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Hydrophobicity In Soil Due To Wildfires

Usually when you drive through the Bridger Valley in Southwestern Wyoming, you can look to the south and see the beautiful Uinta Mountains outlined against the sky. But for a week and a half in the summer of 2016, this was not the case.

In July and August of 2016, the Tokawanna timber and brush fire tore through 1,287 acres of Southwestern Wyoming in the Meeks Cabin Reservoir Area, leaving 8 homes destroyed,131 families displaced, and the soil thirsting for water.

If you travel to the Meeks Cabin Reservoir Area now, it is hard to see the effects from the wildfire. For the most part, the vegetation has replenished and is thriving. But, when you look at the soil underneath, there is where you will see a true battle of life being fought.

In this research paper the following subjects and questions will be covered-

- What is Hydrophobic Soil?
- Why is Hydrophobic Soil a problem?
- How can Hydrophobic Soil help our Rangelands?
- How can you test to see if your soil has become hydrophobic?
- Consequences of Hydrophobic Soil
    - -Erosion
        - -Cameron Peak Fire and burn scar
        - -Poudre Canyon Flash Flood
    - -Reduction of Plant Life and Vegetation
- Fixing Hydrophobic Soils
- Methods to prevent erosion and their advantages and disadvantages
    - -Mulching
    - -Log terraces
    - -Culverts

What is Hydrophobic Soil

The root meaning of Hydro is water and phobia is fear, but that doesn't mean that the soil is actually afraid of water, it just means that it can't absorb it.
Hydrophobic soil is soil that has been extremely heated, causing the plant material to burn and create a waxy substance that penetrates the layer of soil. Once the topsoil is filled with this waxy substance, it can no longer absorb water. In the article, "Rangeland Soil Quality Hydrophobicity" it explains a little bit more in depth about what Hydrophobic Soil actually is. "Soils that repel water are considered hydrophobic. A thin layer of soil at or below the mineral soil surface can become hydrophobic after intense heating. The hydrophobic layer is the result of a waxy substance that is derived from plant material burned during a hot fire. The waxy substance penetrates into the soil as a gas and solidifies after it cools, forming a waxy coating around soil particles. The layer appears similar to non hydrophobic layers. Plant leaves, twigs, branches, and needles form a layer of litter and duff on the forest floor and under chaparral and shrubs. During the interval between one fire and another, hydrophobic substances accumulate in this layer. During an intense fire, these substances move into the mineral soil. Some soil fungi excrete substances that make the litter and surface layer repel water"(Biggam 1).

This description of hydrophobic soil shows that not only is the soil no longer able to absorb water because all the soil particles are coated, but the soil looks and seems normal. Not all wildfires cause hydrophobia, but four things can increase the chance of the soil becoming hydrophobic. In the article, "Rangeland Soil Quality-Hydrophobic" it lists these four factors. The factors are:
-A thick layer of plant litter prior to the fire
-High- intensity surface and crown fires
-Prolonged periods of intense heat
-Coarse textured soils

In the same article it states, "Very high temperatures are required to produce the gas that penetrates the soil and forms a hydrophobic layer. The gas is forced into the soil by the heat of the fire. Soils that have large pores, such as sandy soils, are more susceptible to the formation of hydro- phobic layers because they transmit heat more readily than heavy textured soils, such as clay. The coarse textured soils also have larger pores that allow deeper penetration of the gas" After the Tokawanna fire, the soil was left hydrophobic. At Wyred Range camp this summer a presenter explained hydrophobicity. At this presentation, we were able to test the soil at the Tokawanna site, and it turns out it truly was hydrophobic. We never would have known because the soil seemed so normal, as well as the vegetation and plant life in the area. So even though the soil might seem normal, if there was a fire recently, or depending on the temperature of the fire, in the past, your soil could very well be struggling with hydrophobicity.

Why is Hydrophobic Soil a Problem?

Hydrophobic soils can have many harmful effects on our rangelands. To start off, hydrophobic soil forms in the topsoil layer of the ground. The main problem with this is that the topsoil is where you find the majority of the roots of your plants. This causes a huge danger to our plant life because they cannot get water. Since the soil is coated with the waxy burnt plant material, it cannot soak up water, which will not allow the plants to soak it up either. If the plants can get water through their roots in the soil, they can regerminate and stay healthy. In an article by Homegates, it states, ¨The movement of water through the plant and out the stomata creates a pull that forces the roots to absorb more water from the soil.¨(Korpella 1) This small excerpt shows how and why the roots suck the water up but, if the soil has no water soaked within it because it is hydrophobic, how are the roots able to absorb any water? They are not able to, which leads to the vegetation being destroyed and our rangelands being put in danger of not being able to reproduce this lost vegetation. Hydrophobic soil is also a major problem because the flow channels are destroyed. In the article, “Soil Quality Resource Concerns: Hydrophobicity,” it lists why hydrophobic soils are important. One of the reasons it states was, “Decreased infiltration into the soil results in damaging flows in stream channels” Once the soil has become hydrophobic all the waste from runoff runs into streams and channels clogging them up and making the water unsafe. So overall, hydrophobic soils are a problem because of the effects they have on rangelands.

How can Hydrophobic Soil Help?

While it seems like hydrophobic soils might be the end of our healthy rangelands altogether, there are actually some good things that can come from it. One thing that hydrophobic soils help with is that it gives the soil a lot of nutrients. When the fire destroys the living and decaying vegetation, nutrients such as sulfur, nitrogen, phosphorus and carbon are released. Now there are that many more nutrients for the pants to take in once the soil has healed. In an article called, “Fire Effect on Soil,” it states, “The increased decomposition activity in recently burned soils is viewed as an important nutrient conservation mechanism, as it leads to microbial retention of nutrients that might otherwise be lost from the soil.”(Woodmansee and Wallach, 1981). So even though the plants could be destroyed from the fire and the soil might be damaged, when everything is repaired, the plants will be able to regrow with many more nutrients.

How to Test for Hydrophobic Soil

By just looking at soil it is really hard to just right away see that it is hydrophobic. A simple soil test is all you need to see if your soil is hydrophobic or not. The test only takes a few small steps. In the article, “Rangeland Soil Quality- Hydrophobicity” it tells the exact steps you need to take in order to determine if there is hydrophobicity in your

soil due to a wildfire. “Scrape away the ash layer and expose the mineral soil surface. Place a drop of water on air- dry soil and wait 1 minute. If the water beads, the soil layer is hydrophobic. The upper few inches of the soil commonly are not hydrophobic. In these cases, it is necessary to scrape away a layer of soil ½ to 1 inch thick and repeat the test to find the upper boundary of the water- repellent layer. Once a water- repellent layer is found, continue to scrape additional layers of soil, repeating the water drop test on each layer until a non- hydrophobic layer is reached. This procedure will indicate the thickness of the hydrophobic layer”(National Park Service). Depending on how intense the fire was, or how long it lasted, the thickness of the hydrophobic layer will be different. If the fire burns at an extremely high temperature and for a long period of time, then the hydrophobic layer is going to be thicker. Once you have found the hydrophobic layer you can begin to try and fix it and prevent it from ruining your rangeland.

Consequences of Hydrophobic Soil

After a wildfire so many issues can happen. Structures can be destroyed, people can be hurt and you can have hydrophobic soil. While you may think that hydrophobic soil might not be that big of a problem, when you look at the things that can happen after your soil has hydrophobia, you will see the obvious dangers and effects that come as a result.

Erosion

One of the biggest and most dangerous consequences of hydrophobic soil is erosion. Because the soil can’t absorb the water it just slides straight across it. In an article called “4 Steps to Prevent or Fix Hydrophobic (water repellent) Soil,” it states, “The key challenge with hydrophobic soil is that it behaves like a paved surface. This is for example why we are seeing flash floods when it rains in dried out areas; water is not absorbed so it will flow away to a lower point. So the problem with soil behaving like pavement is that large amounts of water at once won't help getting the soil moist again”(Sensoterra 1). So, when the water comes in contact with water repellent soil, it begins to pick up its speed and velocity. As it moves across the ground, the water picks up the soil surface layer but glides right over the topsoil layer because it is hydrophobic. This leads to the runoff speeding up with a lot more surface layer within it making it very dangerous and causing erosion to be a major factor in the health and safety of our rangelands.

Cameron Peak Fire and Burn Scar

The Cameron Peak fire burned over 208,000 acres near Chambers Lake Colorado. It was the largest recorded fire in the history of Colorado wildfires. In the article, “Cameron Peak Fire,” it states, “The Cameron Peak Fire is the largest wildfire in

Colorado history. It began on August 13, 2020, and burned 208,913 acres of the Arapaho and Roosevelt National Forests in western Larimer County. Thought to be human-caused, the fire ignited on the flanks of Cameron Peak some forty miles west of Fort Collins. After staying under 25,000 acres for three weeks, persistent dry conditions and high winds caused two major blow ups—one on Labor Day weekend, when the fire ran some 80,000 acres, and another on October 14-17, when it made a 30,000-acre run toward Fort Collins followed by a 25,000-acre run toward the Big Thompson Canyon and Estes Park."(Colorado Encyclopedia Staff) In the same article it says, "By the end of October, the Cameron Peak Fire stood at 208,663 acres and 64 percent containment. Colder temperatures and more snowfall over the next two weeks helped crews get the fire beyond 90 percent containment by November 12. Containment finally reached 100 percent on December 3." This article also lists a couple of statistics from the Cameron Peak Fire. "Although no one died, the fire burned some 469 structures, including 224 houses, and forced thousands of evacuations. For three months, the Cameron Peak Fire created toxic air quality along the Front Range from Greeley to Denver. The fire's effects on the Cache la Poudre watershed are yet to be determined, but it is clear that forest and community recovery will likely take many years." After the fire a large burn scar was left in the area. The burn scar is full of hydrophobic soil which led to very dangerous conditions.

Poudre Canyon Floods

Several months after the Cameron peak fire, historic and fatal flooding claimed the lives of four people in the Poudre Canyon Near the Cameron Peak burn scar in Northern Colorado. In an official report by Larimer County it states, "On Tuesday, July 7, 2021, at approximately 6:05 p.m., the Larimer County Sheriff's Office received reports of flooding in the Poudre Canyon above Rustic. A mudslide occurred near Black Hollow Road and sent a large amount of debris into the canyon, destroying at least five structures and damaging the roadway. Emergency crews were in the canyon and alerted residents and visitors to the approaching danger."(Larimer County).After the flood, many people had died, and more were missing or severely injured. The flood seemed to come so unexpectedly and quickly and caught many people off guard. The reason the flood was so intense is because of the burn scar. In a news article about the flood by KKTV it states, "Because of the burn scar, Poudre Canyon remains vulnerable to flash flooding and mudslides anytime a storm rolls through"(KKTV).Because the burn scar was full of hydrophobic soil it became like a pavement surface. As soon as the rainfall hit, it flew down the burn scar quickly and the Poudre river filled and rushed down the canyon leaving behind destruction and tragic memories.

Reduction of Plant Life and Vegetation

Another major consequence that comes from hydrophobic soil is the reduction of plant life and vegetation. In other words, the plant life cannot carry out osmosis, which is a major downfall to our rangelands. In an article from the biology dictionary called, "Osmosis," it explains what osmosis is. "Osmosis is how plants are able to absorb water from soil. The roots of the plant have a higher solute concentration than the surrounding soil, so water flows into the roots. In plants, guard cells are also affected by osmosis. These are cells on the underside of leaves that open and close to allow gas exchange. When the plant's cells are full of water, the guard cells swell and open the stomata, small holes that allow the plant to take in carbon dioxide and release oxygen"(BD editors). If the soil is hydrophobic the soil cannot soak up water so neither can plants. If there is no water in the soil, the plants can't go through the process of osmosis. If the plants can't soak up water and nutrients from the soil through osmosis, then they can't regerminate and the vegetation will be lost.

Fixing Hydrophobic Soil

Hydrophobic is an extreme problem, so you may be thinking, "How can it be fixed?" The only true way that you can fix hydrophobic soil is by giving it time. In the article, "Rangeland Soil Quality- Hydrophobicity," it states, "The combination of these factors along with the extent and thickness of the hydrophobic layer determine the likelihood of increased runoff, overland flow, erosion, and sedimentation. Thicker layers will persist for more than a year and will continue to have an impact on infiltration as well as plant growth. Plant roots, soil micro- organisms, and soil fauna break down the hydrophobic layer" (Biggam 2). If the soil is given time to work the waxy substance out of the soil and away from the surface and plant roots, it will slowly begin to improve. This process takes time, but it does work.

Methods used to prevent erosion and their advantages and disadvantages.

While there is no guaranteed solution for fixing hydrophobic soil, there are several ways to prevent erosion, which is the leading consequence of non-absorbing soils. There are several methods that can be used to prevent erosion that are all very effective. Three of these methods are mulching, log terraces, and culverts. Each of these methods have both their advantages and disadvantages, and as long as they are done correctly, they can easily prevent erosion.

Mulching

One method that can be used to prevent erosion is mulching. This is a technique that can be done in a variety of ways. Mulching is when you take straw or some other material such as wood shavings, and lay it down on a burnt and bare area. Then you cover it with a netting material to hold it down against the soil. In the article, “Soil Erosion Control After Wildfire” it states, “Straw provides a protective cover over seeded areas to reduce erosion and create a suitable environment for revegetation and seed germination”(Moench 1). There are many advantages and disadvantages to mulching. One advantage is that it keeps the soil held down in place so that the runoff can’t sweep it away. Another is that it holds down water and nutrients in the soil. A further advantage is that the regrowth of plants and protection of soil is boosted because the plants can now get water and nutrients and the soil is held down.

The main disadvantage to mulching is that it can cause a fire hazard. The straw is flammable, and that can be very dangerous because having a fire twice in the same spot in such quick succession would damage the plant life and soil immensely. Another disadvantage is that if the straw is applied too thickly then it will suffocate the plants and kill them. The final disadvantage is that the straw gives invasive insects a great hiding space which may cause competition to native insects.

Log terraces

Log terraces are another method that can be used to prevent erosion due to hydrophobicity in soil after a wildfire. Log terraces are used on hillsides of a burnt area with hydrophobia in the soil. In the article, “Soil Erosion Control After Wildfire,” it states, “Log terraces provide a barrier to runoff from heavy rainstorms. Dead trees are felled, limbed, and placed on the contour perpendicular to the direction of the slope. Logs are placed in an alternating fashion so the runoff no longer has a straight downslope path to follow. The water is forced to meander back and forth between logs, reducing the velocity of the runoff, and giving water time to percolate into the soil”(Moench 2). Once the logs are lined up the hill, the erosion can be prevented. The main advantage to this method is that it slows down the velocity of the runoff so it does not come as quickly or dangerously. Another advantage is that the water is slowed down once it gets to the logs so it has more time to slowly soak into the resisting soil. The logs also catch a big amount of the debris, which means it is mostly just water coming down the hill and it does not get as dangerous.

There are a few disadvantages. For instance, the terraces take a lot of manual labor to construct. Also, if they are not built correctly, they can easily cause more erosion if they get swept away with the runoff. Along with this, if they get swept away they can cause large dangerous mudslides.

Culverts

Culverts are the final method that can be used to prevent erosion. They are also a very common device that have more uses than erosion prevention. In the article, “Soil Erosion Control After Wildfire” it states, “A professional engineer is able to determine the size of the drainage area and the amount of runoff for rainfall events of varying intensity that needs to be carried by culverts. Once sized, the culverts must be installed properly at the correct locations. Installing more culverts than previously existed before the fire may be required. The inlet sides must be regularly maintained to prevent sediment and trash from plugging the pipe. It is common practice to armor the ground at the outlet end with rock rip rap in order to dissipate the energy of the discharged water and to spread it over the slope below. The inlet side can have a drop inlet so as to allow sediment to settle out before water enters the pipe. Armoring the inlet side with rock will also prevent water from scouring under and around the pipe and flowing under the road” (Moench 2). Some of the advantages of culverts are that they redirect water back into streams where it is supposed to be. They also keep the water off of burnt and bare areas and because of this, the soil cannot be taken away.

The disadvantages that come with culverts include the erosion of nearby areas if the inlet sides are not protected, and culvert failure, which can cause major flooding.

Conclusion

In conclusion, hydrophobic soil happens as a result of wildfires burning plant material in the soil and converting it to a wax-like substance that coats the soil and does not allow it to soak up any water. It can cause many problems with our rangelands, but can sometimes even help them as well. Even though the problem cannot be fixed entirely, consequences of hydrophobic soils can be decreased by using a few different techniques. Overall, while wildfires may have very visible problems like the destruction of structures and habitats, if you dig a little deeper and look just below the surface, you will find that one of the most immediate dangers of wildfires can be hidden in the soil.

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