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# Fire Induced Changes in Soil Characteristics in Keşan, Turkey

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**ABSTRACT**

This research was conducted in Keşan (Çınarlıdere) area (1689 ha) of Thrace region, Turkey. The forest area was burned naturally in 2000. The aim of this research was to determine the effects of forest fire on some soil characteristics two year after the fire. Soil samples were collected from three locations as replicates from both burned and nearby unburnt sites. According to the study results, urease activity and soil organic carbon values ($P<0.001$), organic nitrogen and total porosity ($P<0.01$), aggregate stability, microbial biomass carbon values ($P<0.05$) were lower in burned soils than those of unburned soils. On the other hand, hydraulic conductivity and available phosphorus in unburned soil was not significantly higher than that of burned soils. This research showed negative effects of fire on some soil characteristics after two years.

**Keywords**: forest fire, soil, soil organic carbon; total organic nitrogen; porosity

## INTRODUCTION

Forest fires are common problem in western and southern parts of Turkey. Fire is an important natural disaster in most forest ecosystems and can lead to rapid changes in physical, chemical and biological properties of soil. Fire effects on these characteristics of forest soils vary from minimal to profound. Depending on factors such as intensity and duration of the fire, soil type, soil moisture content at the time of the fire (Chandler et al. 1983, Pyne et al. 1996). Fire can substantially change surface soil characteristics and erosion rates and can influence patterns of vegetation on the landscape. Fire can have consequences on soil productivity by consuming organic matter and vegetation.

Previous studies on burned forest soils, illustrated that burning could influence the enzyme activities of soil not only of topsoil but also lower layers of soil profile. Zhang Yong-Mei et al. investigated invertase, acid phosphatase, proteinase, catalase, peroxidase and polyphenoloxidase activities in burned soils. It was found that the activities of invertase and proteinase were reduced by burning, but the activities of acid phosphatase, polyphenoloxidase and peroxidase increased.

The extent of fire effects on soil physical properties varies considerably depending on fire intensity, fire severity, and fire frequency. In general, most fires do not cause enough soil heating to produce significant changes to soil physical properties (Hungerford et al. 1990).

Loss of soil organic matter results in a loss of soil structure. By altering soil structure, severe fires can increase soil bulk density (DeByle 1981), and reduce soil porosity (Wells et al. 1979), mostly through the loss of macropores. Soil porosity can also be reduced by the loss of soil invertebrates that channel in the soil (Kettredge 1938). When fire exposes mineral soils, the impact of raindrops on bare soil can disperse soil aggregates and clog pores, further reducing soil porosity (Ralston and Hatchell 1971).

Intense fires may also induce the formation of a water repellent soil layer by forcing hydrophobic substances in litter downward through the soil profile (DeBano 1969). These hydrophobic organic compounds coat soil aggregates or minerals creating a discrete layer of water repellent soil parallel to the surface. Water repellent soil layers are reportedly formed at temperatures of 176-288 $^{0}$C and destroyed at >288 $^{o}$C (Neary et al. 1999). Extensive water repellent layers can block water infiltration and contribute to runoff and erosion.

There are not enough studies in literature on wildfire effects on carbon and nitrogen content in the soil. Groeschl et al. (1991) reported that, one year after a lightning-caused wildfire in Shenandoah National Park- Virginia, measured C and N amounts in low- and high-intensity areas of the wildfire area as well as in an adjacent unburned area. About the soil nutrients, P as phosphate is a nutrient released by burning. Schripsema (1977) found the availability of P to vary by site. Others have found availability to increase (Raison 1979, Kramer 1973, Smith and Owensby 1973, White and Gartner 1975, Christensen 1976). Some studies discuss nutrients other than N and P. Availability of K may increase after fire (Christensen 1976; Raison 1979).

Kavdir et. al. (2005) investigated the influences of forest wild fires that occurred 12, 8, 2 years and 2 weeks before the time of sampling on the composition of the forest floor organic matter by comparing total carbon (C) and total nitrogen (TN), composition of organic functional groups as determined by $^{13}$C CP/MAS-NMR and soil aggregate stability of unburned and burned forest floor in four locations in Çanakkale, Turkey. Soil organic carbon values of three field replicates of burned soils, there was 20% decrease in 1990, 52% in 1994, 43% in 2000 and 11% in 2002 compared to unburned forest floor. Differences between burned and unburned soil organic C values were found to be significant at Kesan and Gelibolu sites. No significant decrease or increase in soil organic C was observed for samples taken from Lapseki and Cumali sites.

This work is aimed to the effects of forest fire, which occurred two years before sampling in Keşan-Edirne, on some soil physical chemical and biological properties. The soil chemical quality indicators are soil pH, electrical conductivity, organic nitrogen, soil organic carbon, cation exchange capacity, and available K and P. The soil biological indicators are urease activity, microbial biomass C. The soil physical quality indicators are aggregate stability, hydraulic conductivity, soil bulk density and soil water content.

## MATERIALS and METHODS

### Study Area

This research was conducted in Keşan (Çınarlıdere) area (1689 ha) of Thrace region, Turkey (Figure 1). The forest area (1689 ha) was burned naturally in 2000. Annual average temperature is 13,55 $^{0}$C and rainfall is 585 mm in the area. The fire type was classified as medium to high intensity.


Figure1. Location of Research Area

### Soil Sampling

Soil samples were taken from three different locations with three replicates in study area which burned in 2000. Each of the replicates was 1 m apart from each other. Burned and unburned sites were approximately 20–30 m apart from each other depending on the site. Burned and unburned disturbed, undisturbed soil samples were taken from 0–5 cm soil depth. Some samples were kept in at 4 °C for biological analysis.

### Laboratory Analysis

Soil organic C was analyzed using the dichromate oxidation technique (Nelson and Sommers, 1996); total N was determined by steam distillation by Kjeldahl automatic analyzer using the Bremner method (Bremner, 1996); pH, EC, and CEC using the methods described in Soil Survey Staff (Soil Survey Staff. 1996), Soil aggregates were separated into their size fractions by sieving them through a 3.3-mm screen. Aggregate stability was determined by the Youder's wet sieving method (Kemper and Rosenau, 1986).

Dry soil samples were extracted with Mehlich I extraction solution. Available phosphorus (P) and potassium (K) were determined by ICP-AES. The method by Tabatabai (1994) was used for determining urease activity. Microbial biomass carbon of soil samples was determined by using the chloroform fumigation method (Howarth W. R., Paul E. A. 1994). Total organic carbon loads in Kg.ha-1 (0-5 cm) were calculated from the soil volume (V), soil bulk density (BD), percentage or concentration of SOC (Con), according to the equations 1 and 2 (Morley, et al. 2004).

$V=10,000\ m^2 \times 0.05\ m$ (1)

$C\ (kg.ha^{-1}) = (V x BD\ (g/cm^3)) \times (Con\ (\%))/100$ (2)

### Statistical Analysis

Collected data were analyzed by a PROC GLM procedure using Statistical Analysis System (SAS) (SAS Institute, 1997). Duncan's LSD test was used to separate means of measured values.

## RESULTS

Variance analysis results in burned and unburned soils presented in Table 1. Means of physical, chemical and biological properties of samples, shown in Table 2.

Table 1. Variance Analysis of the Analyzed Biological-Chemical and Physical Properties

| Parameters | Mean Squares | | |
|---|---|---|---|
| | Fire (df=1) | Replication (df=2) | Error (df=2) |
| **pH** | 0.48* | 0.04 | 0.06 |
| **EC** | 10034.72* | 567.39 | 1702.00 |
| **Total Organic N** | 0.17** | 0.01 | 0.01 |
| **Urease Activity** | 71849.56*** | 648.45 | 2618.26 |
| **Microbial Biomass Carbon** | 2.77* | 0.21 | 0.34 |
| **Available K** | 8683.86* | 173.88 | 1151.29 |
| **Available P** | 121.47 | 36.96 | 30.19 |
| **Total Organic Carbon** | 48.05*** | 0.05 | 2.19 |
| **Cation Exchange Capacity** | 84.76 | 8.82 | 18.86 |
| **Aggregate Stability** | 1063.37* | 26.92 | 170.22 |
| **Total Porosity** | 758.42** | 4.20 | 51.95 |
| **Hydraulic Conductivity** | 10.19 | 6.68 | 8.51 |
| **Soil Water Content** | 86.68* | 11.98 | 18.69 |
| **Soil Bulk Density** | 0.09** | 0.00 | 0.00 |

*, ** and ***: Significant at 0.05, 0.01 and 0.001, respectively.

Table 2. Mean Values of Soil Physical, Chemical and Biological Properties of Burned and Unburned Forest Soils (n=9)

| **Parameters** | **Burned** | **Unburned** | **LSD (0.05)** |
|---|---|---|---|
| **pH** | 5.60b | 5.93a | 0.25 |
| **EC (µS.m$^{-1}$)** | 85.11b | 132.33a | 42.37 |
| **Total Organic N (%)** | 0.20b | 0.39a | 0.11 |
| **Urease Activity (mg.Kg-1.2h$^{-1}$)** | 88.57b | 214.93a | 52.56 |
| **Microbial Biomass Carbon (mg.C g Soil$^{-1}$)** | 0.71b | 1.49a | 0.60 |
| **Available K (mg.Kg$^{-1}$)** | 143.13b | 187.06a | 34.85 |
| **Available P (mg.Kg$^{-1}$)** | 13.94 | 19.13 | - |
| **Total Organic Carbon (%)** | 3.80b | 7.07a | 1.52 |
| **Cation Exchange Capacity** | 14.84 | 19.18 | - |
| **Aggregate Stability (%)** | 75.24b | 90.61a | 13.50 |
| **Total Porosity (%)** | 46.28b | 59.27a | 7.40 |
| **Hydraulic Conductivity** | 3.33 | 4.84 | - |
| **Soil Water Content %** | 15.09 | 19.48 | - |
| **Bulk Density (g.cm$^3$)** | 1.19b | 1.33a | 0.09 |

### Total Organic Nitrogen

One effect of fire on N is volatilization (DeBell and Ralston 1970; Sharrow and Wright 1977; Tiedmann and Anderson 1980). Fire intensity, amount of green material, and moisture has been reported to influence the amount of N lost through volatilization (Dunn and DeBano 1977). However in some researches fire increased soil N due to stimulation of legumes (Mayland 1967), the washing of charred surface material into the soil (Metz et al 1961) and formation of ash which increases growth of nitrifying bacteria (Burns 1952). Nitrifying bacteria are protected from heat and recover quickly to produce nitrates from organic matter (Sharrow and Wright 1977). Organic N contents of both burned and unburned soils are presented in Table 2. Organic N contents of burned soils (0.20%) were found to be lower than unburned soils (0.39%) and this was statistically significant at 0.01 ($P < 0.01$).

### Total Organic Carbon (TOC)

Volatilization causes carbon, hydrogen, and oxygen, (C, H, and 0) release to the atmosphere, along with varying amounts of sulfur (S), and phosphorus (P) depending on the composition of the organic matter burned and the degree of combustion (Raison 1979). As it is seen from the Table 2, negative effects of forest fire on topsoil soil carbon contents were observed two years after the fire. Mean values are, 3.80% and 7.07% for burned and unburned soils, respectively. Difference between mean values is statistically significant ($P < 0.001$).

**Microbial Biomass Carbon (MBC).**

Microbial organisms are an extremely important component of the biologically active portion of soil ecosystems. Soil microbial diversity and bio-mass are very important properties in terms of soil health and quality. According to Table 2, difference is statistically significant ($p < 0.05$). Microbial biomass carbon (MBC) of burned soils (0.71%) was found to be lower than unburned soils (1.49%).

**Urease Activity**

Urease catalyzes the hydrolysis of urea to carbon dioxide and ammonia. It acts on carbon-nitrogen (C-N) bonds other than the peptide linkage. Urease is important in organic N mineralization (Tabatabai, 1982). Urease activity of burned soil was lower (88.57 mg $kg^{-1}2h^{-1}$) than unburned (214.93 mg $kg^{-1}2h^{-1}$) soils. This difference was statistically significant ($p < 0.001$).

**Electrical Conductivity (EC)**

The EC after high-severity fire increased immediately and then decreases to relatively low values, for a relatively long period, due to the quick erosion of the ash layer as well as by the fast wash into subsoil (Tessler et al. 2008). In this research, soil changes persisted for 2 years following fire (Table 2). At the study site soil differences of EC values are statistically significant ($p < 0.05$) (Table 1).

**Phosphorus (P) and Potassium (K)**

White and Gartner (1975) found an increase in available P only if temperatures did not exceed 392 F (200 $^oC$). They also speculated that, as in the case of ammonia, soil moisture and heat determine the extent of the increase in P availability. Soluble K will increase in the litter, and A-1 horizon if temperatures do not exceed 392 F (200 $^oC$) (White et al 1973). Available soil P values of burned soils were lower than unburned soils after 2 years following fire, but this difference was not statistically significant (Tables 1 & 2). Available K values of burned (143.13 $mg.Kg^{-1}$) soils were lower than unburned (187.08 $mg.Kg^{-1}$) soils, and this was statistically significant ($p < 0.05$).

**Cation Exchange Capacity (CEC)**

Fire should not affect the CEC of mineral soils but may change CEC of soils rich with organic carbon,

This was also observed in this study. CEC values of burned soils and un-burned soil were 14.84 $cmol.kg^{-1}$ and 19.18 $cmol.kg^{-1}$, respectively. This difference was not statistically significant.

**Soil Water Content**

Fire induced changes in soil structure and texture can potentially impair soil hydrology. Decreased soil porosity and the formation of water repellent layers decrease water infiltration rates (DeBano 1971). Loss of soil organic matter and increased bulk density can decrease the water storage capacity of soils. In this Research, soil water content of burned and unburned soil samples were 15.09% and 19.48%, respectively, and this difference was not statistically significant.

**Aggregate Stability (AS)**

In areas affected by severe fires, organic matter content in soil was reduces, thus causing reduced aggregate stability. Aggregate stability values of burned and unburned soils are different and this difference is statistically significant ($p < 0.05$).

**Hydraulic Conductivity, Porosity and Bulk Density**

The strong water repellency of burned soils and reduced hydraulic conductivity, together with the loss of plant cover, can be assumed to be the main sources of the increased surface runoff and soil erosion. Difference of Hydraulic Conductivity values was not statistically significant in this study. Soil organic matter holds sand, silt, and clay particles into aggregates, therefore a loss of soil organic matter results in a loss of soil structure. By altering soil structure, severe fires can increase soil bulk density (DeByle 1981), and reduce soil porosity (Wells et al. 1979), mostly through the loss of macropores (>0.6 mm diameter). Soil porosity values of both burned and un-burned soils are presented in Table2. This difference was statistically significant ($p< 0.01$). Soil bulk density values of burned and unburned soils were statistically significant ($p < 0.01$).

## CONCLUSION

Forest fires affect physical, chemical, and biological soil properties directly by transferring heat into soil and indirectly by destroying vegetation and the dynamics of plant nutrients and organic matter. High soil temperatures can kill soil microbes and plant roots; destroy soil organic matter; and alter soil nutrient and water status. The degree of soil heating during fire depends on a variety of factors, including fuel characteristics, fire intensity and residence time, and properties of the soil and litter layer. As a conclusion, the fire after two years reduced soil EC, available P and K, organic N content, CEC, porosity, hydraulic conductivity, urease activity, TOC and soil water content. This study showed that the forest fires do not only cause air pollution but also cause losses in soil properties. Also, negative effects of fire on soils still could be found after 8 years.

## REFERENCES

Bremner, 1996 J.M. Bremner, Nitrogen-Total. In: D.L. Sparks et al., Editors, Methods of soil analysis: Part. 3. Chemical methods, SSSA Book Series vol. 5 (1996), pp. 1085–1121 Madison, WI.

Burns, P.Y. 1952. Effects of fire on forest soils in the Pine Barren region of New Jersey. Yale Univ School of Forestry Bull 57, 50 pp.

Christensen, N.L. 1976. Short-term effects of mowing and burning on soil nutrients in Big Meadows, Shenandoah National Park. J Range Manage 29:508-509.

DeBano, L.F.. 1971. The effect of hydrophobic substances on water movement in soil during infiltration. In: Soil Science Society of America Proceedings. 340-343

DeBell, D.S., and C.W. Ralston. 1970. Release of nitrogen by burning light forest fuels. Proc, Soil Sci Soc Amer 34:936-938.

DeByle, D. C.. 1981. Clear cutting and fire in the larch Douglas-fir forests of western Montana- a multifaceted research summary. General Technical Report, INT-99. U.S.D.A. Forest Service Intermountain Forest and Range Experimental Station

Dunn, P.H., and L.F. DeBano. 1977. Fires effect on the biological properties of chaparral soils. Pp 75-84 In Proc, Int Symp, Environmental Consequences of Fire and Fuel Management in Mediterranean Climate Ecosystems (Forests and Scrublands), U.S. For Serv Gen Tech Rep WO-3.

Ekinci H., 2006, Effect of Forest Fire on Some Physical, Chemical and Biological Properties of Soil in Çanakkale, Turkey, International Journal of Agriculture & Biology, 1560–8530/2006/08–1–102–106.

Gee and Bauder, 1986 G.W. Gee and J.W. Bauder, Particle-size analysis. In: A. Klute, Editor, Methods of soil analysis: Part 1. Physical and mineralogical methods, ASA Monograph vol. 9 (1986), pp. 383–411 Madison, WI.

Groeschl, D.A.; Johnson, J.E.; Smith, D.W.. 1991. Forest soil characteristics following wildfire in the Shenandoah National Park, Virginia. In: Nodvin, S.C.; Waldrop, T.A. , eds. Fire and the environment: ecological and cultural perspectives: Proceedings of an international symposium; 1990 March 20-24; Knoxville, TN. Gen. Tech. Rep. SE-69. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 129-137.

Horwath, W.R., and E.A. Paul. 1994. Microbial biomass. Pages 753-774 in R.W. Weaver, J.S. Angle, P.J. Bottomley, D.F. Bezdicek, M.S. Smith, M.A. Tabatabai, and A.G. Wollum, eds. Methods of Soil Analysis Part 2-Microbiological and Biochemical Properties. Soil Science Society of America, Madison, Wisconsin, USA.

Hungerford, R.D.; Harrington, M.G.; Frandsen, W.H., Ryan, R.C. and Niehoff, J.G.. 1990. Influence of fire on factors that affect site productivity. Symposium on Management and Productivity of Western-Montana Forest Soils.

Kavdir Y., Ekinci H., Yüksel O., Mermut A. R., Soil aggregate stability and 13C CP/MAS- NMR assessment of organic matter in soils influenced by forest wildfires in Çanakkale, Turkey, **Geoderma**
Volume 129, Issues 3-4, December 2005, Pages 219-229

Kemper and Rosenau, 1986 W.D. Kemper and R.C. Rosenau, Aggregate stability and size distribution. In: A. Klute, Editor, Methods of Soil Analysis: Part 1. Physical and mineralogical methods (2nd edition), American Society of Agronomy, Madison, WI (1986), pp. 425–442.

Kettredge, J. 1938. Comparative infiltration in the forest and open. Journal of Forestry. 36: 1156-1157.

Kramer, J.L. 1973. Vegetation and soil responses to burning, mowing, and fertilization in the Sheyenne National Grassland of North Dakota. MS thesis, NDSU, Fargo, 119 pp.

Mayland, H.F. 1967. Nitrogen availability on fall-burned oak-mountain mahogany chaparral. J Range Manage 20:33-35.

Metz, L.J., T. Lotti, and R.A. Klawitter. 1961. Some effects of prescribed burning on Coastal Plain forest soils. U.S. For Serv, Southeastern For Exp Stn, Res Pap SE-133, 10 PP.

Morley, S. C., Grant C. D., Hobbs R. J., and Cramer V. A.. 2003. Long-term impact of prescribed burning on the nutrient status and fuel loads of rehabilitated bauxite mines in Western Australia. Forest Ecology and Management, 190:227-239.

Nelson and Sommers, 1996 D.W. Nelson and L.E. Sommers, Total carbon, organic carbon and organic matter. In: D.L. Sparks, Editor, Methods of soil analysis: Part 3, SSSA Book Ser. vol. 5, ASA and SSSA, Madison, WI (1996), pp. 961–1010.

Raison, R.J. 1979. Modifications of the soil environment by vegetation fires, with particular reference to nitrogen transformations: a review. Plant and Soil 51:73-108.

Ralston, CW. And Hatcher, G.E. 1971. Effects of prescribed burning on physical properties of soil. In: Prescribed burning symposium proceedings, April 14-16, 1971. Charleston, SC. USDA Forest Service, Southeastern Forest Experiment Station, Asheville NC

SAS Institute (1997) SAS User's Guide. SAS Institute, Cary NC.

Schripsema, J. R. 1977. Ecological changes on pine-grassland burned in spring, late spring, and winter. M. A. Thesis. South Dakota State University, Brookings.

Sharrow, S.H., and H.A. Wright. 1977. Effects of fire, ash, litter on soil nitrate, temperature, moisture and tobasagrass production in the Rolling Plains. J Range Manage 30:266-270.

Smith, E.F., and C.E. Owensby. 1973. Effects of fire on true prairie grasslands. Proc, Tall Timbers Fire Ecol Conf 12:9-22.

Soil Survey Staff, 1996 Soil Survey Staff, Soil survey laboratory methods manual, Soil survey investigations report no. 42. Ver. 3.0 USDA-NRCS, U.S. Govt. Printing Office, Washington, DC. (1996), p. 693.

Tabatabai, M.A., 1982. Soil Enzymes. p. 903-943. In (Page, A.L., ed.) Methods of soil analysis. Number 9 (part 2) American Society of Agronomy, Madison, Wisconsin.

Tabatabai MA, (1994) 'Soil Enzymes', In: R.W. Weaver, J.S. Angle and P.S. Bottmley (Eds.), Methods of Soil Analysis. Part 2. Madisson, WI: SSSA, pp. 820-823.

Tabatabai MA, (1994), Soil Enzymes. In: Method of Soil Analysis Part 2. Microbiological and Biochemical Properties. eds: Weaver, R. W. et al. SSSA, Madison, 3rd Ed. Wisconsin pp. 775-833.

Tessler N.,Greenbaum N., Littenberg L., Malkinson D., Geophysical Research Abstracts, Vol. 10, EGU2008-A-00460, 2008 SRef-ID: 1607-7962/gra/EGU2008-A-00460 EGU General Assembly 2008

Tiedmann, A.R., and T.D. Anderson. 1980. Combustion losses of sulfur from native plant materials and forest litter. Pp 22-227 In Proc, 6th Conf on Fire and Forest Meterology, April 22-24, 1980, Soc Amer For, Washington, D.C, 6:220-227.

Wells, C. G., R. E. Campbell, L. F. DeBano, C. E. Lewis, R. I. Fredericksen, E. C. Franklin, R. C. Froelich, and P. H. Dunn. 1979. Effects of fire on soil: A state-of-the-art review. General Technical Report WO-7. Washington D.C.: USDA Forest Service.

White, E.M., and F.R. Gartner. 1975. Immediate effects of prairie fire on the soil nitrate, ammonium, available phosphorous and total N content. Proc, SD Acad Sci 54:188-193.

ZHANG Y.M., WU N., ZHOU G., BAO W., 2005, Changes in enzyme activities of spruce (Picea balfouriana) forest soil as related to burning in the eastern Qinghai-Tibetan Plateau, Agriculture, ecosystems & environment. Applied soil ecology ISSN 0929-1393, vol. 30, no3, pp. 215-225 [11 page(s) (article)] (1 p.1/4).