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Climate change adaption potentials of unsealing strategies in cities – An assessment during heat and drought events based on microclimatic simulations

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Urban areas are particularly affected by climate change effects such as heat or droughts. The high percentage of dark and impervious surfaces leads to high radiation absorption and low evaporative cooling. Negative consequences for urban dwellers will significantly increase in future due to a higher frequency of extreme heat and drought events. At the same time, the high demand for new infrastructure and housing results in an increasing trend of sealed surfaces which is expected to continue in the next decades in many European agglomerations. To reconcile the requirements for climate change adaptation and urban development, strategies are needed to improve infiltration and evapotranspiration as well as decrease shortwave radiation absorption. Unsealed areas can 1) increase surface albedo in contrast to sealed asphalt or concrete roads and pavements, and 2) allow for bare-soil evaporation or evapotranspiration if vegetated, and thus increase latent heat flux and simultaneously reduce sensible heat flux. Furthermore, unsealed urban soils contribute keeping the water in the system of a city for longer time periods. This can reduce flooding and drought effects and improve the urban microclimate through more and longer-lasting evapotranspiration from unsealed soil water storages. Adaptation potentials and thermal effects of unsealing measures depend on many factors such as their size, structure or physical surface properties. The implementation of new unsealed areas is largely limited by urban structural constraints, development and traffic usage. Thus, adaptation potentials of different unsealing approaches must be assessed based on the given local conditions to achieve the best possible cooling effects during heat and droughts. Our study aims to investigate the effects of unsealing surfaces on the urban microclimate using scenario analyses. The high-resolution physically-based 3D ENVI-met model was used for a densely-developed residential research area in Cologne/Germany. The model simulations are driven by our local meteorological measurements and validated using our dense microclimate sensor network within the study area. To evaluate the potentials of various unsealing strategies on air temperature, permeable surfaces are parameterized and implemented in the setup model domain according to the given spatial constraints of the study area. Based on a simulation of the current sealed status quo, three unsealing scenarios are assessed: 1) natural bare-soil unsealings in traffic-free areas, 2) vegetated lawn unsealings in traffic-free areas, as well as 3) usage compatible unsealing measures in private spaces and low-traffic areas (courtyards, little frequented side streets, parking areas) by implementing grass grid pavers, while all main roads remain sealed. The model simulation results of the current situation are compared to the unsealing scenarios with respect to changes in the simulated air temperature. Significant differences were identified. These findings have important implications for urban planning aiming to mitigate future heat stress, droughts, flooding and improve thermal comfort.