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Wildfire effects on biological properties of soils in forest-steppe ecosystems of Russia

E. Maksimova[1,2] **and E. Abakumov**[1,2]

[1]Saint-Petersburg State University, Saint-Petersburg, Russian Federation
[2]Institute of Ecology of Volga basin, Togljatty, Russian Federation

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Correspondence to: E. Maksimova (doublemax@yandex.ru) and E. Abakumov (e.abakumov@bio.spbu.ru)

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Abstract

Soils affected by forest wildfires in 2010 in Russia were studied on postfire and mature plots near the Togljatty city, Samara region. Soil biological properties and ash composition dynamics were investigated under the forest fire affect: a place of local forest fire, riding forest fire and unaffected site by fire-control (mature) during 3 yr of restoration. Soil samples were collected at 0–15 cm. Soil biological properties was measured by the fumigation method. The analytical data obtained shows that wildfires lead to serious changes in a soil profile and soil chemistry of upper horizons. Wildfires change a chemical composition of soil horizons and increase their ash-content. Fires lead to accumulation of biogenic elements' content (P and K) in the solum fine earth. Calcium content is increased as a result of fires that leads to an alkaline pH of the solum. The values of nutrients decreased as a result of leaching out with an atmospheric precipitation during the second year of restoration. Thus, when the upper horizons are burning the ash arriving on a soil surface enrich it with nutrients. The mature (unaffected by fire) soils is characterized by the greatest values of soil microbial biomass in the top horizon and, respectively, the bigger values of basal respiration whereas declining of the both parameters was revealed on postfire soils. Nevertheless this influence does not extend on depth more than 10 cm. Thus, fire affect on the soil were recognized in decreasing of microbiological activity.

1 Introduction

Successions of soil-plant cover (demutation changes, anthropogenic chronoseries) caused not only by climate dynamics, but also by influence of natural (windfalls, pest outbreaks), natural and anthropogenous (wildfires) and anthropogenous (logging) factors are characteristic for forest ecosystems. The important factor disturbing natural processes in the wood are forest fires which are difficult to forecast the consequences (Certini, 2005). Wildfires are a powerful active ecological factor of modern soil formation. Catastrophic changes of the plant cover accompanied by a postpyrogenic soil formation are on postfire territories (Gonzalez-Perez et al., 2004). A simultaneous research of postfire successions of vegetation and soil development is urgent for development of postfire landscapes management methods and for understanding of soil-plant cover regeneration trends.

Wildfires are the strongest factor of forest degradation in the central Russia. Wildfires effect was extremely sufficient appeared in 2010 summer. Forest fires led to the serious economic and ecological problems in some regions of the country (Isaev, 2011). Unfortunately, they sometimes are happened in the Central Black Earth Region. These type of environmental events are more or less constant of Central Black Earth Region which is presented by the most productive and fertile soils – Chernozems or Mollisols in Russia (Forests in Russia, 2009).

Complicated affect of forest wildfires consists in whole ecosystem disturbance by changing of its component organization, functions and stability. This results in soils profiles changes, plant communities degradation and surface biogeochemistry dynamics. The vegetation changes expressed in a rotation of the main edificators, the animal and microorganisms population. Such changes can be short time and differ in degree of impact (Arocena and Opio, 2003).

The soil ambiguously responds to the changes in forest ecosystems as it combines both stable (conservative) and dynamic components (Robichaud, 2000; Baath et al., 1995). The mineral horizons are more stable in sense of the morphological changes that organic ones (Certini, 2005). Organic layers are known as critically important to functioning of soil fauna, mycobiota and bacteria. Besides, these horizons are the most favorable habitat of soil fauna, the fungal flora, as well as the place where microbiological processes proceed (Skripnikova, 2013).

Forest fires radically changes edaphic conditions, and, hence, on microbiological and biochemical processes in the soil. Wildfires change the soil properties, disturb life-sustaining activity of microflora, therefore there is a change of the content and disturbance of the basic soil elements' cycles: carbon and nitrogen.

Fire, on the one hand, is an active ecological agent able to mobilize nutrients and restore soil fertility (Snyman, 2003), but, on the other hand, as a primary cause of soil degradation due to nutrient loss for volatilization, leaching and erosion, especially in severe wildfires (Novara et al., 2013).

The ash consisted of mineral soil particles and charcoal forms after wildfires. The wash of the ash depends on the rainfall characteristics and the ash properties (Cerdà and Doerr, 2008). Ash characteristics depend upon the plant species burned, amount of biomass, fuel moisture content, temperature and residence time of the flames (Pereira et al., 2009, 2013). Moreover, ash is important in case of post-fire runoff and erosion (Pereira et al., 2013; Woods and Balfour, 2010). Several studies have been conducted on the spatial and temporal evolution of ash as ashes are ephemeral features of the fire-affected landscapes (Pereira et al., 2012, 2013).

Biological soil parameters are known as the most sensitive to the changes of the environment and reflect the intensity and direction of modern soil-forming processes (Baath et al., 1995; Skripnikova, 2013; Shrestha, 2009; Certini, 2005). Fire affects biological organisms either directly or indirectly. Direct effects are those short-term changes that result when any particular organism is exposed directly to the hot temperature by killing or injuring the organisms. Indirect effects usually involve longer duration changes in the environment that impact the welfare of the biological organisms like plant succession, soil organic matter transformations and microclimate after the fire has occurred (Neary et al., 2005; DeBano, 1991; Jensen et al., 2001).

The main index of the microbial complexes functioning are values of carbon in microbial biomass (Cmic) while the indicator of activity of microbial community functioning is microbial respiration (basal respiration, BR) of carbon dioxide (Umer and Vankova, 2011; Jenkinson, 1976; Vance, 1987). Microbial respiration is a strong indicator of microbial activity and viability wildfire (Neary et al., 2005). The ratio of these indexes allows calculating the metabolic quotient ($q\mathrm{CO_2}$) (Jenkinson, 1976; Vance, 1987).

The content of the total microbial biomass in forest floor and soils are known as relatively unstable indicator which use to be affected many factors (hydrothermal conditions and values of available soil organic matter) (Wuthrich et al., 2002).

The effect of fire on microbial activity depends on fire intensity, duration and soil temperature reached during burning (Shrestha, 2009; Certini, 2005; Jensen et al., 2001; Neary et al., 2005).

A complex study of postfire soil processes in a more or less homogeneous climatic and geogenic conditions are urgent for an objective environmental assessment of a current state of forest ecosystems. This is also should help to understand ways of a forestation dynamics of forest ecosystems' components and forecast of their state under the different influence of a pyrogenic factor.

The main aim of this work is to investigate some parameters of postpyrogenic soils in the initial stage of demutation postfire sequence of plant cover.

The objectives of this study were:

(i) to estimate an influence of different types of wildfires on biological activity of postfire soils;

(ii) to study chemical composition of the solum of postpyrogenic soils;

(iii) to investigate dynamics of soil parameters' changes after wildfires in the course of time.

2 Materials and methods

Extreme summer temperatures of 2010 in Russia were critically important for appearing of the catastrophic wildfires. Hot weather has been started in the middle of June and occupied the whole Russian European part, Ukraine and Eastern Europe. Finally, the extreme heats lead to drought and wildfires on the vast territories of European and, later, Siberian Russia.

Fires were observed in the republics of Bashkortostan, Tatarstan, Mari El, Chuvashia, Udmurtia and Mordovia, in Moscow, Sverdlovsk, Kirov, Tver, Kaluga, Orenburg, Volgograd, Samara, Saratov, Ulyanovsk, Chelyabinsk and Kurgan regions. Fire area exceeded 8 million ha in the European territory of Russia in 2010 (Maslyakov, 2011). According to the experts, losses from wildfires and the drought reached tens of billions of rubles.

2.1 Study materials

The study plots were co-called "steppe island of pine forests" near Togljatty city, Samara region, which were exposed to catastrophic forest fires in 2010. The study plots are situated in point with coordinates of the study area are: N 58°39′44.55″; E 39°17′48.95″ and the altitude of the study area is 179 m. It is necessary to emphasize that these "steppe island of pine forests" are very important parts of forest-steppe ecosystems which conserve the boreal species of plants and animals as well as some soil which are untypical for steppe zone.

Three soil pits were studied in order to compare the influence of different types of fires on soils: a place of local forest fire (in the end of July 2010), riding forest fire (in the end of July 2010) and unaffected site by fire-control (mature). Sandy loam soils on Late Pleistocene alluvial Volga sands (Classification and diagnostics of Russian soils, 2004) were studied and they have some features of an illuviation of Spodic components without formation of the separate podzolic horizon. These soils were classified as Sod sandy textured soils with weak features of spodic process development with sand and clay contents of 70,5–86,4 % and 0,3–2,6 %, respectively. Data on the general characteristics of the soils are given in Table 1. The control plot was presented by plant cover and soil unaffected by wildfire and this was situated in 1 km far from the intensive fires appearing.

2.2 Study methods

Soil descriptions and sampling and a vegetation description were carried out during 3 field seasons: in September 2010 after removal from the territory of a state of emergency, in August 2011 and September 2012. In this case sampling points were constant. Soil samples for biological analyses were taken at three plots on each postfire site. Simultaneously samples on the control plot were taken. Soil samples for biological properties and ash content determination were collected at 0–15 cm. 9 soil pits (three were on each study plot) were put in 2010, and more than 50 soil samples were analyzed. In 2011 – 6 soil pits and about 30 samples; in 2012 – 10 soil pits and about 50 soil samples.

3 Laboratory analysis

Descriptions of plant communities and soil profiles, as well as sampling were conducted according to the standard methodical guidelines (Vorobyova, 2006). Soil color has been measured by the Munsell chart method in laboratory for air-dry soil samples (Cleland, 2004; Munsell, 1912). All chemical and biological parameters were studied in a fine earth. Biological soil properties were determined according to Jenkinson (1976) and Vance et al. (1987) recommendations. Soil biomass was measured by the fumigation method: soil under the field water capacity was incubated under 20 °C in laboratory for 10 days and then exposed to chloroform for 24 h, after what the fumigant solution were removed and the soil then extracted with 0,5 M K_2SO_4. The metabolic quotient was calculated by dividing the cumulative CO_2 respired by microbial biomass to microbial biomass carbon content. Determination of chemical composition of the litter and upper burned-down soil horizons were carried out according to Williams (1984) and Erich and Ohno (1992) manuals.

4 Statistical analysis

Data obtained were statistically analyzed with SIGMAPLOT 8.0 program (parried t test, mean values, standard deviation) with aim to compare different years of restoration trends as well as between plots differences. Significant differences were considered at $P < 0,05$.

5 Results and discussion

The main morphological feature of burned soils is a pyrogenic horizon characterized by the abundance of charcoal. The new shallow pyrogenic horizon can persist for decades if plant communities do not start to regenerate on a place of wildfires and erosion and infiltration processes do not redistribute charcoal. This horizon is different from those in mature (control) soils in chemical and physical properties and biological circle of elements. Morphological differences between control and burned soils are observed only in the solum (Sapozhnikov et al., 2001).

5.1 Ash elements composition

Changing of mobility of ash elements after wildfires was noted by many authors. In this case its further destiny in a landscape is of particular importance (Certini, 2005).

Determination of ash composition of the solum was carried out in the studied soil samples (Table 2). It should be emphasized that the analysis of ash composition involves definition of composition of plant samples that do not have mineral particles. In this case we had not the precise information about the intial chemical status of the plots. The upper layer of the control soil was the row (moder) humus material consisting of a mechanical mixture of organic remntants, which have different degree of decomposition, with mineral components, and the ash is a mixture of mineral particles with the burned plant remains as dirty-gray ash. Thus, mixed samples of the surface organic soil horizons at all plots were taken for carrying out the analysis of ash composition.

This specification explains the high content of ash (i.e. the ash containing CO_2 and mineral impurities after combustion of a hinge plant material sample) in all samples, especially in the control soil. The ash content varies from 950 $g\,kg^{-1}$ in postfire forest floor to 680 $g\,kg^{-1}$ in mature soils.

Forest fires change a chemical composition of the litter and increment their ash-content. The Table 2 shows that content of ash containing mineral components increases in burned soils compared to the control plot due to of increase in some elements; after one year content of the ash decreases with a reduction of elements' content. The SiO_2 content ranged from 862,1 to 865.7 $g\,kg^{-1}$ and about 611 $g\,kg^{-1}$after fires and in control soils in 2010, respectively, and from 797.1 to 820.8 $g\,kg^{-1}$ in postfire soils in 2011. The content of silicon oxide with impurities in studied soils correlates with the content of the ash since impurities are a large part of it. Fires lead to an increase of a biophile elements' content in the ash horizon – phosphorus and potassium, and this increase is more noticeable in a case of a local fire, probably, due to the full combustion of a soil surface in this case. The phosphorus content increases in the row control → riding fire → local fire as a sequence: 1.5 $g\,kg^{-1}$ → 1.8 $g\,kg^{-1}$ → 2.4 $g\,kg^{-1}$; the potassium content increases in the same row in a next way: 1.9 $g\,kg^{-1}$ → 2.1 $g\,kg^{-1}$ → 2.5 $g\,kg^{-1}$. The phosphorus and potassium content slightly decreased in studied soils as a result of carrying out with an atmospheric precipitation in 2011 as some studies have shown (Pereira et al., 2013). Thus, the ash entering on the soil surface enriches it with nutrients when burning the solum.

The sodium content in the ash does not change as a result of postfire succession.

Calcium content is increased in the ash composition of the burned litter, especially at a local fire, that leads to an alkaline pH of the solum. The CaO content ranged from 16.3 to 18.7 $g\,kg^{-1}$ and about 15.2 $g\,kg^{-1}$after fires and in control soils in 2010, respectively, and from 13.1 to 13.5 $g\,kg^{-1}$ in postfire soils in 2011.The sources of calcium are burned litter and plant organs. CaO reacting with water turns into $Ca(OH)_2$ that is strong alkali sorbing CO_2 from the air; as a result $CaCO_3$ is formed. This process has been proposed to call as a pyrogenic carbonate formation (Aleksandrovsky, 2007).

One year later calcium leaches down the soil profile and its content in postfire soils, that are not protected from erosion, considerably decreases in comparison with the control plot. On the contrary, the magnesium content decreases by the impacts of different types of fires in the same degree, but the next year its content is leveled with the control because of a new plant residues coming on soil surface. The reason for this phenomenon needs to be established during the next researches.

Besides, the molecular relations of oxides – SiO_2/Fe_2O_3; SiO_2/Al_2O_3; SiO_2/R_2O_3 – were calculated. The data obtained indicates that there is an accumulation of silicon with impurities relating to the content of sesquioxides as a result of wildfires (from 65.9 to 51.6 in case of wildfires and mature soils, respectively), but a year later the relative silicon content decreases only in case of a local fire. The charred material of plant residues, formed at a riding fire in large amounts, probably is the reason of the relative increase in the silicon content, as unburned residues are a part of impurities. There is also a relative accumulation of iron and aluminium as a result of wildfires.

The paired t-test show significant differences in ash composition of the upper soil horizons were not revealed ($P \geq 0.15$–0.80).

Thus, data obtained show that there is an accumulation of silicon oxides with impurities relating to the content of sesquioxides as a result of wildfires, but a year later the relative silicon content decreases only in case of a local fire. The charred material of plant residues, formed at a riding fire in large amounts, probably is the reason of the relative increase in the silicon content, as unburned residues are a part of impurities. There is also a relative accumulation of iron as a result of wildfires. There are not any accurate regularities in case of the aluminium content, possibly due to inaccurate method of calculation (the aluminium content was calculated as the difference between the content of sesquioxides and iron and phosphorus oxides).

5.2 Soil biological activity

Wildfires result in essential changes in soil biological activity such as basal respiration, microbial biomass and metabolic quotient that are presented in Table 3.

The microbial biomass values ranged from 0.006 to 0.028 $\mathrm{mg\,g^{-1}}$ and from 0.103 to 0.130 $\mathrm{mg\,g^{-1}}$after fires and in control soils, respectively. The basal respiration values varied from 64.9 to 76.1 $\mathrm{mg\,CO_2\,(100\,g\,soils)^{-1}\,day^{-1}}$ and from 77.1 to 258.3 $\mathrm{mg\,CO_2\,(100\,g\,soils)^{-1}\,day^{-1}}$ after fires and in control soils, respectively. The results of determination of soil microbial activity parameters give an idea that the control soil is characterized by the highest values of microbial biomass in solum and, therefore, a higher value of basal respiration, whereas there is a noticeable decrease of both parameters in case of postfire soils (Table 3). Besides, in the lower horizons is also observed a reduction of the microbial biomass. Thus, there is a degradation of the microbial community as a result of wildfires. The negative impact of pyrogenic factor that leads to depression of soil biological activity was noted by many researchers (Bezkorovainaya et al., 2007; Gonzalez-Perez et al., 2004; Kim et al., 2003; Certini, 2005; Jensen et al., 2001). Postfire reduction of microbial biomass is explained both by decrease of soil humidity level and change in a structure of soil organic matter, that also has an impact on the development of microbial biomass in soils after wildfires.

Statistical significance of differences of levels of microbial biomass was found only between soils that have been subjected to the local and riding fires.

A noticeable decrease of microbial biomass at the local fire is explained by the nature of the fire, which affects on the sphere inhabited by microorganisms. Thus, wildfires lead to a reorganization of the microbial pool that is marked by the decrease of microbial activity and CO_2 emissions as Neary and others (2005) showed.

One year later the situation has changed (Table 3). The reduction of microbial activity after wildfires is also noted in case of upper soil horizons, but in the places affected by wildfires, there is a moving of active microbial activity zone to comparatively deeper soil horizons. Obviously, it is connected with an increase of the amount of mineral nutrients that are gradually leached into the deeper horizons, increase of pH and other chemical changes associated with combustion.

The intensity of carbon dioxide allocation in soils is caused generally by two factors – the availability of nutrients and the quantity of microorganisms, and it is important not only quantity, but also the physiological state of the microbial community. In this case, the amount of microorganisms decreases after wildfires, but the content of biophil elements increases, and it does not mean that they are available to a biota. A reduction of CO_2 emissions is revealed after local and riding wildfires equally. 1–2 yr after the fire the area of the most active "soil respiration" in pyrogenic soils is under the burnt litter immediately. The reduction of carbon dioxide emission by soils after wildfires can be explained by the decrease of respiration of roots and microorganisms that are died during combustion.

Degradation of the microbial community after wildfires is also confirmed by a lack of close correlation between the content of organic matter and microbial biomass, and between microbial biomass and basal respiration. But nevertheless some interrelation of the biological activity with the contents of soil organic matter which is a substrate for the activity of soil microorganisms is visible: in case of wildfires both parameters reduce concerning control.

The results of biological properties in studied soils are in agreement with similar observations reported by other authors (Shrestha, 2009; Certini, 2005; Neary et al., 2005; DeBano, 1991; Jensen et al., 2001) who found decrease of microbial activity and basal respiration.

The data obtained are not in good correspondence with some published data about increasing of the intensity of microbiological processes by warming up the solum after wildfires. The increase in carbon dioxide emission in some areas is connected with high intensity of microbiological processes that have been observed in the upper mineral soil horizons at a favorable combination of trophic (by increasing ash content) (Skripnikova et al., 2013; Baath et al., 1995; Diaz-Ravina et al., 1996; Kutiel and Shaviv, 1989) and hydrothermal conditions (a rain and warm weather at the beginning of September). In addition, the remained roots of the burnt vegetation also can be a nutritious substrate for soil microorganisms; it causes higher basal respiration (Wuthrich et al., 2002). However, probably, the temperature at wildfires reached such a high limits that there was a sharp inhibiting of microbial activity and even it could be fatal for soil inhabitants at studied plots.

A metabolic quotient values characterize the intensity of respiration to the units of microbial carbon (Anderson and Domsch, 1985a, b) and may serve as complex indicator of a state and stability of the soil microbial community.

An inverse relationship between values of the metabolic quotient and the content of the microbial biomass in the studied soils is noted (Umer and Vankova, 2011). The solum of control, where it is a high content of microbial biomass, has low values of the metabolic quotient, and high values are characteristic for postpyrogenic soils with low content of microbial biomass. Forest fires lead to an increase of the metabolic quotient by several times compared with control. Thus, the data presented in Table 3 indicate that the metabolic activity of the microbial community decreases in the sequence: control → riding fire → local fire that also indicates the certain intensive changes in the microbial community.

6 Conclusions

Investigation conducted during 3 yr on one mature and two postfire plots shows that wildfires lead to serious changes in both ecological situation in forests as well as chemical and biological properties of soil profile – activation or inhibition of biological processes, changes in the physicochemical and hydrothermal properties of the solum.

The wildfire significantly reduces a level of biological activity determined by a production of CO_2 and the content of the microbial biomass. But, in general, the impact of wildfires on soil properties does not extend on depth more than 10 cm.

These changes gradually minimize over time, strengthened new microbial and plant associations start making adjustments to the processes taking place in the solum, and the soil is restored and starts returning to its original state.

The metabolic quotient indicates that the more favorable and stable state of the microbial community is characteristic for mature soil, and the lowest intensity of microbiological processes is observed in the case of local fire.

Forest fires enrich soils with ash nutrients, which have accumulated in plants for years. However, there is a danger of leaching of a considerable part of ash elements and their involvement in a large geological cycle under the conditions of relatively slow restoration of vegetation 1–2 yr after wildfires.

Finally, the pyrogenic affect led to degradation of the solum in terms of the biological soil properties, but there is a trend of increasing of the main nutrients content in the upper burned soil horizons.

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Table 1. Morphological features and general properties of soils.

Horizon	Depth cm	Colour	Soil humidity %	pH	Clay content $\mathrm{g\,kg^{-1}}$
		Local fire (2010)			
Burned litter	0–5	10 YR 3/2	2.85	8.0	20.0
AY	5–14	10 YR 4/2	1.45	6.2	25.0
AC	14–27	7.5 YR 5/4	1.38	6.0	26.0
AC	27–36	10 YR 6/4	1.02	5.8	19.0
AC	36–53	10 YR 6/4	0.98	5.3	24.0
C	53–73	7.5 YR 5/4	0.69	5.7	13.0
		Riding fire (2010)			
Burned litter	0–3	10 YR 3/2	2.37	7.9	17.0
AY	3–10	10 YR 4/2	1.43	5.9	20.0
AC	10–15	7.5 YR 5/2	0.86	5.9	17.0
AC	15–24	10 YR 7/4	1.11	5.9	6.0
C	24–44	10 YR 6/3	0.52	5.7	4.0
C	44–64	10 YR 6/3	0.49	5.9	9.0
		Control (2010)			
Litter	0–7	–	5.92	6.5	nd
AY	7–10	10 YR 4/2	1.60	6.3	21.0
AY	10–14	10 YR 6/4	0.78	6.2	18.0
AC	14–23	7.5 YR 3/2	0.78	6.1	13.0
AC	23–33	2.5 YR 8/6	0.42	5.9	4.0
C	33–50	2.5 YR 8/6	0.33	5.7	7.0
C	50–70	2.5 YR 8/6	0.32	5.8	3.0

Table 2. Ash composition of the solum.

Horizon	Ash content g kg^{-1}	SiO_2 with impurities g kg^{-1}	P_2O_5 g kg^{-1}	Fe_2O_3 g kg^{-1}	R_2O_3 g kg^{-1}	K_2O g kg^{-1}	Na_2O g kg^{-1}	CaO g kg^{-1}	MgO g kg^{-1}
Local fire (2010)									
Burned litter	956.3	862.1	2.4	21.7	33.5	2.5	0.6	18.7	4.8
Riding fire (2010)									
Burned litter	946.1	865.7	1.8	21.0	29.9	2.1	0.5	16.3	4.7
Control (2010)									
Litter	685.6	611.6	1.5	14.8	26.2	1.9	0.5	15.2	7.2
Local fire (2011)									
Burned litter	880.3	797.1	2.1	22.5	34.4	2.6	0.5	13.1	4.9
Riding fire (2011)									
Burned litter	899.7	820.8	1.7	19.2	27.3	2.0	0.5	13.5	3.9
Control (2011)									
Litter	689.6	611.5	1.5	14.9	22.4	1.8	0.5	15.0	4.9

Table 3. Basal respiration, microbial biomass and metabolic quotient of studied soils during 3 yr of restoration.

Horizon, depth, sm	Basal respiration mg CO_2 (100 g soils)$^{-1}$ day^{-1}			Microbial biomass mg g^{-1}			Metabolic quotient		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
Local fire									
Burned litter 0-5	75.32	73.00	72.82	0.006	0.010	0.120	0.0343	0.0199	0.0016
AY 5–14	64.98	76.57	75.33	0.013	0.030	0.019	0.0136	0.0070	0.0108
AC 14–27	67.68	55.38	59.35	0.013	0.010	0.010	0.0142	0.0151	0.0162
Riding fire									
Burned litter 0–3	76.13	71.75	69.85	0.020	0.025	0.118	0.0104	0.0078	0.0016
AY 3–10	69.16	72.52	68.16	0.028	0.040	0.013	0.0067	0.0050	0.0143
AC 10–15	64.55	52.34	55.82	0.024	0.013	0.012	0.0073	0.0110	0.0127
Control									
Litter 0–7	258.27	254.3	251.45	0.130	0.110	0.121	0.0054	0.0063	0.0057
AY 7–10	77.13	76.33	76.99	0.121	0.123	0.121	0.0018	0.0017	0.0018
AY 10–14	86.89	80.91	79.35	0.103	0.102	0.101	0.0024	0.0022	0.0022