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CHARACTERISATION OF A FIRE AFFECTED CATENA SEQUENCE FROM LYULIN MOUNTAIN, BULGARIA

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Abstract

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We analysed the effects of a forest fire having occurred in the late summer of 2007 on major characteristics and properties of surface soils and soil profiles characterised as a catena sequence. The objectives of our study were to carry out a detailed morphological description of the individual soil profiles on the ridge and slopes of Lyulin mountain and analyse other chemical, physico-chemical and mineralogical characteristics in the surface horizons mostly affected by fire. Our key findings are: (1) changes were observed in the surface depths and concern mainly the soil organic carbon, primary minerals mineralogy and texture; (2) no major changes in the cation exchange capacity and exchangeable Ca and Mg cation composition between the surface and the lower depths of the soil profiles were found and no additional release of bases as a result of burning was accounted for; (3) total organic carbon increased in all the burnt soils, due to partially combusted organic remnants. As a result of the detailed analysis of the catena sequence we conclude that the fire that occurred was not of high severity and had mainly affected the ridge of the mountain and the surface depths of the higher parts of the hillslope.

Key words: forest fire, catena sequence, morphological, mineralogical, chemical and physico-chemical properties

Introduction

It has been widely accepted that many physical, chemical, mineralogical, and biological soil properties are affected by forest fires. The effects depend on fire temperatures, duration, vegetation and topography of the burnt area (Certini, 2005). At low temperature fires no irreversible ecosystem change occurs but often soil becomes hydrophobic and prone to erosion (Mataix-Solera and Doerr, 2004). Fire intensities depend on the fuel load and the water content of the burned biomass (Brown, 1988) but also on the climatic conditions during the burn, and the size of the area being burned. Heat transfer into the soil depends also on the duration of exposure, on the water content of the soil, and the soil pore distribution (Steward et al., 1990). Forest fires introduce organic burn residues, charcoal and ash into soils. Miltner and Zech (1997) and Ponomarenko and Anderson (2001) suggested fire as a factor of humification, emphasising its capability to entail polymerisation and polycondensation reactions. Organic matter in soil is intimately associated with the mineral phase; it is assumed that fire-induced structural modifications of the organic pool depend also on type of mineralogical assemblage.

The objectives of our study were to: (i) provide a detailed morphological description of the individual soil profiles characterized as catena sequences on slopes affected by fire in Lyulin mountain; and (ii) characterise other chemical, physico-chemical and mineralogical changes in the surface depths as compared to the lower depths of the soil profiles and the catena and make a prediction for the soil response to erosion and fire.

Material and Methods

The study sites were cinnamonic forest soils (Luvisols) on the ridge and the hill and a bogged soil at the footslope (Gleysol) of Lyulin mountain subject to a fire in the late summer of 2007 (FAO classification, Teoharov, 2004). Their classification was based on the different processes of soil formation and hydromorphism which had taken place in situations of interrupted relief and mixed forest-grass vegetation cover. Soil studies were done according the 2[nd] order catena method (Mordkovich et al., 1985; Teoharov, 1981; Teoharov, 2003). For the investigations five soil profiles were studied: on the ridge, the upper and the lower parts of the hill, as well as at the foot of the mountain. Sampling took place in the spring of 2008 after eliminating the litter layer. A characteristic feature of the catena is the homogenous parent rock. i.e. pliocene clays. The vegetation was represented by black pine (*Pinus nigra*) mostly affected by the fire. At the foot of the hill due to bogging and waterlogging, the predominant vegetation is bullrush *Typha angustifolia*. Other vegetation species are represented by meadow fescue, *Festuca Pratensis*. The soils studied are at around 800 m altitude. The surrounding area is characterised by uneven relief. Mean annual temperature is 9.5єC, mean winter T 2єC, mean July T is 19.6єC, mean relative humidity is 71% and mean annual precipitation is 606 mm (Koleva and Peneva, 1990). Total organic carbon (TOC) was measured by the modified Tjurin's method (Kononova, 1963), dichromate digestion at 125єC, 45 min, in the presence of Ag_2SO_4 and $FeSO_4$ titration, CEC according to Ganev and Arsova (1980) as sum of titratable acidity at pH 8.2 and extractable Ca by saturation with K malate. Mechanical composition was determined by the method of Kachinsky (1958) and texture designated through correlation with Texture Diagram of USDA (Soil Survey Staff, 1999). X-ray diffraction analysis on whole soils (H_2O_2 treated) was carried out on diffractometer DRON-1, 30 kV, 9mA current and monochromatic Cu-Kб radiation, rotation velocity 4°/min at room temperature and after heating at 550 °C.

Soil water repellency was determined using the water drop penetration time (WDPT) method after equilibration at an atmosphere of ~ 20°C and 45–55 % relative humidity for 24 h. Three droplets of distilled water (~ 80 mL) were placed on the soil surface and the time recorded for droplet penetration (Doerr, 1998).

Results and Discussion

Soil morphology, chemical and physico-chemical properties

Profie 601 was situated at the ridge of the mountain and has the following morphological characteristics: $A_h – A_b – C_{gk}$. The total soil depth is around 100 cm. The ridge is slightly inclined in the easterly direction. The soil surface was covered by semi-burnt litter of 2 cm thickness (mainly pine bark and needles). Under the litter was present a blackish A_h type horizon of 0-6 cm depth and chroma 10 YR 2/1 (black metallic). The structure was unsteady and texture was classified as silty clay loam. This upper horizon passed sharply into the lower one (chroma 10 YR 4/3 and 6-64 cm depth). The parent rock materials predetermine the heavier silty clay character of this soil horizon and consequently the higher bulk density. Pine roots were spotted in both horizons and no carbonates were detected at these depths.

As shown in Table 1, pH in the surface fire affected layer was near neutral. No changes in cation exchange capacity, exchangeable cations and base saturation were accounted for (Table 2), though some authors have found decreases in CEC of soils under

Table 1
Chemical properties of the experimental soils

Soil profile	Horizon depth, cm	pH	Carbonates, %	TOC, %
601	Ah 0 – 6	6.7	0	18.82
	Ab 6 – 64	7.4	3.53	2.03
	Cgk 64 – 100	7.4	9.94	0.97
602	Ah 0 – 5	7.3	0	10.58
	A 5 - 10	7	0	1.54
	B 10 - 21	7.4	0.39	1.56
	Cgk 21 – 50	7.5	2.54	0.46
603	Ah 0 – 6	6.3	0	16.29
	B 6 – 19	7.3	0	1.84
	Cgk 19 – 50	7.3	1.04	0.46
604	Ag 0 – 20	6.9	0.39	3.49
	Bkg 40 – 60	7.5	1.36	1.27
	Cg 80 – 100	3.2	0	0.65

fire (Ekinci, 2006). It has been found that after a fire, there was an increase of available nutrients in soil, mainly in the form of water-soluble components of ash. Fire has the so called "fertilizing effect" on soils, affects soil microbial populations and is related to an increase of soil pH associated with an increase of exchangeable cations in soil (Pyne, 2001). Release of the alkaline cations (Ca, Mg) bound to the organic matter as a consequence of the release of bases from the combusted organic matter was also accounted for by some authors (Simard et al. 2001; Arocena and Opio, 2002). It has been also found that a month after a wildfire, available Ca and Mg were significantly higher than pre-fire levels, but after further 3 months the increases were almost gone (Adams and Boyle, 1980). No change in cation exchange capacity due to loss of organic carbon and/or collapse of clay minerals was observed by us, either. Total organic carbon reached ~ 19% in the surface horizon probably as a consequence of external inputs from deposition of dry leaves and partially burnt plant materials similarly to increases in soil OM content reported by others (Chandler et al., 1983). According to (Johnson and Curtis, 2001) this increase could be due to incorporation in the mineral soil of unburnt residues that were more protected from biochemical decomposition and/

Table 2
Texture and physico-chemical properties of the experimental soils

Soil profile	Horizon depth, cm	WDPT (s)	Sand, 1 - 0.05 mm	Silt, 0.05-0.001 mm	Clay, % < 0.001 mm	CEC, cmol. kg-1	Ca, cmol.kg^{-1} (% CEC)	Mg, cmol.kg^{-1} (% CEC)
601	Ah 0 – 6	8	22.1	49.5	27.4	51.4	43.2 (84.1)	2.6 (5.1)
	Ab 6 – 64	< 5	19.7	34	45.3	49.3	44.7 (90.7)	2.5 (5.1)
	Cgk 64 – 100	< 5	26.4	47.1	25.5	49.1	45.0 (91.7)	2.5 (5.1)
602	Ah 0 – 5	< 5	15.9	41.9	42.2	50.5	40.2 (79.6)	5.1 (10.1)
	B 10 - 21	< 5	17.3	32.2	50.5	49.2	41.3 (83.9)	4.8 (9.8)
	Cgk 21 – 50	< 5	11.2	43.6	39.5	49	41.5 (84.7)	5.0 (10.2)
603	Ah 0 – 6	3600	32.3	28.4	39.3	45.1	33.5 (74.3)	3.0 (6.7)
	B 6 – 19	< 5	6.8	26.7	56.1	44.8	38.4 (85.7)	2.8 (6.3)
	Cgk 19 – 50	< 5	19.7	35.7	41	44.6	39.1 (87.7)	2.9 (6.5)
604	Ag 0 – 20	< 5	5.1	37.5	57.7	47.2	39.3 (83.3)	5.2 (11.0)
	Bkg 40 – 60	< 5	22.1	15.6	54.9	44.6	39.8 (89.2)	4.8 (10.8)
	Cg 80 – 100	< 5	6.2	37.1	53.4	65.7	40.0 (60.9)	5.6 (8.5)

or to the transformation of fresh organic materials to more recalcitrant forms.

Profile 602 was set at the upper part of the hill and has the morphological composition A_h-A-B-C_{gk} and total depth 50 cm (Table 1). As with Profile 601, the surface was covered by partially burnt litter. Beneath the litter there was a surface A_h horizon of 0-5 cm depth, chroma 10 YR 2/2 and light unsteady structure. The texture is classified as silty clay (Table 2). The roots are smaller due to limitation in the soil formation. In depth the A_h passes into a weekly developed shallow light coloured A horizon of 5 – 10 cm depth and thereafter with sharp distinction into a B subhorizon of 10-21 cm depth, chroma 10 YR 4/6 and granular/blocky structure with rotten roots. The transition between the horizons of the profile was quite sharp. A sharp increase of organic carbon was again accounted for in the surface horizon (0 - 5 cm) as compared to the lower 5 – 21 cm depth, which can again be attributed to input of semi-burnt organic material from the surface litter layer into the lower A_h horizon.

Profile 603 is set at the lower part of the hill and has a vertical morphological structure A_h-B-C_{gk} and total depth of 50 cm. The morphological characteristics and texture vary from clay loam in the surface A_h

Table 3
Major primary minerals with characteristic XRD patterns of the surface horizons of the fire affected catena sequence. Intensity of the highest peak was set at 100 %

Soil profile (horizon depth, cm)	d Å (peak intensity, %)	
601 (0 – 6)	3.21 (100)	plagioclase
	3.32 (30); 4.26	quartz
	4.46	
	7.01 (4)	kaolinite
	10.01(4)	mica
602 (0 – 5)	3.18; 3.21 (40)	plagioclase
	3.33 (100); 4.26	quartz
	4.46	
	5.01; 9.92 (14)	mica
	7.10 (15)	kaolinite/chlorite
	13.80 (13)	chlorite
603 (0 – 6)	2.99 (8)	pyroxene
	3.23 (8)	plagioclase
	4.01; 3.85 (4)	orthoclase
	3.33 (100); 4.25	quartz
	4.44	
	5.01; 9.9 (7)	mica
604 (0 – 20)	2.99 (7)	pyroxene
	3.18; 3.22 (30)	plagioclase
	3.34 (100); 4.27	quartz
	5.01; 10.01 (7)	mica
	7.2 (17)	kaolinite/chlorite
	13.80 (19)	chlorite

horizon to silty clay in the lower depths (Soil Survey Staff, 1999). Here again, a slightly acidic soil reaction was observed in the first depth turning into slightly alkaline downwards the soil profile predetermined by the composition of the geological materials. The total organic carbon content in the surface layer (16.3 %) is again higher than in the lower depths due to partial combustion of organic material from burning litter.

Profile 604 is set at the footslope and is characterised with a morphological composition A_g-B_{kg}-C_g. On the surface there was grass vegetation typical of the boggy soils and partial evidence of sporadic burning. The surface horizon (A_g) of 0-21 cm depth has a colour 10 YR 4/2 and blocky structure. The texture is characterised as clay in the first depth and silty clay in the lower depths. The soil reaction was neutral and organic carbon value was 3.5 % and close to those reported by others for Luvisols (Kolchakov et al., 1999; Sokolovska et al., 2002) in the first 0-20 cm layer and decrease with increasing depth.

Soil water repellency

The only soil that exhibited considerable water repellency was Profile 603 (3600 s) (0 – 6 cm) depth. All the other horizons were wettable (WDPT < 5 s). The surface 0-5 cm depth of this horizon exhibits the highest sand content and the lowest CEC value (Tables 1 and 2) and was highly hydrophobic ("severely water repellent") according to Bisdom et al., 1993. This might be due to special accumulation of hydrophobic organic compounds from the litter layer of pine needles or partial production of new hydrophobic compounds as a result of fire (Doerr, 1998). It is widely accepted that sandy soils are most prone to hydrophobicity due to the smaller surface area and consequently higher coverage by hydrophobic organic material. The consequences from the formation of hydrophobic layer are reduced water infiltration, preferential flows in stream channels, increased erosion with greater amounts of runoff and loss of a topsoil layer. It has been estimated that little change in water repellency occurs when soils are heated at 175°C (DeBano, 1981) or heated between 300°C and 400°C (Giovannini and Lucchesi, 1997), while intense water repellency is formed when soils are heated between 175 and 200°C (DeBano, 1981) and 250 – 300°C (Doerr et al., 2004). It is also considered that a hydrophobic coating of mineral soil particles occurs at lower temperatures and for shorter periods of heating than in the case of longer periods of heating and higher temperatures that destroyed the organic substances responsible for the water repellence (De Bano, 2000). The surface horizon of Profile 601 (0 – 6 cm) depth exhibited slight water repellence, the drop penetration time WDPT was only 8 s. This could be due to a fire > 300°C shown to destroy water repellence in soils or a higher duration low intensity fire, which has not caused considerable water repellence (De Bano, 1981).

The surface soil of Profile 602 was wettable and we speculate that the temperature of burning was rather low (< 175° C) than (> 350°C) to destroy hydrophobicity. We did not have other chemical or physico-chemical indications for a high severity fire, either. The litter cover was also semi-burnt and the TOC contents were much higher than the normally observed values in Luvisols (Sokolovska et al., 2002) as well as compared to the footslope (Profile 604) of the hill where vague and sporadic indications of burning were only observed (Table 1).

Mineralogy

We examined the mineralogy of the whole soil of the surface horizons of the burnt soils at room temperatures and after burning at 550°C, as we did not have morphological, textural, chemical or physico-chemical indications of high severity fires (> 600°C) which are expected to have an effect on clay mineralogy (Ketterings et al., 2000). The mineralogical characteristics of the samples from the surface horizons of the experimental soils are given in Table 3.

Quartz, kaolinite, feldspars (mainly plagioclase), traces of pyroxene, mica and chlorite were found in the XRD spectra. Qualitative and quantitative changes in the primary minerals compositions were accounted for in the surface horizons throughout the catena sequence. For example the surface 0 – 6 cm depth most affected by fire (Profile 601) had the highest concentration of feldspars (plagioclase) while in all the rest surface depths quartz was the predominant phase. In feldspars the Si^{4+} is partly replaced by Al^{3+}, which results in a positive charge balanced by Na^+, K^+ or Ca^{2+} ions. In the alkali feldspars Na^+ and K^+, and in the plagioclase, Na^+ and Ca^{2+} are the dominant accessory cations. The high abundance of plagioclase in the surface horizon of Profile 601 should be owing to the fact that feldspars are actually more abundant in soils that are not leached, like the ridge of the mountain, as compared to the hillside, where extensive leaching takes place, accompanied by erosion process, leading to higher quartz accumulation in the soil. Our observations on plagioclase contents in the surface soil on the ridge (profile 601) and the finer texture of this soil (~ 77 % silt and clay, Table 2) are in accordance with those of Dultz (2001) who consider that changes during soil development intensify physical weathering of feldspars in the sand fractions and shift their appearance in the silt and clay size fractions, causing gains in feldspar in the silt fractions. We can therefore speculate that the high feldspar content on the ridge might be caused mainly by physical weathering, though we can not absolutely refute the hypothesis that fire on the surface had not additionally assisted to the relative accumulation of feldspars.

Some authors (Ulery and Graham, 1993; Ketterings et al., 2000) have observed a transition to coarser textures and change of colour from black to reddish with increasing fire temperature, while others (Arocena and Opio, 2003) think that prescribed fires have caused cracks in amphiboles, leading to reduction in sizes into silt fraction and finer.

Conclusions

The effects of a forest fire having occurred 8 months before analysis in the summer of 2007 on major soil parameters and properties of surface soils and soil profiles characterised as a catena sequence were investigated. The following are key findings:

- The morphological, mineralogical, physical, chemical and physico-chemical analyses of the soil profiles characterized as catena sequences on slopes affected by fire point at changes in the surface depths and concerning mainly the soil organic carbon, mineralogy and texture and point at low temperature fire (< 500°C).

- No major changes in the cation exchange capacity and major cation composition were found between the surface and lower horizons of the analysed soil profiles. No release of bases (Ca and Mg) in exchangeable form as a result of burning was accounted for, as there was no marked change with the subsurface soil. Changes in the CEC between soil profiles on the catena reflect mainly differences in texture and mineralogy.

- Total organic carbon increased in all the burnt soils, due to partially combusted organic remnants. One of the surface soils (at the lower part of the hillslope) studied was severely hydrophobic and had the coarsest texture and the lowest CEC. The surface soils from the lower parts of the hill including the almost unburnt footslope and the sub-surface horizons in the individual soil profiles were hydrophilic.

- The primary minerals in the whole soils in the surface horizons are mainly represented by quartz and feldspars and marked differences were noted between the surface depths of the ridge soil profile (feldspars), as compared to the surface soils on the hillslope (quartz).

- Future analysis will be necessary as to the nature of the organic carbon formed as a result of burning, as well as other transformations induced in the soil chemistry of the affected soils.

References

Adams, P. W. and J. R. Boyle, 1980. Effects of fire on soil nutrients in clearcut and whole-tree harvest sites in Central Michigan. *Soil Science Society of America Journal*, **44**: 847–850.

Arocena, J. M. and C. Opio, 2003. Prescribed fire-induced changes in properties of sub-boreal forest soils. *Geoderma*, **113**: 1-16.

DeBano, L. F., 1981. Water repellent soils: a state-of-the-art. USDA Forest Service General Technical Report PS W-46, 21pp.

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

Bisdom, E. B. A., L.W. Dekker and J. F. T. Schoute, 1993. Water repellency of sieve fractions from sandy soils and relationships with organic material and soil structure. *Geoderma*, **56**: 105–118.

Brown, A. G., 1988. Soil development and geomorphic processes in a Chaparral watershed: Rattlesnake Canyon, S. California, USA. *Catena Supplement*, **12**: 45–58.

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

Certini, G., 2005. Effects of fire on properties of forest soils: a review. *Oecologia*, **143**: 1–10.

Doerr, S. H., 1998. On standardizing the "water drop penetration time" and the "molarity of an ethanol droplet" techniques to classify soil hydrophobicity: a case study using medium textured soils. *Earth Surface Processes and Landforms*, **23**: 663–668

Doerr, S. H., W. H. Blake, R. A. Shakesby, F. Stagnitti, S. H. Vuurens, G. S. Humphreys, G. and P. Wallbrink, 2004. Heating effects on water repellency in Australian eucalypt forest soils and their value in estimating wildfire soil temperatures. *International Journal of Wildland Fire,* **13**:157–163.

Dultz, S., 2002. Effects of parent material and weathering on feldspar content in different particle size fractions from forest soils in NW Germany. *Geoderma*, **106**: 63-81.

Ekinci, H., 2006. Effect of Forest Fire on Some Physical, Chemical and Biological Properties of Soil in Зanakkale, Turkey. *International Journal of Agriculture and Biology*, **8**: 102–106.

FAO. 1998. World reference base for soil resources. FAO, Rome

Ganev, S. and A. Arsova, 1980. Methods of determining the strongly acidic and the slightly acidic cation exchange in soil. *Soil Science and Agro-chemistry*, **15**: 19-33 (Bg).

Giovannini, G. and S. Lucchesi, 1997. Modifications induced in the soil physio-chemical parameters by experimental fires at different intensities. Soil Science **162**, 479–486.

Johnson D. W. and P. S. Curtis, 2001. Effects of forest management on soil C and N storage: meta analysis. *Forest Ecology and Management*, **140**: 227–238

Kachinsky, N. A., 1958. Mechanical and microagregate composition of soils. Methodsof Analysis. Moscow Academy of Sciences, 200 pp.

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

Kolchakov, I., T. Shishkov and R. Ilieva. 1999. Some peculiarities on genesis and classification of the Cinnamonic Forest Soils in Bulgaria. In: Extended abstracts, *Soils with Mediterranean Type of Climate*, 6th International Meeting, University of Barcelona, Spain, pp. 439-442.

Koleva, E. and R. Peneva, 1990. Climatic guide. Preipitation in Bulgaria. BAS. Institute of Meteorology and Hydrology, *BAS*, Sofia, pp.169.

Kononova, M. M., 1963. Soil Organic Matter. (AN SSSR) Publisher, Moscow, 313 pp. (Ru).

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

Miltner, A. and W. Zech, 1997. Effects of minerals on the transformation of organic matter during simulated fire-induced pyrolysis. *Organic Geochemistry*, **26:** 175–182.

Mordkovich, V. G., N. S. Shtohina and A. A. Titlyanova, 1985. Steppe catenas. Izd. Nauka, Novosibirsk, Academy of Sciences SSSR, 115 pp. (Ru).

Ponomarenko, E. V. and D. W. Anderson, 2001. Importance of charred organic matter in black Chernozem soils of Saskatchewan. *Canadian Journal of Soil Science*, **81:** 285–297

Pyne, S. J., 2001. Fire: a brief history. Weyerhauser Environmental Books, Cycle of Fire Series. Seattle, USA: University of Washington Press.

Simard, D. G., J. W. Fyles, D. Parer and T. Nguyen, 2001. Impacts of clearcut harvesting and wildfire on soil nutrient status in the Quebec boreal forest. *Canadian Journal of Soil Science*, **81:** 229–237

Soil Survey Staff, 1999. Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys, 2nd ed.: U.S. Department of Agriculture, Natural Resources Conservation Service, Agriculture Handbook Number 436, 870 pp.

Sokolovska, M. G., J. Bech, L. Petrova and A. Lansac, 2002. Comparative studies on the processes of humus formation in soils from Turkey, Greece, Bulgaria and Spain. In: Zdruli P., P. Steduto and S. Kapur S. (editors). Options Mйditer-ranйennes : Sйrie A. Sйminaires Mйditerranйens ; n. 50. ISBN 2-85352-248-2. *7th International Meeting on Soils with Mediterranean Type of Climate*, 2001/09/23-28, Valenzano (Italy).

Steward, F. R., S. Peter, and J. B. Richon, 1990. A method for predicting the depth of lethal heat penetration into mineral soils exposed to fires of various intensities. *Canadian Journal of Forest Research*, **20**: 919-926

Teoharov, M., 1981. Genesis and diagnostics of shallow soils formed on silicate rocks in some areas of South Bulgaria. *Ph.D.thesis*, Nikola Poushkarov ISS, Sofia.

Teoharov, M., 2003. Specificity of pedogenesis in characteristic areas from South-West Bulgaria. *Habilitation thesis*, Nikola Poushkarov ISS, Sofia.

Teoharov, M., 2004. Correlation of soils indicated in map and classification of Bulgaria with World Reference Base (WRBSR, 2002). *Soil Science*, *Agrochemistry and Ecology,* **39**: 3 – 13 (in Bg).

Ulery, A. L. and R. C. Graham, 1993. Forest fire effects on soil color and texture. *Soil Science Society of America Journal,* **57**:135–140.

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