An Assignment

on

Effects of forest fire on physical, chemical, and biological soil properties

Submitted to

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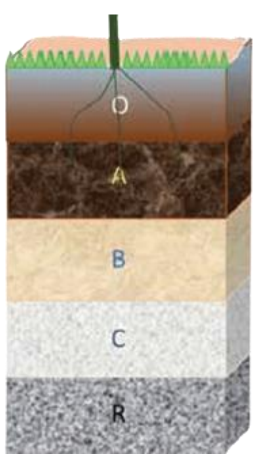
Table of Contents

Today, forest fires have become a natural phenomenon, whether natural or man-made. Effect of forest fires on the soil complex, affecting soil organic matter, macronutrients and micronutrients, and physical soil properties such as texture, color, pH, bulk density as well as soil biota. It also depends on the severity of the fire. The role of fires on the forest floor has been less studied than its effects on the soil propertites. Due to the complexity of the experiments and the complexity of the data composition before, during, and after the combustion period.

Fire is beneficial as well as harmful for the forest soil depending on its severity and fire return interval. In low-intensity fires, the combustion of litter and soil organic matter increases plant-available nutrients, which results in the rapid growth of herbaceous plants and a significant increase in plant storage of nutrients. Whereas high-intensity fires can result in complete loss of soil organic matter, volatilization of N, P, S, K, death of microbes, etc. Intense forest fire results in the formation of some organic compounds with hydrophobic properties, which results in high water repellent soils. Forest fire also causes a long-term effect on forest soil. The aim of this paper is to determine the effects of wildfires on various soil properties, which are important for maintaining a healthy ecosystem.

Introduction:

The soil profile has four distinct layers: 1) O horizon; 2) A horizon; 3) B horizon, or subsoil; and 4) C horizon, or soil base (Figure A). The O horizon has freshly decomposing organic matter—humus—at its surface, with decomposed vegetation at its base.



Decomposed/undecomposed materials. Intense biologically activity.

Leached mineral horizon (dark color) with high content of organic matter (Topsoil).

Zone of accumulation of fine materials & mineral precipitations (Subsoil)

Partly weather rock.

Hard bedrocks.

Fig A: Soil layer, with forest fire effect on the different layers of soil

Not all soil layers are affected by fires of the same severity. Moreover, the effect of fire is usually very limited in depth because of poor thermal conductivity, being negligible from the first few inches in most cases (Zavala, De Celis, and Jordán 2014)**.** The extent and duration of these effects initially depend on the severity of the fire. The severity of a fire is controlled by several environmental factors that affect the combustion process, including amount, type, humidity, temperature and humidity, wind speed, the topography of live and dead fuel. There are two components to the severity of a fire: intensity and duration. Soil characteristics can experience short-term, long-term, or permanent fire changes, primarily depending on the type, severity, frequency of fire, and post-fire climatic conditions. There are two basic types of forest fires: prescribed (controlled) fires and wildfires. Regulated forest burning or naturally accumulating swidden burning after tree extraction is a common practice to reduce fuel levels. In contrast, wildfires often occur when large amounts of dry, heavy fuel are present and can therefore be very severe. Fire can reduce total on-site nutrients through losses due to evaporation, smoke, ash transport, leaching, and erosion. After burning restore nutrients in the soil.

Fires of low to moderate severity, are the most imperative in forest management, renewing common vegetation by removing unwanted species and temporarily raising pH and nutrients available maintenance. Fast. There is no irreversible change in the ecosystem, but an increase in hydrophobicity reduces the ability to absorb water from the soil and makes the soil more susceptible to erosion. Severe fires, such as wildfires, often have a negative impact on the ground. These include significant removal of organic matter, deterioration of structure and porosity, loss of important nutrients by evaporation, ash accumulation in the smoke column, leaching and erosion, and the presence of microbial communities and soil invertebrates. Causes significant changes in both quantity and composition of seeds. The pre-fire level of most traits can be restored and even upgraded. Some physical, chemical and biological properties of the soil are more affected than others (Figure B).

Physical

- Water repellence.
- Structure stability.
- Bulk density.
- Ph.
- Color & texture.
- Temperature

Chemical

- Organic Matter
- Nutrients
- Exchangeable capacity

Biological

- Microbial biomass
- Invertebrates
- Vertebrates

Fig B: Soil properties that are most affected my Forest fire.

Fire directly affects the physical and chemical properties, and biological activity of soils in natural ecosystems, and indirectly causes soil changes by changing successional pathways and modifying the floral community (DeBano et al. 1998; DeBano 2000; Arocen and Opio 2003; Hebel et al. 2009; Aref et al. 2011). Wildfires may produce several changes in the short- and long-term in the landscape and in the soil system.(Zavala, De Celis, and Jordán 2014). The magnitude of these changes induced by fire in the components of ecosystems (water, soil, vegetation and fauna) depends on fire properties (fire intensity and severity) and environmental factors (vegetation, soil, geomorphology, etc.) (Zavala, De Celis, and Jordán 2014). Due to the forest fire increase soil erosion, decrease biomass, enhancement water repellency and changes in the structure and soil components. The long-term effects of fire depending on the severity of fire and regions. It's sometimes beneficial for maintaining ecosystem and sometimes not. The influence of fire on forest soil is determined by several factors, including the severity of the fire, the amount of fuel present, and the moisture content of the soil.

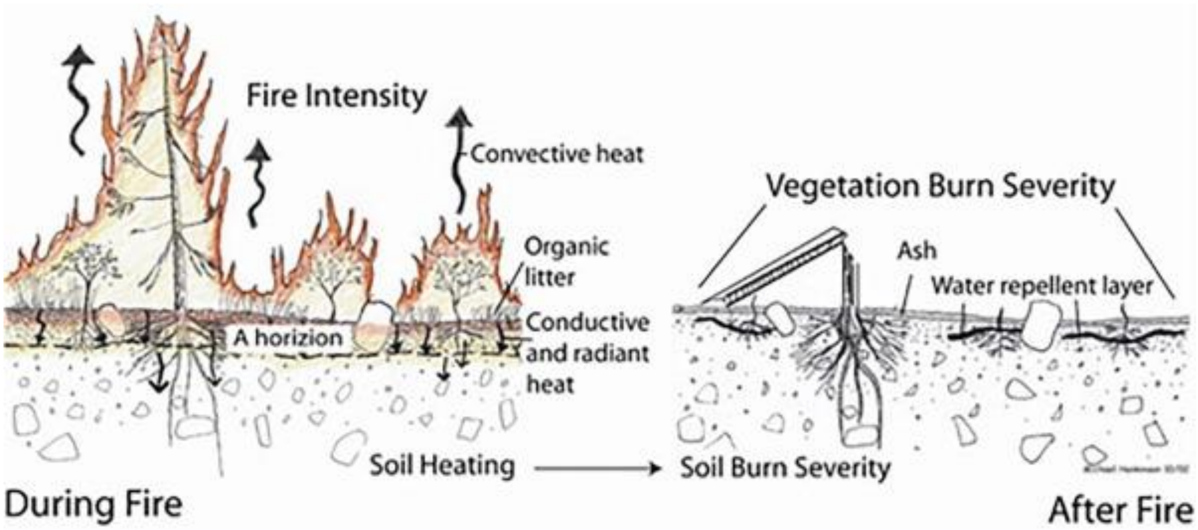


Fig C. Illustrates the effect of fire intensity on above-ground vegetation and below-ground soil properties.

Ketterings and Bigham (2000) show that low intensity fires have little effect on the chemical and biological properties of the soil. However, in intense fires, it is possible that basic and fundamental soil properties such as texture and cation exchange capacity are altered (Ketterings and Bigham 2000). (Ekinci 2006) reported that fire after two weeks increased soil pH, EC, P and K availability, organic N content; reduction of CEC, porosity, Ksat, urease activity, TOC and soil water content in burnt and unburned forest areas around Lapseki town in Canakkale province, Turkey in 2002. Wildfires are a cause major cause of land and ecosystem change.

1.0 Impact of Fire on Physical Properties of Soil

Soil physical properties include texture, structure, density, porosity, consistence, temperature, and color. Severe fire can alter fundamental soil properties such as texture and mineralogy (Ketterings and Bigham 2000).

1.2 Soil color and texture

Many physical properties of soil can be affected by wildfires. The effects were mainly due to the severity of the burn (Ketterings and Bigham, 2000). Soil color and texture were most altered in heavily burned soils under concentrated fuels compared with nearby lightly or moderately burned soils (Ulery and Graham, 1993). At higher temperatures, the soil turns red, and a matrix appears. A redder color occurs in burnt soil, apparently due to oxidation of oxides and complete removal of organic matter (Ulery and Graham, 1993; Certini, 2005). In iron-rich soils, Ketterings et al. (2000) observed that Munsell color became more yellow, while value and saturation decreased after short-term exposure of 300600o C, or redness does not appear until after 45 minutes of exposure to temperatures of 600o C. Ulery and graham also observe that Organic C content was also significantly reduced in the blackened layers, so the lower Munsell values were probably due to the charring of the organic matter that remained. The reddened soil layers had significantly less clay than either the unburned soils or blackened layers, which had clay contents that were not significantly different from each other. While in low to moderate fire ground is covered by a layer of black or grey ash (Certini, 2005). Reddening at a high temperature (6000C) did not occur until after 45 min of exposure. In severely burned lands, the underlying layer was blackened with a thickness of 115 cm and a lower Munsell value (Ulery and Graham, 1993). The structural components of the soil (sand, alluvium and clay) have a high temperature threshold and are generally not affected by fire unless subjected to high temperatures at the mineral soil surface (Ahorizon). At temperatures of 700 to 8000 °C, complete destruction of the clay's internal structure can occur (Neary et al., 2008). Ulery and Graham (1993) reported that after burning, the red soil layers had significantly lower clay content than the unburnt soil.

1.3 Soil pH and bulk density

Soil pH increases inevitably due to soil warming following denaturation of organic acids (Certini 2005). Soil pH often increases after a forest fire (Tufeccioglu et al., 2010; Aref et al., 2011; Boerner et al., 2009). However, a significant increase occurred only at higher temperatures (450500 °C) (Certini, 2005). The presence of ash can increase soil pH due ***to high*** ash ***pH (***Molina et al., 2007; Schafer and Mack, 2010). Density is the mass of dry soil per unit cubic volume (in g/cm3) and, relative to ***porosity, is*** the volume of voids in a soil sample (non-solid mass) divided by mass. overall sample size. Forest land ***density increases*** significantly after ***a forest*** fire (Boerner et al., 2009; Certini, 2005). Certini (2005) reported that a significant increase in pH occurred only at higher temperatures (450–500 C) concomitant ***with complete*** combustion of the fuel and subsequent release of the base. High pH and high density are not good for soil and plants.

1.4 Water repellency

Soil water repellency (WR) is one of the properties most affected by combustion during a forest fire (Mataix-Solera et al., 2012). Water repellency is a property of some soils which reduces its affinity for water, reducing the rate of infiltration of water during periods of hours, days or weeks (Jordán et al., 2013). A direct effect of moderate fires on physical properties is the creation of a discreet and continuous water-repellent front parallel to the surface that decreases soil permeability (Imeson et al. 1992).

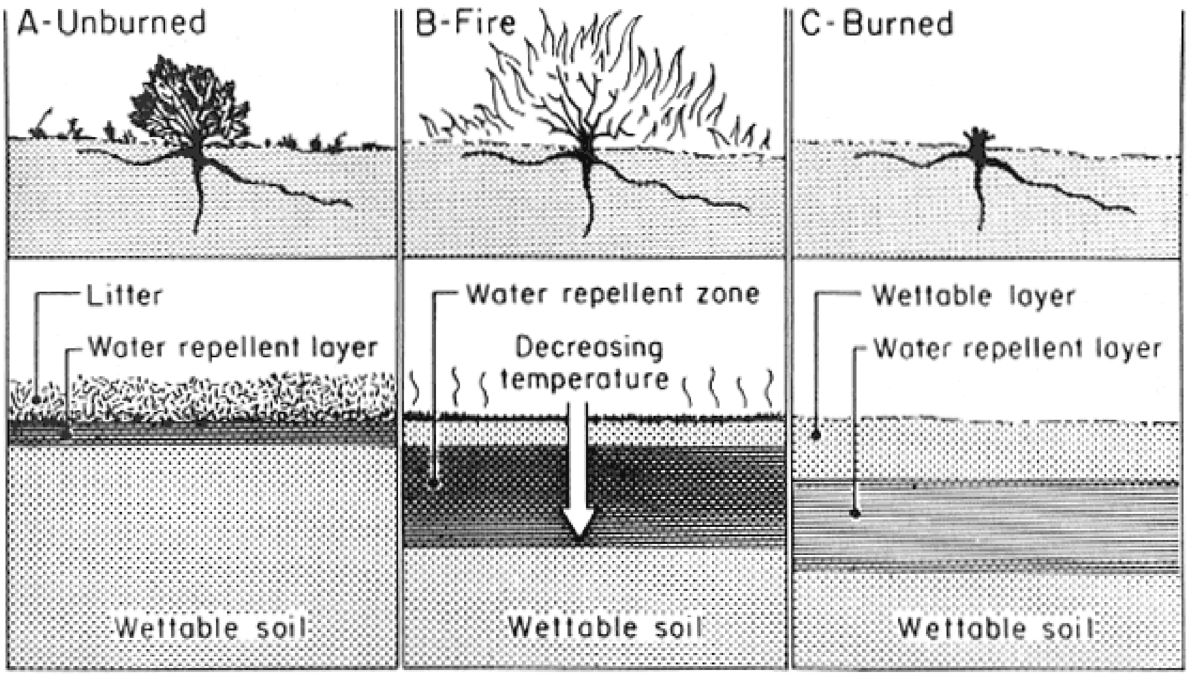


Fig. D. Soil water repellency in unburned brush is found in the litter, duff, and mineral soil layers immediately beneath the shrub plants. (B) When fire burns, hydrophobic substances are vaporized, moving downward along temperature gradients. (C) After the fire has passed, a water repellent layer is present below and parallel to the soil surface on the burned area (adapted from DeBano, 1981).

Soil water content of un-burned soil was higher than burned soil, but the difference was not Soil water content (Table 1). Since vegetations are destroyed by fire, evaporation increases in burned areas during dry and significant (Tables I). Since vegetations are destroyed by fire, evaporation increases in burned areas during dry and hot season (Creighton & Santelices, 2003). Consequently, soil water content decreases. Another reason the main effect of fire on soil physical properties is to eliminate the storage capacity of water in the organic horizons (several cm).

High surface temperatures 'burn' off organic materials and create vapors that move downward in response to a temperature gradient and then condense on soil particles causing them to become water repellent (Letey, 2001). Soil water repellency is induced or enhanced at temperatures of 200-250o C. If temperature is greater than 300oC, it can be destroyed (Zavala, De Celis, and Jordán 2014). Studies on water repellent soil after fire was started in 60's and enough studies have been done on this topic (DeBano, 2000). Future research on water repellent soil should consider the response of soil water repellency for microbial activity, decomposition rates and plant productivity. Consequently, there is a need for systematic manipulation experiments investigating the effects of dryness and heat on water repellent soil.

2.0 Impact of Fire on Chemical Properties of Soil

Studies on the effects of fire on soil report mixed results on changes in soil chemical properties. (Ekinci 2006) reported that pH, electrical conductivity (EC), organic nitrogen, bulk density, potassium and phosphorus values available in soil samples taken from burned areas were higher than those of area is not burned. In contrast, hydraulic conductivity (Ksat), total porosity, soil water (%), cation exchange capacity (CEC), urease activity and soil organic conductance (Ksat), total porosity, water in soil (%), cation exchange rate (CEC), urease and soil organic carbon (SOC) activities were higher than in unburnt areas. In contrast, soil microbial biomass carbon (SOC) was found to be higher in unburnt areas than in burned areas. In contrast, the microbial biomass in the soil did not change before and after burning. Compare burned areas. In contrast, the microbial biomass in the soil did not change before and after burning.

Although fire generally increases nitrogen and carbon levels in burned areas compared with unburnt areas, Banj Shafieia et al. (2010) found that there were no significant differences when comparing nitrogen and carbon concentrations in the burned and control regions of the Hyrcanian mixed forest in Iran.

Heydari et al. (2012) showed that, in general, the chemical properties are affected by the severity of the fire rather than the physical properties of the soil. Barn and associates. (2011) investigated gradual changes in soil properties in the Mediterranean regions and reported that soil organic matter, acidity and electrical conductivity returned to baseline levels within one year after the clouding. on fire. Vegetables et al. (2009) concluded that burning increases nitrogen, phosphorus, calcium, magnesium, manganese and zinc in semi-arid ecosystems. Neff et al. (2005) studied the effects of fire on the organic matter, composition and nutrients of the soil in northern Alaska and concluded that great fire destroys the surface of the soil and increases the number of elements such as carbon and phosphates. phosphorus, potassium, calcium and nitrogen. In the area.

2.1 Soil acidity

Both high and low pH have a negative impact on the ecosystem. Low pH (<5) means a large amount of oxide ions, while high pH (<8) means a large amount of ***OH ions and vice versa***. Soil acidity is usually reduced ***after fire*** due to the destruction of organic acids and the contribution of carbonates, bases and oxides from ash (Kutiel et al., 1990; Ulery et al., 1995; Grange ***et al.,*** 2011a, b). After high-intensity fires due to combustion and reduction of soil organic matter, pH can rise by 4 or 5 units, mainly due to the loss of OH groups from clay minerals and the formation of oxides (Ulery et al., 1995***).*** Giovannini ***et al.,*** 1988, 1990).

2.2 Cation exchange capacity Fire

Fires directly affect the cation exchange capacity (CEC) by burning soil organic matter and converting clay minerals (Zavala, De ***Celis, Jordán*** 2014). As a result, CEC is reduced after a fire, especially in the first few centimeters of soil depth. This decrease can increase or decrease depending on the strength of the fire, pre-fire organic matter content, soil mineralogy, ***and clay*** content (Gil et al., 2010).

2.3 Impact on organic matter (OM)

The most intuitive change soils experience during burning is the loss of organic matter (Certini 2005). The oceanic pool is the largest, followed by the geologic, pedologic (soil), biotic and the atmospheric pool. Soil organic matter (SOM) represents the third largest terrestrial carbon pool, with a global estimated total of 1526 pgC (Lal, 2004). Low-intensity prescribed fire usually results in little change in soil carbon, but intense prescribed fire or wildfire can result in a huge loss of soil carbon (Johnson, 1992). Moderate to high intensity fires convert most soil organic nitrogen to inorganic forms (Certini 2005).
The recovery of soil organic matter in the burnt areas starts with the natural or artificial reintroduction of vegetation and generally is fast, thanks to the high net primary productivity of secondary ecological successions (Certini 2005). The relative yield of aromatic C was comparatively higher in the burnt soil.

2.4 Impact on nutrient dynamics

Most of the nutrients in a soil are in the O horizon and the A horizon. Research suggests that after forest fire soil nutrient decreases but their plant available forms increase (Kutiel and Naveh, 1987). Burned soils have lower nitrogen than unburned soils, higher calcium, and nearly unchanged potassium, magnesium, and phosphorus stocks (Neff et al., 2005).

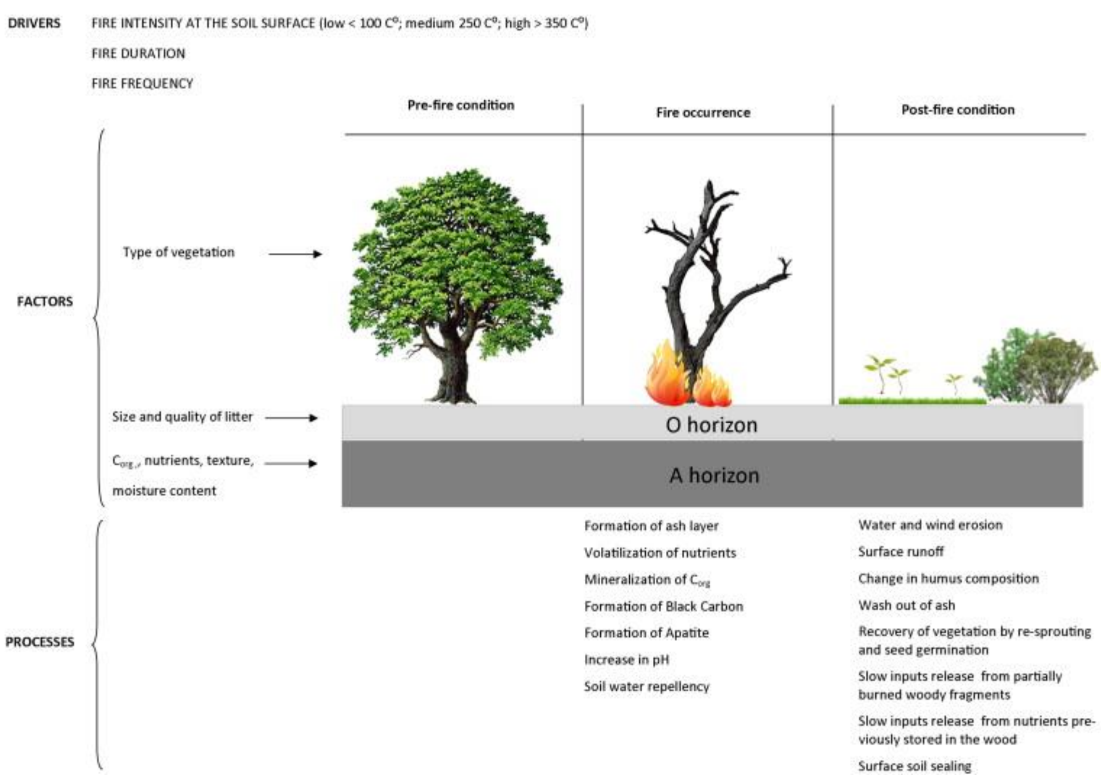


Fig. 1. Main drivers, factors and processes involved in changes in soil nutrient status after a fire.

2.4.1 Nitrogen Nitrogen

Nitrogen is one of ***the most*** affected nutrients in fire (Mataix Solera and Guerrero, 2007). Volatilization of nitrogen during combustion is directly related to the temperature reached in the soil and the amount of organic matter consumed, but nitrification conditions are ***usually improved*** after combustion (MataixSolera and Guerrero, 2007). Inorganic N concentrations tend to increase in the burned area rather than in the unburned control area during the first few years after the fire (Smithwick et al., 2005; Turner et al., 2007; Boerner et al., 2009***.)***. Scientists have observed various effects of fire on the availability of N, but predictions are limited due to poor understanding of the post-fire process (Smithwick et al., 2005).

2.4.2 Organic Carbon

Combustion reduces the organic C content of the soil, but the effects of a fire can be much more complex depending on the intensity of the **fire and** the processes in the soil. After a low-intensity fire, organic C content can be increased from partially pyrolysis plant residues. On the other hand, a medium or high intensity flame reduces the organic C content of the soil (Mataix Solera et al., 2002). According to Knoepp et al. (2005), more than 99% of the organic matter content can be destroyed by heating the soil to 450 °C for two hours or to 500 °C for 30 minutes. However, the loss of organic matter can be offset by the contribution of partially burned remnants and charred leaves that fall within hours or days after the fire (GimenoGarcía et al., 2000; Terefe et al., 2008; Grange et al., 2011a, b). Johnson and Curtis [58] reported a significant 8% increase in soil carbon in the **burned horizon** after a meta-analysis of 48 studies.

Heavy rainfall from April to June in the 4 years following the fire is likely to be the main contributor to the reduction in SOC levels, which can erode the soil surface and **remove fine** organic-rich sediments from the soil. land surface.

2.4.3 Macronutrients

The immediate effect of fire on soil macronutrients is their loss through evaporation due to high temperatures (Certini, 2005; Neary et al., 1999). In a high intensity fire, the temperature reaches 675°C while in a medium and low intensity fire the temperature reaches 40°C and 250°C, respectively (Neary et al., 1999). At 5000 °C, half of the nitrogen in organic matter can be evaporated (Neary et al., 1999; Knicker, 2007). This nutrient fortification is mainly limited to the soil **surface (**05 cm); only soluble N seems to be increased in the subsoil (510 cm) (Marion et al., 1991). The most important short-term effects of wildfires are increased soil solution concentrations and/or leaching of mineral **forms N**, S and P (Murphy et al., 2006). Some changes led to increased availability of nutrients such as soluble phosphorus, nitrate nitrogen, potassium, and increases in pH that may be beneficial to plant growth after burning, especially in the Zagros region where soil fertility is often limiting to plant growth (Fattahi and Ildoromi 2011). However, the **total nitrogen** content decreased (Knight, 1996). Magnesium (Mg), calcium (Ca) and manganese (Mn) are relatively less sensitive than nitrogen due **to the** high threshold temperatures of 1107 °C, 1484 °C and 1962 °C, respectively (DeBano, 1990). Phosphorus (P), potassium (K) and sulfur are partially affected by intense fires (DeBano and Conrad, 1978).

2.4.4 Micronutrients

The fire behavior of micronutrients such as Fe, Mn, Cu, Zn, B, and Mo is unknown due to the lack of specific studies (Certini, 2005). The impact of fire on micronutrient availability helps to understand the impact on soil and plant recovery after fire (García Marco and González Prieto, 2008). Few studies suggest that micronutrients also decrease in quantity after a forest fire.

3.0 Impact of Fire on Biological Properties of Soil

Wildfires can reduce soil fauna abundance and richness in the short term (VerblePearson and Yanoviak, 2014) due to the immediate death of many organisms from the direct effects of fire (Gongalsky et al., 2016). Fire affects biological organisms either directly or indirectly. Direct effects cause shortterm changes. Indirect effects any organism is exposed directly to the flames, glowing combustion, hot gases, or is trapped in the soil and other environments where enough heat is transferred into the organism`s immediate surroundings to raise the temperature sufficiently to either kill or severely injure the organism. Indirect effects usually cause longterm changes in the environment that impact the welfare of biological organisms. These indirect effects can include competition for habitat, food supply, and other more subtle changes that affect plant and animal recovery and inheritance.

Soil respiration is a general measure of soil biological activity and is released by the oxidation of plant roots, soil microorganisms, and, to a lesser extent, root exudates, plant debris, and moist organic matter. Measured by the amount of **CO_2 (**Raich and Schlesinger 1992). Most of the organisms that inhabit the soil are **found** on the surface, and the organic fraction, which consists mainly of plant debris, animal debris, and moist substances, dominates the minerals and forms the "organic horizon." This **horizon, commonly** indicated by a capital O, is fuel and is therefore the most dangerous location in the event of a fire (Swengel, 2001; Doamba et al., 2014). Below the E layer, the lethal temperature is limited to a **few centimeters** due to **poor heat** conduction in "mineral" soils (Enninful and Torvi, 2008).

3.1 Soil-dwelling vertebrates

Vertebrates spending much time on or in soil comprise small mammals and herpetofauna which, in turn, comprises reptiles and amphibians. Small land mammals mainly include rodents: moles, rats, mice, squirrels, hamsters, porcupines, etc. When fires approached, they fled or went through tunnels. Those that sleep or hibernate in burrows are protected from the direct effects of fire (Dawson et al., 2019), but when they return to the burned surface, exhausted from fasting, they may die from alteration. required in the composition of the diet. or higher predation pressure. But they exist to reduce daytime activity and vocalization (a physiological adaptation). The time required for mammalian recovery, if any, varies and depends on species and environmental conditions.

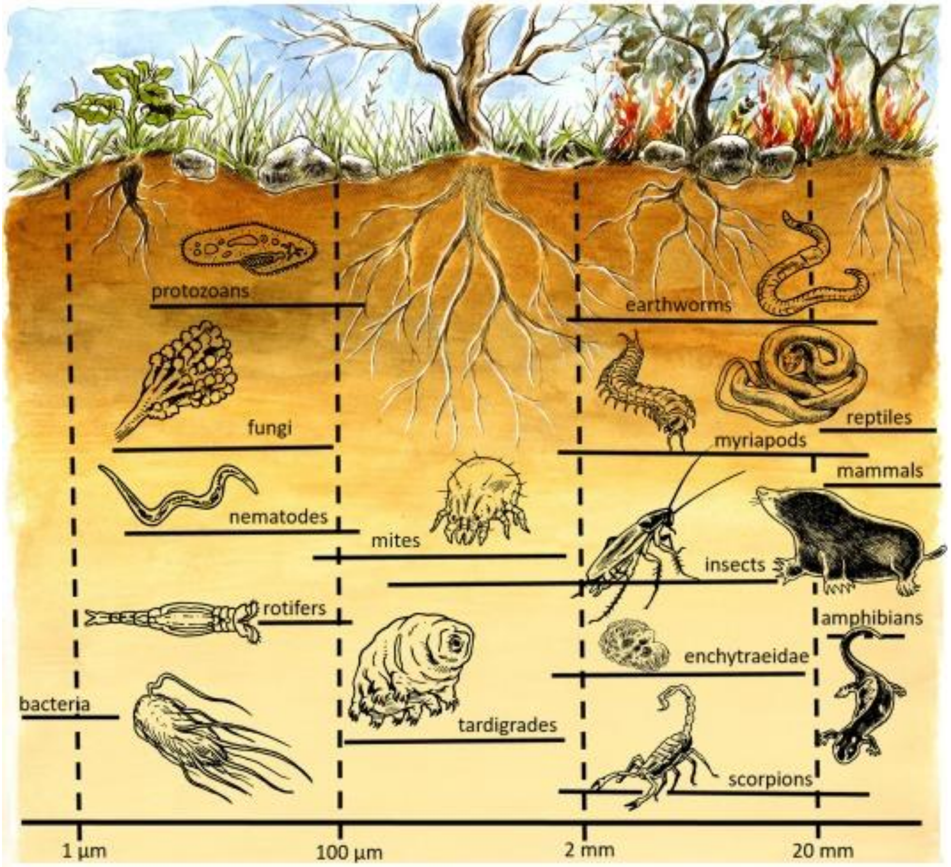


Fig: A schematic representation of the major representatives of the variegated underground living world, classified according to body range size for each group (Background and organisms drawn by Gianluca Borgogni). Note that the figure accounts for neither the physical distribution of organisms according to depth nor the usual thickness and features of the surface O horizon.

3.2 Impact on invertebrates

Invertebrates include most soil-dwelling animals and can be conveniently divided according to their size, i.e., Macro Meso and Microfauna, although their size is somewhat variable depending on the system. possible ecological and environmental conditions. In addition to this convenient subdivision, here we focus on the major taxa of arthropods, earthworms, helminths, ladybugs and rotifers, roundworms, and protozoa. Invertebrates easily withstand fire, but some insects have considerable mobility. The lethal temperature for invertebrates is not higher than for other organisms. For many soil arthropods, death can occur at temperatures around 40 °C, but prolonged exposure to slightly lower temperatures can be fatal (Malmstrom, 2008). It mainly depends on the anatomical features of the individuals, also on their stage of development and habitat. Dwelling on flying surfaces can escape the fire, while organisms closely attached to the ground, such as earthworms and some arthropods, can move deeper to avoid the heat associated related to fire (Gongalsky et al., 2012; New, 2014). The recovery of invertebrates after burning depends on the quantity and quality of the litter (Zaitsev et al., 2014).

3.3 Impact on micro-organisms

By far, microorganisms are the most abundant living organisms in soil. Therefore, each reduction in their biomass, activity and diversity can lead to a decline in some ecosystem function (Wagg et al., 2014). The literature on the effects of fire on soil microorganisms is larger than on larger organisms, allowing firm conclusions to be drawn. Based on meta-analyses, Holden and Treseder (2013) and Pressler et al. (2019) concluded that burning leads to a significant reduction in microbial biomass in the soil by reducing more fungi than bacteria. Soil microorganisms play an important role in nutrient cycling and energy flow, and they are extremely sensitive to environmental changes. Soil microorganisms have many functional roles in forest ecosystems, including acting as a source and reservoir of major nutrients and as catalysts for nutrient metabolism; acting as an engineer and maintainer of the soil structure; and the formation of mutualistic relationships with roots improves plant growth (Hart et al., 2005). Wildfires can significantly alter microorganisms affecting large-scale processes such as nutrient cycling (Neary et al., 1999). The immediate effect of fire on soil microorganisms is to reduce their biomass. Intense fire can reduce a significant amount of microbial biomass. In fact, the maximum temperature often exceeds that required to kill most organisms (DeBano et al., 1998).

3.3.1 Impact on soil bacteria

There are insufficient **data on** the effects of wildfires on soil bacteria. Very few **studies on** bacteria in **soil after** wildfires show that the microbial community structure is significantly altered after the fire. While Jaatinen et al. (2004) studied that there was no significant effect of wildfire on methane-oxidizing bacteria. Bacteria are the smallest and most diverse soil **organisms (**Schloss and Handelsman, 2006), with varying heat tolerances. For example, Pseudomonas are very susceptible, while other genera, such as Bacillus or Clostridium, produce resistant spores that allow them to survive at 100–120 ◦C (Theodorou and Bowen, 1982).

Bacteria are generally more resistant to the direct effects of **fire than** fungi (Hart et al., 2005), and benefit from a higher post-fire soil pH (Rousk et al., 2010) and higher C/N ratios than weak substrates (Pourreza et al., 2014) to dominate them.

3.3.2 Impact on Mycorrhiza

Fungi are essential decomposers in the soil food web because they convert indigestible organic matter into more digestible forms that other organisms can use. Another important role of soil fungi is to bind mineral particles into stable aggregates through their long hyphae (Figure 7) to improve soil porosity and permeability (Certini et al. 2021). Wildfires drastically reduce the number of basidiomycetes ("fungi") species and fruiting body biomass (Hern'andezRodríguez et al., 2013; V'asquez Gassibe et al., 2014), with clear dispersion in the feed. breed. Fire recovery of mycorrhizae from mycorrhizal regrowth from surviving root or seedling segments is usually relatively rapid, on the order of months (Bellgard et al., 1994; Rashid et al., 1997; Alem and colleagues). associates, 2020). Mycorrhizal fungi maintain the overall health of the forest. They play an important role in absorbing nutrients, extending root life and protecting against root pathogens. Stendelle et al. (1999) investigated that the total root shoot biomass in the unburnt plots did not differ for any central strata, while in the burned area, the destruction of the organic layer of the litter caused reduced total spirulina biomass eight times. The mycelium biomass in the two mineral layers was not significantly reduced by burning. Wildfires can affect arbuscular mycorrhizal (AM) fungi by altering soil conditions and directly altering AM proliferation (Rashid et al., 1997). Rachid et al. (1997) reported that compared with a nearby control area, the burned area had a similar total number of spores but a lower number of viable AM fungi. To establish the relationship between mycorrhizal activity, time after burning, and soil edema factors, the dynamics of plant succession and related AM fungal populations need to be further investigated, especially is in the rainforest.

Research gap

Knowledge of soil fertility changes following wildfires is relatively small because of the lack of suitable comparable control sites and/or lack of pre-fire data (Xue, Li, and Chen 2014).

Summary and Conclusion

Currently, there is a widespread understanding of the effects of fire on the physical and chemical properties **of soil**. **However, few** studies have approached studying these effects more comprehensively. A holistic and **interdisciplinary approach** is needed to study the effects of fire on soils, helping to understand the complexity of the interactions between the physical, chemical and biological properties of the soil, as well as as hydrogeological and geomorphological consequences at different scales. This will contribute to the development of appropriate strategies to restore fire-affected areas. (Verma and Jayakumar 2012) Regulated burns and wildfires have a significant impact on forests. These fires increase the water resistance of the forest floor, leading to seepage and soil erosion. Fire also affects soil color, pH, bulk density, texture, and more. The chemical changes in the soil after a forest fire are more significant. Because changes **in nutrient** cycling and soil organic matter can alter ecosystem productivity. The effects of wildfires on SOM vary from complete combustion to increasing numbers. The effects of wildfires on **nitrogen also** vary widely. **Most studies** suggest an increase in the total form of nitrogen available to plants (NH_4^+) but a decrease **in total** nitrogen. This nitrogen **reduction is** due to evaporation. Other nutrients are less affected than nitrogen. High The biological properties of the soil are also strongly affected. Fire decreases the number and species richness of both soil dwelling invertebrates and microorganisms. But in comparison to microorganisms, soil dwelling invertebrates are less affected because of their high mobility and burrowing habit. The effect of fire on soil has been studied in various parts of the world. But their effect is not well studied in tropical **forests. (**Verma and Jayakumar 2012). There is still a need to quantify consumption and soil heating in a tropical forest. Soil microorganisms are complex, and their response to fire will depend on many factors, including the intensity and extent of the burning, site characteristics, and pre-combustion composition (Verma and Jayakumar) 2012). Different types of vegetation, burned at different intensities over a period of 1 to 10 years, can have long-term effects on the abiotic and biotic components of the soil. Understanding these responses is essential**.**

References

Alem, D., Dejene, T., Oria-de-Rueda, J.A., Geml, J., Casta˜no, C., Smith, J.E., Martín-Pinto, P., 2020. Soil fungal communities and succession following wildfire in

Aref IM, Atta HA, Ghamade AR. 2011. effect of forest fires on tree diversity and some soil properties. International Journal of Agriculture and Biology, 13: 659-664

Arocena, J.M.; Opio, C. Prescribed fire-induced changes in properties of subboreal forest soils. Geoderma 2003, 113, 1–16.

Banj Shafiei A, Akbarinia M, Jalali GH, Alijanpour A (2010) Effect of forest fire on diameter growth of beech (Fagus orientalis Lipsky) and hornbeam (Carpinus betulus L.): a case study in Kheyroud forest. Iran J For and Pop Res 17:464–474 (in Persian).

Bárcenas-Moreno, G.; García-Orenes, F.; Mataix-Solera, J.; Mataix-Beneyto, J.; Bååth, E. Soil microbial recolonisation after a fire in a Mediterranean forest. Biol. Fertil. Soils 2011, 47, 261–272.

Bellgard, S.E., Whelan, R.J., Muston, R.M., 1994. The impact of wildfire on vesicular-arbuscular mycorrhizal fungi and their potential to influence the re-establishment of post-fire plant communities. Mycorrhiza 4, 139–146.

Bird M, Veenendaal E, Moyo C, et al. 2000. Effect of fire and soil texture on soil carbon in a sub-humid savanna (Matopos, Zimbabwe). Geoderma, 94(1): 71-90

Blackwell, P.S. 2000. Management of water repellency in Australia, and risks associated with preferential flow, pesticide concentration and leaching. Journal of Hydrology 231-232, 384- 395.

Boerner REC, Hart S, Huang J. 2009. Impacts of Fire and Fire Surrogate treatments. Ecological Applications, 19(2): 338–358

Boerner, R.E.J., Huang, J.J., Hart, S.C. 2009. Impacts of fire and fire surrogate treatments on forest soil properties: a meta-analytical approach. Ecological Applications 19, 338-358.

Boerner, R.E.J.; Brinkman, J.A.; Smith, A. Seasonal variations in enzyme activity and organic carbon in soil of a burned and unburned hardwood forest. Soil Biol. Biochem. 2005, 37, 1419–1426.

Boerner, R.E.J.; Decker, K.L.M.; Sutherland, E.K. Prescribed burning effects on soil enzyme activity in a southern Ohio hardwood forest: A landscape-scale analysis. Soil Biol. Biochem. 2000, 32, 899–908.

Certini G. 2005. Effect of fire on properties of soil - A review. Oecologia, 143: 1-10

Certini, Giacomo, Daniel Moya, Manuel EsFigure 1teban Lucas-Borja, and Giovanni Mastrolonardo. 2021. "The Impact of Fire on Soil-Dwelling Biota: A Review." Forest Ecology and Management 488 (October 2020). https://doi.org/10.1016/j.foreco.2021.118989.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud and D. Williams, 1983. Forest fire behavior and effects, Fire in Forestry vol. I, Wiley, New York

Coachrane MA. 2003. Fire science for rainforests. Nature, 421: 913-919

DeBano L, Neary D, Ffolliott P. 1998. Fire Effects on Ecosystems. John Wiley and Sons, USA

DeBano LF, Conrad CE. 1978. The effect of fire on nutrients in a chaparral ecosystem. Ecology, 59(3): 489- 497

DeBano LF. 1990. The effect of forest fire on soil properties. Symposiam on Management and Productivity of Western- Montane Forest Soil. 151-156, Boise, ID, USA

DeBano LF. 2000. The role of fire and soil heating on water repellency in wildland environments: a review. Journal of Hydrology, 231-232: 195-206

Doamba, S.W.M.F., Savadogo, P., Nacro, H.B., 2014. Effects of burning on soil macrofauna in a savanna-woodland under different experimental fuel load treatments. Appl. Soil Ecol. 81, 37–44.

Doerr, S.H., Shakesby, R.A., Dekker, L.W., Ritsema, C.J. 2006. Occurrence prediction and hydrological effects of water repellency amongst major soil and land-use types in a humid temperate climate. European Journal of Soil Science 57, 741-754.

Doerr, S.H., Shakesby, S.H., Walsh, R.P.D. 2000. Soil water repellency: its causes, characteristics and hydro-geomorphological significance. Earth-Science Reviews 51, 33-65.

Ekinci, Huseyin. 2006. "Effect of Forest Fire on Some Physical , Chemical and Biological Properties of Soil in Çanakkale , Turkey." *International Journal of Agriculture & Biology* 8 (1): 102–6.

Enninful, E.K., Torvi, D.A., 2008. A variable property heat transfer model for predicting msoil temperature profiles during simulated wildland fire conditions. Int. J. Wildland Fire 17, 205–213.

Ethiopian dry Afromontane forests, a highly diverse underexplored ecosystem. Forest Ecology and Management 474, Art. n. 118328. https://doi.org/10.1016/j. foreco.2020.118328.

Gil, J., Zavala, L.M., Bellinfante, N., Jordán, A. 2010. Acidez y capacidad de intercambio catiónico en los suelos afectados por incendios. Métodos de determinación e interpretación de resultados. In Actualización en métodos y técnicas de estudio de los suelos afectados por incendios forestales, A. Cerdà, A. Jordán (eds.), Cátedra de Divulgació de la Ciència, Valencia, pp. 315-331.

Gimeno-García, E., Andreu, V., Rubio, J.L. 2000. Changes in organic matter, nitrogen, phosphorus and cations as a result of fire and water erosion in a Mediterranean landscape. European Journal of Soil Science 51, 201-210.

Giovannini, G., Lucchesi, S., Giachetti, M. 1988. Effect of heating on some physical and chemical parameters related to soil aggregation and erodibility. Soil Science 146, 255-262.

Giovannini, G., Lucchesi, S., Giachetti, M. 1990. Effect of heating on some chemical parameters related to soil fertility and plant growth. Soil Science 149, 344-350.

Goldammer J. 1990. Fire in the Tropical Biota. Springer, Berlin, Germany.

Gongalsky, K.B., Malmstr¨om, A., Zaitsev, A.S., Shakhab, S.V., Bengtsson, J., Persson, T.,

Gonza´lez-Pe´rez JA, Gonza´lez-Vila FJ, Almendros G, et al. 2004. The effect of fire on soil organic matter— a review. Environment International, 30: 855– 870

Granged, A.J.P., Zavala, L.M., Jordán, A., Bárcenas-Moreno, G. 2011b. post-fire evolution of soil properties and vegetation cover in a Mediterranean heathland after experimental burning: a 3-year study. Geoderma 164, 85-94.

Hamman, S.T.; Burke, I.C.; Knapp, E.E. Soil nutrients and microbial activity after early and late season prescribed burns in a Sierra Nevada mixed conifer forest. For. Ecol. Manag. 2008, 256, 367–374.

Hart, S.C., DeLuca, T.H., Newman, G.S., MacKenzie, M.D., Boyle, S.I., 2005. Post-fire vegetative dynamics as drivers of microbial community structure and function in forest soils. For. Ecol. Manage. 220, 166–184.

Hern´andez, T., García, C., Reinhardt, I., 1997. Short-term effect of wildfire on the chemical, biochemical and microbiological properties of Mediterranean pine forest soils. Biol. Fertil. Soils 25, 109–116.

Heydari M, Salehi A, Mahdavi A, Adibnejad M (2012) Effects of different fire severity levels on soil chemical and physical properties in Zagros forests of western Iran. Folia Forestalia Polonica 54:241–250.

Holden, S.R., Treseder, K.K., 2013. A meta-analysis of soil microbial biomass responses to forest disturbances. Frontiers in Microbiology 4, Art. n. 163. https://doi.org/10.33 89/fmicb.2013.00163.

Imeson AC, Verstraten JM, van Mulligen EJ, Sevink J (1992) The effects of fire and water repellence on infiltration and runoff under Mediterranean type forest. Catena 19:345–361

Johnson DW. 1992. Effects of forest management on soil carbon storage. Water, Air, and Soil Pollution, 64: 83-120.

Johnson, D.L.; Curtis, P.S. Effects of forest management on soil C and N storage: Meta analysis. For. Ecol. Manag. 2001, 140, 227–238.

Jordán, A., Zavala, L.M., Mataix-Solera, J., Doerr, S.H. 2013. Soil water repellency: Origin, assessment and geomorphological consequences. Catena 108, 1-5.

Ketterings, Q.M., Bigham, J.M., Laperche, V. 2000. Changes in soil mineralogy and texture caused by slash-and-burn fires in Sumatra, Indonesia. Soil Science Society of American Journal 64, 1108-1117.

Knicker H. 2007. How does fire affect the nature and stability of soil organic nitrogen and carbon? A review. Biogeochemistry, 85: 91-118.

Knight H. 1996. Loss of nitrogen from the forest floor by burning. The Forestry Chronicle, 42(2): 149-152.

Knoepp, J.D., DeBano, L.F., Neary, D.G. 2005. Soil Chemistry. In Wildland fire in ecosystems: effects of fire on soils and water, D.G. Neary, K.C. Ryan, L.F. DeBano (eds.), General Techical Report RMRS-GTR-42-vol.4. United States Department of Agriculture, Forest Service and Rocky Mountain Research Station, Ogden, UT, pp. 53-71.

Kutiel P, Naveh Z. 1987. The effect of fire on nutrients in a pine forest soil. Plant and Soil, 104: 269-274.

Kutiel, P., Naveh, Z., Kutiel, H. 1990. The effect of a wildfire on soil nutrients and vegetation in an Aleppo pine forest on Mount Carmel, Israel. In Fire and ecosystems dynamics. Mediterranean and northern dynamics, J.C. Goldamer, M.J. Jenkins (eds.), SPB Academy Publishing, The Hague.

Lal R. 2004. Soil carbon sequestration to mitigate climate change. Geoderma, 123: 1-22

Leighton-Boyce, G., Doerr, S.H., Shakesby, R.A., Walsh, R.P.D. 2005. Quantifying the impact of soil water repellency on overland flow generation and erosion: a new approach using rainfall simulation and wetting agent on in situ soil. Hydrological Processes 21, 2337-2435.

Letey J. 2001. Causes and consequences of fire-induced soil water repellency. Hydrological Processes, 15(15): 2867-2875.

Malmstr¨om, A., Persson, T., Ahlstr¨om, K., 2008. Effects of fire intensity on survival and recovery of soil microarthropods after a clearcut burning. Can. J. For. Res. 38, 2465–2475.

Marion G, Moreno J, Oechel W. 1991. Fire severity, ash deposition, and clipping effects on soil nutrients in chaparral. Soil Science Society of America journal, 55(1): 235-249

Mataix-Solera J, Arcenegui V, Tessler N, et al. 2012. Soil properties as key factors controlling water repellency in fire-affected areas: Evidence from burned sites in Spain and Israel. CATENA (in press).

Mataix-Solera, J, Gómez, I., Navarro-Pedreño, J., Guerrero, C., Moral, R. 2002. Soil organic matter and aggregates affected by wildfire in a Pinus halepensis forest in Mediterranean environment. International Journal of Wildland Fire 11, 107-111.

Mataix-Solera, J., Cerdà, A., Arcenegui, V., Jordán, A., Zavala, L.M. 2011. Fire effects on soil aggregation: A review. Earth-Science Reviews 109, 44-60.

Mataix-Solera, J., Doerr, S.H. 2004. Hydrophobicity and aggregate stability in calcareous topsoils from fire-affected pine forest in southeastern Spain. Geoderma 118, 77-88.

Mataix-Solera, J., Guerrero, C. 2007. Efectos de los incendios forestales sobre las propiedades edáficas. In Incendios forestales, suelos y erosión hídrica, J. Mataix-Solera (ed.), Caja de Ahorros del Mediterráneo CEMACAM, Alcoi, pp. 5-40.

Molina M, Fuentes R, Calderón R, et al. 2007. Impact of forest fire ash on surface charge characteristics of Andisols. Soil Science, 172(10): 820-834.

Murphy JD, Johnson DW, Walker WW, et al. 2006. Wildfire effects on soil nutrients and leaching in a Tahoe Basin Watershed. Journal of Environmental Quality, 35: 479-489.

Neary DG, Klopatek CC, DeBano LF, et al. 1999. Fire effects on belowground sustainability: a review and synthesis. Forest Ecology and Management, 122: 51-71

Neary DG, Ryan KC, DeBano LF. 2008. Wildland Fire in Ecosystems: Effects of Fire on Soils and Water. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, USA

Neff J, Harden J, Gleixner G. 2005. Fire effects on soil organic matter content,composition, and nutrients in boreal interior Alaska. Canadian Journal of Forest Research, 35: 2178-2187

Piccolo, A., Mbagwu, J.S.C. 1999. Role of hydrophobic components of soil organic matter in soil aggregate stability. Soil Science Society of America Journal 63, 1801-1810.

Raich JW, Schlesinger WH (1992) The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B:81–99.

Rashid, A., Ahmed, T., Ayub, N., Khan, A.G., 1997. Effect of forest fire on number, viability and post-fire re-establishment of arbuscular mycorrhizae. Mycorrhiza 7, 217–220.

Rau BM, Johnson DW, Blank RR, Chambers JC (2009) Soil carbon and nitrogen in a Great Basin pinyon–juniper woodland: influence of vegetation, burning, and time. J Arid Environ 73:472–479.

Ritsema, C.J., Dekker, L.W. 1994. How water moves in a water repellent sandy soil. 2. Dynamics of fingered flow. Water Resources Research 30, 2519-2531.

Rousk, J., Brookes, P.C., Bååth, E., 2010. Investigating the mechanisms for the opposing pH-relationships of fungal and bacterial growth in soil. Soil Biol. Biochem. 42, 926–934.

Schafer JL, Mack MC. 2010. Short-term effects of fire on soil and plant nutrients. Plant Soil, 334: 433-447.

Schloss, P.D., Handelsman, J., 2006. Toward a census of bacteria in soil. PLoS Computational Biology 2 e92.

Smithwick, E.A.H., Turner, M.G., Mack, M.C., Chapin, F.S. 2005. Postfire soil N cycling in northern conifer forests affected by severe, stand-replacing wildfires. Ecosystems 8, 163-181.

Stendell ER, Horton TR, Bruns TD. 1999. Early effects of prescribed fire on the structure of the ectomycorrhizal fungus community in a Sierra Nevada ponderosa pine forest. Mycological Research, 103(10): 1353-1359.

Swengel, A.B., 2001. A literature review of insect responses to fire, compared to other conservation managements of open habitat. Biodivers. Conserv. 10, 1141–1169.

Terefe, W.T., Mariscal, S.I., Gómez, M.V., Espejo, S.R. 2008. Relationship between soil color and temperature in the surface horizon of Mediterranean soils: a laboratory study. Soil Science 170, 495-503.

Theodorou, C., Bowen, G.D., 1982. Effects of a bushfire on the microbiology of a south Australian low open (dry sclerophyll) forest soil. Australian Forest Research 12, 317–327.

Tufeccioglu A, Kucuk M, Bilgili E, et al. 2010. Soil properties and root biomass responses to prescribed burning in young corsican pine (Pinus nigra Arn.) stands. Journal of Environmental Biology, 31: 369-373

Tufeccioglu A, Kucuk M, Bilgili E, et al. 2010. Soil properties and root biomass responses to prescribed burning in young corsican pine (Pinus nigra Arn.) stands. Journal of Environmental Biology, 31: 369-373

Turner, M.G., Smithwick, E.A.H., Metzger, K.L, Tinker, D.B., Romme, W.H. 2007. Inorganic nitrogen availability after severe stand-replacing fire in the Greater Yellowstone ecosystem. Proceedings of the National Academy of Sciences 104, 4782-4789.

Ulery AL, Graham RC. 1993. forest fire effects on soil color and texture. Soil Science Society of America Journal, 57(1): 135-140

Ulery, A.L., Graham, R.C., Chadwick, O.A., Wood, H.B. 1995. Decade scale changes of soil carbon, nitrogen and exchangeable cations under chaparral and pine. Geoderma 65, 121-134.

Verma, Satyam, and S Jayakumar. 2012. "Impact of Forest Fire on Physical, Chemical and BiologicalProperties of Soil: A." *Proceedings of the International Academy of …* 2 (3): 168–76. http://www.iaees.org/publications/journals/piaees/articles/2012-2(3)/impact-of-forest-fire.pdf.

Verble-Pearson RM, Yanoviak SP. Effects of fire intensity on litter arthropod communities in Ozark oak forests, Arkansas, U.S.A. Am Midl Nat. 2014;172:14-24. https://doi.org/10.1674/0003-0031-172.1.14

Wagg, C., Bender, S.F., Widmer, F., van der Heijden, M.G.A., 2014. Soil biodiversity and soil community composition determine ecosystem multifunctionality. PNAS 111, 5266–5270.

Wan S, Hui D, Luo Y. 2001. Fire effects on nitrogen pools and dynamics in terrestrial ecosystems: A meta- analysis. Ecological Applications, 11(5): 1349-1365.

Xue, Li, Qiujing Li, and Hongyue Chen. 2014. “Effects of a Wildfire on Selected Physical, Chemical and Biochemical Soil Properties in a Pinus Massoniana Forest in South China.” *Forests* 5 (12): 2947–66. https://doi.org/10.3390/f5122947.

Zavala, L.M., R. De Celis, and A. Jordán. 2014. “How Wildfires Affect Soil Properties. A Brief Review.” *Cuadernos de Investigación Geográfica* 40 (2): 311. https://doi.org/10.18172/cig.2522.