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Desertification danger: the aridification of humid regions

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ABSTRACT

Several periods in the Earth's history were warmer than today and provide insight into future impacts of global warming. Climate and atmospheric changes can reactivate the continental dunes presently stabilised by vegetation. They are most likely to be reactivated in today's humid regions, threatening desertification within the densely-populated temperate zones of the northern hemisphere.

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A major ongoing threat to our planet is global warming. One of the main implications of global warming is the aridification of the continents, which is when a region becomes dry. Both natural (e.g., higher temperature, reduced precipitation, increased evaporation) and human influenced changes (e.g., intensive agriculture, deforestation, greenhouse gas emissions) can cause a region to turn into a dryland. To simulate and understand the outcomes of climate changes, scientists are developing more complex and precise models that are partially based on the past. Historically, the Earth has known periods that were both colder and warmer than today. By understanding the climate mechanisms that caused these changes in the past, we can better forecast what lies ahead of us.

One important consequence of aridification is the destruction of natural vegetation when plants are essential to stabilise dunes through their root network. One type of dunes in particular, parabolic dunes, are heavily vegetated and thus strongly rely on this vegetation cover to be stabilised. Parabolic dunes are sand dunes formed by the wind that adopt a hairpin shape when developing. They are distributed all over the globe, on all continents, and can be categorised

into two groups: coastal and continental. Since climatic conditions control vegetation changes, the migration of continental parabolic dunes is known to be highly dependent on climate variations, which makes them particularly sensitive to aridification.

About 6000 years ago, during a period called mid-Holocene, the average global temperature was about 1 °C higher than today, and up to 4 °C higher in the northern hemisphere. The relative aridification with respect to the present is indicated by lake levels, which suggest that some regions were exposed to extreme aridification whereas other regions became more humid. Episodes of dune migration, both present and past, provide capital insight into which regions are more likely to incur desertification by dune migration, and under which climate conditions.

Continental parabolic dunes that have been active during the last millennium are located in the Americas, Northern Europe, Western India, Central and Northern China, and in Australia. Based on global climate databases, most of these regions have three characteristics in common: an arid to semi-arid environment, a savannah to shrub type of vegetation, and winds strong enough to transport sand. In the areas not presenting these properties, dune migration has been attributed to human activities (e.g. grazing, intensive farming, urban infrastructures).

The dune activity of the mid-Holocene was concentrated in the Americas and in Northern Europe, which are all regions that had lower lake levels indicating drier climatic conditions. In contrast, dunes in Eurasia and in South Sudan showed signs of stabilisation during this period, correlating with higher lake levels and increased humidity.

Global humidity is strongly influenced by the tropical rain belt, which is responsible for major seasonal wind changes, monsoons, and more generally precipitation around the globe. The global atmospheric circulation controls the position of the tropical rain belt. During the mid-Holocene, changes in atmospheric circulation forced the tropical rain belt to move north, causing the aridification of the northern hemisphere while favouring wetter conditions in Central America, Africa, and Central Asia via more intense monsoons.

In summary, desertification in continental interiors is strongly linked to atmospheric circulation. Although arid regions are more at risk today, information on past periods suggest that future changes in atmospheric settings are more likely to affect now-humid regions. Potential consequences include reduced precipitation, loss of vegetation, and migration of dunes over human infrastructures (e.g. crops, habitation). This is critical for water management in the temperate zones where the vast majority of the world's human population resides, especially in the northern hemisphere.