Seed size and forest floor conditions determine tree seedling survival in extreme weather: Study

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University of Vermont (UVM) researchers mimicked climate change-triggered extreme precipitation events in an experiment at the UVM Jericho Research Forest in northwestern Vermont. They discovered severe drought and rainfall events can greatly affect tree seedling survival in the forest, but survival largely depends on tree species' traits, like seed size, and on seedbed or soil conditions. Credit: Peter Clark

Global climate change brings increases in precipitation extremes, from severe drought to heavy rainfall events, both expected to become more prevalent through the 21st century. Powerful weather events already impact human environments, with intense fires and flooding, and greatly transform natural ecosystems.

How will these periods of excessive rainfall or drought affect establishment of forest tree species and their future distribution—how they migrate, survive, and adapt to a changing climate? In the life of a tree, the young seedling stage is the most sensitive to climate extremes due to shallower roots and less access to water stored in soil.

In a new study published in *Ecology*, researchers at the University of Vermont (UVM) investigated the impacts of extreme precipitation patterns on tree seedling survival in a northern hardwood forest. They found that survival depends on the combined effects of seedbed condition, seed size, and variation in precipitation—not simply on the occurrence of severe drought or rainfall events. They documented survival differences among 10 tree species.

"Our findings highlight the importance of seedbed conditions and tree species regeneration traits, like seed size, in buffering the effects of extreme precipitation on seedling survival in temperate forests in the northeastern United States," said Peter Clark, a UVM postdoctoral associate who conducted this research as a Ph.D. student.

Extreme rainfall and drought impacts

Clark and Anthony D'Amato of the Rubenstein School of Environment and Natural Resources manipulated rainfall in a field experiment at the UVM Jericho Research Forest in northwestern Vermont. They tested first-year survival rates of seedlings grown from seed under three different extreme precipitation scenarios (drought, drought plus episodes of heavy rainfall, and frequent heavy rainfall) along with historic rainfall.

The researchers created three one-quarter-acre forest canopy openings—gap sizes that might be caused by trees falling during wind disturbance or by forest harvesting commonly practiced in the northeastern region. They constructed a greenhouse-like structure in each opening to exclude natural precipitation, which they collected to use in the shelters for irrigation to simulate rainfall events.

The survival of seeds sown in the enclosures strongly depended on the amount of precipitation they received. Although precipitation increased seedling survival, when it followed a drought, even extreme rainfall events did not deliver enough water to make up for the dry period. Given that scientists predict future precipitation will be more sporadic with longer periods of drying punctuated by heavy rain events, this research highlights the potential consequences of these climate changes on future forest regeneration.

Seedbed effects

Seedbed conditions on the forest floor are an intricate balancing act for tree seedling survival. To establish and grow, seedlings need access to a stable moisture supply around the roots. The researchers tested two seedbed types commonly found in the forest. An undisturbed seedbed contained intact soil covered with natural leaf litter and a decomposed humus layer. And a scarified seedbed had loosened upper soil and exposed mineral soil, a condition naturally found at the base of windthrown trees or deliberately created as a forest management technique.

In this study, even though precipitation played a critical role, seedbed type was over twice as important at determining seedling survival.

Seedlings in the scarified seedbeds had seven times the survival rate of seedlings in undisturbed beds. While exposed soils likely dry out quicker, conditions in scarified beds also allow moisture to soak into the soil faster which can prevent seedling death.

The harmful effects of extreme drought or heavy rain events were offset by the capacity for seedlings to survive at higher rates when grown in exposed, scarified soils. Using this new information, forest managers may elect to apply soil scarification in management strategies to buffer the negative effects of shifting precipitation on forest regeneration in the Northeast.

Tree species differences

Researchers chose to study tree species native to the region, including several expected to increase in abundance in response to changing climate conditions. Species included: American beech, American chestnut, bitternut hickory, black or sweet birch, black cherry, eastern hemlock, eastern white pine, northern red oak, sugar maple, and yellow birch.

They sowed seed to look at survival of newly germinated seedlings. Given mounting enthusiasm for tree planting initiatives aimed at global change adaptation and greenhouse gas mitigation, they also planted some four-year-old nursery grown seedlings to assess how results change by age.

Sensitivity to moisture varied among species and depended on seed size. Under drought conditions, the larger the seed, the more resistant the seedling. Seed size was not a survival factor under wet conditions.

Precipitation treatment—wet or dry—did not change survival for tree species with large seed—northern red oak, American chestnut, bitternut hickory, American beech, and black cherry. Species with smaller seed—sugar maple, eastern white pine, eastern hemlock, black birch, and yellow birch—had better survival rates under wet conditions than under dry conditions.

The combination of rainfall and a scarified seedbed improved survival of these small-seeded, moisture-sensitive species by 28%. For some tree species, like sugar maple, leaf litter provides nutrients, protective cooling, and moisture retention. On the other hand, exposed mineral soils can help seedlings get started, particularly for those with smaller seeds, like yellow birch, that would otherwise fail to penetrate forest floor litter layers.

"By testing sown seeds, much like natural regeneration in the forest, results show that future precipitation patterns may impact germination and survival for certain tree species but that these impacts will vary based on seedbed conditions," said D'Amato, a professor of forestry. "These findings will help conservation biologists and natural resource managers who are considering different artificial regeneration techniques to maintain, restore, or adapt forested ecosystems under future climate conditions."

Precipitation treatment did not affect survival of the more mature nursery-grown seedling transplants, which had much higher survival rates than first-year seedlings grown from seed, especially for small-seeded eastern white pine, eastern hemlock, and black birch.

The researchers suggest that seed traits will likely separate out plant response to future climate, with smaller-seeded species not faring as well under long periods of drying interrupted by bursts of intense rainfall. Species, such as northern red oak, which are more tolerant to a wider variability in precipitation extremes may be better adapted to new and changing conditions.

"Our findings support mounting evidence that while climate remains important, other biophysical factors may interact with or potentially override the effects of climate change on forest tree establishment and distribution, at least in the near term," said Clark. "This work helps to refine species distribution models and informs reforestation strategies to maintain forest biodiversity and ecosystem function under increasing climate extremes."

More information: Peter W. Clark et al, Seedbed not rescue effect buffer the role of extreme precipitation on temperate forest regeneration, *Ecology* (2022). DOI: 10.1002/ecy.3926

Provided by University of Vermont

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