Wildfire Risk Does Not Ignite Only in the Sky, But Also in the Soil

Why soil moisture, vegetation water stress, biodiversity, and life belowground must now be part of how we read wildfire risk

> ***"A fire may begin with a spark. But its ability to spread is often prepared over weeks in the water the land managed to keep — or lose."***

ALAIN BÉLANGER
Forest Engineer · Entrepreneur · Beyond Sustainable Tech
Global Initiative for Regenerative Watersheds | August 2026

A DIFFERENT WAY TO READ WILDFIRE RISK

When a wildfire breaks out, our first instinct is to look at the sky. What is the temperature? How strong is the wind? How dry is the air? Was there lightning?

Those are essential questions. Immediate weather strongly influences ignition, direction, and rate of spread.

But weather does not tell the whole story. The first article in this series examined how roads, ditches, culverts, and compacted surfaces can form a second drainage network superimposed on a watershed. It asked a simple question: by protecting each road individually from water, have we adequately measured the cumulative effect of the entire network on the land's ability to retain that same water?

This second article begins where the first one left off. A road does not automatically start a wildfire. A ditch does not ignite a forest. But if our infrastructure helps move water out of the landscape too quickly, it may change the conditions the next spark will encounter. The question is therefore not only 'What starts a fire?' It is also 'What hydrological and biological condition is the territory in when the fire begins?'

The Spark and the Territory Are Two Different Questions

The cause of ignition and the capacity of a fire to spread are not the same thing. The spark may come from lightning, a power line, equipment, a vehicle, an escaped campfire, or human negligence. But the same spark can produce very different outcomes.

In a moist, shaded, biologically functional landscape, a start may remain limited. In a landscape that has been under deep water stress for weeks, during high temperatures and strong winds, the same spark may encounter fuels capable of supporting much faster spread. Weather matters. Topography matters. Fuel type and arrangement matter. But recent science shows we must pay far more attention to a variable beneath our feet: soil moisture.

Weather Describes the Moment. The Soil Stores the Memory of the Season.

A weather bulletin tells us what is happening today and what may happen over the next few days. Soil moisture tells a longer story. It integrates the rainfall received — or missed — over many weeks. It reflects evaporation, plant transpiration, soil texture, rooting depth, groundwater recharge, and the speed at which water has left the territory.

The soil therefore acts as a hydrological memory. A heavy rain may have fallen a few days earlier, yet the territory can still remain in deficit if much of that water ran off rapidly, was concentrated into ditches, or never infiltrated deeply enough to rebuild storage. That is why a landscape can experience a torrential rain event and still remain, functionally, in drought.

The amount of water that falls is not enough on its own. We must also consider where the water falls, how fast it moves, how long it remains in the soil, how deeply it infiltrates, and how capable the living system is of absorbing and redistributing it.

What 196 Wildfires Revealed

In 2025, researchers associated with the U.S. Forest Service published an important study based on approximately 5,400 daily progression maps from 196 wildfires in the Northern Rockies between 2012 and 2021. They tested the ability of different variables — weather, fuels, topography, hydroclimate, soil moisture, and vegetation hydraulic stress — to explain daily fire growth.

Their result is worth remembering: soil moisture and plant hydraulic stress were the dominant variables for predicting spread. Adding those variables improved model performance by roughly 8 to 9 percent compared with models using only weather and fuels. This does not mean soil moisture will always be the leading variable in every ecosystem. It was a regional study, and the authors themselves recommend replication elsewhere. But it demonstrates that the accumulated hydrological state of a territory can explain a substantial part of fire behaviour that same-day weather does not fully explain.

196 wildfires analysed, Northern Rockies, 2012–2021	**~5,400** daily fire-progression maps modelled	**+8–9%** prediction accuracy gained by adding soil moisture

Figures drawn from Holden et al., Geophysical Research Letters, 2025 [1].

This insight is already beginning to move from research into operations. In 2026, the same team described an operational forecasting system for the Pacific Northwest and Northern Rockies, developed from more than 500 fires and combining weather with soil-moisture information to produce daily spread-potential maps. Soil moisture is therefore no longer only an interesting scientific variable. It is becoming a practical fire-management tool.

From Water in the Soil to Water in the Plant

The connection between soil and fire runs largely through vegetation. A living plant is not just another dry fuel. It draws water from the soil through its roots. That water moves through its tissues, supports photosynthesis, helps regulate temperature, and contributes to the moisture of leaves, needles, and small branches.

When water available in the soil declines, the plant begins to experience hydraulic stress. Stomata close to reduce water loss. Photosynthesis slows. Water potential declines. Depending on species, rooting depth, soil type, and drought intensity, the moisture content of living tissues may also decline. Live fuel moisture is a central variable in flammability and fire behaviour. Recent work is increasingly linking fuel moisture to plant physiology rather than treating all living vegetation as if it responded the same way.

In Mediterranean-type forests, plant-hydraulic models suggest that extreme drought can reduce leaf and canopy moisture and increase wildfire vulnerability. The mechanism is not just the water present in a leaf at one moment. It is the plant's ability to keep supplying that leaf from the soil. Soil, roots, stem, canopy, and atmosphere form one hydraulic continuum. When we alter water availability in the soil over time, we indirectly influence the future state of vegetation.

The Living Territory Beneath Our Feet

We often talk about soil as though it were inert material: sand, clay, gravel, and organic matter. But a functional soil is also an ecosystem. It contains bacteria, fungi, protozoa, nematodes, arthropods, roots, and countless organisms that transform matter, cycle nutrients, and help build structure.

That biodiversity is not merely present in the soil. It contributes to how the soil works. Fungi develop hyphal networks that connect particles. Microorganisms produce compounds that contribute to aggregation. Roots create channels. Organic matter supports a porous structure capable of letting water in and keeping part of it available.

> **A living soil is not just a container filled with water. It actively shapes how water infiltrates, moves, remains available, and gradually returns to vegetation. Soil biodiversity is part of a territory's natural hydrological infrastructure.**

Does Drought "Automatically Kill" Soil Life?

The science is more nuanced. It would be inaccurate to say that all microorganisms die as soon as the soil dries. Some enter dormancy. Some alter their metabolism. Some species are better adapted to water stress than others. Bacteria and fungi do not respond in the same way.

Moderate or infrequent drying events can be followed by relatively rapid recovery when water returns. A 2024 study in Nature Communications found that severe drought reduced microbial growth rates by about 48 percent and also reduced soil respiration, while still observing rapid recovery after rewetting. Fungi remained notably active during drought, in part by investing more in storage compounds.

But intensity and repetition change the response. In another experiment, a high-intensity drought triggered a persistent shift in the microbial community, reduced network complexity, and diminished some functional capacities even after moisture returned. At a global scale, a survey of 80 dryland sites on every continent except Antarctica found that increasing aridity reduced the abundance and diversity of both soil bacteria and fungi, an effect driven largely by declining soil organic carbon.

The most accurate statement is therefore not 'Less water means all soil life dies.' It is this: more intense, longer, or more frequent drought can reduce biological activity, alter community composition, simplify networks, and weaken some of the functions that help soils remain resilient.

Why Does Belowground Life Matter for Water Resilience?

How much water a soil can retain depends on many factors: texture, depth, organic matter, compaction, porosity, root distribution, topography, and biological activity. No single microorganism controls the system. But many studies show that soil organisms can materially influence structure.

Mycorrhizal fungal hyphae bind and bridge soil particles. They contribute to water-stable aggregate formation and are associated with glomalin-related proteins that help maintain aggregate stability. A 2024 paper in Geoderma experimentally separated root effects from fungal-network effects in a calcareous soil and found that arbuscular mycorrhizal hyphal networks and glomalin-related soil protein both promoted aggregation under normal conditions and under drought.

That structure in turn influences pore continuity, infiltration, erosion resistance, aeration, root access to water and nutrients, and the soil's ability to remain physically coherent during intense rainfall. This does not mean that every loss of microbial diversity immediately causes drought. It means that a territory gradually losing moisture, organic matter, root vitality, and biological function may also lose some of the mechanisms that helped it absorb and retain water in the first place.

The Hydrological and Biological Domino Effect

The mechanism we now need to study can be summarized as a chain of interactions:

1. Water leaves the territory too quickly. Ditches, compacted surfaces, culverts, and other drainage corridors intercept and concentrate water that might otherwise have infiltrated.

2. Soil storage declines. Moisture falls earlier or more deeply during dry periods, and late-season flows and shallow groundwater become more fragile.

3. Vegetation enters hydraulic stress. Plants have less available water, and the moisture of some live fuels may decline.

4. The biological community reorganizes. Microbial growth and activity may slow, and the most severe or repeated events can reduce diversity, simplify networks, and alter functions.

5. Natural recovery capacity may weaken. Structure, aggregation, nutrient cycling, plant–microbe relationships, and root growth can all be affected.

6. The territory dries more quickly during the next drought. A stressed canopy, warmer soil, degraded structure, and limited storage reduce the system's safety margin.

7. The next spark encounters a more vulnerable landscape. The drainage system did not "cause" the fire on its own, but the accumulated hydrological state may help determine how the fire behaves.

Less water can weaken the living soil. A weakened living soil can reduce some resilience functions. And a less resilient territory can then lose water even faster during the next drought. This chain is a synthesis across several domains of research. It is not yet a single study proving that one road network caused microbial losses and then caused a fire. But each of the main links is strong enough to justify direct field investigation.

Landscape Simplification Can Amplify the Problem

This is where another modern pattern becomes important. We have become very good at simplifying landscapes — in agriculture and in forestry. Monocultures are often easier to plant, manage, mechanize, and harvest. But homogeneity can also synchronize vulnerability.

When the same species, age class, rooting depth, and growth pattern dominate a territory, water demand often becomes more synchronized. Recovery pathways may be fewer. The canopy can respond more uniformly to stress. The belowground biological community may also be less functionally diverse.

Diversity is not a universal recipe and should never be romanticized as a cure-all. But it often increases the number of mechanisms a system can mobilize under stress: complementary rooting patterns, different drought strategies, varied litter inputs, more continuous cover, stronger microbial associations, and more ways to recover after shock.

In agriculture, cover crops and more diverse rotations have repeatedly improved infiltration and aggregation on average across large evidence bases. In forestry, mixed stands have in many cases shown stronger drought resistance, while soils under mixed forests have also shown better microbial resistance to drying–rewetting cycles than soils under single-species stands. The exact effect will always depend on species, soil, climate, and management. But the general direction is important: oversimplification can reduce resilience.

France: A Territory That Still Receives Water but Struggles to Keep It

France is a useful case study for why this discussion is becoming urgent. Eurostat's regional drought indicator tracks the area affected by reduced vegetation productivity linked to soil-moisture deficits.

186,000 km² average area affected per year, EU, 2013–2023	**650,000 km²** area affected in 2022, the peak year	**19** French regions among the most heavily affected

Figures drawn from Eurostat Regional Yearbook 2025 [9].

What matters here is that the indicator does not measure only a lack of rainfall. It explicitly links soil-moisture anomalies with negative anomalies in vegetation productivity. In other words: less water in the soil, less functioning vegetation.

The 2026 summer reinforced that signal. Météo-France reported that June 2026 was the hottest June ever recorded nationally, at 3.8 °C above the 1991–2020 normal. Precipitation deficit for the month reached nearly 50 percent, and by the end of June soil drought had become generalized across metropolitan France and Corsica. By 8 July, 54 departments were classified at high or very high wildfire danger.

These data do not show that roads caused drought in France. They do show that, in a territory facing irregular precipitation, extreme heat, and generalized soil-moisture deficit, any infrastructure that unnecessarily accelerates the exit of water deserves to be re-examined.

The Economic Cost Is No Longer Only Ecological

The Triodos Bank report Hot Summer Economics adds a dimension that is particularly useful for Regenerative Access Infrastructure. It estimates that extreme heat in 2026 could shave around 1 percent from European Union GDP — roughly €180 billion — through effects on agriculture and food, energy production, transport and logistics, labour productivity, health, and ecosystem services. France emerges as one of the countries most economically exposed.

We should not attribute those losses to roads. The report does not say that. But it does force an important question: if heat, drought, and wildfire now generate losses of that magnitude, what economic value should we assign to infrastructure choices that help a territory retain more water, reduce hydrological stress, and preserve resilience?

> **Water kept in a territory should increasingly be understood not only as an ecological asset, but also as an economic one.**

In Québec, the Visible Reserve

The same logic can be illustrated from another angle in Québec. In June 2026, concerns about low hydraulicity and lower energy storage in Hydro-Québec reservoirs brought public attention to the visible reserve of water stored behind dams. Caniapiscau was reported at about 24 percent at one point, and projected energy storage was described as the lowest in 21 years.

This is not proof of a road effect. It is a reminder that a reservoir can only manage the water that reaches it. Dams do not replace the soils, forests, peatlands, wetlands, and upstream landscapes that retain, release, and regulate water before it ever reaches a generating station.

Prevent Before the First Flame

Wildfire management traditionally focuses on preventing ignitions, monitoring weather, detecting starts quickly, reducing some fuels, creating access, organizing evacuation, and suppressing fires from the ground and air. All of these remain necessary.

But a complete strategy should also ask: how do we help the territory remain hydrated long enough to stay more resilient when extreme conditions arrive? We cannot control the wind. We cannot prevent every heat wave. We cannot guarantee that no spark will occur. But we can influence residence time of water, its distribution through the landscape, soil compaction, local recharge, canopy protection, and the biological quality of soil.

This is a form of fire prevention that begins months or years before the fire itself.

What Regenerative Access Infrastructure Changes

Regenerative Access Infrastructure is not a fire-suppression technology. It does not replace firefighters, fuel management, or emergency planning. It acts further upstream. It imposes a new requirement on infrastructure: an access corridor should not only remain passable; it should also avoid, as much as possible, weakening the hydrological and biological system it crosses.

That means, among other things, distributing loads without systematically drying out the soil; avoiding the concentration of all water into a few discharge points; slowing water before evacuating it; filtering where water quality requires it; and preserving the living system by reducing unnecessary compaction and helping moisture remain available for roots and soil life.

The technology we are developing at Beyond Sustainable Tech is one possible application of these principles. But the issue is broader than our solution. What must evolve is the way all access corridors are planned, evaluated, built, and maintained.

What a Real Pilot Project Should Measure

A pilot focused on resilience to fire should not measure only structural performance. It should compare a conventional corridor, a control area, and an infrastructure designed to support retention and infiltration. Measurements should include:

Hydrology: soil moisture at several depths; water residence time; peak flows; water volume exported; local water-table or saturated-zone behaviour; infiltration rate; lateral distribution of moisture.

Soil physics: bulk density; compaction; porosity; aggregate stability; soil temperature; organic-matter content; erosion resistance.

Soil biology: microbial biomass and activity; soil respiration; bacterial and fungal diversity and composition; mycorrhizal presence; enzymatic activity; recovery after drought.

Vegetation and fuels: plant water potential; live foliage moisture; litter moisture; growth and mortality; microclimate; fine-fuel evolution.

Infrastructure: load-bearing performance; freeze–thaw behaviour; maintenance requirements; life-cycle costs; post-removal soil condition.

Those measurements would allow us to move from a strong hypothesis supported by converging research to a complete field demonstration.

Build Resilience Before the Fire

Wildfire response often begins when the smoke appears. Resilience begins much earlier. It begins with the rain the territory manages to keep. With soils that remain porous. With roots that continue to access water. With microorganisms that cycle nutrients and help maintain structure. With canopy cover that shades the ground. And with infrastructure that helps direct water without emptying the landscape.

A road does not automatically cause a wildfire. But it always participates, in some way, in the functioning of the territory it crosses. It can concentrate water or distribute it. It can accelerate its exit or prolong its presence. It can compact the soil or help preserve its structure. It can contribute to drying or to resilience.

For a long time, we have read fire risk mainly in the sky: temperature, wind, and relative humidity. We must now learn to read it in the soil as well — in the water it contains, in the life it supports, and in the engineering decisions that determine how long that water remains in the territory.

> ***“The best water for fighting a wildfire may first be the water the watershed never lost.”***

NEXT ARTICLE

> **The Myth of the ‘Cleaned’ Forest Floor. A common argument in fire prevention is simple: less biomass means less fuel, and less fuel means less fire risk. There is some truth in that logic. But it becomes dangerous when it leads us to believe that cutting, clearing, or ‘cleaning’ more automatically produces a safer landscape. The next article will examine canopy cover, shade, wind, temperature, litter, and**

moisture to understand why the debate should not be framed as ‘remove everything’ versus ‘do nothing.’

OPEN QUESTION

In your organization’s fire-prevention plans, are you measuring only the visible variables — weather, wind, and fuel quantity — or are you also measuring soil moisture, the life the soil supports, and the territory’s capacity to retain water?

ABOUT THE AUTHOR

AB	**Alain Bélanger** · Forest Engineer and Entrepreneur For more than thirty-five years, he has worked in forestry, land management, and environmental technologies. He is the co-founder and CEO of Beyond Sustainable Tech, a member of Top Tier Impact, and is working on the Global Initiative for Regenerative Watersheds and the structuring of the Regenerative Access Infrastructure concept.

KEY REFERENCES

The links below were accessible at the time this document was prepared, in August 2026.

[1] Soil Moisture is a Stronger Predictor of Forest Fire Spread Potential Than Weather in the U.S. Northern Rocky Mountains

Holden et al., Geophysical Research Letters, 2025.
https://www.fs.usda.gov/rm/pubs_journals/2025/rmrs_2025_holden_z001.pdf

[2] Operational Fire Spread Potential Forecasting for the Pacific Northwest and Northern Rockies U.S.A.

Same research team, 2026. Primary publication not yet indexed with a stable public link at time of writing; cited via research communications.
Link to be added once the primary publication is indexed.

[3] Combining Ecophysiology and Combustion Traits to Predict Conifer Live Fuel Moisture Content

Fire Ecology, 2025.
https://fireecology.springeropen.com/articles/10.1186/s42408-025-00361-8

[4] Plant Hydraulic Modelling of Leaf and Canopy Fuel Moisture Content Reveals Increasing Vulnerability of a Mediterranean Forest to Wildfires Under Extreme Drought

Ruffault et al.
https://pubmed.ncbi.nlm.nih.gov/36366950/

[5] High Intensity Perturbations Induce an Abrupt Shift in Soil Microbial State

Cordero et al., The ISME Journal, 2023.
https://www.nature.com/articles/s41396-023-01512-y

[6] Soil Fungi Remain Active and Invest in Storage Compounds During Drought Independent of Future Climate Conditions

Canarini et al., Nature Communications, 2024.
https://www.nature.com/articles/s41467-024-54537-y

[7] Increasing Aridity Reduces Soil Microbial Diversity and Abundance in Global Drylands

Maestre et al., PNAS, 2015.
https://www.pnas.org/doi/10.1073/pnas.1516684112

[8] Arbuscular Mycorrhizal Hyphal Networks and Glomalin-Related Soil Protein Jointly Promote Soil Aggregation and Alter Aggregate Hierarchy in Calcaric Regosol

Ji et al., Geoderma, 2024.
https://www.sciencedirect.com/science/article/pii/S0016706124003252

[9] Environment Statistics at Regional Level — Eurostat Regional Yearbook 2025

Eurostat.
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Environment_statistics_at_regional_level

[10] Bilan climatique de juin 2026 — Météo-France
Météo-France.
https://meteofrance.fr/actualite-0/bilan-climatique-juin-2026-est-le-mois-de-juin-le-plus-chaud-jamais-enregistre

[11] Hot Summer Economics — Triodos Bank
Triodos Bank, 2026.
https://www.triodos.com/en/articles/2026/hot-summer-economics

[12] Hydro-Québec reservoir and energy-storage context (June 2026)
La Presse, June 5, 2026.
https://www.lapresse.ca/affaires/entreprises/2026-06-05/nord-du-quebec/le-plus-important-reservoir-d-hydro-quebec-a-son-niveau-le-plus-bas.php

---