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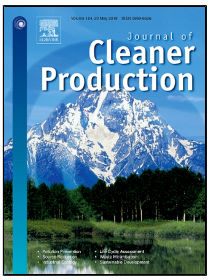

Aerosol pollution, including eroded soils, intensifies cloud growth, precipitation, and soil erosion: A review

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Aerosol pollution, including eroded soils, intensifies cloud growth, precipitation, and soil erosion: A review

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Abstract
The Earth's critical zone is vulnerable to atmospheric aerosol pollution due to aerosol impacts on cloud microphysics, precipitation characteristics, soil erosion, and the subsequent interactions of the soil-vegetation-atmosphere transfer of water, energy and aerosols. This review explains the individual and inter-connected processes of aerosol loading, cloud microphysics, precipitation characteristics, and soil erosion. A by-product of soil erosion is the generation of additional atmospheric aerosols, as well as the enhancement of surface erosion due to increased runoff. The literature includes empirical and theoretical studies within and across these domains. Case studies from China and Italy are provided to illustrate the key concepts connecting this system. The knowledge of the multiscale-impacts of aerosol pollution enables actions toward cleaner production processes to reduce aerosol pollution as well as forest and vegetation management to reduce soil erosion vulnerability. This review provides our community new insights on how to assess and manage earth's critical zone and our energy, food, water, and human resources.

Keywords. aerosol pollution; cloud physics; precipitation climatology; storm erosivity; adaptation and mitigation options; cleaner production

1. Introduction
The Earth's critical zone contains the soil, plant, atmospheric interface and is managed by humans for life support, including food production and drinking water supply. A reliable supply of ecosystem services depends on managing production inputs (i.e., resource extraction) and outputs, which include also pollutants releases, so they do not degrade the critical zone (e.g.: Gray and Sadoff, 2007; Rockström et al., 2009; OECD, 2012; Steffen et al., 2015). Secondary impacts from anthropogenic pollution can be hardest to manage, given their spatial, temporal, and cause-effect distance from problems. Such a challenge is exacerbated by a lack of comprehensive and multi-disciplinary scientific literature. In this review, we are compiling literature that addresses the impact to the critical zone of aerosol pollution, that lead to intensified precipitation, increased soil loss, and reduced food and water supply. Despite several decades of research predicting increased weather extremes (Kunkel et al., 2013; Field et al., 2015; Lavers et al., 2015), the literature has only recently established a cause-effect explanation of how aerosol pollution (Stocker, 2014) modifies clouds, precipitation, and soil erosion.

The impacts of anthropogenic aerosols on the critical zone's atmospheric component, and