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TECHNICAL BRIEF

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Global Sand and Dust Storm Source Base Map

An Innovative Approach to Identifying Potential Sources

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Abstract

This technical brief describes the method by which maps were created to identify potential sources of sand and dust storms. It employs global datasets for four indicators to estimate the extent of source potential and derive source intensity values: (i) soil texture (proportion of sand, silt, and clay), (ii) soil moisture (absolute minimum value), (iii) soil temperature (absolute maximum value), and (iv) land cover (bare land fraction). The Global Sand and Dust Storm Source Base Map, a visualisation tool (https://maps.unccd.int/sds), presents annual and seasonal maps that allow the user to zoom in, evaluate source intensity values, and distinguish among land cover types. The main objective of the tool is to show the distribution of areas with the potential to generate blowing sand and dust events and to provide spatially explicit references for conducting assessments that can more accurately identify potential sources and appropriate response measures. This approach to sand and dust storm source mapping was developed by the United Nations Convention to Combat Desertification (UNCCD), in collaboration with the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

Introduction

Over the past few decades, land degradation has contributed significantly to the increased number and size of anthropogenic sand and dust storm (SDS) sources.[4] Current trends in deforestation, agricultural expansion, and more frequent and severe droughts and heatwaves make countries more susceptible to SDS hazards and threaten the achievement of 11 of the 17 Sustainable Development Goals (SDGs).[5]

Knowing where SDS events may originate is critical to the more effective management of this growing hazard, including through early warning systems and proactive measures that reduce the likelihood, scale, and intensity of SDS events.[6] To date, the mapping of SDS sources has been largely based on direct or remote observations. This method can be effective for large, well known, and frequent SDS sources (e.g. North Africa, West and Central Asia, North America) but less so for infrequent, new, or expanding source areas where changes in weather, climate, and surface conditions or human activities are increasing the risk of, and vulnerability to, SDS events.

This technical brief describes an innovative approach to estimating SDS source potential. Open source global datasets on topsoil characteristics, soil condition (temperature and moisture), and land cover (including their dynamics of change) are employed by an algorithm to identify potential SDS sources which can be activated under certain weather and wind conditions. The results, in the form of static annual and seasonal maps, can be accessed through the Global Sand and Dust Storm Source Base Map (G-SDS-SBM), a visualisation tool that maps potential source intensity levels over all four seasons.[7]

The largest areas with high SDS source intensity and event potential are located in the Northern Hemisphere, extending from the west coast of Northern Africa to the Horn of Africa, and into West, South, Central and Northeast Asia. While drylands in the Southern Hemisphere have fewer active sources, their intensity can be significant in Central Australia, Southern Africa, and the Atacama Desert of South America. Furthermore, climate change can cause a decrease in the duration of snow cover, the retreat of glaciers, and an increase in drought and heatwave intensity and frequency, resulting in topsoil conditions that can increase the probability of SDS events in high latitude regions.[8]

Mapping Sand and Dust Storm Sources

A SDS source can be defined as any land surface that has the potential to emit sand and dust particles under favourable wind conditions.[9] SDS sources are mainly distributed over larger areas in the drylands, but also occur in mid- and high-latitude areas due to unsustainable land management practices, water scarcity, and climate change.

The conventional approach to identifying SDS sources, intensities, and impact locations has been through the direct and remote (satellite) observation of SDS events which can be useful for mapping larger and frequently active SDS sources. A comprehensive treatise of SDS source mapping methodologies and relevant information can be found in the *Sand and Dust Storms Compendium: Information and Guidance on Assessing and Addressing the Risks*.[10]

The approach taken to create the G-SDS-SBM uses data on soil characteristics, weather impacted soil conditions, and land cover to identify locations with the potential to generate SDS events given sufficient wind speeds. In some cases, a dense distribution of previously unrecognised small-scale sources can merge and develop into a large-scale SDS event.

This method can be used to complement observation-based data and information by identifying: (i) **high intensity source areas** or hotspots that were previously unknown; (ii) **existing source areas** which are infrequent or have localised impacts; and (iii) **potential new source areas** caused by natural or anthropogenic drivers. The use of soil and land cover indicators provides an important layer of spatially explicit data to help identify potential source areas before they begin to emit and can be observed.

This mapping technique, along with field assessments, can be used by land users and managers to take anticipatory action and reduce the likelihood of a SDS event. This methodology for SDS source mapping can also improve forecasting and early warning by identifying localised hotspots within larger observed SDS sources which are only active under specific soil and land conditions.

Datasets and Flow Chart

The process of mapping potential SDS sources based on soil and land cover conditions, using publicly available global datasets, is summarised in Figure 1. Datasets over a 5 year period (2014-2018) were used to determine the most favourable conditions for emissions and thus capture the largest possible extension of SDS source areas. The results can be improved by using national or sub-national level data, where available.

Soil texture (as measured by the relative weight proportion of sand, silt, and clay) defines the particle distribution by size, which impacts the emission potential of SDS sources.[11] [12] Data for soil moisture (minimum values) and soil temperature (maximum values) is produced at coarser resolution, derived from reanalysis techniques which combine past short-range weather forecasts with observations through data assimilation.[13] Land cover (as measured by the bare land fraction) indicates whether a land surface is covered with vegetation, snow, ice, or water. Land cover data is complemented with data on their dynamics of change throughout the year, derived from vegetation indices generated from satellite data.[14]

Figure 2 presents a flow chart to describe the process of assessing whether a grid cell at 30 arcsec (approximately 1 km^2 at the equator) has the potential to become a SDS source using the indicators and datasets described above. The size of the grid cell for analysis can vary with the detail of the data available. Additional information and references can be found in Chapter 8.6.2 of the *Sand and Dust Storms Compendium: Information and Guidance on Assessing and Addressing the Risks*.[15]

Figure 1 **Data Used to Generate the G-SDS-SBM**

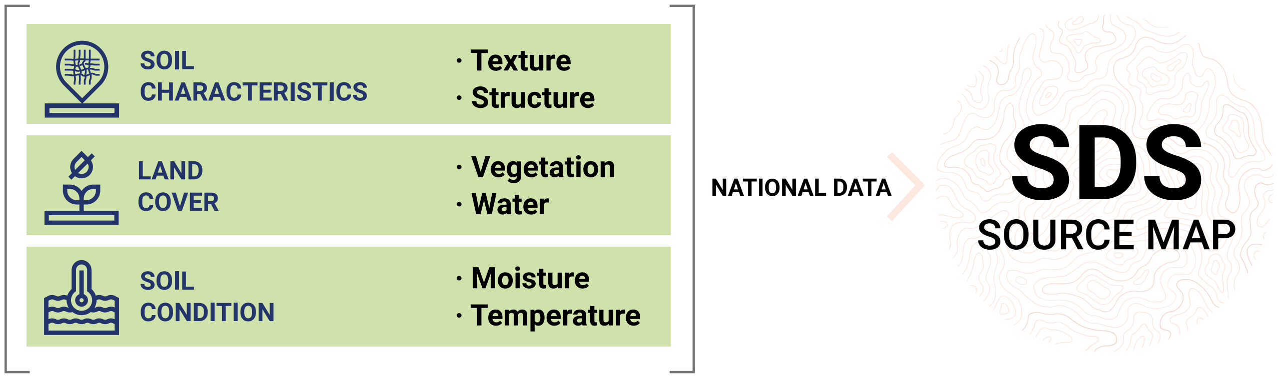
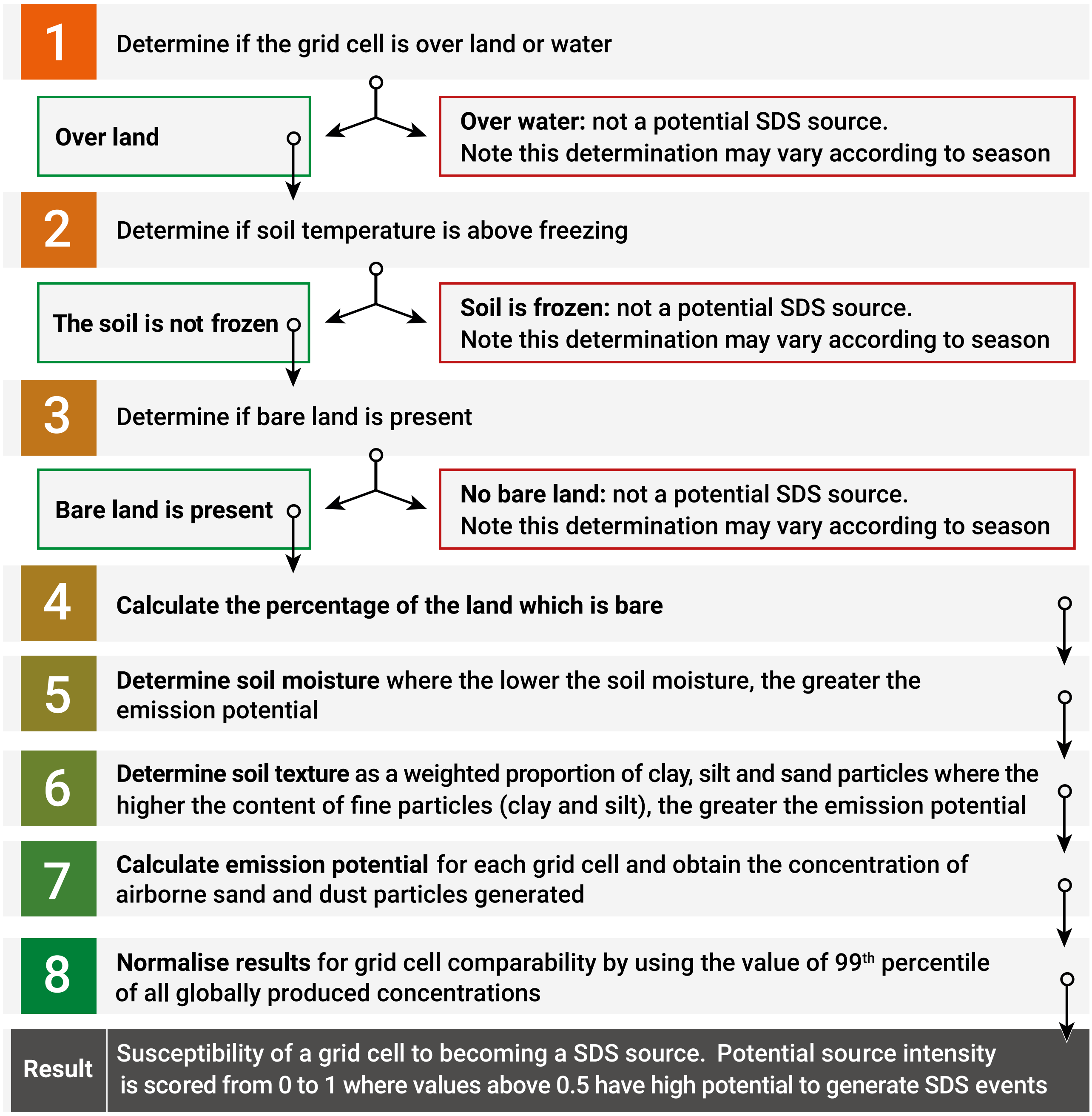


Figure 2 SDS Source Potential Analysis Flow Chart



1 Determine if the grid cell is over land or water

Over land

Over water: not a potential SDS source.
Note this determination may vary according to season

2 Determine if soil temperature is above freezing

The soil is not frozen

Soil is frozen: not a potential SDS source.
Note this determination may vary according to season

3 Determine if bare land is present

Bare land is present

No bare land: not a potential SDS source.
Note this determination may vary according to season

4 **Calculate the percentage of the land which is bare**

5 **Determine soil moisture** where the lower the soil moisture, the greater the emission potential

6 **Determine soil texture** as a weighted proportion of clay, silt and sand particles where the higher the content of fine particles (clay and silt), the greater the emission potential

7 **Calculate emission potential** for each grid cell and obtain the concentration of airborne sand and dust particles generated

8 **Normalise results** for grid cell comparability by using the value of 99th percentile of all globally produced concentrations

Result Susceptibility of a grid cell to becoming a SDS source. Potential source intensity is scored from 0 to 1 where values above 0.5 have high potential to generate SDS events

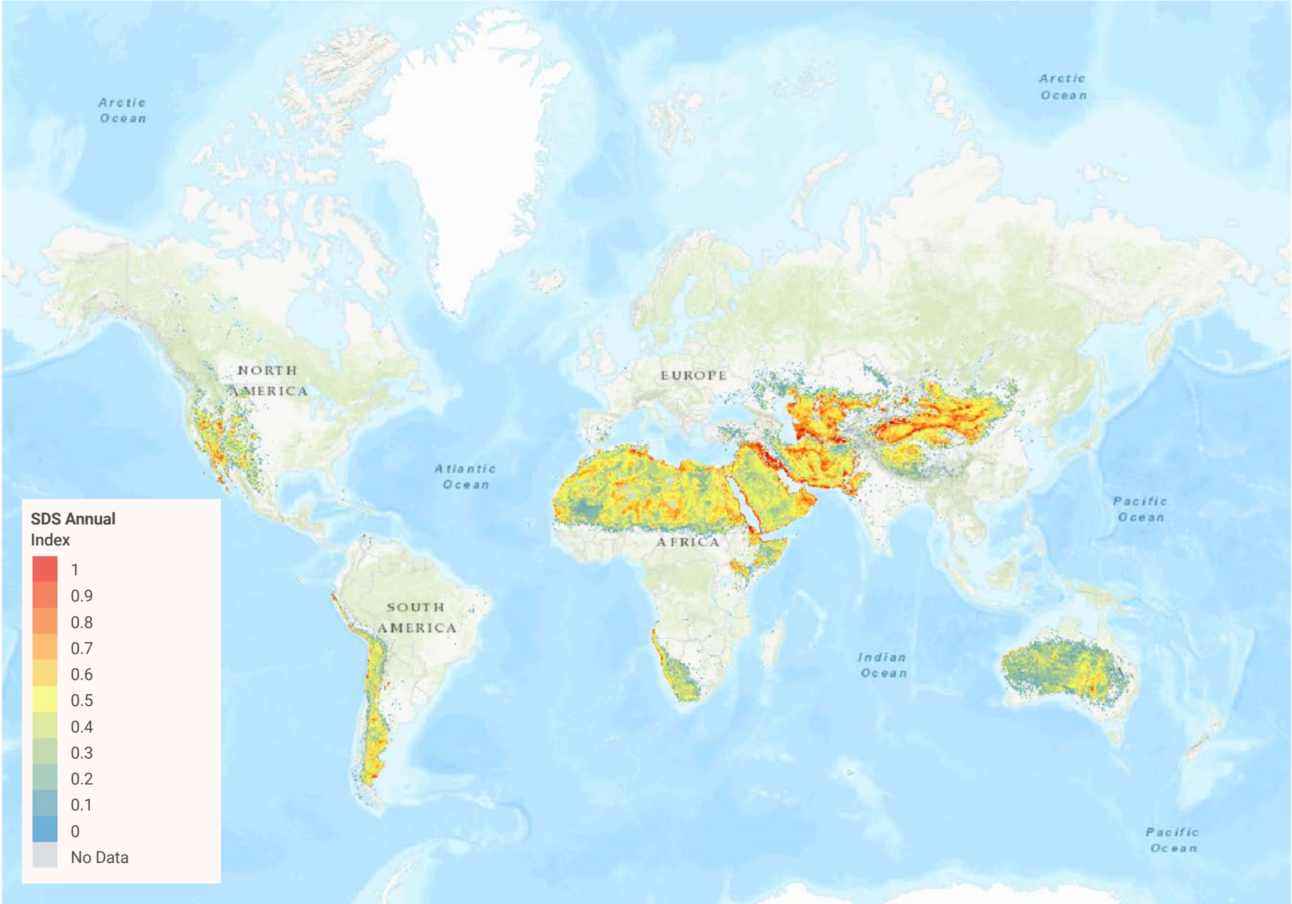
Annual and Seasonal Maps

Once source potential and intensity were determined, the results were mapped at a resolution of 30 arcsec (about 1 km^2 at the equator). Each grid cell represents the potential of the land surface to emit soil particles, with source intensities depending on surface conditions and actual surface wind velocities. A grid cell marked as a hotspot indicates that the location has higher potential for sand and dust emissions. Figure 3 presents the annual map of potential SDS sources based on an index where 0 (blue) indicates the minimum emissions potential and 1 (red) indicates the maximum emissions potential for land areas.

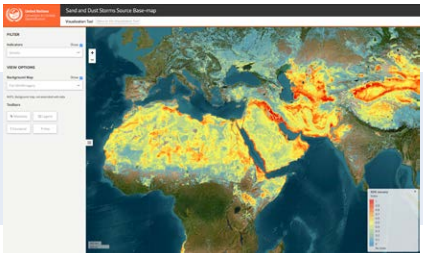
Permanent SDS sources are areas where emission potential exists throughout the year, primarily in the desert and dryland regions, while source intensity can vary due to changes in soil condition and land cover. Temporary sources are found primarily bordering permanent sources (e.g. West or Central Asia, the Southwest of North America); some with very or extremely high emission potential can be found far from permanent sources (e.g. higher latitudes in the Northern Hemisphere, Eastern and Southeast Europe). Both types of SDS sources have complex spatial patterns and temporal variability that influence their emission potential.

Recognising that the likelihood of SDS events can vary throughout the year, a set of seasonal maps were produced under the assumption that soil and land surface characteristics and conditions can be represented by data values for a single month. To identify potentially emissive surfaces, including those subject to extreme weather conditions, data values were selected to correspond to the most favourable conditions for sand and dust emissions for each month (e.g. driest, warmest, most barren).

Figure 3 **Annual SDS Source Base Map**



To access the seasonal maps, visit https://maps.unccd.int/sds/

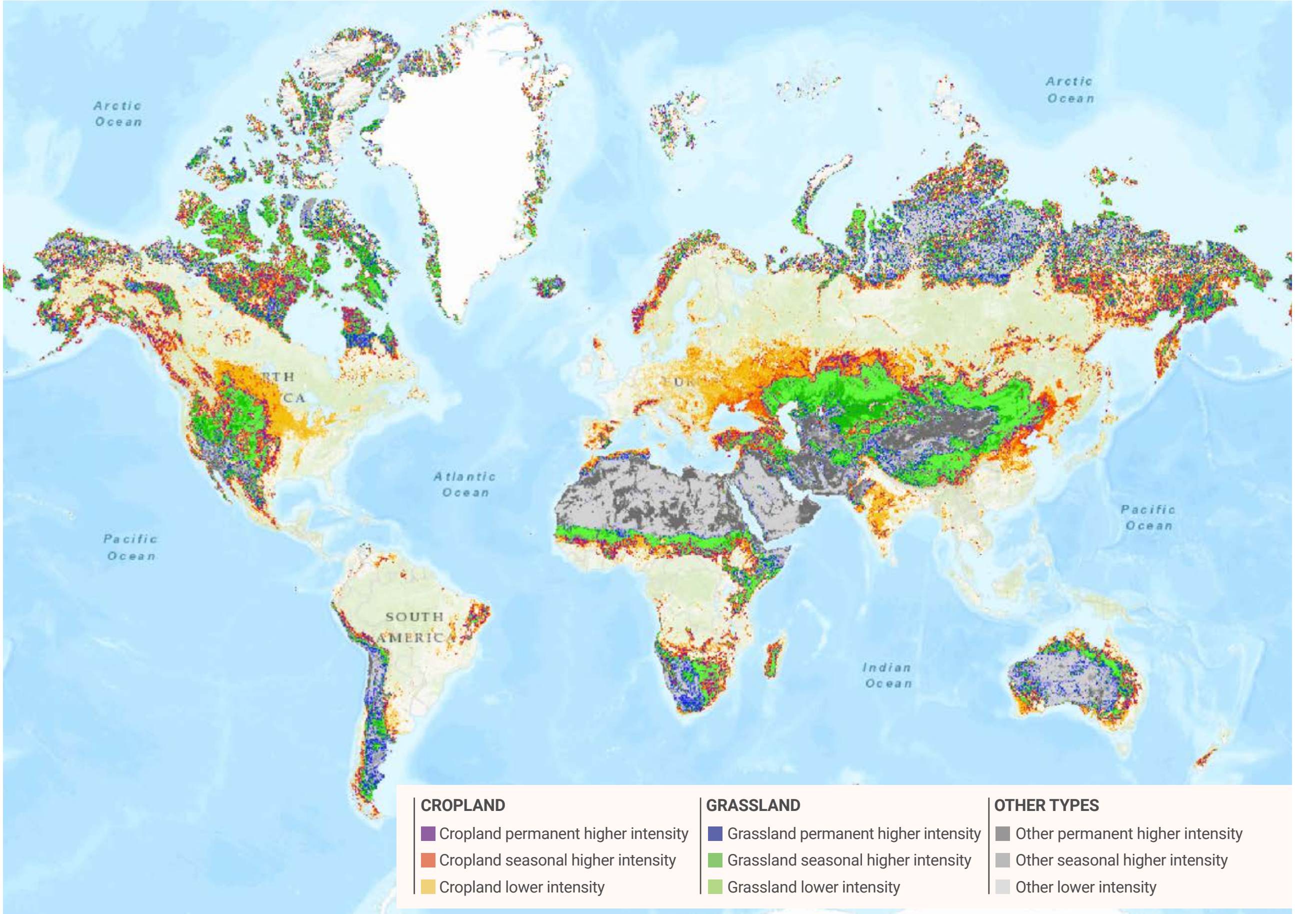


January	The lowest temperatures coincide with minimum vegetation in the Northern Hemisphere (Winter), while the opposite conditions are seen in the Southern Hemisphere (Summer).
April	Vegetation development starts in the Northern Hemisphere (Spring), while the opposite conditions are seen in the Southern Hemisphere (Fall).
July	Maximum temperatures coincide with fully developed vegetation in the Northern Hemisphere (Summer), while the opposite conditions are seen in the Southern Hemisphere (Winter).
October	Vegetation decreases in the Northern Hemisphere (Fall), while the opposite conditions are seen in the Southern Hemisphere (Spring).

Sources by Land Cover

One way to assess and better understand potential SDS sources is to overlay the projections generated by the G-SDS-SBM with land cover types. This can help identify locations where human activities may be a factor in the creation or expansion of SDS sources or where improvements in land and water management can reduce the frequency or intensity of SDS events. Figure 4 provides a map of potential SDS sources and their intensities according to broad land cover types: croplands, grasslands, and others. Sources where the intensity is variable but with high emission potential require specific attention.

Figure 4 **Global Distribution of Potential Sources by Land Cover**



Conclusion

It is important to note that SDS have always been a critical part of the Earth's bio-geochemical cycles, influencing weather patterns, nutrient cycling, and biomass productivity. More recently, human activities have contributed to the growth of existing and new SDS source areas, increasing their socioeconomic and transboundary impacts. The risks and impacts associated with SDS hazards are often underappreciated, pointing to serious gaps between current knowledge and the policy actions needed to prevent and reduce harm to affected communities and economic sectors.[16]

This method to map SDS sources and its data visualisation tool (G-SDS-SBM) has limited precision in identifying lower intensity sources due to the lack of data as well as the high degree of uncertainty associated with soil-related data. Despite these limitations, the G-SDS-SBM provides a sound basis for further investigation which can inform SDS-related policy development, planning and implementation, risk and vulnerability assessments, modelling and forecasting, and the creation of early warning systems as part of a proactive approach to SDS management.

Future efforts to improve the functionality and utility of the outputs generated by the G-SDS-SBM should focus on increasing the availability of, and access to, data and information. Greater integration with relevant high-resolution datasets at national, (sub) regional, and global scales would enhance the accuracy and value of the G-SDS-SBM for more informed policy and investment decision-making, specifically for datasets on:

(i) soil texture and structure, soil moisture and temperature, and soil organic content and erodibility;

(ii) land use (e.g. management practices) and land cover (e.g. vegetation, snow, water) as well as topographic and geomorphological information (e.g. surface roughness); and

(iii) climate and weather conditions and forecasts (e.g. observations of surface wind, dust emissions, visibility, drought, and heatwaves).

Endnotes

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