Influence of the Red Wood Ant *Formica lugubris* Zetterstedt, (Hymenoptera: Formicidae) on the Surrounding Forest Soil

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Abstract

Red wood ants build their nests as above-ground mounds by collecting organic materials from the forest floor. The effects of ant nest to the soil carbon and nitrogen along with the soil pH, were measured. There was an increase in pH with distance from the nests while there was a decrease in C and N concentration with the distance from the nest increases. The carbon content at the mound and nests center was differ, with carbon percentage more than double at the nests mound than in the center of the nest. In contrast the nitrogen percentage was higher at the nest center but with no significant difference. The pH was increased at the nests center while the soil was more acidic at greater ratio. Red wood ants' mounds do not significantly alter the C and N concentrations in the forest ecosystem, but they increase spatial heterogeneity of the forest floor by storing organic matter and nutrients.

Keywords: Red wood ants, pH, C and N concentrations, forest soil, forest ecosystem.

Introduction

Ant nests are considered as natural occurring disturbances in the forest ecosystem, contributing to the soil property complexity as it was described by Wagner et al. (1997). Red wood ants, (particularly the members of the *Formica rufa* Group) could be found mostly in coniferous forests as well as in mixed and deciduous forests of the temperate zone. Their nest is made of organic materials from the forest floor, they are above ground and can remain active for many years (Holldobler and Wilson, 1990).

The chemical properties and decomposition rates of the nest building material differ from those of the forest floor. Several factors, like low moisture, higher average temperature,

and chemical properties along with microbial activity influence decomposition rate in the nest (Czerwiński et al., 1971; Pokarzhevskij, 1981; Frouz, 2000). By that, the carbon pool in the nest is higher than in the forest floor and soil (Frouz et al., 1997; Laakso and Setälä, 1998; Lenoir et al., 2001). Lenoir et al. (2001) in Swedish scots pine forests, found that C concentrations can be nearly 20% higher in the center of the mound than in the forest floor, while N concentrations differed from site to site. The C and N concentrations were always higher in four different forest types in Switzerland, even though C concentrations were significantly higher among forest types whilst N concentrations were not (Risch et al., 2005). Frouz et al. (1997) found similar results in the Czech Republic. Such carbon pools however contain only a small fraction of the total forest floor carbon pool, but they contribute significantly at the spatial heterogeneity of C distribution in the forest ecosystem (Rosengren and Sundstrom, 1987; Gosswald, 1989).

Ant nests are well known also for altering soil pH significantly, tending to neutralize it (Dlusskij, 1967; Frouz et al., 2003). In acidic forest soils, ant nests have higher pH than humus (Brady and Weil, 1999) and forest soil (Jilkova et al., 2010). Laakso and Setälä (1997) in Finnish boreal forests found that pH on the nest surface can be significantly higher than that of the soil. Though, not all ant species alter the pH in the same manner e.g., *Formica polyctena* Förster, 1850 and *Formica lugubris* Zetterstedt, 1938 alter pH from acid to neutral values more intensively than *Formica pratensis* Retzius, 1783 (Malozemova and Koruma, 1973).

Even though there are many studies on the impact of red wood ants in soil in even-aged boreal and central Europe forests, studies in Mediterranean or all-aged forest stands are lacking. In the present study we measured pH and C and N concentrations in the red wood ants' nests and the surrounding soil. The purpose of this research was to find the differences of these factors between the nests and the soil in an all-aged forest.

Materials and Methods

The study area was in Elatia forest, located in Northern Greece (41° 28 '50.85' N, 24° 19'16.70' E) with an area of approximately 7 hectares (7,034 ha). The altitude ranges between 1500-1650 meters with mild to moderately strong slope. It is an all-aged managed forest dominated by Norway spruce (*Picea abies* L. H. Karst), Scots pine (*Pinus sylvestris* L.), and Copper beech (*Fagus sylvatica* L.). The site type is classified as Vaccinio-Piceion (Cajander, 1949). According to the closest meteorological station in Skaloti (altitude 900m) the average temperature is 11.46 ^{o}C and the average annual precipitation is 955.1 mm, However, at the study area precipitation was higher, as it was reported by Ganatsas (1993).Bedrock of the study area is dominated of granite and gneiss (Zagas, 1990; Tsiaoussi, 1996), while at the location of the recorded nests, the parent rock material was gneiss.

In early August 2013, a total of 46 nest mounds were counted in the study area; five typical representative mounds were selected. Stockan et al. (2016) key was used to identify the species. A soil sample of 0-20cm and 10-30cm soil depth was sampled at points 0,5m and 1m uphill and downhill from the ant mound edge, 0-20cm soil depth from the center of the nest, and nest building materials from the center of the above ground nest with a soil corer and trowel, a total of 55 soil samples. The samples were oven dried, sieved through 0.8cm and 0.2cm sieve and stored in a polyethylene (PE) bag.

In the laboratory, we measured pH at 1:1 soil water suspension (Thomas, 1996). Organic matter (OM) and carbon (C) were measured by the Walkley and Black method (1937), and total nitrogen (N) was determined with the Kjeldahl digestion (Bremner and Mulvaney, 1982).

Data statistical analysis was made with one way ANOVA followed by a Tukey posthoc test for pairwise comparison, while the N data did not follow the normal distribution, and therefore they analysed with non-parametric Kruskal Wallis test, followed by U Mann-Whitney tests.

Results and Discussion

All nests belonged to the 'hairy red wood ant' (*Formica lugubris* Zetterstedt, 1938).

Soil pH seems to decrease as we fend off the mound (Fig. 1). The mean pH values are from 4.84 at the 1 m distance to 4.94 and 5.08 at the center of the nest (Fig. 2, Table 1). PH neutralization in the center of the nest is well documented in several other studies. The species *Acrogypa sp.* in Bode et al. (1999) in acidic soils in Iowa, as well as *Formica perpilosa* Wheeler, 1910 in arid regions of south-western United States (Wagner et al., 1997) also tended to neutralize the pH in their nests. The soil layer near the nest was also affected showing an increased pH. However, soil acidity may not be influenced by the accumulated litter at the nest. Coniferous forests' litter has the tendency to acidify the soil layers below. Such pattern was not present at the present or any other similar studies. Suggesting no direct relation among the litter and humus layers to the soil chemistry at the nest region. Other microbiological related factors could explain these results.

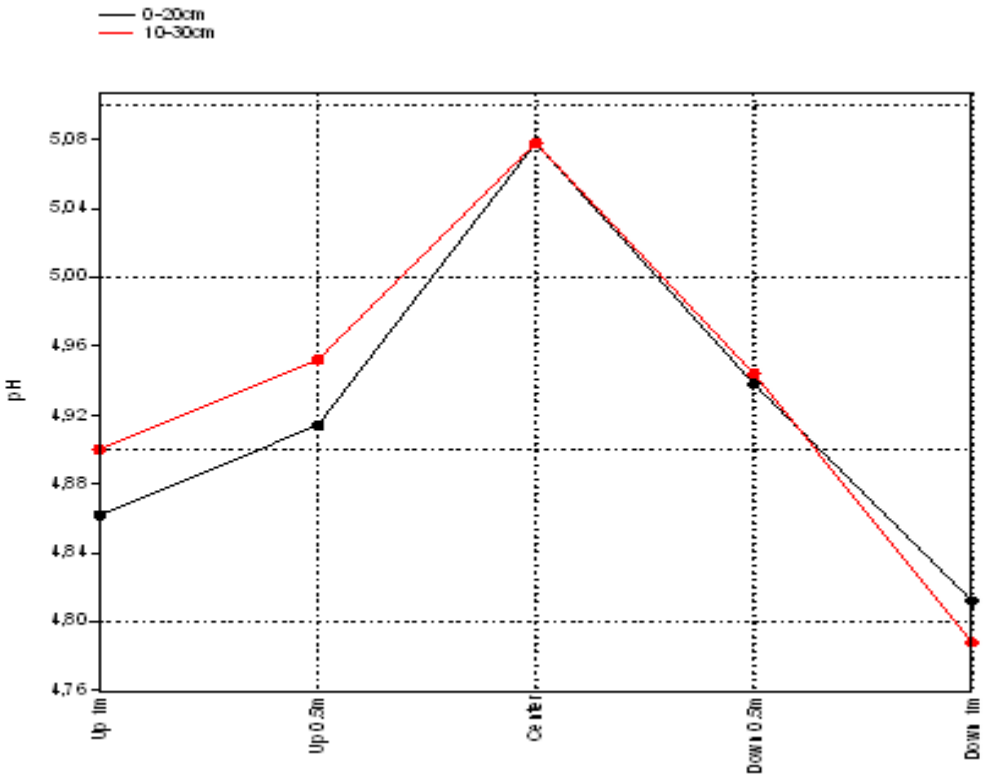

Fig 1. *Changes in pH value uphill (Up), in the center (Center) and downhill the nest (Down).*

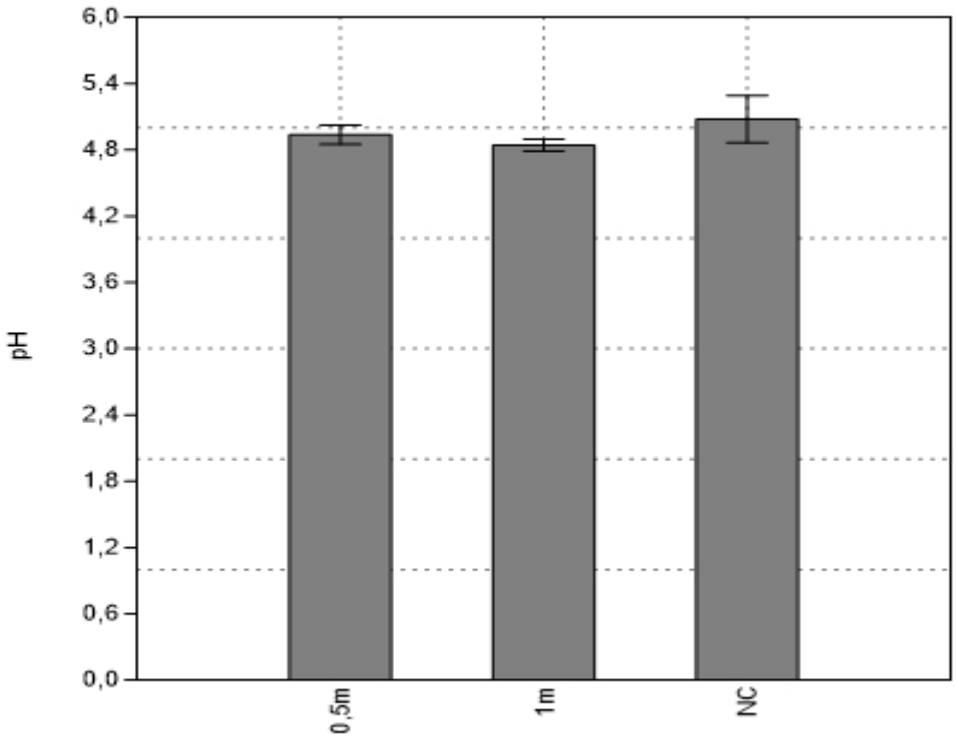

Fig 2. *Mean pH and standard error of soil from distances of 0,5m, 1m and from the center of the nest (NC).*

Table 1. *pH values in 0.5m and 1m distance from the mound, and in the nest center.*

	pH		
	0.5m	1m	nest center
Max.	4.340	4.320	4.540
Min.	5.820	5.400	5.600
Mean	**4.937**	**4.841**	**5.078**
SD	0.384	0.244	0.478

Both nitrogen (Fig. 3, 4) and carbon (Fig. 5, 6) were significantly higher in above-ground mounds than the average values in reference soils (Table 2). That was as expected since the nest building material was consisted mainly of coniferous needles. The data analysis of the C and N content agree with the existed literature, as it was documented in coniferous forests in Moscow (Zakharov et al., 1981), in subalpine coniferous forests in Switzerland (Risch et al., 2005) and in mixed coniferous-broadleaf forests in Finland (Kilpeläinen et al., 2007). The hypothesis that the accumulated litter may have significant effect on the chemical properties probably is not correct. The main building material of the above-ground mounds consists mainly of coniferous needles. This explains the high concentrations of C. In contrast, N concentrations in the nest is much higher that the litter. Increased microbial activity (Lenoir et al., 2001), as well as the increased resin content of the building material of the nests explain the findings. Similar results were described by Berg et al. (2000). Frouz et al. (1997) found a much higher number of nitrogen-binding bacteria in the nests of red wood ant *Formica polyctena* Foerster, 1850 compared to the forest floor.

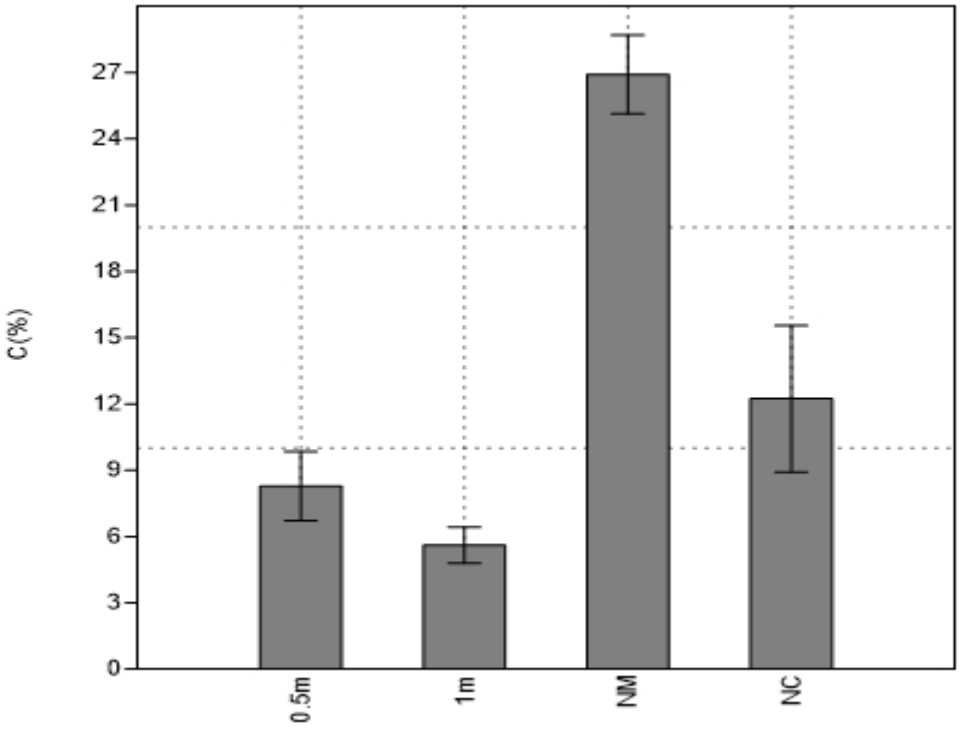

Fig 3. *Mean C concentration (%) and standard error of soil from distances of 0,5m, 1m, from the mound material (NM) and from the center of the nest (NC).*

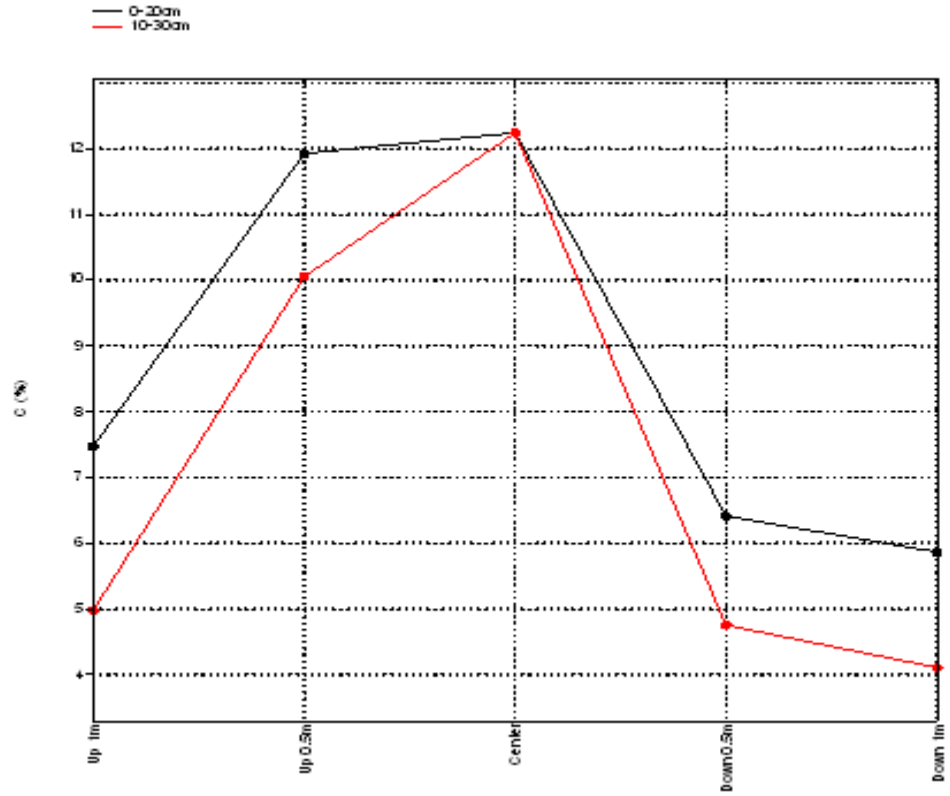

Fig 4. *Changes in C concentration (%) uphill (Up), in the center (Center) and downhill the nest (Down).*

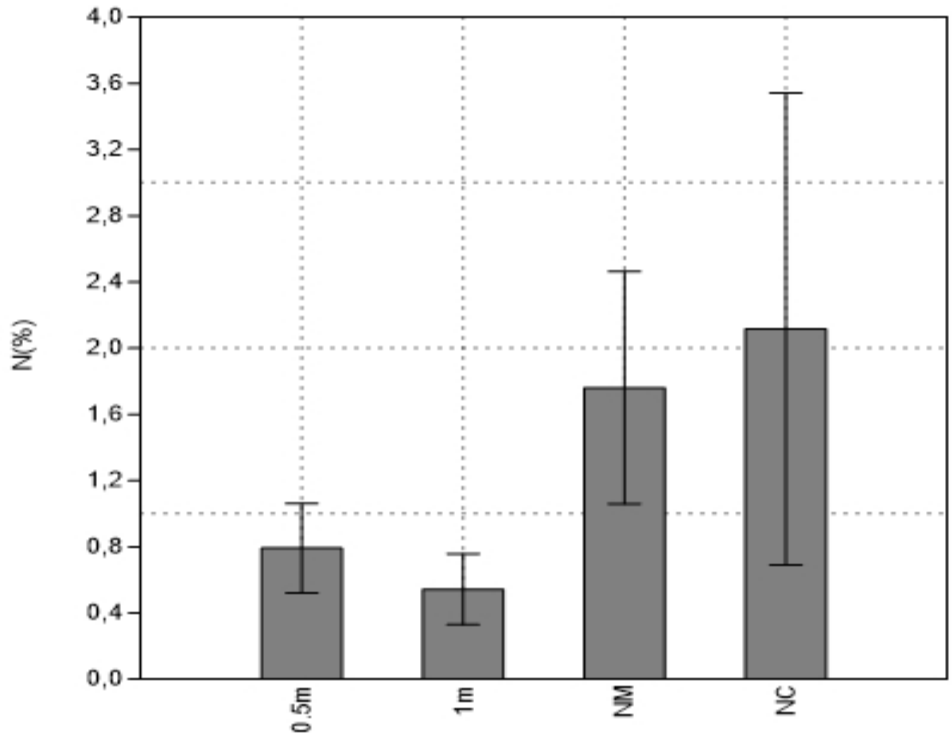

Fig 5. *Mean N concentration (%) and standard error of soil from distances of 0,5m, 1m, from the mound material (NM) and from the center of the nest (NC).*

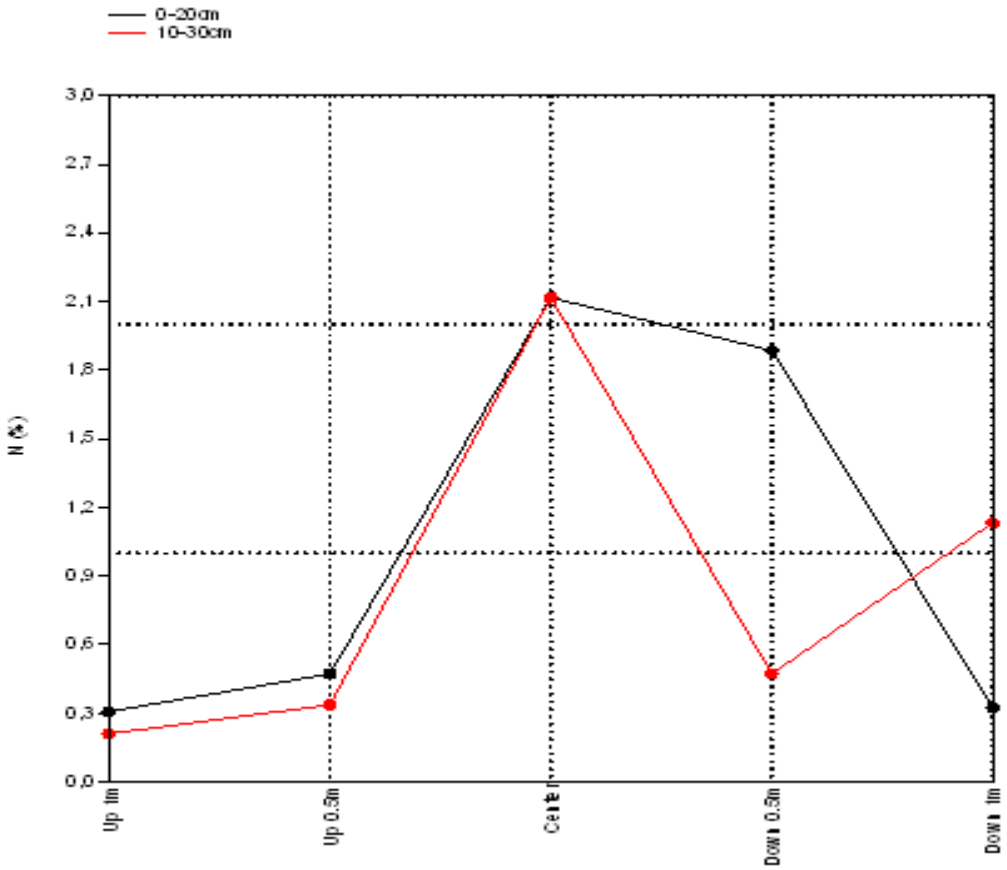

Fig 6. *Changes in N concentration (%) uphill (Up), in the centre (Center) and downhill the nest (Down).*

Table 2. *C and N concentrations (%) in 0.5m and 1m distance from the mound, in the nest building materials and in the nest center.*

	0.5m		1m		Nest material		Nest center	
	C	**N**	**C**	**N**	**C**	**N**	**C**	**N**
Max.	0.706	0.054	0.319	0.083	17.787	0.802	4.027	0.147
Min.	25.157	5.201	12.482	4.464	34.557	8.048	24.160	7.710
Mean	**8.287**	**0.792**	**5.605**	**0.543**	**26.914**	**1.761**	**12.240**	**2.117**
SD	6.969	1.204	3.668	0.957	5.633	2.217	7.409	3.188

Conclusion

Red wood ants increase pH at the nest in acidic soils, although such effect is minimal. Their influence on the forest soils is minimal, although they significantly increase the heterogeneity of the soil environment. They do not seem to alter the chemical properties of the soil significantly, but they increase the spatial heterogeneity of the forest soil in organic matter and nutrients. These are stored and retained in the nests, and when the colony is abandoned, they decompose and return to the soil, contributing to geochemists cycles locally.

References

Berg, B., M.B. Johansson, V. Meentemeyer, 2000. Litter decomposition in a transect of Norway spruce forests: substrate quality and climate control. Can. J. Forest Res. 30, 1136–1147.

Bode, S., A. Goose, C. Warpehoski, 1999. Ant mounds influence soil composition, but not vegetation. Tillers, 1, 25-29.

Brady, N.C., R.R. Weil, 1999. The Nature and Properties of Soils. Prentice-Hall: Upper Saddle River, New Jersey.

Bremner J.M., C.S. Mulvaney, 1982. Nitrogen total. In: Methods of soil analysis. Agron. no. 9. Part 2: chemical and microbiological properties, 2nd edn, Page AL (ed). American Society of Agronomy: Madison, WZ; 595–624.

Cajander, A.K., 1949. Forest types and their significance. In: Acta Forestalia Fennica 56(5): 1–71. Helsinki: Finnish Society of Forest Research.

Czerwiński Z., H. Jakubczyk, J. Pętal, 1971. Influence of ant hills on the meadow soils. Pedobiologia, 11, 277–285.

Dlusskij, G.M., 1967. Muravji roda *Formica*. Nauka, Moskva 236pp. (in Russian)

Frouz, J., H. Santruckova, J. Kalcik, 1997. The effect of wood ants (*Formica polyctena* Foerst.) on the transformation of phosphorus in a spruce plantation. Pedobiologia, 41, 437–447.

Frouz, J., 2000. The effect of nest moisture on daily temperature regime in the nest of *Formica polyctena* wood ants. Insectes Sociaux, 47, 229-235.

Frouz, J., M. Holec, J. Kalcik, 2003. The effect of *Lasius niger* (Hymenoptera, Formicidae) ant nests on selected soil chemical properties. Pedobiologia, 47, 205-212.

Ganatsas, P., 1993. Stand structure and natural regeneration of spruce forest in Elatia Drama, northern Greece. Ph.D. Thesis. School of Forestry and Natural Environment, Aristotle University of Thessaloniki, Greece.

Gösswald, K., 1989. Die Waldameise. Band 1. Biologische Grundlagen, Okologie und Verhalten. AULA, Wiesbaden, Germany. (in German)

Hölldobler, B., E.O. Wilson, 1990. The ants. Harvard, Cambridge, Massachusetts, USA.

Jilkova, V., J. Frouz, T. Domisch, L. Finer, 2010. The effect of wood ants (*Formica s. str.*) on soil chemical and microbiological properties. 19th World Congress of Soil Science, Soil Solutions for a Changing World 1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Kilpeläinen, J., L. Finer, P. Niemela, T. Domisch, S. Neuvonen, M. Ohashi, A.C. Risch, L. Sundström, 2007. Carbon, Nitrogen and Phosphorus dynamics of ant mounds (Formica rufa group) in managed boreal forests of different successional stages. Applied Soil Ecology 36:156–163.

Laakso, J., H. Setälä, 1997. Nest mounds of red wood ants (*Formica aquilonia*): hot spots for litter-dwelling earthworms. Oecologia, 111, 565-569.

Laakso, J., H. Setälä, 1998. Composition and trophic structure of detrital foodweb in ant nest mounds of *Formica aquilonia* and in the surrounding forest soil. Oikos, 81, 266–278.

Lenoir, L., T. Persson, J. Bengtsson, 2001. Wood ant nests as potential hot spots for carbon and nitrogen mineralization. Biology and Fertility of Soils, 34, 235–240.

Malozemova, L.A., N.P. Koruma, 1973. Influence of ants on soil. Ekologia, 4, 98-101. (in Russian)

Pokarzhevskij, A.D., 1981. The distribution and accumulation of nutrients in nests of ant *Formica polyctena* (Hymenoptera, Formicidae). Pedobiologia, 21, 117–124.

Risch, A.C., M.F. Jórgensen, M. Schótz, D.S. Page-Dumroese, 2005. The contribution of red wood ants to soil C and N pools and to CO2 emissions in subalpine forests. Ecology, 86, 419–430.

Rosengren, R., L. Sundstrom,1991. The interaction between red wood ants, *Cinara* aphids and pines. A ghost of mutualism past? In: Huxley, C.R. & Cutler, D.F. (Eds.), Ant-plant interactions. Oxford University Press, Oxford, New York, Tokyo, pp. 80–91.

Stockan, J.A., E.J.H. Robinson, J.C. Trager, I. Yao, B. Seifert, 2016. Introducing wood ants: evolution, phylogeny, identification and distribution. In: Wood Ant Ecology and Conservation, eds. Jenni A. Stockan and Elva J. H. Robinson. Published by Cambridge University Press. Cambridge University Press 2016 pp. 17-52.

Thomas, G.W., 1996. Soil pH and soil acidity. p. 475–490. In D.L. Sparks (ed.) Methods of soil analysis. Part 3. Chemical methods. SSSA Book Ser. 5. SSSA, Madison, WI.

Tsiaoussi, V. (Project Leader), 1996. Specific Management Plan for the Site Periochi Elatia (GR1 140003). The Goulandris Natural History Museum-Greek Biotope/Wetland Centre. Thermi. 197 p.

Wagner, D., M.J. Brown, D.M. Gordon, 1997. Harvester ant nests, soil biota and soil chemistry. Oecologia, 112, 232-236.

Walkley, A., I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29-38.

Zagas, T., 1990. Conditions for natural establishment of Pinus sylvestris in an area of Rhodopi mountain, northern Greece (p. 170). Ph.D. thesis. Thessaloniki: Aristotle University.

Zakharov, A.A., E.F. Ivanickaja, A.E. Maksimova. 1981. Accumulation of nutrients in nests of *Formica sp*. (Hymenoptera, Formicidae). Pedobiologia 21, 36–45.