How rain is dependent on soil moisture

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On days with high soil moisture, afternoon precipitation falls in particular in regions with dry soil. (Photo: Solange_Z / iStock On days with high soil moisture, afternoon precipitation falls in particular in regions with dry soil. Credit: Solange_Z /iStock

It rains in summer most frequently when the ground holds a lot of moisture. However, precipitation is most likely to fall in regions where the soil is comparatively dry. This is the conclusion reached by researchers at ETH Zurich following an analysis of worldwide data. Their study contributes to a better understanding of soil moisture, a little explored climatic factor.

The water content of soil has a great impact on the regional climate, but many of the connections are still not clear. Researchers at ETH Zurich's Institute for Atmospheric and Climate Science, together with colleagues from Belgium and the Netherlands, examined when and where it rains most frequently on summer afternoons. They wanted to clarify whether more rain fell on days when the soil was dry or moist. And where exactly it was most likely to rain on these days. The contradictory findings of other scientists was the reason for their study. Some researchers observed afternoon precipitation in particular on days with high soil moisture, while others seemingly came to the opposite conclusion - the rain fell in places where the soil, compared with surrounding areas, was driest.

The new study now provides some clarity. "On average, it rains most on days with high soil moisture," explains Benoit Guillod, the first author, who led the study as part of his doctoral thesis in the group of Sonia Seneviratne, Professor for Land-Climate Dynamics, and who is now working at the University of Oxford. "Most precipitation falls, however, over the driest sub-region." The phenomena can be explained in the following way: over the course of a day, the sun warms the earth's surface, causing the water in lakes, rivers, oceans and the ground to evaporate. This water vapour rises throughout the day, where it meets colder layers of air and condenses. It then starts to rain. The soil's moisture content plays a decisive role, particularly in areas far from the coast: The more moisture in the soil, the more water can evaporate, which increases the likelihood of precipitation.

But where exactly does it rain? Within a humid area, the areas with lower soil moisture produce the warmest air, permitting the water vapour to rise the highest and thus meet the colder air layers the soonest. As a result, it rains most frequently at these locations.

Soil moisture as a climatic factor is still insufficiently researched

In order to reach this conclusion, the scientists had to consult myriad data. Although soil moisture is an important climatic factor, there is a lack of global information. Until now, Switzerland has been one of the few trailblazers in this area: a monitoring network, initiated by the Institute for Atmospheric and Climate Sciences, has been in existence since 2008. Together with the Agroscope Reckenholz-Tänikon and MeteoSwiss, ETH has established 19 sites with soil sensors across Switzerland as part of the SwissSMEX project. The soil temperature and moisture content are recorded at various depths.

Such detailed measurements are rare worldwide. For the study, scientists had to rely on satellite data, which delivered information regarding the moisture at the soil surface to a depth of two to three centimetres. For an accurate examination of water evaporation, however, the data from the surface was not sufficient. Much water evaporates through the vegetation as plants absorb water through their roots from deep in the soil and transport it up. The scientists estimated the soil moisture up to a depth of one metre; to do so, in addition to data on precipitation and surface soil moisture, they also used information on radiation and temperature.

More than 100,000 rain events analysed

"We laid a grid over the earth's surface, and with the help of an algorithm we identified more than 100,000 individual rain events between 2002 and 2011, and we then analysed the soil moisture before these events," explains Guillod. Previous studies were either limited to the spatial aspect - where it rains - or the temporal aspect - when it rains. "Our study was the first to show the overall temporal and spatial correlation between soil moisture and precipitation," says Guillod.

Nevertheless, he warns against premature conclusions: "The question of when exactly rainfall occurs is not yet completely clear due to the complexity of the process." Higher performance computers, detailed simulations and model experiments should deliver further answers in the future about the extent to which rain events are influenced by soil moisture and atmospheric processes.

The answers to these questions might help a better understanding of other climate processes in the future. "They may allow further conclusions to be drawn, for example, about the interaction between soil moisture and plant growth," explains Seneviratne. Such information may serve, for example, as the basis for research on the ramifications of large-scale irrigation systems in farming. Or they could shed light on whether the expansion of arid areas could be curbed through planting and irrigation.

More information: Guillod BP, Orlowsky B, Miralles DG, Teuling AJ, Seneviratne SI: Reconciling Spatial and Temporal Soil Moisture Effects on Afternoon Rainfall. Nature Communications 2015. 6: 6443, doi: 10.1038/ncomms7443 Guillod BP, Orlowsky B, Miralles DG, Teuling AJ, Seneviratne SI: Reconciling Spatial and Temporal Soil Moisture Effects on Afternoon Rainfall. *Nature Communications* 2015. 6: 6443, doi: 10.1038/ncomms7443

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