Hacettepe Journal of Biology and Chemistry (2002), 31: 95-105

POSTFIRE CHANGES IN SOIL PROPERTIES OF *Pinus brutia* TEN. FORESTS IN MARMARİS NATIONAL PARK, TURKEY[1]

Çağatay TAVŞANOĞLU[2] and Behzat GÜRKAN[2]

Abstract

This study was conducted to determine long-term postfire changes in physical and chemical properties of soils of *Pinus brutia* Ten. forests in Marmaris National Park, Turkey. The synchronic method was used: three sites burned in different years (2, 6 and 22 years ago) and a control site which had not burned at least 45 years were selected to form a successional gradient. Chemical (organic material %, nitrogen %, exchangeable cation content, electrical conductivity, pH) and physical (soil texture structure) analyses of soil samples collected from different soil layers (0-10 cm, 10-20 cm, 20-30 cm) were performed. It was detected that postfire soil chemical properties change after fire, but return its prefire levels in a short period of time and this result fits the general idea on postfire soil properties in Mediterranean environments. There was not any important change in soil texture after fire. Soil pH was very low in 22-year-old site because of the soil erosion occured immediately after fire. Since postfire changes in soil properties may facilitate or restrict plant regeneration, it is important to have an information on postfire soil properties of the burned area to decide a postfire management strategy.

Keywords: Fire, Marmaris National Park, Soil chemistry, Soil texture

---

[1] This study was a part of the requirements for the MSc degree submitted to Hacettepe University on 25th February 2002.

[2] Hacettepe Üniversitesi Biyoloji Bölümü Ekoloji Anabilim Dalı Beytepe 06532 Ankara-Türkiye

Introduction

Prolonged summer-droughts (1), nutrient-deficient soils (2, 3) and wildfires (4, 5) are the most important evolutionary selective forces in Mediterranean-type ecosystems. Mediterranean vegetation has been shaped by all of these traits which are evaluated as natural parts of these ecosystems (5).

In general, postfire regeneration of Mediterranean-type communities is rapid (6-12). But, changes in soil chemical and physical properties induced by fire may affect this regeneration of the plant species (3, 13). The most common problem of the soils of postfire Mediterranean environments is soil erosion (14). With removing of the plant cover after fire (14-17) and increasing water repellency by fire (18), the burned areas become open to soil erosion by rains and by winds (14, 19, 20). Studying soil properties of the burned areas in such ecosystems is an important issue, because the results of ecosystem and landscape ecology studies have a leading potential to determine the postfire management strategies (21).

The effect of fire on soil properties has been well documented in several habitat and community types (15). But, postfire soil properties have not been studied widely in burned *Pinus brutia* Ten. stands. Although there are a few studies that describe the effect of fire on soil characteristics (22, 23), the change of soil properties during a postfire succession has not been studied in these stands. The aim of the present study was to determine long-term postfire changes in physical and chemical properties of soils of *Pinus brutia* Ten. forests in Marmaris National Park, Turkey.

Methods

Study Area

The study area was Marmaris National Park, which is located in Muğla province in the southwestern of Turkey (Figure 1). The climate was typically Mediterranean, with dry summers and wet winters. The study area has been subjected to frequent fires; therefore the National Park is an ideal area for postfire ecological studies.

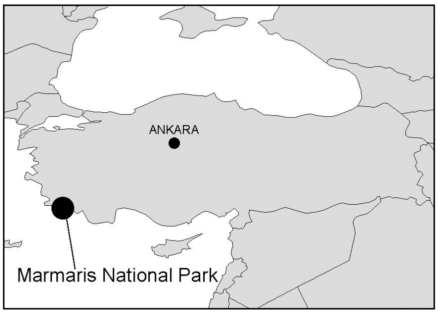

Figure 1. Location of Marmaris National Park in Turkey.

It was used the synchronic method: three burned sites (in different years; 1999, 1995 and 1979) and a control site (had not burned at least 45 years) were selected to form a successional gradient. So, it was possible to follow changes in soil parameters during a whole successional process. The study sites were on the same geological material (ophiolithic rocks) and were located very close to each other (Table 1).

Table 1. Location and some other features of the study sites.

Site	Location	Aspect	Last burned	Burned area
1999 site	N 36°50'11'' E 28°18'10''	W-NW	June 1999	109 ha
1995 site	N 36°51'16'' E 28°17'14''	SE-E	June 1995	205 ha
1979 site	N 36°49'37'' E 28°19'34''	NW-N	September 1979	13600 ha
Control site	N 36°50'47'' E 28°17'24''	NW-N	~45 years ago	?

Collecting and Analysis of Soil Samples

Two replicates of soil samples were collected from three soil layers (0-10 cm, 10-20 cm and 20-30 cm). Chemical and physical analyses of the these samples were carried out in Central Anatolian Forestry Research Institute (Ministry of Forestry) laboratories by using the techniques defined in Anonymous (1984) and Tüzüner (1990). At the end of these analyses, organic material (%), nitrogen (%) and exchangeable cation content, electrical conductivity and soil reaction (pH) values and texture structure of the soil samples were determined. The texture triangle based on sand %, silt % and clay % values was used to determine soil type (26, 27).

Since the soil samples were collected in October 2001, the results are based on 2nd, 6th and 22nd postfire years, respectively for 1999, 1995 and 1979 study sites.

Results

Soil organic matter %, nitrogen (N) %, conductivity values and exchangeable cation content values were higher in 1999 site and in Control site than other study sites (1995 and 1979 sites). Organic matter %, N % and conductivity values decrease with increasing soil depth in all of the study sites (Table 2).

The highest pH value was in near-surface (0-10 cm) soil layer of the 1999 site and contrary to other sites, pH values decreased with soil depth in this site. The lowest pH values were in 1979 site (Table 2).

Table 2. Soil chemical properties of the study sites according to soil depth (mean±SE).

	Organic matter (%)	Total N (%)	pH	EC* (mS)	Exchangeable cations (ppm)			
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
1999 site								
0-10 cm	8.33±0.85	0.42±0.04	6.98±0.04	0.20±0.01	6292±484	1375±430	59.8±18.4	253.5±11.7
10-20 cm	4.12±0.65	0.21±0.03	6.70±0.05	0.10±0.02	3872±0.00	1714±139	55.2±23.0	202.8±7.80
20-30 cm	1.87±0.58	0.09±0.03	6.61±0.10	0.08±0.00	3388±484	2143±569	23.0±0.00	187.2±23.4
1995 site								
0-10 cm	3.30±0.30	0.16±0.02	6.47±0.03	0.09±0.00	3388±0.00	1169±418	48.3±25.3	144.3±3.90
10-20 cm	2.04±0.14	0.10±0.01	6.58±0.02	0.08±0.02	3146±242	1871±272	32.2±9.20	144.3±19.5
20-30 cm	1.84±0.54	0.09±0.03	6.60±0.11	0.06±0.01	2662±726	2857±1271	23.0±0.00	148.2±23.4
1979 site								
0-10 cm	6.17±3.16	0.31±0.16	6.12±0.05	0.11±0.00	3388±484	1029±12.0	32.2±4.60	171.6±39.0
10-20 cm	4.08±1.90	0.20±0.10	6.28±0.05	0.08±0.01	3388±0.00	1169±139	32.2±4.60	167.7±27.3
20-30 cm	3.16±0.85	0.16±0.04	6.38±0.08	0.07±0.00	2904±0.00	902.4±139	32.2±4.60	144.3±11.7
Control site								
0-10 cm	11.4±5.98	0.57±0.30	6.49±0.03	0.38±0.22	6292±2420	1792±60.0	39.1±11.5	163.8±31.2
10-20 cm	4.01±1.43	0.20±0.07	6.72±0.06	0.16±0.03	4840±968	2525±998	57.5±34.5	171.6±46.8
20-30 cm	3.04±0.83	0.15±0.04	6.68±0.05	0.10±0.00	4114±1210	2543±388	36.8±13.8	171.6±46.8

* EC; electrical conductivity.

It was detected that sand, silt and clay percentages of the soil samples from all of the study sites were not different. Consequently, there was no difference in soil texture properties and in soil types of the study sites except 1995 site according to texture triangle results (Table 3).

Table 3. Soil texture properties of the study sites according to soil depth (mean±SE).

	Sand (%)	Silt (%)	Clay (%)	Soil type
1999 site				
0-10 cm	46.0±1.5	27.5±2.5	26.5±4.0	Loam
10-20 cm	43.0±3.5	23.5±2.5	33.5±6.0	Clay Loam
20-30 cm	41.0±5.5	23.5±2.5	35.6±8.0	Clay Loam
1995 site				
0-10 cm	50.2±0.25	24.4±0.85	25.3±0.50	Sandy Clay Loam
10-20 cm	44.2±3.8	21.0±0.35	34.8±4.0	Clay Loam
20-30 cm	41.0±3.5	17.6±0.35	41.4±3.2	Clay
1979 site				
0-10 cm	41.0±1.0	33.3±0.0	25.8±1.0	Loam
10-20 cm	36.0±0.0	29.3±1.0	34.8±1.0	Clay Loam
20-30 cm	41.0±1.0	27.3±0.0	31.8±1.0	Clay Loam
Control site				
0-10 cm	47.0±5.0	30.3±1.0	22.8±4.0	Loam
10-20 cm	41.5±6.5	26.8±1.5	31.8±5.0	Clay Loam
20-30 cm	40.0±6.0	26.8±1.5	33.3±4.5	Clay Loam

Discussion

Postfire changes in soil properties may be a factor that facilitate postfire plant regeneration. For example, the first germinations and vegetative growth are induced by increased soil temperatures (a result of the increase in absorbance of sunlight) (23), and by increased available nutrition for plants with emergence of the ash layer (15, 28-30). Therefore, if someone will decide to a postfire management strategy, it is important to have an information about postfire soil properties of the burned area.

Our results on postfire changes in soil properties of *Pinus brutia* forests support the general idea of that postfire soil chemical properties change after fire, but return its prefire levels in a short period of time (22, 23). Such a discuss may also be generalized to all of the Mediterranean environments beyond *Pinus brutia* stands, since the soils under other vegetation types has same postfire regeneration properties (13, 31).

It is known that percentage of organic matter in the soil increase in burned areas and soil conductivity has high values because of the bases found in the ash (22, 31). These parameters which are changed immediately after fire can return to their prefire values in three years in *Pinus brutia* ecosystems (22, 23) and in one year in a *Quercus coccifera* garrigue (31). Leaching and eroding of exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) from the upper soil layers, and increased decomposing of organic matter by increased microorganism activity after fire may be main reasons of this rapid recovery (22, 32, 33).

Exchangeable cations stored in plant tissues and in debris are returned to soil by fire and consequently, soil fertility increase in the first postfire years (22, 23, 30, 34). Exchangeable cations found in ash also increase soil pH immediately after fire, therefore the soil become more basic (22, 23, 31, 32, 35). It was pointed out that with postfire time exceeds, these high soil pH values decrease and return to their prefire values in three years (23). This is due to leaching and eroding of cations which increase immediately after fire (22). Moreover, formation of some organic (acetic acid, humic acid) and some inorganic (HNO_3, H_2SO_4, H_3PO_4) acids during decomposing of organic matter is another factor that decrease pH (27, 31). So, it is usual that high pH values returns their lower prefire values in a short period of time by increased microorganism activity and increased organic matter decomposition.

Even two years after fire, it was found in the present study that electrical conductivity, percentage of total N, percentage of organic matter, pH and amounts of exchangeable cations were higher, and this results fit other studies mentioned above on postfire changes of soil chemical properties in *Pinus brutia* ecosystems (22, 23). All of these parameters except pH values in 1979 site firstly decreased with time by probably the effect of erosion and leaching of exchangeable cations, and then began to increase with increasing vegetation cover and slowing erosion rate.

According to the results, pH values in 1979 site were very lower than the control and 1995 sites which have normal soil pH values (Table 2). It is known that most of the area burned in 1979 fire in Marmaris subjected to soil erosion since any forestry practice could not apply (22). This may be mainly due to the vastness of the burned area (Table 1). Additionally, Tavşanoğlu (2002) showed that after the 1979 fire in September, very high amounts of rainfall was fallen during two months according to Meteorological data.

Vegetation cover (14, 37) and dead material (38) may be important factors in preserving soils from erosion. With falling of the heavy rains immediately after fire in the 1979 site which have not such a protecting cover on the ground, exchangeable cations might be removed from soil. It is known that the greatest losses of soil take place in the 4 months after fire (34). As mentioned above, a reason of decreasing in soil pH is removal of exchangeable cations from soil by rains (22, 27). This may be explain the presence of a more acidic soil in 1979 site.

Although soil pH can return to its prefire level in three years after fire in *Pinus brutia* ecosystems (23), if such a mechanism did not operate as not in 1979 site, there would be dramatic results on regeneration of plant species, especially of seeders. Thus, the poor establishment of *P. brutia* in 1979 site may be mainly due to the lower soil pH levels (36).

Although there was a change in soil chemical properties after fire, soil texture was not changed considerably by the effect of fire. Since physical changes in soil texture after fire are negligible except where soil heating is extreme (3), fire may not responsible from the little difference in soil texture of 1995 site and this difference may be due to site heterogeneity. It was pointed out that potassium found much more in soils with a thinner texture (27). So the main reason of that amount of potassium ion (K^+) was lower in the near-surface soil layers (0-20 cm) in 1995 site may be presence of a rougher soil texture in this site.

It is known that percentage of organic matter and percentage of total N decrease but pH values increase with going deep inside the soil (22, 23). Our results support such a change in the soil. But we detected that only pH values decrease with increasing soil depth (Table 2). This was due to the effect of the ash layer which is abundantly found in the near-surface soil layers.

As discuss, even if there was a change in soil chemical properties after fire, these properties may return their prefire levels in a short period of time and this event point out a rapid regeneration of soil properties. Because of higher soil fertility would produce higher survival and growth after fire (30), the first postfire years in which soil fertility is relatively high are important for regenerating plant species in nutrient-poor Mediterranean soils.

Acknowledgements

The authors thank Sinan Kaynaş and Burçin Y. Kaynaş for their assistance during the collecting of soil samples. The authors also thank G. Berna Belindir and Ramazan Asan for their helps in the chemical and physical analysis of the soil samples. This study was supported by Hacettepe University Research Foundation (project no: 00.02.601.005).

References

1. Akman, Y. Biyocoğrafya. Palme Yayınları, 379 pp., Ankara, 1993.
2. Mooney, H.A., Dunn, E.L. Convergent evolution of Mediterranean-climate evergreen sclerophyll shrubs. Evolution 24, 292-303, 1970.
3. Christensen, N.L. The Effects of Fire on Physical and Chemical Properties of Soils in Mediterranean-Climate Shrublands. *In*: Moreno, J.M., Oechel, W.C. (eds). The Role of Fire in Mediterranean-Type Ecosystems, Springer-Verlag, New York. pp. 79-95, 1994.
4. Neyişçi, T. Orman yangınlarına ekolojik yaklaşım. Orman Mühendisliği Dergisi, 1, 26-29, 1988.
5. Trabaud, L. Postfire plant community dynamics in the Meditarranean basin. In: Moreno, J.M., Oechel, W.C. (eds). The role of fire in Mediterranean-type ecosystems, Springer-Werlag, New York, pp 1-15, 1994.
6. Westman, W.E. Diversity relations and succession in Californian coastal sage scrub. Ecology 62(1), 170-184, 1981.
7. Arianoutsou-Faraggitaki, M. Post-fire successional recovery of a phryganic (East Mediterranean) ecosystem. Acta Oecologica/Oecol. Plant. 5(4), 387-394, 1984.
8. Moravec, J. Regeneration of N.W. African *Pinus halepensis* forests following fire. Vegetatio 87, 29-36, 1990.
9. Türkmen, N., Düzenli, A., Çakan, H. Yangınların Doğu Akdeniz bölgesindeki fitolojik zenginlikler üzerine etkisi. In: II. Ulusal Ekoloji ve Çevre Kongresi Bildirileri, 11-13 Eylül 1995, pp. 15-25, Ankara, 1995.
10. Herranz, J.M., Martinez-Sanchez, J.J., De Las Heras, J., Ferrandis, P. Stages of plant succession in *Fagus sylvatica* L. and *Pinus sylvestris* L. forests of Tejera Negra National Park (central Spain), three years after fire. Israel Journal of Plant Sciences 44, 347-358, 1996.
11. Trabaud, L. Post-fire regeneration of *Pinus halepensis* forests in the west Mediterranean. In: Ne'eman, G., Trabaud, L. (eds). Ecology, biogeography and management of *Pinus halepensis* and *Pinus brutia* forest ecosystems in the Mediterranean basin. Backhuys Publishers, pp. 257-268, The Netherlands, 2000.
12. Tavşanoğlu, Ç., Kaynaş, B.Y., Gürkan, B. Early postfire regeneration of a *Pinus brutia* forest in Marmaris National Park, Turkey. In: Book of Abstracts of International Conference on Conservation, Regeneration and Restoration of Mediterranean Pines and their Ecosystems (MEDPINE 2), 8-13 September, Chania, Crete, Greece, 2002.
13. Thomas, A.D., Walsh, R.P.D, Shakesby, R.A. Nutrient losses in eroded sediment after fire in eucalyptus and pine forests in the wet Mediterranean environment of northen Portugal. Catena 36, 283-302, 1999.
14. Giovannini, G. Postfire soil erosion risk: how to predict and how to prevent. In: Eftichidis, G., Balabanis, P., Ghazi, A. (eds). Wildfire Management (Proceedings of the Advanced

Study Course held in Marathon, Greece, 6-14 October 1997), Algosystems SA & European Commission DGXII, Athens, pp. 305-321, 1999.

15. Wright, H.A., Bailey, A.W. Fire Ecology: United States and Southern Canada. Wiley-Interscience, New York, 1982.
16. Reina, L., Ubeda, X., Sala, M. Study of the changes in hydrology after forest fires in a Mediterranean environment. In: Eftichidis, G., Balabanis, P., Ghazi, A. (eds). Wildfire Management (Proceedings of the Advanced Study Course held in Marathon, Greece, 6-14 October 1997), Algosystems SA & European Commission DGXII, Athens, pp. 483-486, 1999.
17. Kato, E., Haridasan, M. The effects of fire on infiltration rates and surface sealing in a latosol under cerrado vegetation in central Brazil. In: Viegas, D.X. (ed). Forest Fire Research & Wildland Fire Safety (Proceedings of the IV International Conference on Forest Fire Research & 2002 Wildland Fire Safety Summit, 18-23 November, Luso, Coimbra, Portugal), pp. 225, 2002.
18. Valera, M.E., de Blas, E., Benito, E., Lopez, I. Changes induced by forest fires in the aggregate stability and water repellency of soils in NW Spain. In: Viegas, D.X. (ed). Forest Fire Research & Wildland Fire Safety (Proceedings of the IV International Conference on Forest Fire Research & 2002 Wildland Fire Safety Summit, 18-23 November, Luso, Coimbra, Portugal), pp. 224, 2002.
19. Whelan, R.J. The Ecology of Fire. Cambridge University Press, UK, 346 pp, 1995.
20. Coelho, C.O.A., Ferreira, A.J.D., Boulet, A.K., Keizer, J.J. Overland flow generation process, erosion yields and nutrient loss under fires with different intensities – Lessons learned from analysis at different scales. In: Viegas, D.X. (ed). Forest Fire Research & Wildland Fire Safety (Proceedings of the IV International Conference on Forest Fire Research & 2002 Wildland Fire Safety Summit, 18-23 November, Luso, Coimbra, Portugal), pp. 197, 2002.
21. Naveh, Z. The role of fire and its management in the conservation of Mediterranean ecosystems and landscapes. In: Moreno, J.M., Oechel, W.C. (eds). The Role of Fire in Mediterranean-Type Ecosystems, Springer-Verlag, New York. pp. 163-185, 1994.
22. Eron, Z., Gürbüzer, E. Marmaris 1979 yılı orman yangını ile toprak özelliklerinin değişimi ve kızılçam gençliğinin gelişimi arasındaki ilişkiler. Ormancılık Araştırma Enstitüsü, Teknik Bülten No: 195, Ankara, 1988.
23. Neyişçi, T. Kızılçam orman ekosistemlerinde denetimli yakmanın toprak kimyasal özellikleri ve fidan gelişimi üzerine etkileri. Ormancılık Araştırma Enstitüsü, Teknik Bülten No: 205, Ankara, 1989.
24. Anonymous. Orman Toprak Laboratuvarlarının Kuruluş Esasları ve Laboratuvar Teknikleri. T.C. Orman Bakanlığı, Eskişehir Orman Toprak Müdürlüğü, 1984.
25. Tüzüner, A. Toprak ve Su Analiz Laboratuvarları El Kitabı. Tarım Orman ve Köyişleri Bakanlığı, Köy Hizmetleri Genel Müdürlüğü, Ankara, 1990.

26. Sutherland, W.J. Ecological Cencus Techniques. Cambridge University Press, UK, 1996.
27. Boşgelmez, A., Boşgelmez, İ.İ., Savaşçı, S., Paslı, N. Ekoloji-II: Toprak. Başkent Klişe Matbaacılık, Ankara, 2001.
28. Christensen, N.L. Shrubland Fire Regimes and Their Evolutionary Consequences. In: Pickett, S.T.A., White, P.S. (eds). The Ecology of Natural Disturbance and Patch Dynamics, Academic Press, London. pp. 85-100, 1985.
29. Christensen, N.L. The biogeochemical consequences of fire and their effects on the vegetation of the coastal plain of the southern United States. In: Trabaud, L. (eds). The role of fire in ecological systems. SPB Academic Publishing, pp. 1-21, The Hague, Netherlands, 1987.
30. Pausas, J.G., Gimeno, T., Vallejo, R. Fire severity and pine regeneration in the eastern Iberian Peninsula. In: Viegas, D.X. (ed). Forest Fire Research & Wildland Fire Safety (Proceedings of the IV International Conference on Forest Fire Research & 2002 Wildland Fire Safety Summit, 18-23 November, Luso, Coimbra, Portugal), pp. 182, 2002.
31. Trabaud, L. The effects of different fire regimes on soil nutrient levels in *Quercus coccifera* garrigue. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M.(eds). Mediterranean-type ecosystems: role of nutrients. Springer, Berlin Heidelberg New York, pp., 233-243, 1983.
32. Çepel, N. Orman yangınlarının mikroklima ve toprak özellikleri üzerine yaptığı etkiler. İstanbul Üniversitesi Orman Fakültesi Dergisi, Seri: B, 15(1), 71-93, 1975.
33. Ne'eman, G., Meir, I., Ne'eman, R. The effect of ash on the germination and early growth of shoots and roots of *Pinus*, *Cistus* and annuals. Seed Science and Technology 21, 339-349, 1993.
34. Gimeno-Garcia, E., Andreu, V., Rubio, J.L. Changes in organic matter, nitrogen, phosphorus and cations in soil as a result of fire and water erosion in a Mediterranean landscape. European Journal of Soil Science 51, 201-210, 2000.
35. Kimmins, J.P. Forest Ecology. Prentice Hall, USA, pp. 531, 1987.
36. Tavşanoğlu, Ç. Marmaris Milli Parkı'nda yangın sonrası sekonder bitki süksesyonu üzerine çalışmalar. Yüksek Lisans Tezi. Hacettepe Üniversitesi, Fen Bilimleri Enstitüsü, pp. 118, Ankara, 2002.
37. Vallejo, V.R. Post-Fire Restoration in Mediterranean Ecosystems. In: Eftichidis, G., Balabanis, P., Ghazi, A. (eds). Wildfire Management (Proceedings of the Advanced Study Course held in Marathon, Greece, 6-14 October 1997), Algosystems SA & European Commission DGXII, pp. 199-208, Athens, 1999.
38. Neyişçi, T. Kızılçamın Ekolojisi. In: Öktem, E. (ed). Kızılçam, Ormancılık Araştırma Enstitüsü Yayınları, El Kitabı Dizisi, No:2, pp. 23-56, 1987.