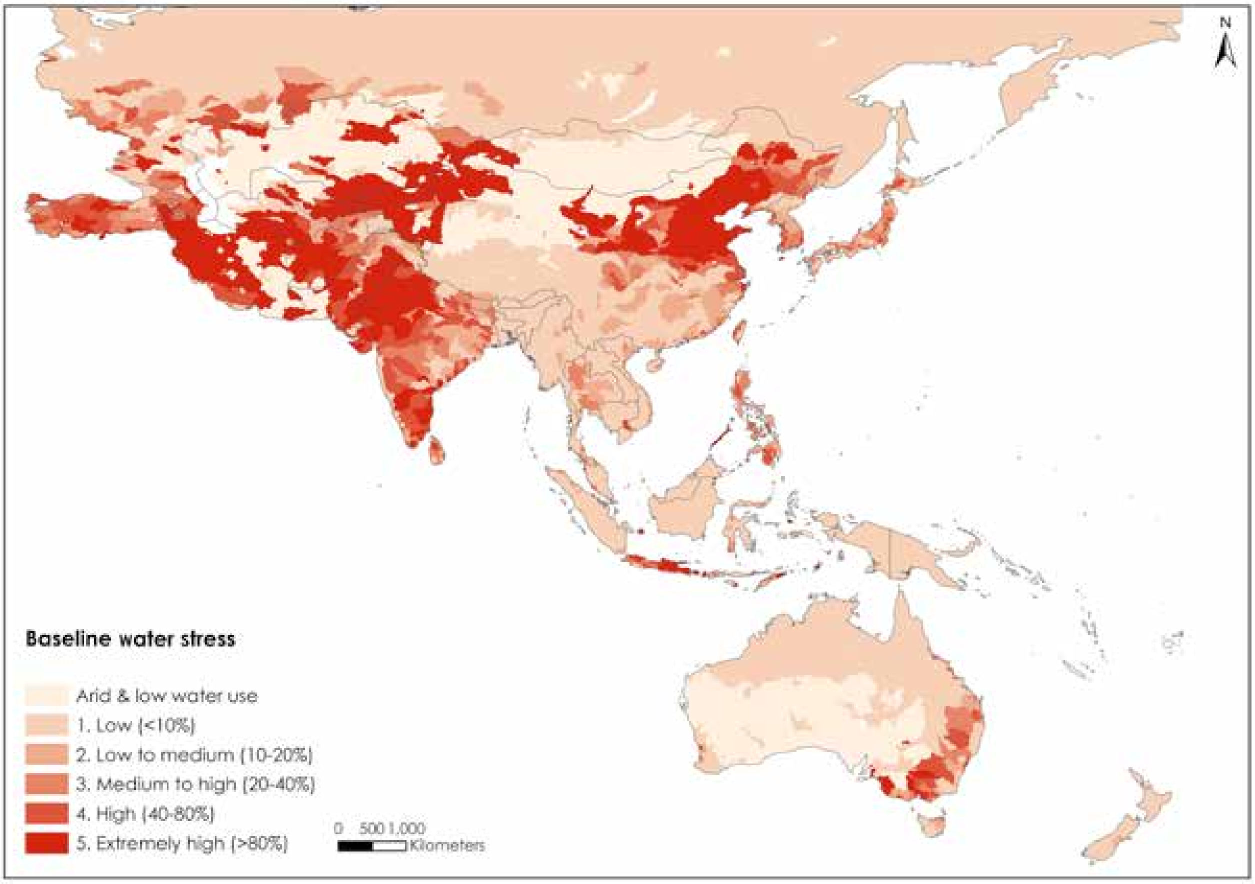


Source: Babel, 2018.

Global warming is leading to an increase of dry areas and has contributed to the upward trend in drought-affected areas since the 1980s. In the first decade of this century alone, drought areas increased by about 8 per cent. In 2017, extreme heat and drought contributed to many destructive wildfires in various parts of the world. A study by Dai (2013) suggested that over the next 30–90 years there will be widespread droughts due to either decreased precipitation or increased evaporation. This will lead to severe water stress across the Asia-Pacific region (see figure 2.2). South Asia ranks high among the most threatened regions, but it is far from the only place where scientists say global warming could change the fabric of society. A number of Persian Gulf cities will reach unliveable temperature thresholds by 2100 (Pal and Eltahir, 2015).

Figure 2.2

Water stress in Asia and the Pacific, 2018

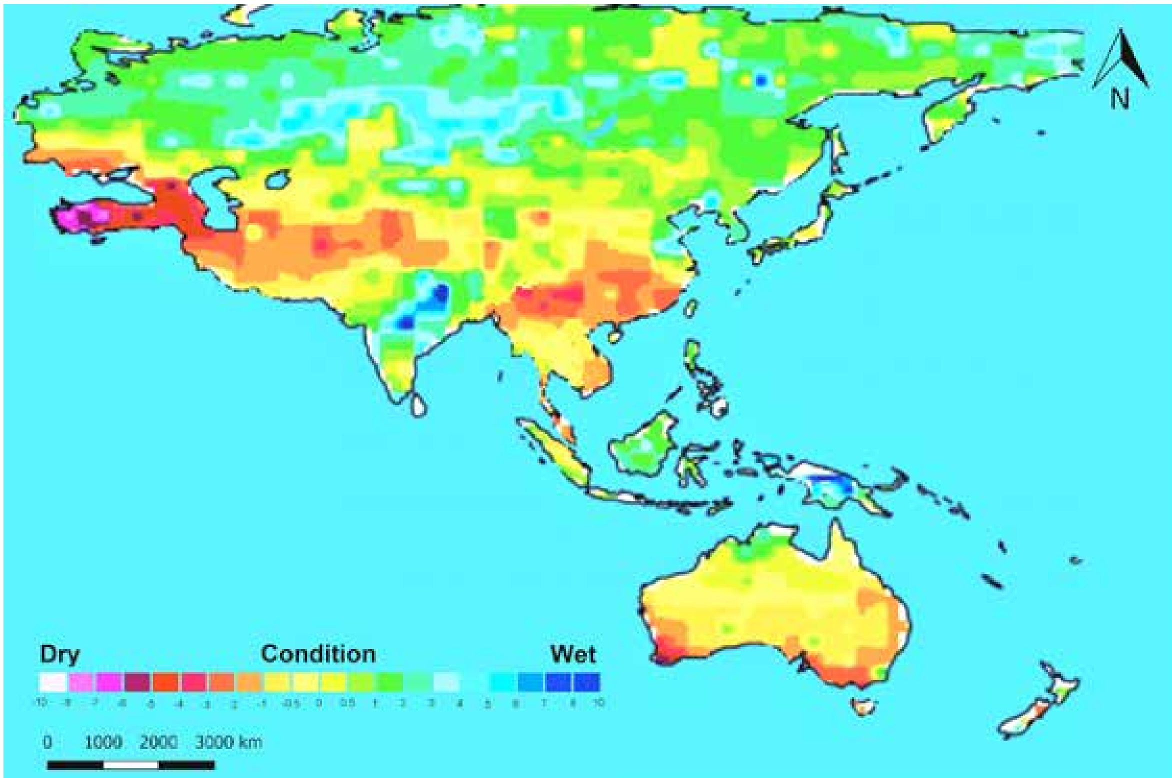


Source: ESCAP, 2018.

Figure 2.3 indicates the trends as well as the geographical expansion of drought-affected areas. The example reflects values from the Palmer Drought Severity Index, which is a measure of dryness based on precipitation and temperature parameters. By 2030, drought risk will have increased substantially in many parts of Asia and the Pacific. There also will be a shift in the geography of drought: in South Asia towards the west and in South-East Asia towards the east (ESCAP, 2018). Hence, it can be expected that sand and dust storms will become more severe and shift more towards the western part of the subregion. Because prolonged droughts contribute substantially to desertification and land degradation, which when compounded with wind erosion leads to sand and dust storms in arid and semi-arid subregions, the forecasted situation for the Asia-Pacific region indicates increasing incidence and severity of sand and dust storms.

Figure 2.3

Forecasted areas for increased drought risk, by 2030



Source: ESCAP, 2018, based on Dai, 2011.
Note: Calculated from the Palmer Drought Severity Index. Lower values indicate more severe drought risk.

Connection between climatic variables and sand and dust storms

Several studies have found that regional climate variables heavily influence dust storm activity. For example, higher air temperature, less precipitation and strong wind are favourable climate conditions for dust storm development (Guan and others, 2015). Wind speed, turbulence, air temperature, air pressure and freeze-thaw action reinforce wind erosion, while precipitation as well as air temperature and freeze-thaw action are known to also reduce wind erosion–depending on the process involved (UNEP, WMO and UNCCD, 2016). And as just pointed out, wind erosion and drought collude to increase sand and dust storm activity.

Precipitation and temperature have likely been instrumental in the increase of sand and dust storm frequency since 2000. Wind speed (especially of 10-20 miles per second) is the main factor controlling sand and dust storms' monthly variability, whereas precipitation is a primary cofactor of inter-annual variability, although strong wind is still the main control factor (see table 2.1). Analysis of storms in the Tengger Desert in China revealed that dust storms were more frequent between March and May; and the frequency of sand and dust storms was found to be significantly high from 2000 to 2007, compared with the 1980s (Guan and others, 2015).

Temperature and precipitation level also have an indirect effect on sand and dust storm activity due to their influence on vegetation growth. Storm data from China and Mongolia from 1980 to 2015 show that annual dust emissions and annual wind speed had a positive correlation (R=0.49), annual dust emissions and annual precipitation had a negative correlation (R=-0.34), and annual dust emissions and annual temperature had a positive correlation (R=0.13) (Song and others, 2017). The data thus indicate wind speed and air temperature intensify sand and dust storms. Also, humidity is an important control of the wind speed required for the entrainment of particles into an air flow and is known to vary in spatial scale (Neuman and Sanderson, 2008). Dust emission is also enhanced by certain synoptic meteorological patterns, such as frontal and cyclonic systems known to generate dust storms in the Middle East (Trigo, Bigg and Davies, 2002 and 1999). Unusual climatic and meteorological conditions and historically unprecedented aridity, for instance, had a prominent role in triggering a September 2015 storm in the Middle East. This suggests that if dust storms are indeed resulting from aridity and synoptic meteorology, which are significantly affected by climate change, then prolonged impacts in the Middle East may be unavoidable (Parolari and others, 2016).

Table 2.1 Physical factors influencing wind erosion

Climate	Soil or sediment	Vegetation	Landform
Wind speed (+)	Soil or sediment type	Type	Surface roughness (+/-)
Wind direction	Particle composition	Coverage (-)	Slope (-)
Turbulence (+)	Soil or sediment structure	Density	Ridge
Precipitation (-)	Organic matter (-)	Distribution (+/-)	
Evaporation (+)	Carbonates (-)		
Air temperature (+/-)	Bulk density		
Air pressure (+)	Degree of aggregation (-)		
Freeze-thaw action (+/-)	Surface moisture (-)		

Source: Babel, 2018.
Note: (+) indicates that the factor reinforces wind erosion; (-) indicates that the factor has a protective effect, reducing wind erosion; (+/-) indicates the effect can be positive or negative, depending on the process involved.

Facing our possible future

IPCC (2012) highlights slight increase in average temperature may lead to warmer weather and hot weather (Field and others, 2012). And as previously noted, the past three years have been the warmest on record (WMO, 2018).

Even with all governments' current mitigation commitments and pledges fully implemented, climate change implications are inevitable. By 2100, the mean annual temperature is projected to increase by 1°C to 5°C, depending on the scenarios and location.[4] Due to changes in frequency and intensities of precipitation and temperature patterns, the return periods of maximum daily temperature and the maximum daily precipitation are decreasing, which implies more frequent extreme weather events. For instance, the frequency of 20-year return-period temperature for the Special Report on Emissions Scenarios (SRES) B1 scenario is expected to increase to once in every 2 to 8 years for South Asia, 2 to 18 years for Central Asia and 1.5 to 4 years for West Asia and 2 to 5 years globally between 2046 and 2065. The frequency of 20-year return-period precipitation events is expected to increase to once in every 8 to 20 years for South Asia, 9 to 20 years for Central Asia, 9 to 50 years for West Asia and 9 to 15 years globally in that same time period and scenario (Field and others, 2012). By the end of 2100, the annual maximum wet bulb temperature in Abu Dhabi, Dubai, Doha, Dhahran and Bandar Abbas is expected to exceed 35°C several times over a 30-year period; and the present-day 95th percentile summer event will become a normal summer day (Pal and Eltahir, 2015).

Table 2.2 presents forecasted changes in temperature and precipitation over South Asia, Central Asia and South-West Asia in 2016–2035, 2046–2065 and 2081–2100, compared with 1986–2005. The forecasts are based on 42 global climate models for the representative concentration pathways (RCP) 4.5 scenarios. Peak summer (June–August) and winter periods (December–February) and annual averages are considered for the minimum, maximum and three inter-quartile ranges for both temperature and precipitation.

4 See http://climate4development.worldbank.org/.

Table 2.2 Future changes in temperature and precipitation

Representative concentration pathways 4.5 scenarios			Temperature (°C)					Precipitation (%)				
Region	Month	Time period	min	25%	50%	75%	max	min	25%	50%	75%	max
South Asia	Dec.–Feb.	2016–2035	0.1	0.7	1.0	1.1	1.4	-18	-6	-1	4	8
		2046–2065	0.6	1.6	1.8	2.3	2.6	-17	-3	4	7	13
		2081–2100	1.4	2.0	2.3	3.0	3.7	-14	0	8	14	28
	July–Aug.	2016–2035	0.3	0.6	0.7	0.9	1.3	-3	2	3	6	9
		2046–2065	0.9	1.1	1.3	1.7	2.6	-3	5	7	11	33
		2081–2100	0.7	1.4	1.7	2.2	3.3	-7	8	10	13	37
	Annual	2016–2035	0.2	0.7	0.8	1.0	1.3	-2	1	3	4	7
		2046–2065	0.8	1.4	1.6	1.9	2.5	-2	3	7	9	26
		2081–2100	1.3	1.7	2.1	2.7	3.5	-3	6	10	12	27
Central Asia	Dec.–Feb.	2016–2035	-0.1	0.8	1.3	1.6	2.4	-6	0	4	8	19
		2046–2065	0.6	1.7	2.4	2.9	4.0	-9	-2	4	10	17
		2081–2100	1.0	2.3	2.7	3.3	5.4	-12	-1	5	12	25
	July–Aug.	2016–2035	0.3	0.9	1.1	1.4	2.1	-13	-3	2	6	17
		2046–2065	1.1	1.7	2.1	2.6	4.3	-22	-5	1	6	16
		2081–2100	0.9	2.1	2.7	3.4	5.0	-17	-3	1	5	18
	Annual	2016–2035	0.2	0.8	1.1	1.3	2.0	-6	-1	2	6	13
		2046–2065	0.7	1.7	2.2	2.5	3.6	-13	-2	2	6	16
		2081–2100	0.8	2.2	2.6	3.2	4.8	-12	-4	4	8	18
South-West Asia	Dec.–Feb.	2016–2035	0.0	0.8	1.1	1.4	1.8	-12	0	3	6	14
		2046–2065	0.5	1.5	1.9	2.3	3.2	-10	-1	2	7	21
		2081–2100	0.6	1.9	2.4	2.9	3.8	-11	-3	4	9	20
	July–Aug.	2016–2035	0.2	0.9	1.1	1.3	2.1	-10	-2	1	5	55
		2046–2065	1.1	1.7	2.1	2.6	4.0	-20	-6	-3	2	51
		2081–2100	1.2	2.0	2.7	3.4	4.7	-29	-6	-1	4	60
	Annual	2016–2035	0.1	0.9	1.0	1.2	1.8	-9	-2	3	4	27
		2046–2065	0.7	1.7	1.9	2.3	3.2	-12	-2	0	4	27
		2081–2100	0.9	2.1	2.5	3.1	4.1	-19	-2	1	6	28

Source: Hartmann and others, 2013.

Temperatures (minimum to maximum) are expected to increase in all three regions (South Asia, Central Asia and South-West Asia) in all future periods. The greatest increase in future minimum and maximum temperature is expected during 2081–2100, compared with 2016–2035 and 2046–2065, in all three regions. Central Asia and West Asia are expected to have a greater increase in maximum temperature than South Asia (see table 2.2).

Minimum precipitation is expected to decrease even more in the future, with the greatest decrease expected in South-West Asia. However, the maximum precipitation is expected to increase in all three regions in all future periods. Thus, more droughts and floods are expected in all future periods (2016–2035, 2046–2065 and 2018–2100) and mostly intensifying along those time scales.

A comparison of the mean wind speed data using WCRP-CMIP3 under the A1B scenario for 1981–2000 and the projected data for 2081–2100 indicated an increase of wind speed greater than 10 per cent in eastern India and some parts of western Asia (Yemen and Oman) but a 5-10 per cent decrease in Afghanistan, Uzbekistan and some parts of Central Asia. There is a dominant shift in directional wind to a clockwise direction in western India and to an anti-clockwise direction in Saudi Arabia, the Islamic Republic of Iran, Iraq and parts of Central Asia (McInnes and others, 2011).

Hartmann and others (2013) suggested that evaporation will likely increase in the future in South Asia, Central Asia and South-West Asia by up to 5 per cent in 2016–2035, based on the RCP 4.5 scenario, in comparison with 1986–2005. And there will be humidity increases in all three regions, from 2.5 per cent to 5 per cent, under the same scenario. Multiple-modal analysis using 14 CMIP5 models found decreases in soil-moisture content ranging from 5 per cent to 15 per cent by 2080–2099 in the top-10-centimetre layer over most of the Americas, Europe, Southern Africa, most of the Middle East, South-East Asia and Australia (Dai, 2012). The annual run-off volume by the middle of the twenty–first century will likely change (increase or decrease) in different countries of those regions. Relative to 1900–1970 and in the SRES A1B emission scenario, run-off will mostly increase in South Asia and decrease in South-West and Central Asia (Milly and others, 2008). An IPCC report suggested that by 2050, annual average run-off will have increased by 10-40 per cent at high latitudes and decreased by 10-30 per cent over some dry regions at mid-latitudes and semi-arid low latitudes (Hartmann and others, 2013).

The intensity and frequency of drought are expected to increase globally due to climate change (Prudhomme and others, 2014; Trenberth and others, 2014; Dai, 2013). Hydrological drought will greatly intensify, due to the combined result of climate change and increased water use (Wanders and others, 2015).

Based on documented analysis in scientific literature, the possible changes in the future climate for the three regions of South Asia, Central Asia and South-West Asia and the corresponding likely influence on future sand and dust storms are summarized in table 2.3.

Table 2.3 Possible future climate conditions and their likely influence on sand and dust storm activity

Climatic variable	Expected change in the future			Likely influence on future sand and dust storms		
	South Asia	Central Asia	South-West Asia	South Asia	Central Asia	South-West Asia
Temperature[a]	+	+	+	+	+	+
Precipitation[a]	+	+	+	-	-	-
Evaporation[a]	+	+	+	-	-	-
Run-off[a]	-/+	-/+	-/+	+/-	+/-	+/-
Drought[a]	+	+	+	+	+	+
Specific humidity[a]	+	+	+	-	-	-
Soil moisture[b]	-	-	-	+	+	+
Wind speed[c]	+	-	+	+	-	+

Note: + indicates increase and - indicates decrease

Source: a = Hartmann and others, 2013; Field and others, 2012; Kirtman and others, 2013;
b = Dai, 2013; Zahid, Iqbal and Rasul, 2014;
c = McInnes, Erwin and Bathols, 2011; Mori and others, 2013.

What all these predictions reinforce is that climate mitigation and adaptation activity from this point in time onward needs to be even more robust than ever.

Looking forward

The uncertainties among future climate projections are large, and more robust studies on climate change and sand and dust storms are necessary. Climate data forecasts are available mostly for a regional scale. Translating global and regional forecasted climate data at the smaller spatial scale (sand and dust storm source areas) is necessary to assess the influence on sand and dust storm activity. While dealing with the information accessibility at the local, national and regional levels, monitoring programmes based on satellite observation and meteorological stations should be prioritized in order to mitigate or adapt to sand and dust storm events. These monitoring activities must extend to climate, soil, vegetation and landform at the local levels for improved understanding of cause-and-effect relationships with sand and dust storms. Especially in arid and semi-arid regions, drought monitoring should be a priority. Along with developing more accurate and reliable early warning systems, translating the impacts to societal implications (vulnerability and risks) is essential to prepare suitable adaptation and mitigation strategies.

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3

SAND AND DUST STORM IMPACTS ON THE SUSTAINABLE DEVELOPMENT GOALS

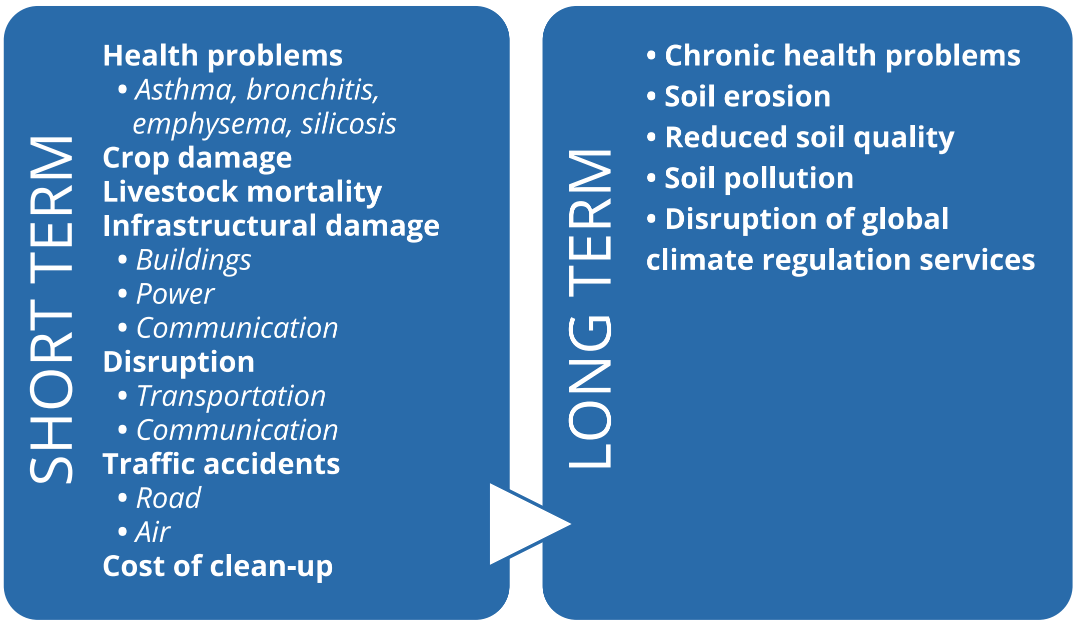
3. SAND AND DUST STORM IMPACTS ON THE SUSTAINABLE DEVELOPMENT GOALS

Sand and dust storms significantly impact human health, the environment and economies. These storms damage buildings and paralyse infrastructure operations, such as the functioning of transportation hubs (airports), communication networks and power and water supply systems (Jung, 2016). Ultimately, the impacts of sand and dust storms impede progress towards achieving the Sustainable Development Goals (SDGs), either directly or indirectly.

Sand and dust storms have wide-ranging economic impacts, both immediate and in longer terms. Short-term costs include crop damage, livestock mortality, infrastructural damage (buildings, power and communications), interruption of transport and communication systems, air and road traffic accidents and the expense of clearing away sand and dust. Longer-term costs include chronic health problems, soil erosion, reduced soil quality, soil pollution through the deposition of pollutants and the disruption of global climate regulation services (see figure 3.1) (UNEP, WMO and UNCCD, 2016).

Figure 3.1

Short- and long-term impacts of sand and dust storms



Source: Based on UNEP, WMO and UNCCD, 2016.

Sand and dust storms as extensive and intensive risks

Because of their unique origin, geographical coverage and cross-sector links, sand and dust storms are characterized as either extensive[5] or intensive[6] risk, both of which cause severe short- as well as long-term impacts. In terms of the economic impact, desert dust events cost up to an estimated $5.6 billion annually in the Asia-Pacific region.

The following examples illustrate the various extensive and intensive impacts of sand and dust storms.

Sand and dust storm as extensive risk: The Zabol region (Sistan Basin) of the Islamic Republic of Iran, 2000–2004

The Zabol region of south-eastern Islamic Republic of Iran has arid and semi-arid climate. It covers an area of approximately 15,197 square kilometres and has a population of about 400,000 people. The region is subject to severe winds, with speeds occasionally reaching 120 kilometres per hour. The 1999 drought, which caused the Hamoun Lake to dry up and changed land use from agriculture to waste land, increased the susceptibility of the soil to erosion. In turn, there has been an increase in dust storms (Miri and others, 2009).

5 Extensive risk: "The widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts" (UNISDR, 2009).

6 Intensive risk: "The risk associated with the exposure of large concentrations of people and economic activities to intense hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss" (UNISDR, 2009).

Figure 3.2

Streamers of pale dust swirl over the arid terrain of Afghanistan (top), the Islamic Republic of Iran (left) and Pakistan (bottom right) on 20 August 2003

©Jacques Descloitres, MODIS Rapid Response Team, NASA/Goddard Space Flight Center

Dust storms affected the Zabol region for a total of 338 days between 2000 and 2004. This included 18 days of intensive dust storms and 51 days of moderate dust storms. Researchers attempted to quantify the damage costs using an analytical-descriptive method, based on questionnaires completed by communities and local organizations (Pahlavanravi and others, 2012; Miri and others, 2009). They estimated the extent of damage due to sand and dust storms for that time period at more than $200 million.

Sand and dust storm as intensive risk: North-western China

In May 1993 in north-western China, around 1.1 million square kilometres of land (11.5 per cent of total land territory) were directly affected by dust storms–threatening 12 million people. In the end, the damages totalled an estimated $70 million (Gengsheng, Honglang and Wanquan, 2001).

Sand and dust storm as intensive risk: New South Wales, Australia, 2009

In their study, Tozer and Leys (2013) estimated the impact on the state economy of New South Wales at nearly AUD300 million due to a single large dust storm, called Red Dawn, that passed over the eastern coast of Australia on 23 September 2009.

While the occurrence of sand and dust storms can be scientifically determined, quantifying their impact on society, the environment and an economy is more difficult due to the lack of relevant data. For example, the three geographic events just cited all relied on different methodologies to estimate damage done and thus the findings are not directly comparable. While the various methods give an indication of the costs involved, there is a critical need for a standardized method to assess the economic impact of storms.

There is also urgent need to generate high-quality relational datasets. Sand and dust storm risk assessments need to be more comprehensive–in a way that captures the direct and indirect losses over large geographical expanses in source and impacted areas.

Sand and dust storm impacts on SDG progress

In the context of arid and semi-arid subregions, sand and dust storms can negatively affect the progress to be made or already made on at least eleven of the 17 SDGs:[7] ending poverty in all forms (SDG 1), ending hunger (SDG 2), good health and well-being (SDG 3), safe water and sanitation (SDG 6), 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 life (SDG 14), on land (SDG 15) and partnerships for the goals (SDG 17) (see table 3.5).

A well-crafted sand and dust storm policy can help advance the progress being made on those goals (and most likely all the others, considering their close interrelationships). Conversely, achieving sustainable development as envisioned through the SDGs will help reduce the occurrence and impacts of sand and dust storms.

7 Because the SDGs are all interlinked, impeded progress with one goal could possibly affect all 16 other SDGs.

Table 3.1 Sand and dust storm risks in relation to SDG targets

	SDG target	Sand and dust threats
	Goal 1: End poverty in all its forms everywhere	
1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	Drought is a background factor that influences dust storms, and the accumulated effect of multiple-year droughts leads to dry-land degradation and desertification. Land degradation negatively impacts productivity and can increase poverty.
	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	Sand and dust storms can intensify damages to the livelihood and food security of millions of small farmers and pastoralists. Sand and dust storms also damage agricultural infrastructure, such as irrigation canals and agricultural machinery, and can impact production, subsequently having negative impact on food security.
	Goal 3: Ensure healthy lives and promote well-being for all at all ages	
3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	People's health and well-being are often affected as a direct result of sand and dust storms in both the long term and short term. Chronic exposure to fine particulates is associated with premature death due to cardiovascular and respiratory diseases, lung cancer and acute lower respiratory infections. Dust can cause or aggravate diseases, such as bronchitis, eye infections, skin irritations, meningococcal meningitis, valley fever and diseases associated with toxic algal blooms. It can also cause mortality and injuries related to highway accidents due to reduced visibility.
	Goal 6: Ensure availability and sustainable management of water and sanitation for all	
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all	Sand and dust deposited into water resources can negatively impact water quality. Ineffective water resource management can dry up water basins, thereby increasing the prevalence of sand and dust in the environment.

	SDG target	Sand and dust threats
6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation, as appropriate	
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
8.1	Sustain per capita economic growth in accordance with national circumstances and, at least 7 per cent gross domestic product growth per annum in the least developed countries	Sand and dust storms can severely impact economic growth by damaging crops, filling irrigation canals, triggering power blackouts, disturbing transportation operations, etc.
	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	
9A	Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States	Infrastructure, such as road, power and water networks, is a basic requirement of a competitive economy. When infrastructure fails during sand and dust storm events, vital services may be interrupted and the sustainability of large and small businesses is threatened. For example, power failures may disrupt the supply of water and transport during sand and dust storms.
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	
11.5	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	The world is increasingly becoming urban–urbanization is projected to reach more than two-thirds of the world's population. The urban areas exposed to sand and dust storm risk are likely be impacted severely.
	Goal 13: Take urgent action to combat climate change and its impacts	
13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Through changing temperatures and precipitation levels, among other factors, global climate change is modifying sand and dust storm hazard levels and exacerbating the risks. Due to changes in the climate conditions, dry lands are becoming drier and, consequently, more prone to wind erosion and sand and dust storms.

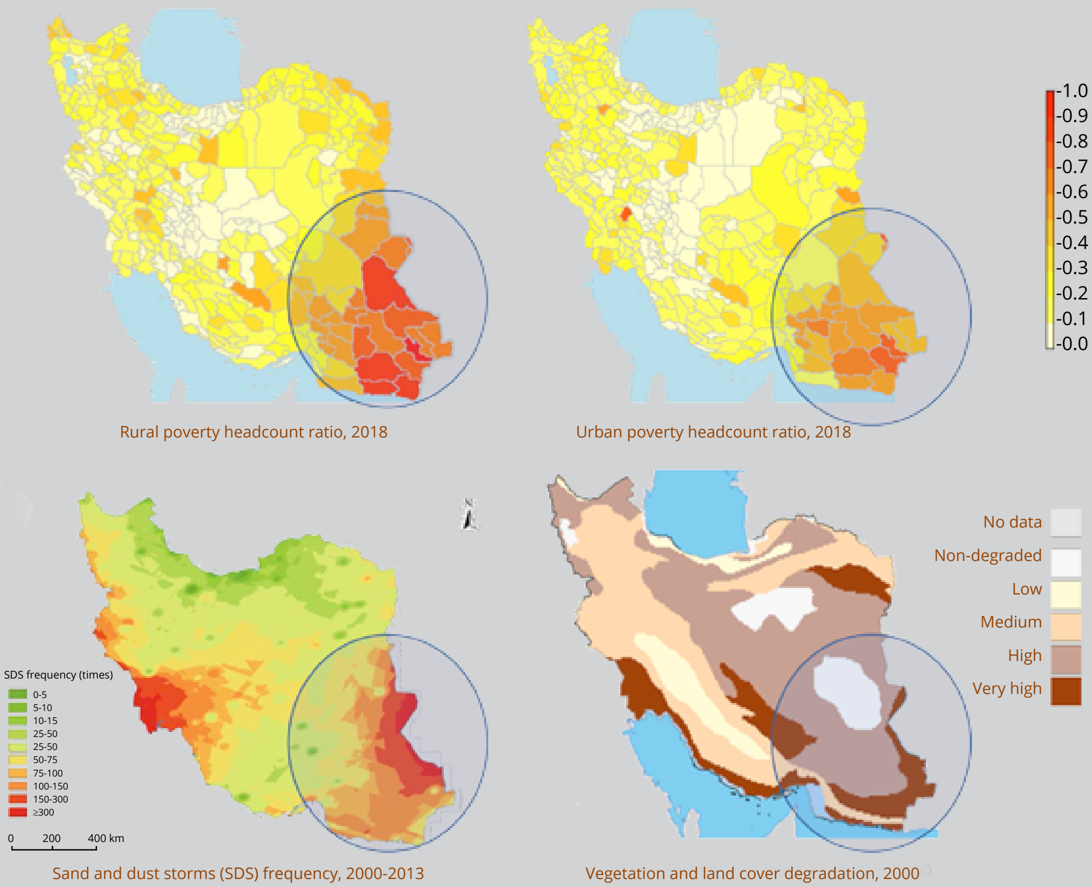
	SDG target	Sand and dust threats
13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	
	Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular, from land-based activities, including marine debris and nutrient pollution	Sand and dust storms have both positive and negative impacts on the oceans. On the positive side, dust deposits provide nutrients to surface waters, thereby boosting primary productivity. On the negative side, dust and sand deposition in coastal areas adversely affect coral reef ecosystems (UNEP, WMO and UNCCD, 2016).
	Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	Ecosystem degradation erodes the resilience of communities and nations and exposes them to increased risks of and impacts from disasters.
	Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development	
17.6	Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular, at the United Nations level, and through a global technology facilitation mechanism	Sand and dust storms with transboundary origins and impacts have been causing extensive and intensive losses in large geographical areas and in multiple sectors of relevance to achieving the SDGs in arid and semi-arid zones. For example, sand and dust storms originating from hotspot sources in countries neighbouring the Islamic Republic of Iran and dried-up wetlands within the country are causing a great deal of discomfort to habitants in some south-western and south-eastern provinces. Desertification, degradation of dry lands and destruction of coastal forests and wetlands increase the risk of sand and dust storms by making new hotspot sources or expanding the current ones. Combating desertification and protecting ecosystems and restoration (in pastures and wetlands) offers sustainable and cost-effective solutions for sand and dust storm risk reduction.

Box 3.1

Sand and dust storms exacerbate existing poverty and inequalities

An emerging area of concern in grappling with the many impacts of climate change is the growing phenomenon of sand and dust storms, which mostly occur in arid and semi-arid regions, particularly in South, South-West, Central and North-East Asia. Sand and dust storms that co-exist with drought, land degradation and desertification exacerbate existing poverty and inequality levels within impacted countries. In the Islamic Republic of Iran, for example, cross-referencing district-level poverty data with storm frequency and land degradation maps for the past decade revealed strong correlations between the areas that were hit by multiple episodes of sand and dust, areas that had a high level of land degradation and areas that had high poverty rates (see the following figures).

Correlation between poverty, frequency of sand and dust storms and land degradation in the Islamic Republic of Iran



Rural poverty headcount ratio, 2018

Urban poverty headcount ratio, 2018

Sand and dust storms (SDS) frequency, 2000-2013

Vegetation and land cover degradation, 2000

The effect of the combined stresses can increase the already elevated levels of poverty by endangering livelihoods through the destruction of crops and livestock and the increased incidence of chronic disease in communities that are potentially the least capable to cope. From 2000 to 2004, the economic cost of sand and dust storms in the Zabol region in south-eastern Islamic Republic of Iran was approximately $31 million in the health sector and around $48 million in the agriculture sector. In addition, populations living in these areas experienced high levels of well-being losses (health, nutrition, education, etc.) because they could not rely on savings to smoothen out the impacts from the storms. Households with weak socioeconomic resilience are less able to minimize the impacts to their well-being.

Source: ESCAP Theme Study 2018: Inequality (forthcoming).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4

POLICY ACTIONS FOR COMBATING SAND AND DUST STORMS

4. POLICY ACTIONS FOR COMBATING SAND AND DUST STORMS

Improved policy coordination at the global and regional levels and regional cooperation are essential for tackling the transboundary issues regarding the sources as well as the impacts of sand and dust storms. Defined as the movement of sand and dust through the air, sand and dust storms require continuous monitoring and early warning to allow people downwind to take preventive measures to minimize their impact on human health, the environment and a country's economy (Akhlaq and others, 2012).

A policy framework for coping with sand and dust storms must cover both adaptation and mitigation: (i) addressing underlying vulnerabilities and building up resilience along with monitoring, prediction and early warning for impact mitigation; and (ii) source mitigation with a comprehensive multi-hazard risk reduction approach that follows the Sendai Framework for Disaster Risk Reduction 2015–2030 (see box 4.1).

To implement a policy framework for combating the problems associated with sand and dust storms, strong partnerships and the following cross-cutting actions are needed:

- Identify best-practice policy options and policy failures at the regional, national and subnational scale.
- Identify sand and dust storm knowledge gaps to better focus research.
- Mainstream sand and dust storm issues into disaster risk reduction. Sand and dust storm risks should be fully integrated into multi-hazard management plans for disaster risk reduction at all levels and across all sectors.
- Build institutional capacity for coordinated and harmonized sand and dust storm policy development and implementation at the regional, national and subnational levels.
- Explore innovative financing opportunities and other resources needed for sand and dust storm actions.
- Establish a coordination mechanism for partnerships with relevant United Nations organizations to consolidate the global policy on sand and dust storms to strengthen synergies and cooperation.
- Establish an international and regional platform for disseminating critical data and exchanging experiences.
- Strengthen regional and subregional cooperation.

Box 4.1

Recommendations for action emerging from the thirteenth session of the Conference of Parties, United Nations Convention to Combat Desertification, in Ordos, China, in 2017

I. Adaptation actions: Monitoring, prediction, early warning and preparedness for impact mitigation

- Implement comprehensive early warning systems at the national and regional levels.
- Identify and scale up best-practice techniques for physical protection of assets, including infrastructure and agriculture, against sand and dust storms in affected areas.
- Identify and scale up best-practice strategies to minimize negative impacts of sand and dust storms on key sectors and population groups, including women.
- Establish and implement coordinated emergency response measures and strategies across sectors, based on systematic impact and vulnerability mapping and assessments.

II. Source mitigation

- Identify and monitor sand and dust storm source areas.
- Identify and scale up best-practice techniques for source mitigation, with evidence-based systems to evaluate effectiveness of solutions.
- Highlight synergies among the Rio Conventions and related mechanisms and initiatives for sand and dust storm source-area mitigation strategies. Sustainable land and water management and integrated landscape management practices, restoration interventions and climate change mitigation options can all contribute towards the mitigation of anthropogenic sand and dust storm source areas.
- Integrate sand and dust storm source-area mitigation practices into national efforts towards achieving SDG target 15.3 on land degradation neutrality. Sand and dust storm source mitigation could be linked to land degradation neutrality target setting and included as a voluntary sub-target in source countries.

Source: Advocacy policy frameworks: Gender, drought and sand and dust storms, Conference of the Parties Thirteenth session, Ordos, China, 6–16 September 2017.

United Nations initiatives on combating sand and dust storms

There has been growing awareness of the multifaceted impacts of sand and dust storms on the environment, climate conditions, human health, livelihoods, agriculture and the socioeconomic well-being of societies. The United Nations system is confronting the problem from various perspectives, as the following highlights.

In 2007, the 15th Congress of the World Meteorological Organization highlighted the importance of the problem and endorsed the launch of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), with its global steering committee and three regional nodes: for Northern Africa, the Middle East and Europe; for Asia; and for the Americas.[8] In February 2014, the World Meteorological Organization established the Barcelona Dust Forecast Center, whose operations generate and distribute forecasts for North Africa, the Middle East and Europe.

The IPCC dedicated a section to sand and dust storms in its 2012 special report: Managing the Risks of Extreme Events and Disaster to Advance Climate Change Adaptation. The United Nations General Assembly resolutions on combating sand and dust storms adopted in 2015 (A/RES/70/195) and 2016 (A/RES/71/219) acknowledge that the particulate phenomenon represents a severe impediment to the sustainable development of many developing countries and the well-being of their peoples.

A/RES/70/195 calls for a global assessment of the sand and dust storm phenomenon. The United Nations Convention to Combat Desertification (UNCCD) secretariat, led by the United Nations Environment Programme (UNEP) in collaboration with the World Meteorological Organization, produced in 2016 the Global Assessment of Sand and Dust Storms as a response to the resolution.

A/RES/71/219 takes note of the offer from the Government of the Islamic Republic of Iran to organize an international event in Tehran in 2017 to discuss combating sand and dust storms. In July 2017, the Iranian Department of Environment and Ministry of Foreign Affairs, in cooperation with UNEP, the United Nations Development Programme, the United Nations Department of Economic and Social Affairs, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and other United Nations entities, hosted an international conference that led to adoption of the Tehran Ministerial Declaration (see box 4.2). These two resolutions emphasize the need to strengthen the leadership role of the United Nations system in promoting international cooperation to mitigate and contain sand and dust storms.

8 See www.wmo.int/sdswas and http://sds-was.aemet.es for Northern Africa, the Middle East and Europe; http://eng.nmc.cn/sds_was.asian_rc for Asia; and http://sds-was.cimh.edu.bb/ for the Americas.

The associated work of ESCAP is guided by ESCAP resolution 72/7, which requests the secretariat to establish a regional cooperation mechanism to combat sand and dust storms in Asia and the Pacific. It is also guided by the United Nations Environment Assembly resolution 2/21 on sand and dust storms. Table 4.1 breaks down the activities of the World Meteorological Organization, the Food and Agriculture Organization of the United Nations (FAO), UNEP and the UNCCD secretariat in combating sand and dust storms.

Table 4.1 Area of sand and dust storm-related activities of United Nations entities

World Meteorological Organization (SDS-WAS)	Monitoring, risk assessment, forecasting, early warning systems, training and awareness
Food and Agriculture Organization of the United Nations and United Nations Environment Programme	Agriculture investment, green belts, water use, ecosystem management, land use plans and adaptation
United Nations Convention to Combat Desertification secretariat	Desertification, sustainable land and drought mitigation

Box 4.2

Tehran Ministerial Declaration, International Conference on Combating Sand and Dust Storms, Tehran, 3–5 July 2017

"Agree to cooperate on combating sand and dust storms at sub-regional regional, and international levels on the following:

1. Share information, lessons learnt and best practices, exchange views and expertise, develop mitigation and adaptation policies and measures, exchange technical and monitored data and forecasting information to reduce the risk of sand and dust storms.
2. Strengthen national legal and institutional frameworks to share early warning information of sand and dust storms and raise awareness and promote integrated and synergistic actions across sectors and foster strengthened cooperation among relevant institutions at global, regional and national levels.
3. Enhance public awareness on the impact and cost of Sand and Dust Storms on human health, agricultural practice, food security, infrastructure, transport and in general socio-economic sectors and the environment and partnerships among relevant stakeholders on mitigation of the impacts.
4. Collectively endeavour to enhance cooperation and coordination at global, regional and sub-regional levels to address the causes and impacts of Sand and Dust Storms including through the promotion of sustainable water use and land management, to reduce future Sand and Dust Storms risks and impacts.

5. Develop and implement a strategy on disaster risk reduction and resilience to promote sustainable land management and water use in croplands, rangelands, wetlands, deserts as well as rural and urban areas.

6. Strengthen research activities for effective monitoring, impact-based assessment and forecasting and early warning mechanism for Sand and Dust Storms, to address disaster prevention and mitigation and for development of appropriate preparedness and effective response to Sand and dust storms.

7. Encourage enhanced regional and international cooperation to observe and forecast, mitigate and cope with the adverse effects of Sand and Dust Storms, and seek technical and financial support from the relevant United Nations organisations to that end.

8. Consider to further develop policy dialogue on responding to the issues of sand and dust storms among interested countries in partnership with relevant international bodies and organizations, including the establishment of a future platform, in synergy with relevant United Nations System.

9. Recognize the role of the Asian and Pacific Center for the Development of Disaster Information Management (APDIM), regional seas programs and SDS-WAS, to develop human and institutional capacity through strengthened regional cooperation in disaster information management.

10. Invite the Environment Management Group (EMG) of the [United Nations] to consider initiating an inter-agency process involving relevant UN system warranting to prepare a global response to Sand and Dust Storms including a situation analysis, Strategy and an Action Plan. This could result in developing a UN-wide approach in addressing Sand and Dust Storms which can be used as an inter-agency framework for mid- or long-term cooperation and division of labour.

11. Request the [United Nations] General Assembly to consider this declaration for appropriate actions.

12. Express our deepest gratitude to the Government and people of the Islamic Republic of Iran for the excellent arrangements and the warm hospitality they extended to participants in this important Conference."

Source: See http://www.ir.undp.org/content/iran/en/home/presscenter/articles/2017/07/05/text-of-tehran-ministerial-declaration.html.

Gaps and unmet needs

The origins as well as impacts of sand and dust storms are not only transboundary but also cover large geographical areas. Managing and mitigating the risk of sand and dust storms thus remains challenging. Critical gaps endure in terms of access to information, intergovernmental cooperation and partnership, and institutional capacity to suitably deal with the phenomenon.

Access to transboundary risk information

There are significant gaps in the information supply chain at the local, national and regional levels. Information on sand and dust storms is mostly sparse and incomplete. Additionally, the information is often generic and not actionable for designing or carrying out sand and dust storm mitigation plans. The scale of risk information is vast and varies from regional and national to local levels. Assessments on the impacts of sand and dust storms are also insufficient in various sectors and at both the national and regional levels.

Information at different levels of the sand and dust storm disaster management cycle is not readily available. Specialized surveys on needs, capacities, challenges and opportunities are required to respond adequately.

Knowledge about the processes in place at the local level is insufficient–more precise information for each area is needed. This situation is exacerbated by a mismatch of local studies with the special needs required by a transboundary disaster, which leaves some local response efforts less efficient than they could be. There are not enough economic and health impact studies in relation to sand and dust storms. Also, there is no disaster-impact database that records sand and dust storm activity, especially as an extensive risk. Similarly, there is no proper mechanism or platform to record sand and dust storm events in accordance with their transboundary nature.

Remote-sensing techniques can help bridge the information gaps by monitoring the transboundary origins and impacts of sand and dust storms over large geographical reach. Tools exist for monitoring sand and dust storms, such as the Earth-observation satellite services, air quality stations and meteorological reports. But these need to be better harnessed to improve the quality of early warning systems and to facilitate sand and dust storm adaptation and mitigation efforts.

Clear quantitative evidence of the cost of impacts and benefits from action taken is needed to make a case for governments (ministries) as well as international financial institutions to fund sand and dust storm adaptation and mitigation activities among many competing needs and sectors.[9] To appropriately confront sand and dust storms, decision makers need knowledge, good statistics and indicators, effective governance and smart approaches (see box 4.3).

9 Report of the International Conference on Combating Sand and Dust Storms Tehran, Islamic Republic of Iran, 3–5 July 2017. Available from www.un.org.ir/images/Documents/sandandduststorms/SDS_Conference_Report_07_15_July_2017.pdf.

Box 4.3

Regional forecasting model: Unified Atmospheric Chemistry Environment for Dust in China

China has been monitoring dust storm events since the 1950s as a part of its routine weather monitoring (Wang and others, 2008). The Chinese Unified Atmospheric Chemistry Environment for Dust (CUACE/Dust) model is an integral part of a real-time mesoscale sand and dust storm forecasting system for East Asia. The system produces 24-hour, 48-hour and 72-hour forecasts. In addition to meteorological data and dust aerosol conditions, the CUACE/Dust model incorporates information on the distribution of deserts and semi-deserts, soil grain size, soil moisture content, snow cover, land use and surface roughness length (Zhou and others, 2008). Identifying and analysing these factors allows scientists to make more educated assumptions about how land would be affected if a dust storm were to occur. In addition, the aerosol module that is used with the CUACE/Dust can differentiate the size of suspended particles (Zhou and others, 2008). From this information, analysts make inferences about transport distance, noting that fine particles remain suspended in the atmosphere longer and can travel farther than coarse particles. The CUACE/Dust model is acknowledged as a suitable model for sand and dust storm events in East Asia and is included as a forecast model in the Asian node of the World Meteorological Organization's SDS-WAS.

Source: UNEP, 2017.

Capacity development for building up resilience to the impacts of sand and dust storms

Managing sand and dust storm impacts requires substantial capacity for risk reduction and mitigation action. The capacity of countries exposed to sand and dust storms, particularly in South and South-West Asia as well as in North and Central Asia, however, needs to be substantially enhanced to combat the problem using well-informed risk-sensitive plans of action. While there are several sand and dust storm adaptation and mitigation action plans at the regional and national levels, limited institutional capacity has been a constraining factor to the follow-through. This is where the need for capacity building through knowledge sharing, technical expertise, technical cooperation, best practices and lessons learned takes on great significance.

What is specifically needed are demand-driven and customized training services for various types of stakeholders in addition to a regional platform and cooperation mechanism for exchanging experts and experiences in sand and dust storm mitigation.

Interregional and regional cooperation

There is also a need to deepen cooperation between the countries that are sand and dust storm sources and the affected areas at the regional as well as interregional levels to bring about synergy and coherence among various response initiatives to cope with the impacts.

A framework that brings together specialized United Nations bodies (such as UNEP, the World Meteorological Organization and the UNCCD secretariat) and intergovernmental United Nations regional commissions (such as ESCAP and the Economic Commission for Africa and the Economic and Social Commission for West Asia) from one side and national governments in source and sink areas from the other side is essential to tackle both the adaptation and mitigation challenges of sand and dust storms, especially because there is no operational mechanism in place. Such a framework is critical for promoting the regional and interregional cooperation that is necessary for overcoming the gaps in understanding the transboundary nature of sand and dust storm risks and for institutional capacity development.

The ESCAP mandate

ESCAP resolution 72/7,[10] adopted during the Commission's annual session in 2016, extends it four mandates to combating sand and dust storms as follows:

1. "Within existing mandates and expertise, accord priority focus on the work of the Commission relating to sand and dust storms as a great transboundary challenge."
2. "Work, including through the Asian and Pacific Centre for the Development of Disaster Information Management, as well as with other relevant regional organizations, utilizing a combination of existing funds and extrabudgetary contributions, to promote regional and interregional networking on sand and dust storms."
3. "Work closely with the United Nations Environment Programme, the World Meteorological Organization and the secretariat of the United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa, in the process of preparing the global assessment on sand and dust storms."

10 See www.unescap.org/sites/default/files/E72_RES7E.pdf.

4. “Report to the Commission at its seventy-third session and thereafter on a biennial basis on progress in the implementation of the present resolution.”

In implementation of this Resolution, the Asian and Pacific Centre for the Development of Disaster Information Management (APDIM) provides information management services and specialized capacity development training for transboundary hazards, including sand and dust storms. The APDIM programme is designed to fill the information management gaps and provide capacity development by deepening regional and South-South cooperation. In this regard, the work of APDIM on transboundary disaster risk assessment is expected to contribute to intergovernmental discussions (along with other scientific assessments) on related regional cooperation issues for combating sand and dust storms. It will draw from and contribute to ESCAP's Asia-Pacific Disaster Resilience Network (APDRN), which is based on a multi-hazard cluster approach that includes extreme weather events, geophysical disasters and slow-onset disasters.

Addressing shared vulnerabilities through multi-hazard early warning systems for transboundary disasters is also a recognized priority in several ESCAP policy documents, notably the Regional Road Map for Implementing the 2030 Agenda for Sustainable Development in Asia and the Pacific and the 2017 Ministerial Declaration on Regional Economic Cooperation and Integration in Asia and the Pacific.[11]

11 From the Second Ministerial Conference on Regional Economic Cooperation and Integration in Asia and the Pacific, in Bangkok, 21–24 November 2017. Available from www.unescap.org/sites/default/files/MCREI-2_L3_E.pdf.


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5

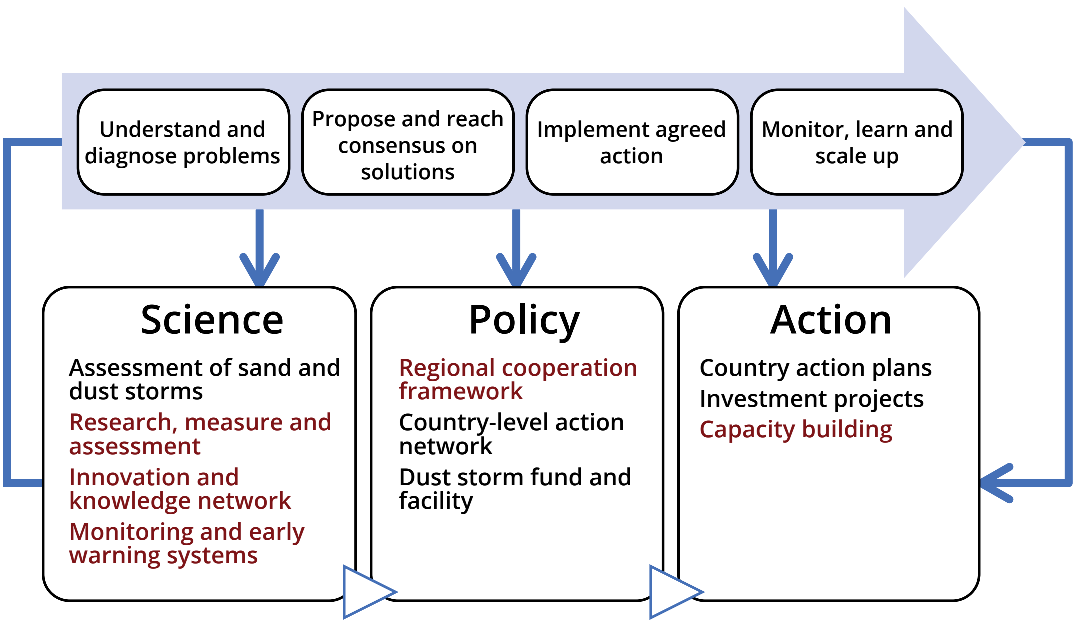
SCIENCE, POLICY AND ACTION: CONNECTING THE DOTS

5. SCIENCE, POLICY AND ACTION: CONNECTING THE DOTS

The adaptation and mitigation actions for sand and dust storms need to be guided by a science and policy interface. Periodic scientific assessment of sand and dust storm transboundary risks–based on state-of-the art tools, techniques and models, including Earth-observation satellite data and products–in conjunction with aerial and ground-based measurements of storm parameters and indicators will help to understand their complexity and dynamics and thus to diagnose appropriate responses. Assessments may provide an account of shared vulnerabilities to sand and dust storm risks, which can become a basis for regional and subregional cooperation for information and knowledge sharing, capacity development and collective action. The regional cooperation mechanism that ESCAP is working to establish, based on its resolution 72/7 mandate, essentially aims to put into practice a platform of stakeholders for regular dialogue and collective action to reinforce adaptation and mitigation responses to sand and dust storms (see figure 5.1).

Figure 5.1

Science, policy and action for combating sand and dust storms: A framework for the proposed ESCAP regional cooperation mechanism to deal with slow-onset disasters



Source: Adopted from Haddad, 2015.
Note: This framework follows the one that UNEP proposed in 2015.

Understanding the nexus of the slow-onset disasters: Drought, desertification, land degradation and sand and dust storms

As discussed earlier, there is a complicated socioeconomic and environmental intertwining related to sand and dust storms. Droughts, which result from irregularities in annual or season precipitation, can negatively affect land and lead to ecological degradation. Ecosystem degradation can lead to deforestation and desertification. Desertification, in combination with high-speed wind, leads to sand and dust storms (Abdi, Glover and Luukkanen, 2013). This natural process can combine with socioeconomic conditions to speed up the occurrence of such storms. For example, increasing populations place more pressure on land use, which can result in unsustainable land management and, ultimately, land degradation (see box 5.1). In addition to encouraging sand and dust storms, land degradation reduces productivity and increases poverty (see figure 5.2).

Box 5.1

Nexus of poverty, drought, desertification, land degradation and sand and dust storms in Mongolia

Dry lands, characterized by arid and semi-arid regions, are largely located in developing countries. Globally, about half of all dry-land inhabitants are impoverished–about a billion people in total. They are dubbed the "forgotten billion" because they have been habitually neglected in development processes (Middleton and others, 2011).

There are empirical evidences of the links between desertification by overgrazing, drought and dust storms from the Gobi Desert of Mongolia. The country's mobile pastoralism traditions stretch back more than a thousand years, but overgrazing of rangeland by pastoralists has been the most commonly cited cause of desertification in global dry lands for more than 30 years. Although overgrazing, desertification and dust storms are frequently connected, drought was found to be an important driver of vegetation cover change in and around the Gobi Desert. Vegetation cover adversely affected by drought was further reduced by grazing; the combined conditions led to loss of livelihood opportunities and increased household poverty.

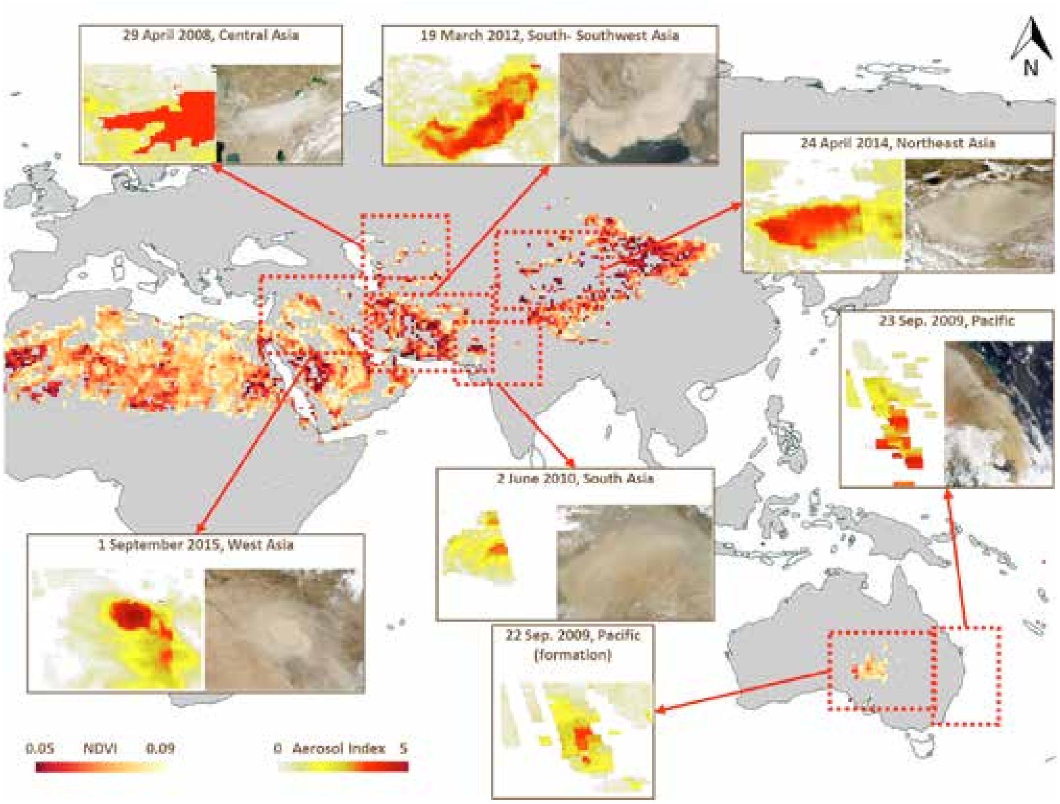
Source: Middleton, 2016.

Nexus in arid and semi-arid subregions

Mappings of sand and dust storm events have demonstrated their co-existence with drought, desertification and land degradation in arid and semi-arid subregions. The Earth-observation satellite-based Normalized Difference Vegetation Index (NDVI) and the Aerosol Index are used to understand the geography of that nexus and to forecast future events. The lowering of NDVI values, for instance, is a signal for potential long-term drought and subsequent expansion of sand and dust source areas. Similarly, rising values in the Aerosol Index is an indicator of actual sand and dust concentration in the atmosphere. Figure 5.2 illustrates a comparison of the NDVI and the Aerosol Index values for six sand and dust storm events in the Asia-Pacific region over the past decade. Combining the varying timescales of the NDVI and Aerosol Index helps to monitor and assess the multi-hazard risks; that information is then used to develop an alert system that generates early warning of sand and dust storms as well as drought, desertification and land degradation.

Figure 5.2

Comparison of NDVI and Aerosol Index values at the time of sand and dust storms in the Asia-Pacific region, 2008–2015



Source: ESCAP, based on data from https://worldview.earthdata.nasa.gov (accessed 7 March 2018).
Note: NDVI values between 0.05 and 0.09 indicate the area of land with high potential to generate a sand and dust storm (base map). The Aerosol Index and the true-colour images reflect particular sand and dust storms (see boxes).

Real-time risk assessment and monitoring

When analysed in conjunction with surface and aerial measurements, Earth-observation satellite-based indices capture the real-time impacts of sand and dust events from their source to regions across large geographical expanses. When a sand and dust storm inundated the province of Khuzestan in the Islamic Republic of Iran from 19 to 23 January 2018, its impacts across vast geographical areas were captured by a National Aeronautics and Space Administration's (NASA) Earth-observation satellite (see figure 5.3). The satellite monitoring actually had predicted the storm in Khuzestan Province (see figure 5.4), which turned out to be more intense than anticipated. The surface measurements at selected locations during the event indicated that the dust density readings reached 2,808 milligrams per centimetre–almost 20 times the standard of 150 milligrams per centimetre (Financial Tribune, 2018). Additionally, the Agriculture Stress Index that indicates the incidence and severity of drought was applied to Khuzestan Province after the storm. The percentage of cropland affected by drought was not assessed because the storm coincided with the off season (winter) for agricultural activity. Much of the country at that time, however, had experienced more than a negative 80 per cent precipitation anomaly relative to the long-term average for the month (see figure 5.5)–a situation that typically leads to the dry conditions that trigger sand and dust storms. The physical factors contributing to the January 2018 storm were most likely the limited vegetation growth during the off season and the dry conditions.

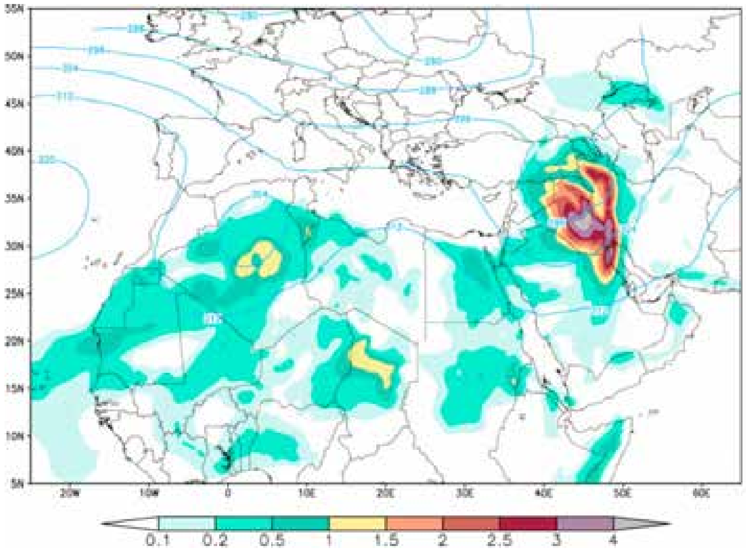
Figure 5.3

Sand and dust storm in the Islamic Republic of Iran, on 21 January 2018, as captured by the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board the joint NOAA/NASA Suomi-NPP satellite

Source: Sehatkashani, 30–31 January 2018, based on NASA: Earthdata, 2018.

Figure 5.4

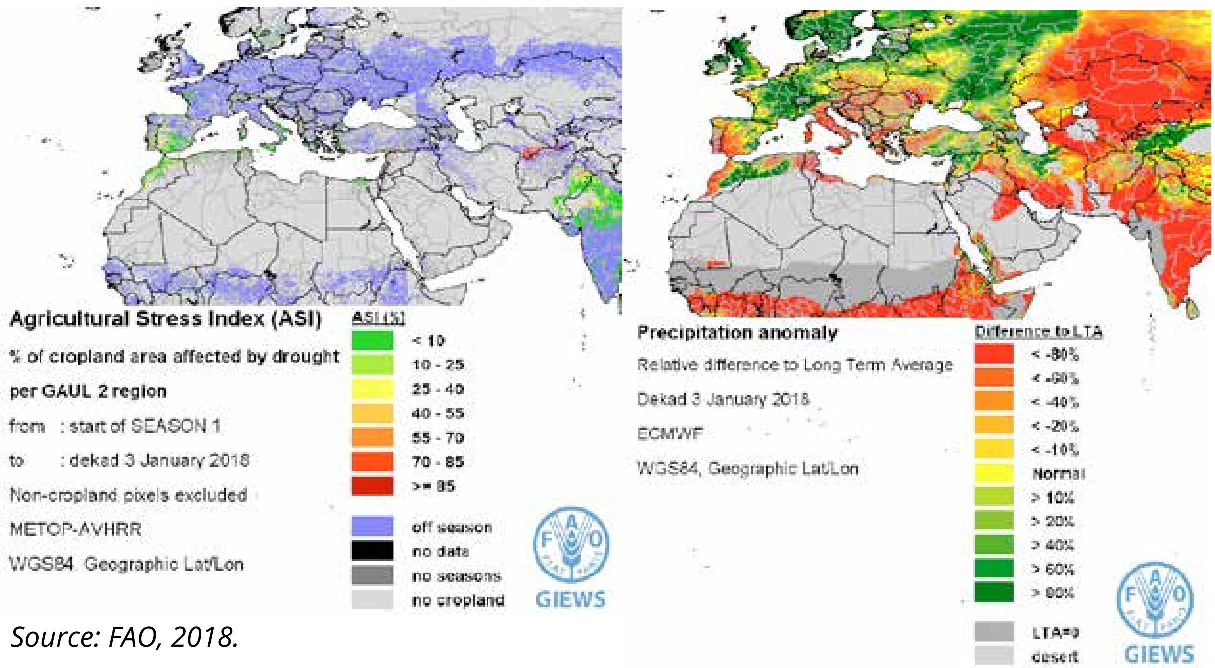
The sand and dust forecast (0.25 degree resolution, Goniux dust source map) of sand and dust storms in and around the Islamic Republic of Iran, January 2018



Source: Sehatkashani, 30–31 January 2018, based on Vukovic, 24 January 2018.

Figure 5.5

Agricultural Stress Index and precipitation anomalies for the Islamic Republic of Iran, January 2018



Source: FAO, 2018.

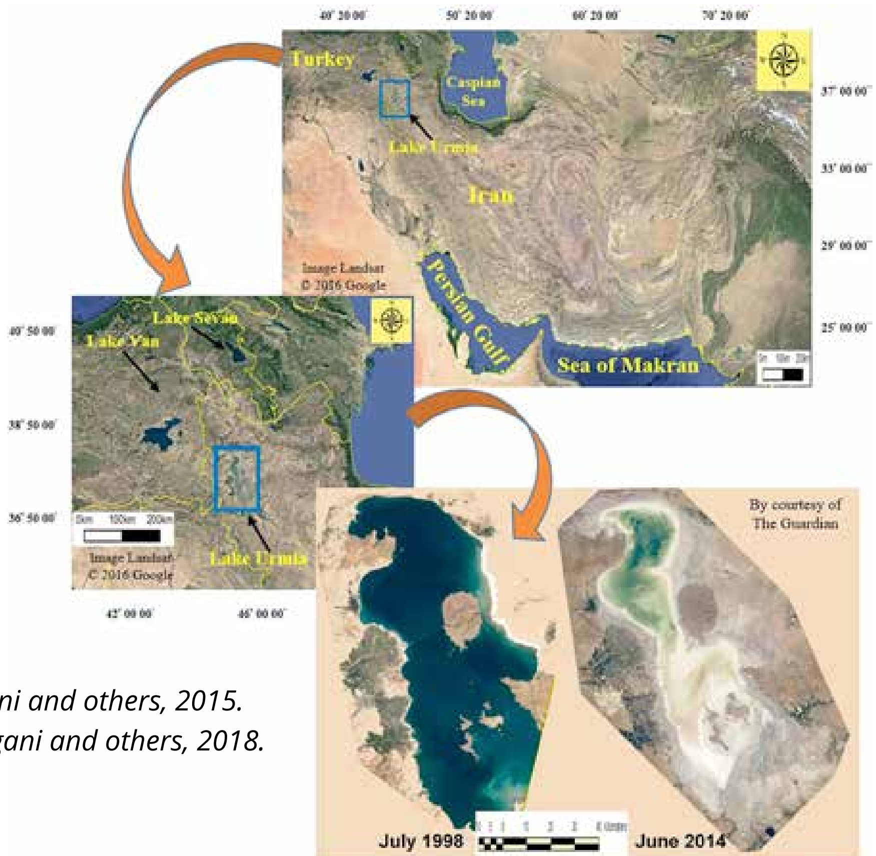
Multi-hazard risk accumulation

Risks accumulate over years, and one hazard typically triggers another in a specific context of arid and semi-arid regions. For example, droughts are typically associated with vegetation decline and drier soil. Sparse vegetation cover, in combination with dry and friable land soil and sediment, creates conditions conducive to sand and dust storm activity.

The hypersaline Lake Urmia in north-western Islamic Republic of Iran, for example, lost 90 per cent of its surface area between July 1998 and June 2014, which resulted in desertification, sand dunes and sand and dust storms. Earth observation products for the area surrounding the lake indicated a decline in vegetation health between June 1984 and July 2017 (see figure 5.6). Due to the hypersaline state of Lake Urmia, an estimated 6 million people in the vicinity experience damage from salt storms generated by the now-exposed shoreline. Sand and dust storms exacerbate their difficulties by impacting their agricultural lands and the health condition of vegetation. The decrease in Lake Urmia's water level has been attributed to high water-consumption development, agricultural use, water infrastructure placement and water use after prolonged upstream drought (Ahmady-Birgani and others, 2018).

Figure 5.6

The Lake Urmia, in north-western Islamic Republic of Iran, June 1998 and June 2014



Sources: Kaveh Madani and others, 2015.
Ahmady-Birgani and others, 2018.

Chapter 5

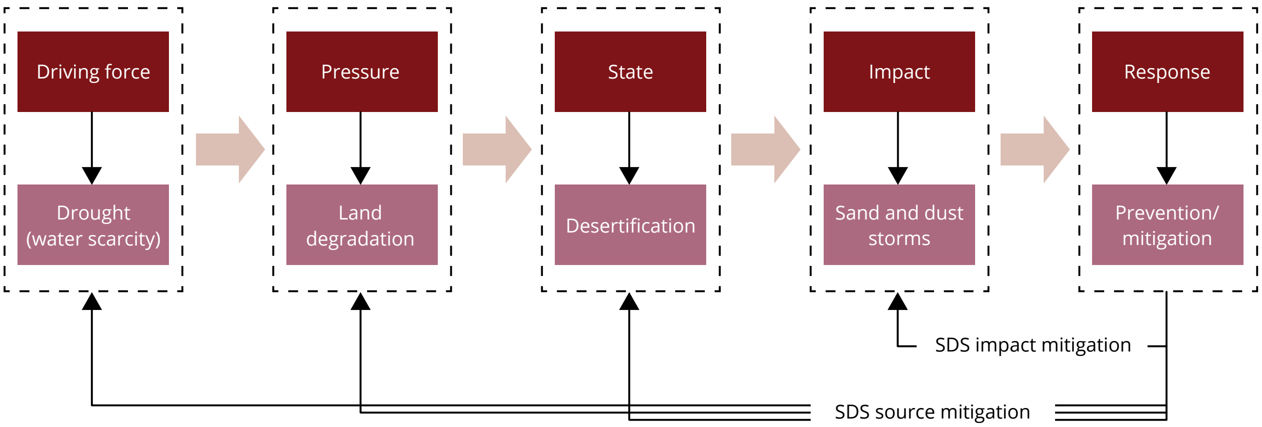
DPSIR framework for action

The European Environmental Agency devised a framework in 1999 that distinguishes driving forces, pressures, states, impacts and responses and is known by the abbreviation of those elements–DPSIR (see figure 5.7). Used for environment reporting in many countries, the DPSIR framework provides a basis for analysing the cause-and-effect relationships between interacting components of complex social, economic and environmental systems and in managing the information flows between their parts.

The DPSIR framework can be used when designing mechanisms to combat all the physical and anthropogenic components of sand and dust storms. In addition to its five elements (driving forces, pressures, states, impacts and responses), it combines environmental processes and states with human action in which driving forces trigger a process.

Figure 5.7

DPSIR framework in the context of slow-onset hazards

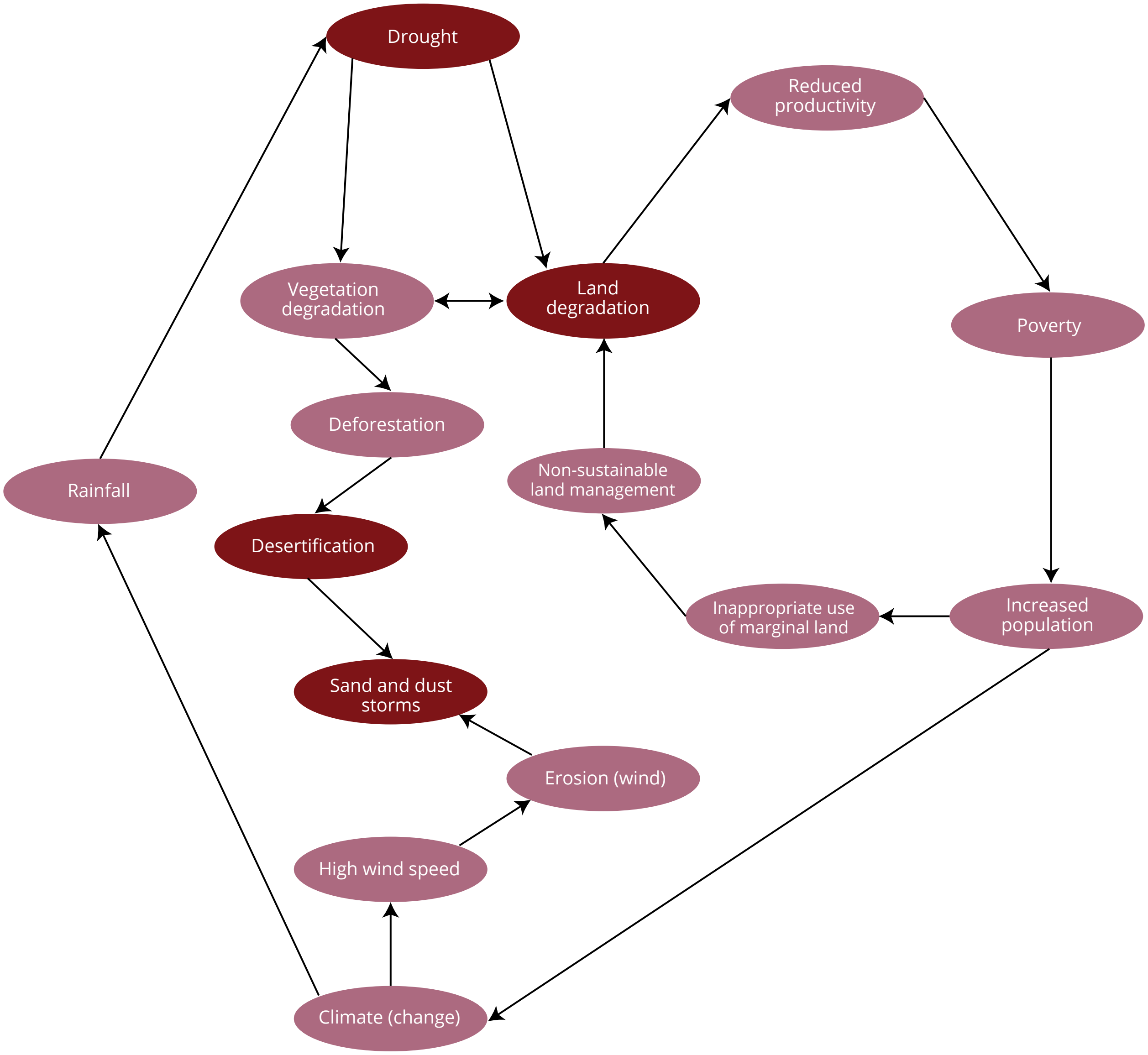


Note: SDS=sand and dust storm.

Drought is considered a primary trigger for sand and dust storms in the DPSIR framework. Pressure affects the driving force and represents processes affecting resources (land and water). Dry-land degradation (wind erosion) is considered a pressure. The physical and biological pressures on the natural system consequently change the state of the system. In this case, desertification is the new state, caused by land degradation (pressure). The impact of the changes in the state (desertification) is a sand and dust storm (see figure 5.8).

Figure 5.8

Causal loop of the process of land degradation, desertification and sand and dust storms



Source: Based on Abdi, Glover and Olavi, 2013; FAO, 1992.

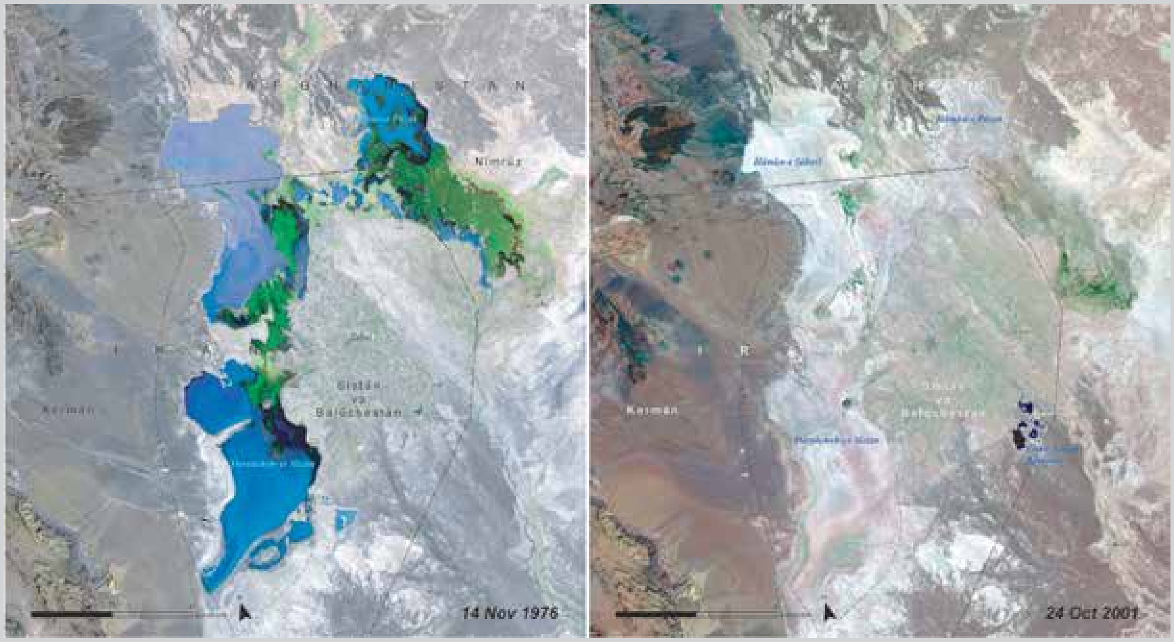
In a generic decisional context, the perceptions of relevant impacts induce decision makers to develop responses that work to prevent, compensate or mitigate the negative outcomes of changes to a state context. Responses may be targeted to the driving forces (drought), the pressures (land degradation), the state (desertification) or the impact (sand and dust storms). The following example of the Sistan Basin highlights drought as a driver of sand and dust storms in the Islamic Republic of Iran (see box 5.2).

Box 5.2

Drought as a driver of sand and dust storms in the Islamic Republic of Iran: The Sistan Basin

Sustained drought in quick succession and reduced precipitation in the Sistan Basin of the Islamic Republic of Iran dried the Hamoun Lake, caused severe land degradation and resulted in substantial reduction in land cover between 1999 and 2004. As a result, the total number of dust storm events and the number of hours of dusty air increased dramatically; the Dust Storm Index of incidence from 10 and 13 days during 1990–1998 to 54 and 88 days during 1999–2004, respectively. Although this shift was found to be associated with an increase in wind speed, rainfall reduction, the drying of Hamoun Lake and drought occurrence, drought was the primary driver of the sand and dust storms in the Sistan Basin.

Satellite images of Hamoun Lake in 1976 (left) that shows the lake and local vegetation and in 2001 (right) showing a dried lake, degraded land and depleted vegetation cover



Source: Miri and others, 2010.

Monitorable indicators

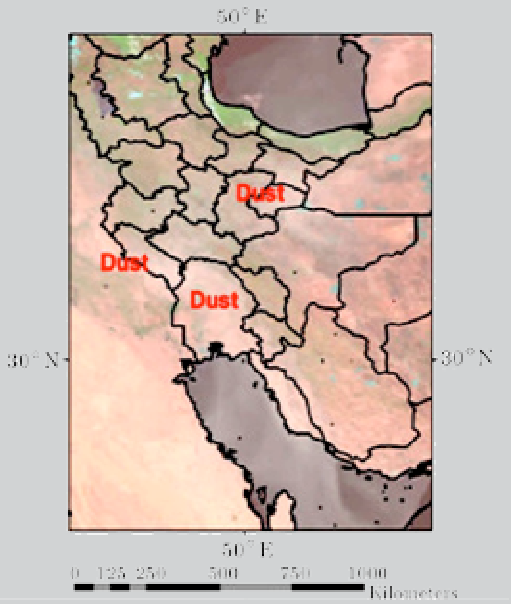
There are various indicators for detecting drought, land degradation (wind erosion), desertification and, consequently, sand and dust storms: change in vegetation cover and condition, land-use status and change, and change in agricultural productivity. As noted previously, a combination of Earth-observation satellite and surface-based observations capture these primary indicators by providing the basis to estimate certain variables, such as aerosol optical thickness and visibility (see box 5.3).

Box 5.3

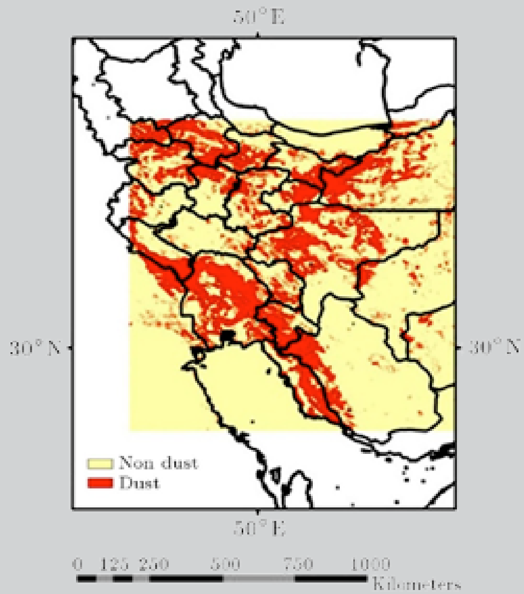
Aerosol optical thickness estimation and dust detection (visibility) using satellite images

Sehatkashani and others (2016) introduced an empirical equation for estimating the aerosol optical thickness and visibility reduction based on three main dust indices: the Normalized Difference Dust Index (NDDI), the brightness temperature differences (BTD) and the Thermal Infrared Dust Index. All three indices were used to evaluate the enhancement of bright to dark background after a storm event. The evaluation of results revealed a remarkable correlation between the aerosol optical thickness and dust enhancement indices over 11 synoptic stations: BTD (R2=0:73), NDDI (R2=0:67) and TDI (R2=0:71). The aerosol optical thickness and visibility reduction were obtained using a multi-regression equation, with the NDDI and BTD as variables. The accuracy assessment indicated a good correlation (R2=0:74) between both the estimated the aerosol optical thickness and what was reported by air quality control stations. The results confirmed the advantage of the proposed aerosol optical thickness as a consistent index for dust enhancement over bright surfaces and for dust classification.

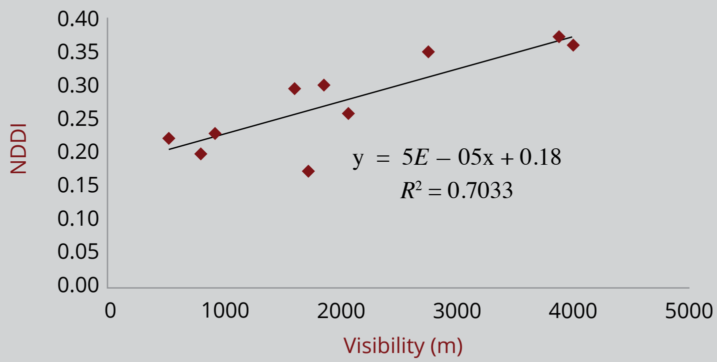
Detection of an extreme dust event on 6 July 2009 using a MODIS tre-colour image



Detection of an extreme dust event on 6 July 2009 using the Normalized Difference Dust Index



Comparison of dust index, with visibility over 11 synoptic stations (NDDI vs visibility)



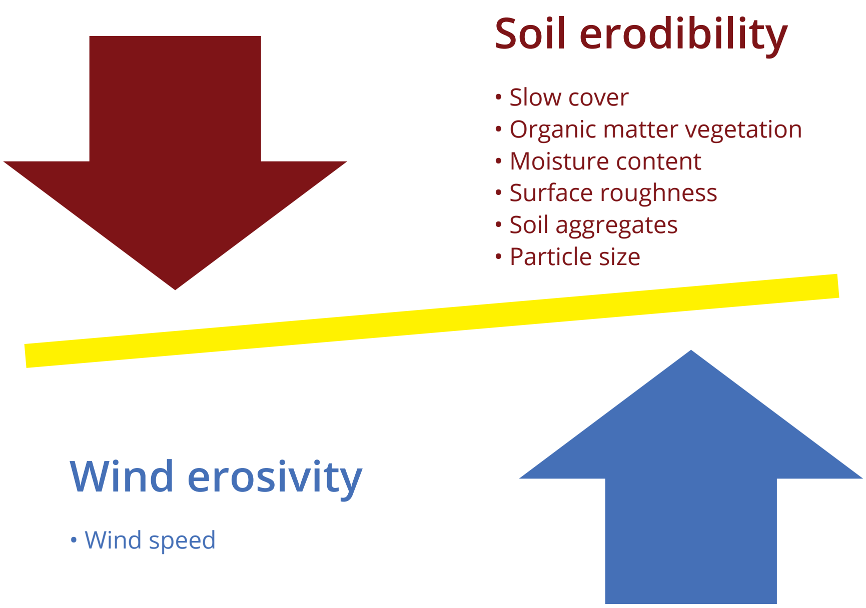
Source: Sehatkashani and others, 2016.

The indicators are also linked with trigger mechanisms. The initial condition for the formation of sand and dust storms requires the resistive force offered by surface soil particles (wind erosivity) that are exerted by wind (wind speed) to exceed the soil surface (soil erodibility) (see figure 5.9). Soil erodibility is determined by particle size, soil aggregates, surface roughness, moisture content, organic matter vegetation and snow cover.

The wind speed at which wind erosivity exceeds soil erodibility is called "threshold wind speed", or V_t. This threshold depends on the land-surface conditions. It is a function of soil type, roughness length, vegetation cover, snow cover and soil wetness.

Figure 5.9

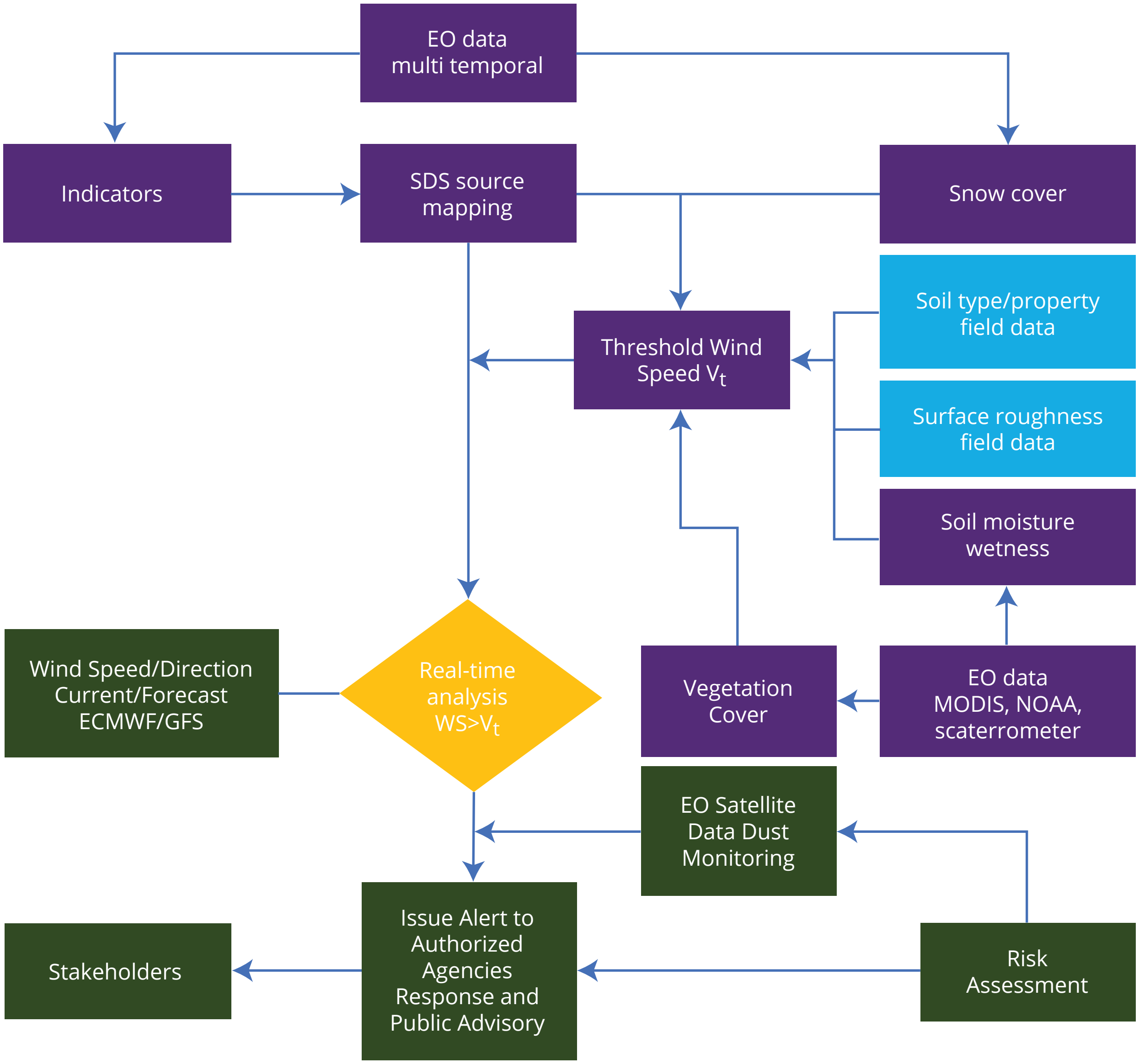
Dust storms occur when wind erosivity exceeds soil erodibility



Forecasting and warning systems both rely on the measuring and monitoring of the indicators (see figure 5.10). Earth-observation satellites (SRTM, ASTER, CartoDEM) provide the mapping and monitoring data for vegetation cover, snow cover and soil moisture and wetness, along with surface topography. Other indicators, such as soil type, soil aggregates, soil moisture, organic matter and surface roughness length, require field data.

Figure 5.10

A multi-hazard risk assessment monitoring system adapted as a sand and dust storm alert system



Source: Ajai, 2018.

Note: *EO = Earth observation*
SDS = Sand and dust storms
WS = Wind speed
NOAA = National Oceanic and Atmospheric Administration
ECMWF = European Centre for Medium-Range Weather Forecasts
V_t = Threshold wind speed

Science, policy and action through regional cooperation

Quite often, sand and dust sources and impacted regions are transboundary in nature, which requires dialogues and cooperation among the related countries for risk-informed policy interventions. Recognizing that source and impact mitigation of sand and dust storms are spatially linked. Interventions at sand and dust sources and impacted regions need to be scientifically analysed. For example, sand and dust storm sources in China are thousand kilometres away from the impacted regions. The policy interventions taking into account the geospatial links between the source and impacted regions of sand and dust storms are making positive impacts on both adaptation as well as mitigation aspects (Box 5.4).

Because sand and dust storms are consequences of drought, land degradation, desertification and wind erosion, they are a multifaceted phenomenon that requires a comprehensive multi-hazard response–starting with improved policy coordination among stakeholders at the global and regional levels. To inform that coordination and those policies, the multi-hazard approach entails scientifically assessing the physical factors that engender sand and dust storms. Then the multi-hazard approach uses policy to promote scientific processes of mitigation, such as ecological restoration, which was initiated in China.

Box 5.4

Ecological restoration as a policy for combating sand and dust storms in China

The aerosol composition measurements, the PM2.5–10 (particulate matter with aerodynamic diameter between 2.5 and 10 μm) and mass concentrations (referred to as PMC) are used to measure sand and dust storm severity and dust pollution events. The following figure illustrates the sand and dust storm episode average in China in terms of PMC to indicate dust pollution events.

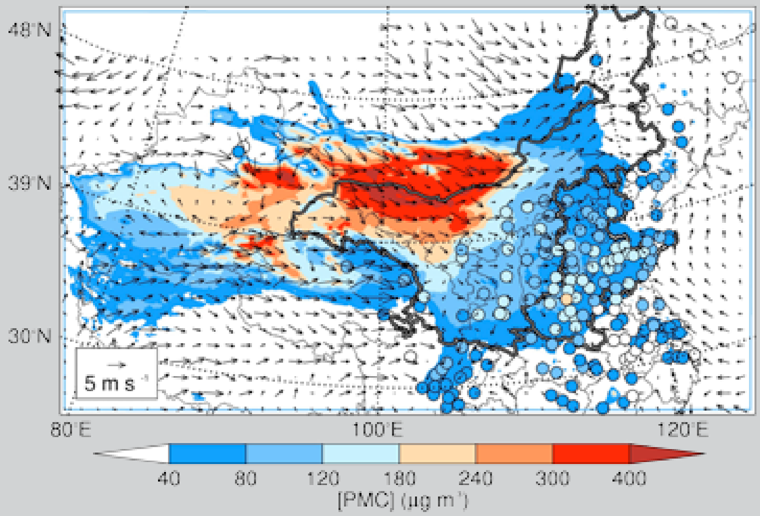
In recent years, the Government of China initiated a large-scale ecological restoration programme to reduce dust pollution. Using the satellite measurement product, Moderate Resolution Imaging Spectroradiometer (MODIS), the changes in land cover introduced by the ecological restoration programme are quantitatively evaluated.

Figures i and ii indicate the two regions of interest: (i) the polluted and densely populated downwind areas of dust storms in the North China Plain, covering the five provinces of Beijing, Tianjin, Hebei, Henan and Shandong; and (ii) the dust source region and surrounding areas, including five provinces in the north-west of the North China Plain (Ningxia, Gansu, Shanxi, Inner Mongolia and Shanxi).

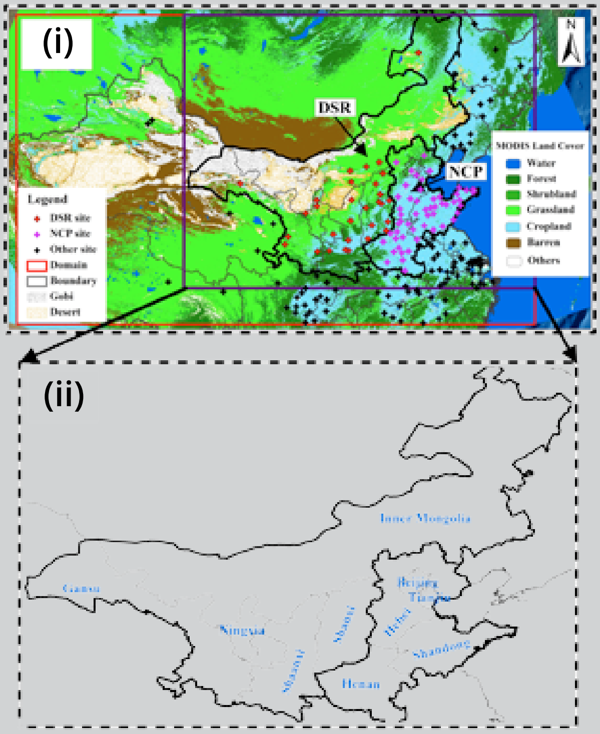
The analysis indicates that grass and forest have increased in berried lands and deserts in north-western China, which are located in the upwind regions of the populated areas of the North China Plain of the eastern part. As a result, the changes in land cover impact dust pollution in eastern China (see the noted detail under the following figure B regarding areas with ambient monitoring sites and the source region).

To assess the effect of the ecological restoration programme on dust pollution, a regional transport and dust model (the Weather Research and Forecast model with dust) was applied to investigate the evolution of dust pollution during a strong dust episode (2–8 March 2016). The calculation indicated that the ecological restoration programme significantly reduced dust pollution, especially in Beijing, Tianjin and Hebei provinces. During the episode when the dust storm was transported from the source region to the affected areas, the reduction induced by the programme ranged from -5 per cent to -15 per cent, with a maximum reduction of -15.3 per cent (-21.0 µg 42 m-3) in Beijing, Tianjin and Hebei provinces and -6.2 per cent (-9.3 µg m-3) in the North China Plain. This study concluded that the ecological restoration programme helped to reduce sand and dust storms and consequently air pollution in the region, especially in springtime, suggesting the important contribution of such a response to air pollution control.

Average sand and dust storm episode-simulated image of the polluted and densely populated downwind areas of dust storms of the North China Plain and the dust source region and surrounding areas, indicating dust pollution events in China

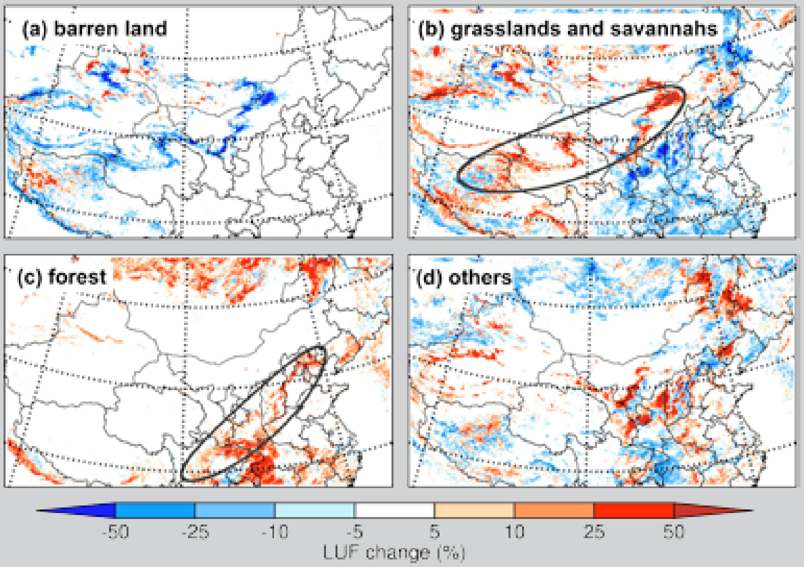


(i) Weather research and forecast model with dust simulation domain with surface land properties and major natural dust source regions (DSR) in the North China Plain (NCP)
(ii) Details for regions of interest for dust sources and surrounding areas and the downwind North China Plain region



Note: The borders represent centres with ambient monitoring sites (the dust source region contains five north-western provinces (Ningxia, Gansu, Shanxi, Inner Mongolia and Shanxi) and the North China Plain includes the five provinces of Beijing, Tianjin, Hebei, Henan and Shandong.

The horizontal distribution of land-cover changes (land use proportion) induced by the ecological restoration programmes from 2001 to 2013 for the categories of (a) barren land, (b) grasslands and savannahs, (c) forest and (d) others



Source: Long and others, 2017.

Regional cooperation: The potential role of ESCAP

Having discussed in previous chapters the transboundary nature of sand and dust storms, both in origin and impacts, a regional cooperation mechanism could tackle the gaps in knowledge and action. Such a mechanism would align with the Sendai Framework for Disaster Risk Reduction 2015–2030 and the Regional Road Map for Implementing the 2030 Agenda for Sustainable Development in Asia and the Pacific.

There is a possible role for ESCAP to facilitate such cooperation around three main components:

Multi-hazard risk assessment: A multiple-hazard risk assessment and modelling approach can better capture the drivers of sand and dust storms, such as land degradation, poor water management, drought, desertification and climate change and their interactions. This could be applied in South, South-West and Central Asia.

Alert system: Given the strong correlation between drought, desertification and sand and dust storms, the tools and techniques being developed under the ESCAP Regional Drought Mechanism and implemented within the World Meteorological Organization's Sand and Dust Storms Warning Advisory and Assessment System could be used to develop an alert system for the semi-arid subregions of South, South-West and Central Asia.

Partnerships/network: Stakeholders involved in combating sand and dust storms would be brought together to form an Asia-Pacific sand and dust storm network. The network would support analytical work, such as periodic risk assessments, provide feedback on the alert system, and potentially develop joint action plans involving both source and impacted countries.

ESCAP's long-standing programme to strengthen regional cooperation for disaster risk reduction and resilience provides the foundation for its work in facilitating action around the three components outlined above to observe, predict, mitigate and adapt to the increasingly costly impacts of sand and dust storms on societal well-being.

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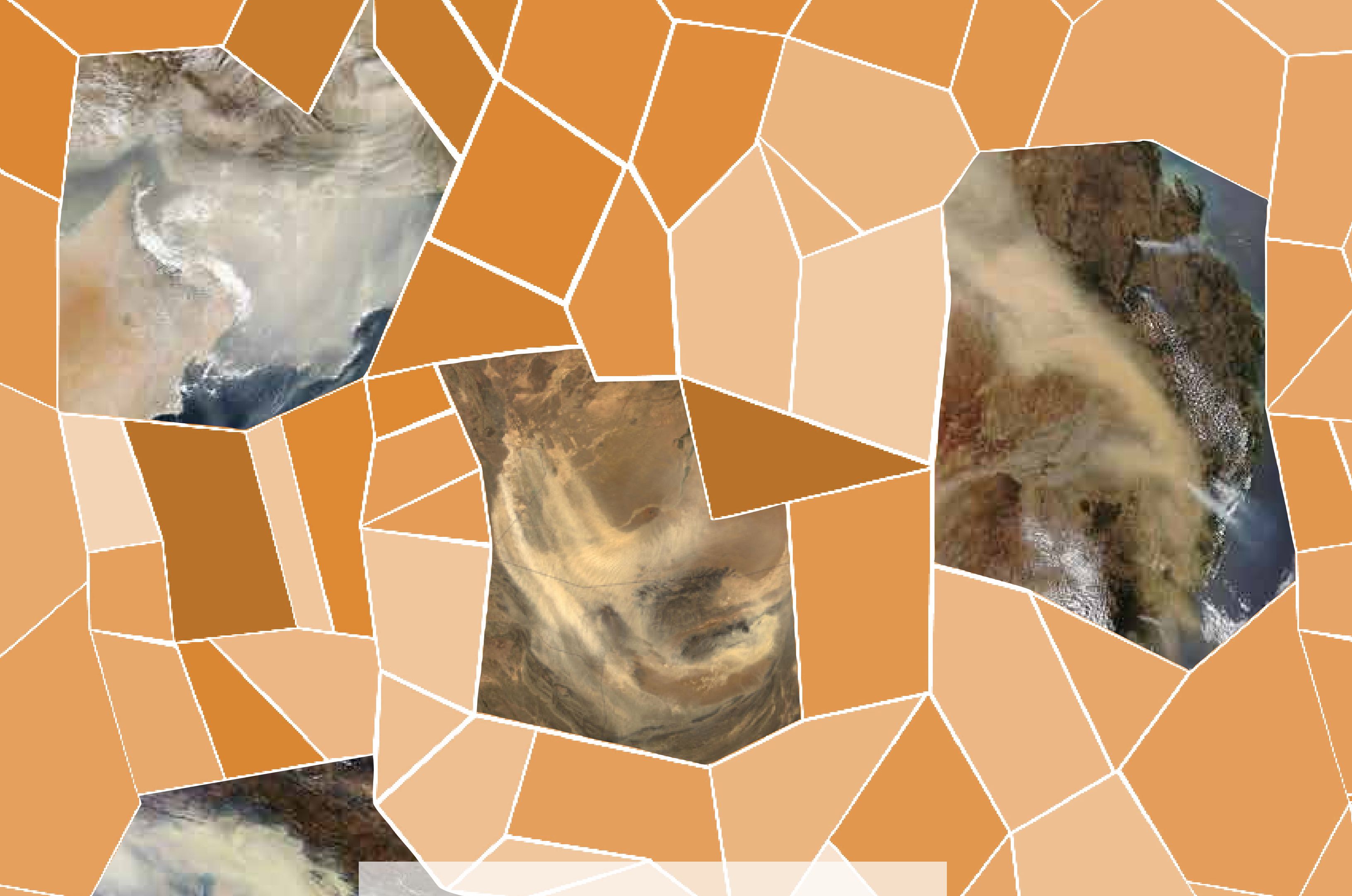

This report—***Sand and Dust Storms in Asia and the Pacific: Opportunities for Regional Cooperation and Action***—analyses potential drivers, points to the risk of problem areas and identifies gaps in information, cooperation and policy action to enhance the science-based understanding of the phenomenon among policymakers. It aims to support the development of adaptation and mitigation policies related to sand and dust storm at the regional and national levels.

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