Role of soil in regulating runoff processes in Pine-and Oak-dominated headwater catchments of the Western Himalayas

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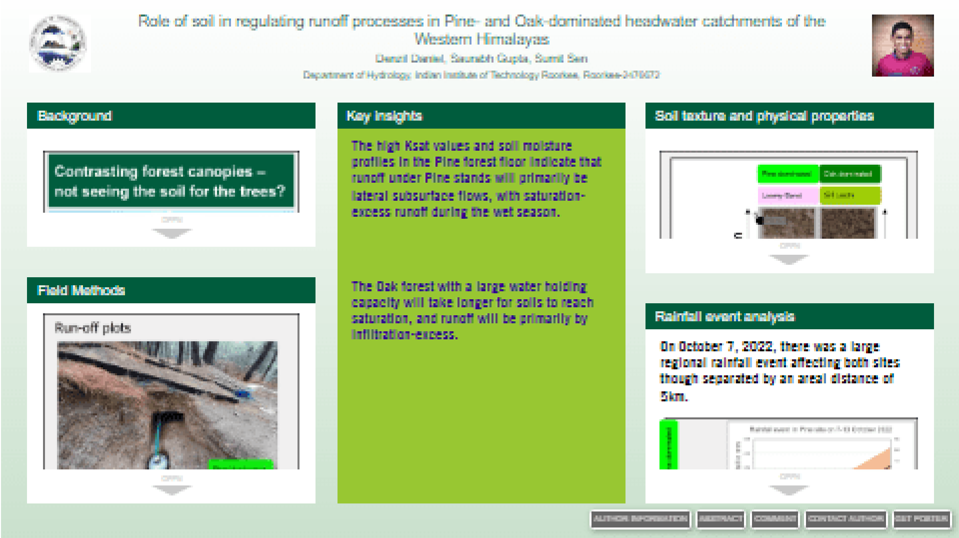

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PRESENTED AT:

BACKGROUND


Contrasting forest canopies – not seeing the soil for the trees?
Pine dominated site near Kayala
Oak dominated site near Sitlakhet

- The mid-elevations in the Western and Central Himalayas have seen ecological succession and competition between two dominant tree species- Pinus roxburghii (Chir Pines) and Quercus sp. (Oak species).

- In the recent past, human-induced disturbances driven by forest management policy have resulted in stunted and retrograde ecological succession, with Oak forests being replaced by Pine forests.

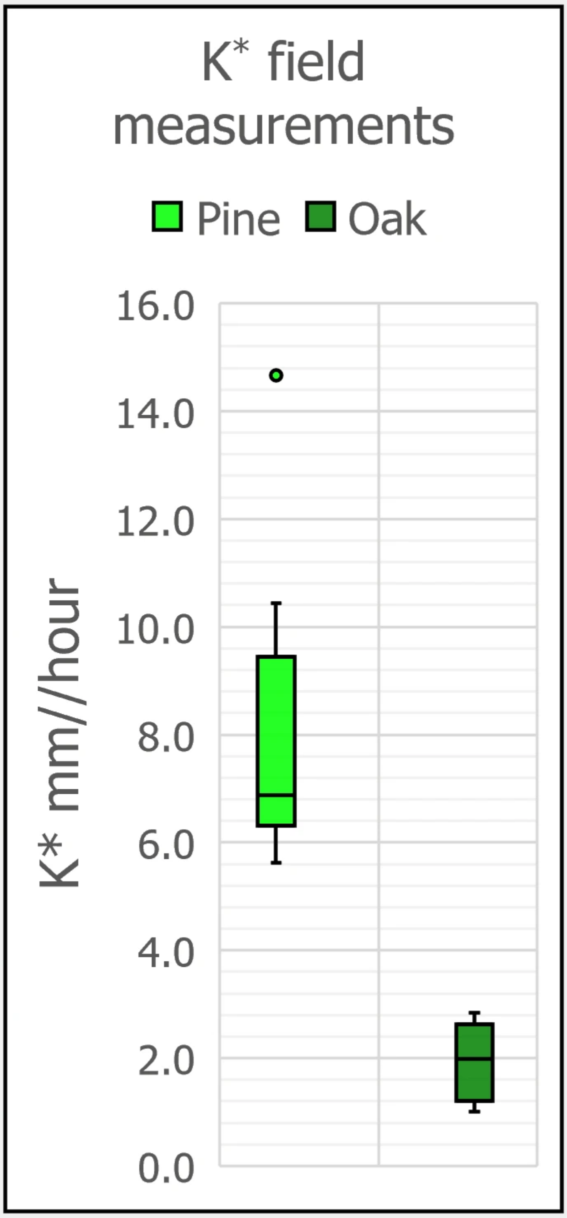
- This has implications for hydrological processes in the region.

FIELD METHODS

Run-off plots

<u>Experimental Plots Set-up:</u>
Three plots in each ecosystem of size 3m × 1.5m.
0.6′ HS-Flume at outlet fitted with capacitance water level recorder.

Field unsaturated hydraulic conductivity

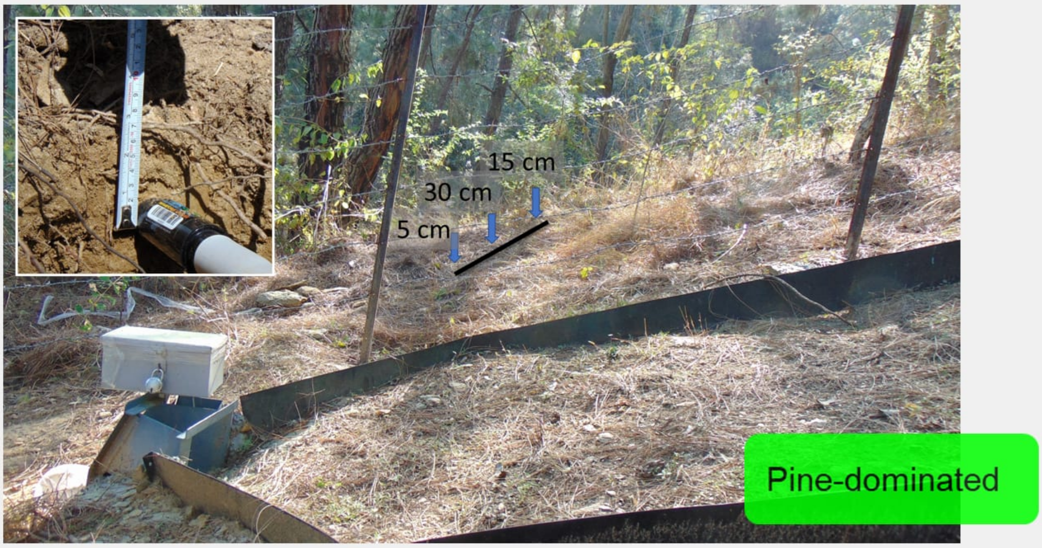


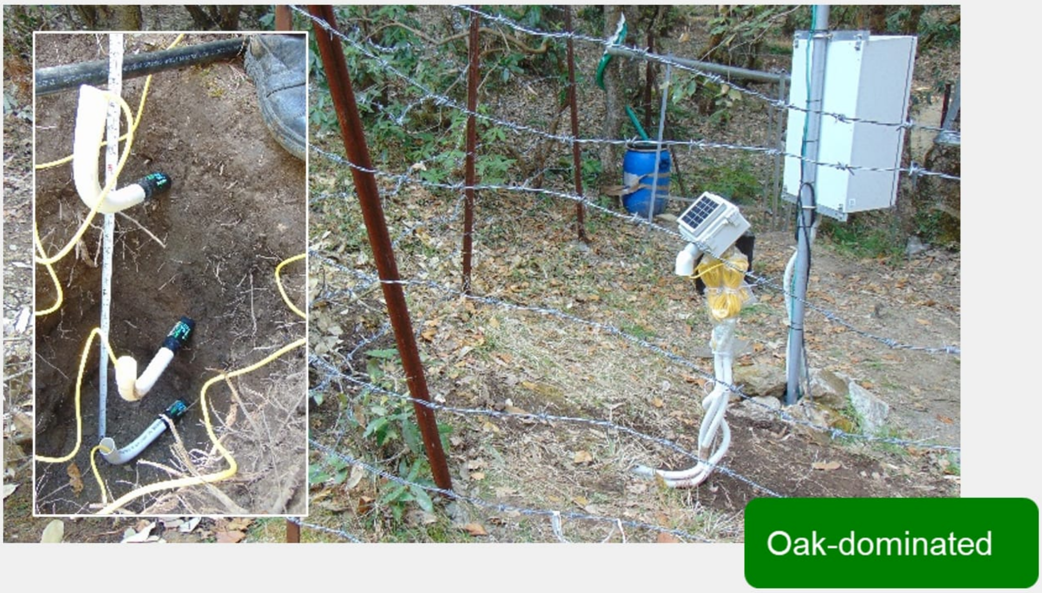
The minidisk infiltrometer was used on the run-off plots to determine the field unsaturated hydraulic conductivity (K^*) at the surface.

K^* for pine plots is 8.08 ± 5.71 mm/hr.

K^* for oak plots is 1.94 ± 1.46 mm/hr.

Soil moisture probes





Soil moisture probes (Acclima TDR 310-H) were installed at 3 depths adjacent to the runoff plots in the summer of 2022 prior to the rainy season.

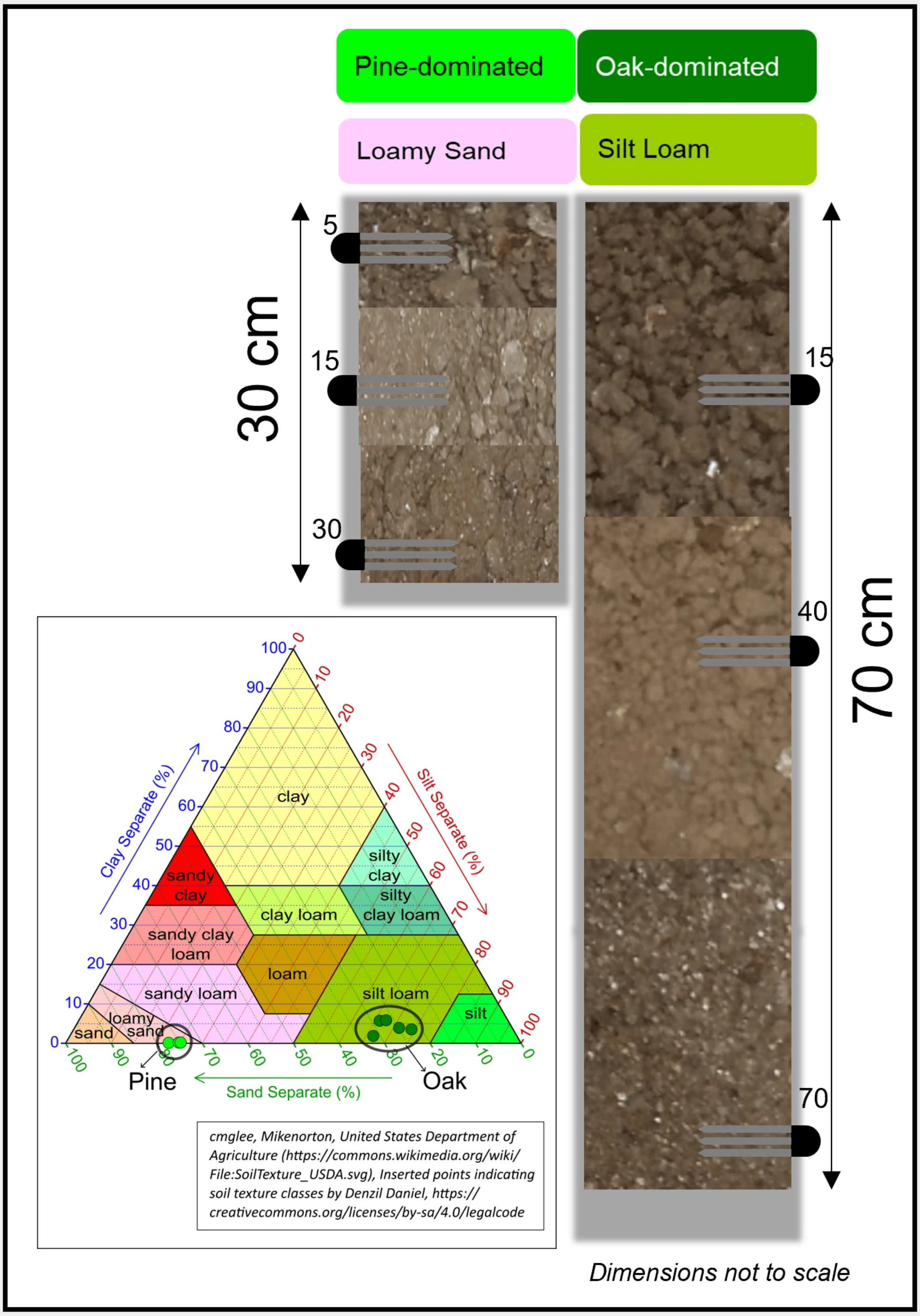
The continuous soil moisture observations will help track vertical moisture movement through the soil layers in each ecosystem.

KEY INSIGHTS

The high Ksat values and soil moisture profiles in the Pine forest floor indicate that runoff under Pine stands will primarily be lateral subsurface flows, with saturation-excess runoff during the wet season.

The Oak forest with a large water holding capacity will take longer for soils to reach saturation, and runoff will be primarily by infiltration-excess.

SOIL TEXTURE AND PHYSICAL PROPERTIES



Textural analysis of the fine fraction of soil shows silt-rich soil of deep soil profiles under the Oak forests, while soils in the Pine forests are shallow, sandy, and derived from mica schists.

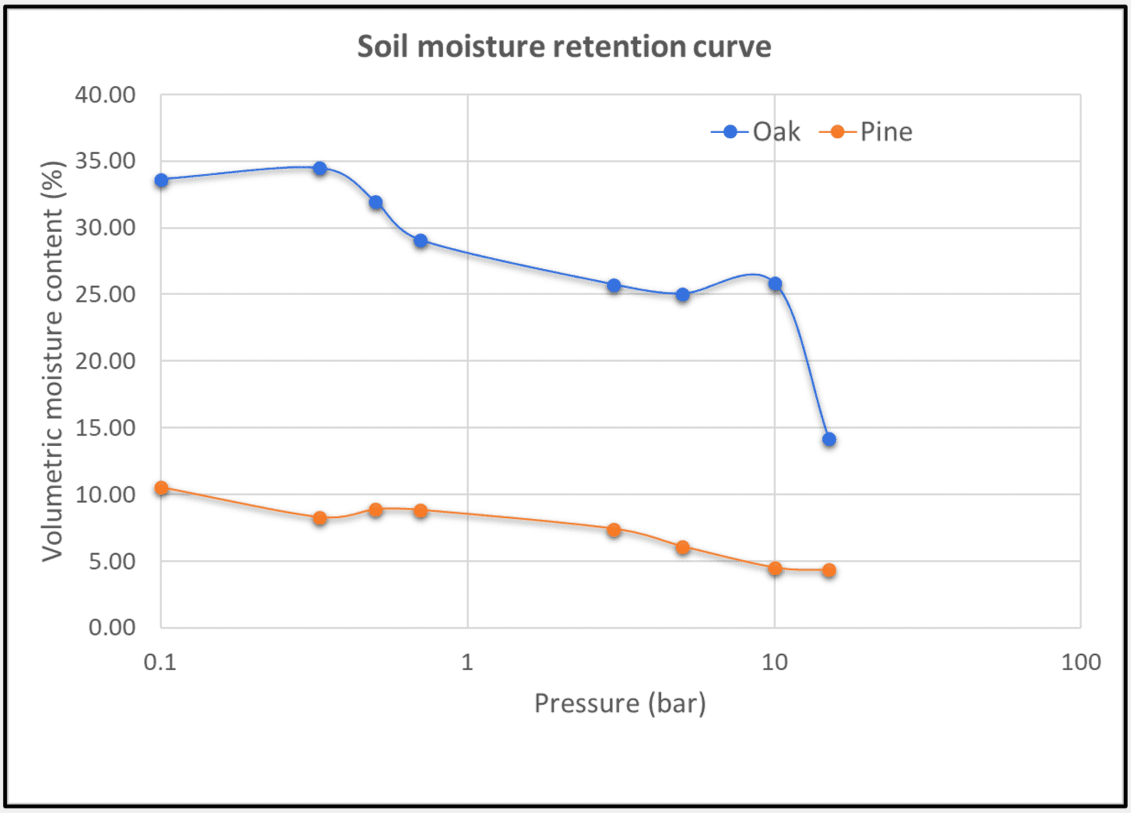
Bulk Density of dry soil (g/cc)	
Pine-dominated	Oak-dominated
1.626	1.090
1.709	1.153
1.759	1.439

Porosity (%)	
Pine-dominated	Oak-dominated
36.4	53.3
34.9	51.8
32.0	41.2

Volumetric M.C. at Saturation (%)	
Pine-dominated	Oak-dominated
42.1	53.0
37.7	50.9
38.2	43.6

Saturated hydraulic conductivity (mm/hr)	
Pine-dominated	Oak-dominated
57.0	8.6
4.0	4.8
0.2	4.0

Soil physical properties were measured in the laboratory from undisturbed soil samples extracted from 3 depths at each site using an Eijkelkamp core sampler of core volume 100cm^3. The saturated hydraulic conductivity was determined using constant head method on the ICW lab permeameter apparatus.

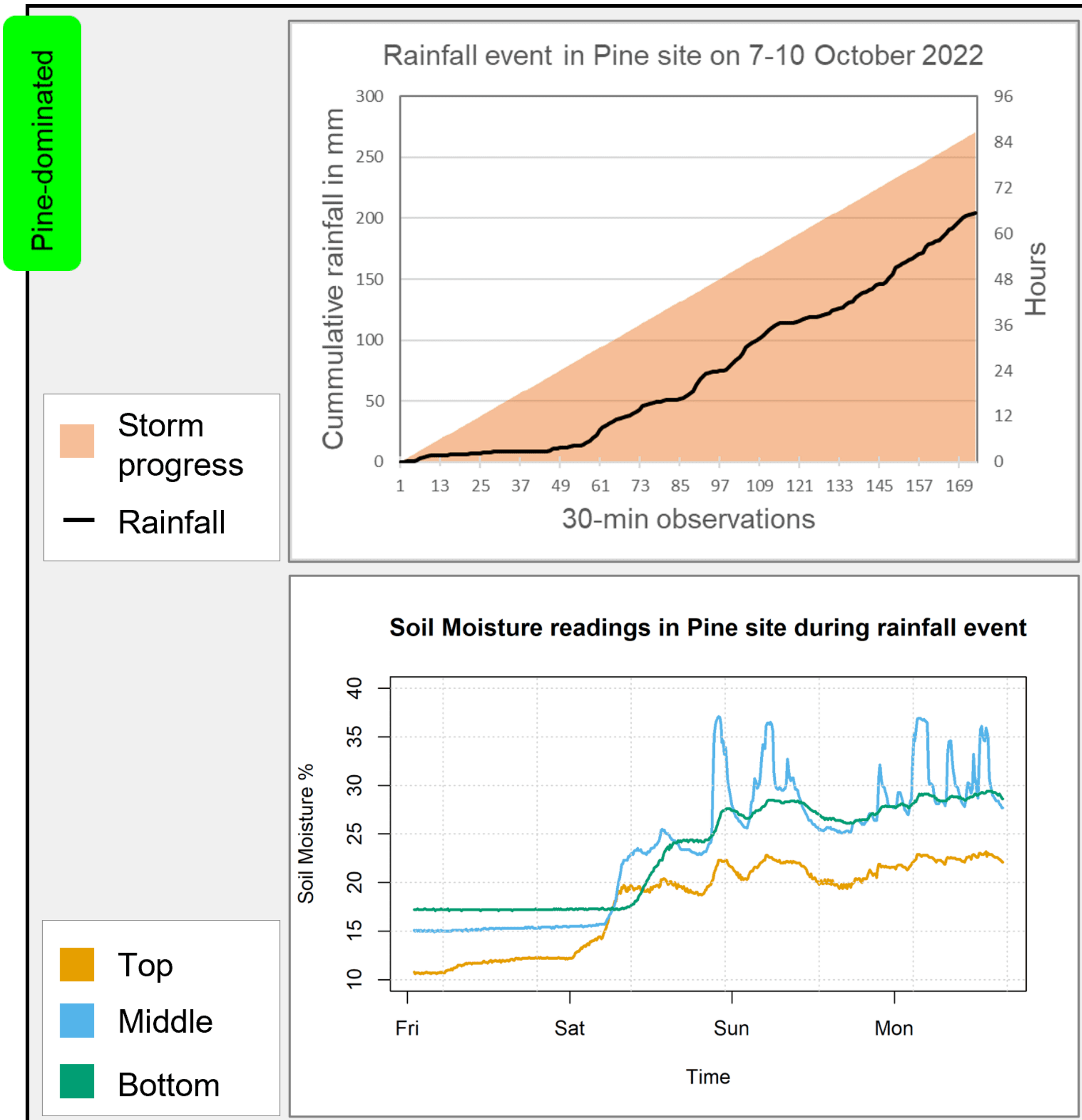


Soil moisture retention curve for disturbed soil samples from Pine and Oak sites were developed based on the laboratory pressure plate experiment.

The available water content in the Pine forest soils at saturation is 4%, while that in the Oak forest is 20%. In absolute numbers, for the Pine site with an average soil depth of 30 cm, the total available water is only 12 mm, while at the Oak site with deeper soil depths (>70 cm), the total available water is >140 mm.

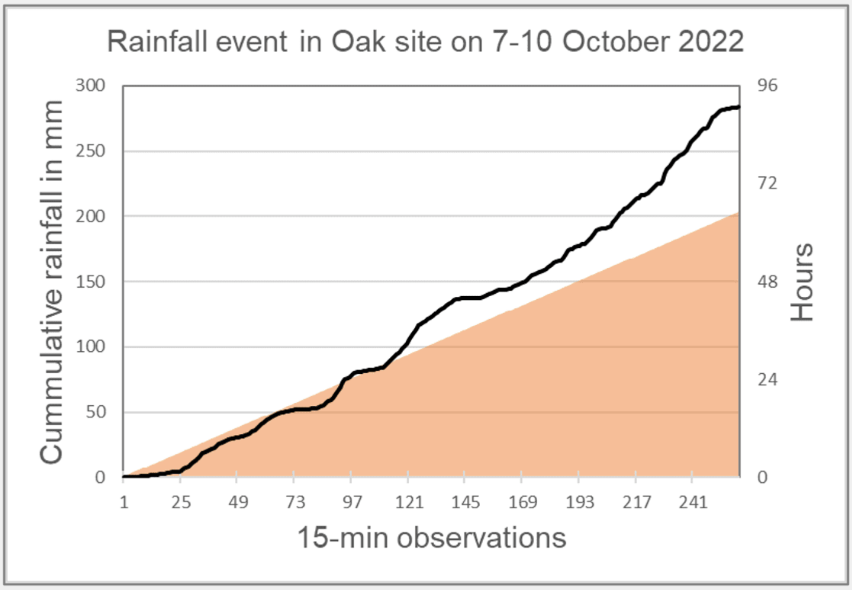
RAINFALL EVENT ANALYSIS

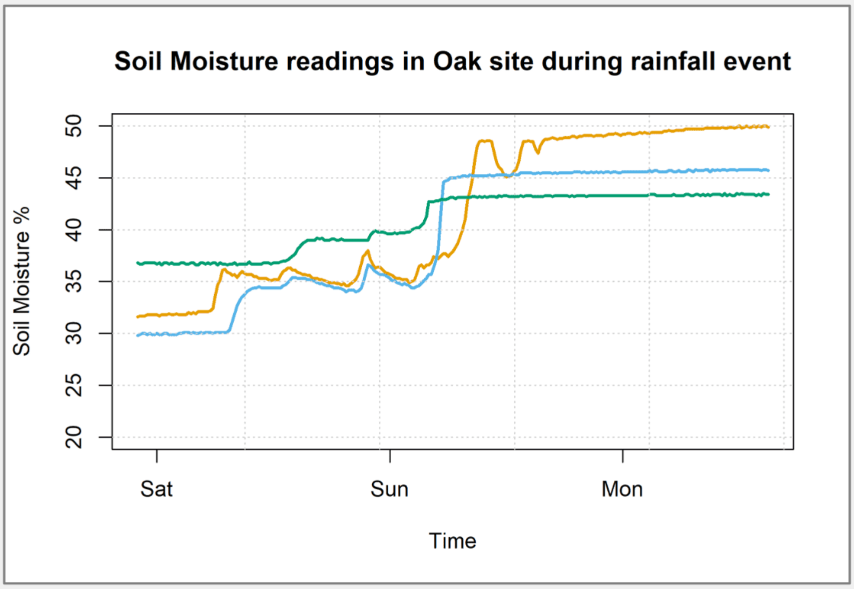
On October 7, 2022, there was a large regional rainfall event affecting both sites though separated by an areal distance of 5km.



As expected, soil moisture in the Pine stand almost immediately rises in the middle soil layer. None of the soil layers reach saturation. The middle layer obtains saturation in brief instances (blue peaks), but water quickly drains away.

Oak-dominated





The Oak forest floor on the other hand reaches saturation at all depths evident by horizontal soil moisture profiles.

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ABSTRACT

The traditional perception in the Western Himalayas is that Oak (*Quercus* spp.) forests provide the most effective water conservation. In contrast, Pine (*Pinus roxburghii*) forests are colonizers replacing Oak forests in large areas while consuming excessive water. We conducted field experiments in two forested microcatchments (< 100 hectares each), representing Pine- and Oak-dominated forests, to understand the controls on runoff generation and ecosystem services exerted by soils under both forests in the Western Himalayan headwaters.

The soil under the Pine forest was sandy loam of shallow depth, while that under the Oak forest was silty loam with deep soil profiles. The field capacity and residual moisture of soils under Pine (Oak) forests are 8% (34 %) and 4% (14%), respectively, corresponding to 0.33 bar and 15 bar soil water potential on the soil moisture characteristic curves constructed using the pressure plate experiment. Based on the water retention characteristics, we expect the Oak forests with deeper soils to behave like sponges with moisture stored in the soil profile during wet seasons and gradually released throughout the year to the streams. Observational evidence indicates this to be the case with the first-order streams draining the Pine forest drying up during the summer months while the streams in the Oak forest headwaters remain perennial.

Measurement of field saturated hydraulic conductivity (K_{sat}) showed large spatial variability, yet consistently higher values in Pine forests (~24 cm d^{-1}) as compared to Oak forests (~8 cm d^{-1}). The high K_{sat} values in the Pine forest indicate that surface runoff under Pine stands will primarily be saturation-excess runoff during the wet season. The Oak forest with a large water holding capacity will take longer for soils to reach saturation, and runoff will be primarily by infiltration-excess.

These findings have important implications for forest management policy in the Indian Himalayas in changing the narrative that forests primarily govern water flows. The evidence from this study highlights the role of other controls, for example, soils, in regulating runoff processes in forested headwater catchments.