ECOLOGIA BALKANICA
2010, Vol. 2 December 2010 pp. 39-56

The Effects of Gap Disturbance on Soil Chemical and Biochemical Properties in a Mixed Beech – Hornbeam Forest of Iran

Y. Kooch[1], S. M. Hosseini[2], J. Mohammadi[3], S. M. Hojjati[4]

1 - Ph.D. Candidate of Forestry, IRAN
2 - Associate Professor of Forestry, Tarbiat Modares University. IRAN
E-mail: hosseini@europe.com, hosseini@modares.ac.ir
3 - Associate Professor of Soil Sciences, Shahrekord University. IRAN
4 - University of Natural Resources and Agriculture Sciences of Sari. IRAN

Abstract. The present study aimed to examine the impacts of small (85.12 m^2), medium (325.21 m^2), large (512.11 m^2) and very large (723.85 m^2) gaps on soil properties in a mixed beech – hornbeam stand of northern Iran. As well as the value of pH, organic matter and carbon, total nitrogen, cation exchange capacity (CEC), phosphorus, potassium, calcium, nitrogen mineralization, microbial respiration, earthworms density and biomass of soil samples (0 – 15, 15 – 30 and 30 - 45 cm depths from gap center, edge and closed canopy positions) were measured in laboratory. Significantly effects of gaps size were found on soil properties as the highest values of CEC, density and biomass of earthworms observed in small gaps. The highest values of carbon to nitrogen ratio, phosphorus, potassium and calcium were detected in medium gaps. The most amounts of organic matter and carbon, nitrogen mineralization devoted in very big gaps. Greater amounts of pH, total nitrogen and microbial respiration were detected in big and very big gaps. It was found that gap position had a profound effect on soil characters as the highest values of pH, organic matter and carbon, total nitrogen, phosphorus, potassium, calcium, nitrogen mineralization, microbial respiration observed in gap center. The greatest amounts of carbon to nitrogen ratio, CEC, density and biomass of earthworms were detected in closed canopy. According to the results, soil upper layers showed the highest values organic matter and carbon, soil nutrition elements and biochemical activities, whereas the highest amounts pH, carbon to nitrogen ratio, CEC and density and biomass of earthworms were observed in deeper soil. It is concluded that opening areas of canopy cover should be less than 400 m^2 in beech forests of northern Iran with considering of soil properties.

Keywords: gap size, gap position, nutrient availability, earthworm, soil.

Introduction

Beech (*Fagus orientalis* Lipsky) is one of the most important forest species in the temperate broad - leaf forest biome and represents an outstanding example of the re - colonization and development of terrestrial ecosystems and communities after the last ice age, a process which is still ongoing (MOSADEGH, 2000; MARVIE MOHADJER, 2007). In the north of Iran, pure and mixed oriental beech forests cover 17.6 per cent of the surface land area and represent 30 per cent of the standing biomass. Beech is the most valuable wood – producing species in the Caspian forests (RESANEH *et al.*, 2001). The beech trees are found in small groups up to 500 m a.s.l. while individuals have been reported from 110 m up to 2650 m. At low altitudes, they occur mixed with hornbeam (*Carpinus betulus* L.) (MARVIE MOHADJER, 2007).

Disturbance is ubiquitous in forest ecosystems. Defined as "any relatively discrete event in time that disrupts ecosystems, community or population structure and changes resources, substrate availability, or the physical environment", disturbance determines forest species composition, structure, and process. Furthermore, disturbances exert their influence over a wide range of temporal and spatial scales. This disturbance, in turn, promotes changes in resource fluxes, changes that lead to some form of reorganization of the disturbed patch or gap at structural and functional levels that may be similar or dissimilar to pre - disturbance levels. Resource levels and inputs are changed and species respond accordingly (MCCARTHY, 2001; SAMONIL *et al.*, 2009; JONASOVA *et al.*, 2010; KATHKE & BRUELHEIDE, 2010).

In Iran beech forests, formation of gaps by wind throw is a characteristic natural disturbance event. Gap size varies greatly from the size of only a single crown to vast open fields with diameters of many tree lengths. However, changes in abiotic and biotic conditions depend both on gap size and within - gap position (HOLEKSA, 2003; KWIT & PLATT, 2003). Consequently, it is not easy to predict how soil properties react to gap formation. Disturbances caused by canopy gaps received much attention in the last decades and they are regarded as important factors in forest dynamics. Canopy openings as a result of tree falls create an environment different from the adjacent forest, which influences plant regeneration. In addition, gap processes partly determine forest structure and play an important role to maintain plant species richness. Thus, the creation of gaps in forests is an opportunity for the system to change in both species dynamics and ecological processes (MUSCOLO *et al.*, 2007).

Although it is recognized that gaps modify soil resources, few studies have focused on below - ground processes (GRAY *et al.*, 2002). Soil processes are controlled by a set of relatively independent state factors (climate, organisms, relief, parent material and time) and by a group of interactive controls (e.g., disturbance regime and human activities) (JENNY, 1994). Forest gaps are examples of natural interactive controls with direct impacts on state factors (e.g., climate and organisms). Forest gaps represent dramatic top - down trophic interactions between vegetation and the soil microbial - mediated processes (SCHARENBROCH & BOCKHEIM, 2007).

Most studies of gaps have addressed vegetation dynamics, regeneration through seedling establishment, effects of microclimate variables on the regeneration and, in general have concentrated on aboveground processes (RITTER *et al.*, 2005; MUSCOLO *et al.*, 2007). Relatively few studies have addressed belowground effects of canopy gaps on soil chemical and biochemical properties. Thus, the objectives of this study were to examine the impacts of small, medium, large and very large gaps on soil properties, a "sink" and "source" of plant nutrients in beech - hornbeam stands in northern Iran. The present paper assesses experimentally the effects of gap creation on soil nutrient supply. Specifically, the following hypotheses were tested: is gap size an important factor in controlling nitrogen mineralization, microbial respiration and consequently organic matter breakdown and nutrient amounts? The study included investigation of soil properties and biological activities about 4 years after gaps creation.

Material and methods

Site characteristics. This research was conducted in Tarbiat Modares University Experimental Forest Station located in a temperate forest of Mazandaran province in the north of Iran, between 36° 31′ 56″ N and 36° 32′ 11″ N latitudes and 51° 47′ 49″ E and 51° 47′ 56″ E longitudes. The maximum elevation is 1700 m and the minimum is 100m. Minimum temperature in December (6.6°C) and the highest temperature in June (25°C) are recorded, respectively. Mean annual precipitation of the study area were from 280.4 to 37.4 mm at the Noushahr city metrological station, which is 10 km far from the study area. For performing this research, 20 ha areas of reserve parcel (relatively undisturbed) considered that was covered by *Fagus orientalis* and *Carpinus betulus* dominant stands. This limitation had an inclination 60 - 70 percent with northeast exposure at 546 - 648 m a.s.l.

Bedrock is limestone - dolomite with sandy - clay - loam soil texture. Presence of logged and bare roots of trees is indicating rooting restrictions and soil heavy texture (ANONYMOUS, 2002). The current study is based on several wind throw events in the experimental forest station in during 2005 to 2006.

Gap selection. In the summer of 2009, twenty hectare areas of Tarbiat Modares University Experimental Forest Station were considered. Geographical position and all of canopy gaps were recorded by Geographical Position System (GPS). Gaps required a minimum canopy opening of 30 m^2 and trees growing in the gap to be less than two thirds the height of the closed adjacent forest (RUNKLE, 1992). Canopy gaps areas were measured in the field according to RUNKLE (1992). Sampling protocol was built up by locating and measuring two perpendicular lines in each gap: one along the longest line visible and one perpendicular to it at the widest section of the gap.

Soil sampling and analysis. For this purpose, three positions were distinguished including gap center, gap edge and closed canopy. Soil samples were taken at 0 - 15, 15 - 30 and 30 - 45cm depths from all positions using core soil sampler with 81cm^2 cross section (RAHMANI & ZARE MAIVAN, 2004). Roots, shoots and pebbles in each sample were separated by hand and discarded. The air - dried soil samples were sieved (aggregates were crushed to pass through a 2 mm sieve) to remove roots prior to chemical analysis. Soil pH was determined using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. Soil organic carbon was determined using the Walkey - Black technique (ALLISON, 1975). The total nitrogen was measured using a semi Micro - Kjeldhal technique (BREMNER & MULVANEY, 1982). The available P was determined with spectrophotometer by using Olsen method (HOMER & PRATT, 1961). The available K and Ca (by ammonium acetate extraction at pH 9) were determined with Atomic absorption spectrophotometer (AAS) and Cation Exchange Capacity (CEC) with flame photometer (BOWER *et al.*, 1952). Soil microbial respiration was determined by measuring the CO_2 evolved in 3 days incubation experiment at 25°C, in which 50 g of each soil samples (remoistened to 55% its water holding capacity) were placed in a glass jar. Glass vial holding 10 ml of 0.5 M NaOH was placed in the glass jar to trap the evolved CO_2. The excess alkali, after precipitating the CO_3^{2-} with 0.5 M $BaCl_2$ solution was titrated with standard 0.5 M dequate HCl to a phenolphthalein end point (ALEF, 1995).

Kinetic of nitrogen mineralization was measured using a laboratory incubation procedure under controlled conditions by 100 g of each soil samples. Soil samples were with moisture up to 55% of its water holding capacity. The containers were closed tightly and kept in the dark in a temperature - controlled chamber at 25°C. The samples were re-aerated weekly for adequate oxygen supply. Nitrogen mineralization was estimated from the increase KCl extractable inorganic N after incubating soil samples for 56 days. Initial inorganic N (NO_3-N and NH_4-N) was analyzed before incubation using the steam distillation method (BREMER, 1965) after extraction with 1 M KCl for 2 h (soil: extracting ratio of 1:5). Final inorganic N (NO_3-N and NH_4-N) concentrations were measured at the end of incubation on day 56. Net N-mineralization was calculated by subtracting initial mineral N from final mineral N for each sample (ROBERTSON *et al.*, 1999). The earthworms were collected simultaneously with the soil sampling by hand sorting, washed in water and weighed with milligram precision. Biomass was defined as the weight of the worms after drying for 48 hours on filter paper at oven (60˚C) (EDWARDS & BOHLEN, 1996).

Statistical analysis. Normality of the variables was checked by Kolmogrov - Smirnov test and Levene test was used to examine the equality of the variances. Differences between gap different areas, gap positions and soil depths in soil characteristics were tested with three - way analysis (ANOVA) using the GLM procedure, with areas (small, medium, large and very large), positions (gap center, gap edge and closed canopy) and depth (0 - 15, 15 - 30 and 30 - 45 cm) as independent factor. Interactions between independent factors were tested also. Duncan test was used to separate the averages of the dependent variables which were significantly affected by treatment. Significant differences among treatment averages for different parameters were tested at P≤ 0.05. SPSS v.11.5 software was used for all the statistical analysis.

Results

Canopy gap characteristics. Twenty one canopy gaps with different areas were detected in study site (Table 1). Gaps classified in four classes: four gaps in 30 - 200 m^2 area class (small gap with area mean of 85.12 m^2), five gaps in 200 - 400 m^2 area class (medium class with area mean of 325.21 m^2), eight gaps in 400 - 600 m^2 area class (large class with area mean of 512.11 m^2) and four gaps in more than 600 m^2 area class (very large class with area mean 723.85 m^2). Result is indicating the most present gaps in study area have 300 - 500 m^2 area.

Table 1. Characteristics of canopy gaps in study area

Gap class (m^2)	Gap number	Gap area mean (m^2)	Minimum and maximum of gap area (m^2)
30 – 200	4	85.12	40.11 – 130.13
200 – 400	5	325.21	260.12 – 390.30
400 – 600	8	512.11	435.22 – 589
> 600	4	723.85	626.12 – 821.58

Soil properties. Soil pH was significantly (P < 0.01) higher in very large and large gaps in comparison to small and medium gaps (Table 2 and Fig. 1). The highest value of this character was detected in gap center position and deeper layers of soil (Table 2 and Fig. 1). Organic matter and carbon significantly (P < 0.01) increased with increasing size of the gaps, decreased with soil depth and from gap center to closed canopy (Table 2; Fig. 2 and 3). Greater amounts of carbon to nitrogen ratio were found in medium gap, closed canopy position and deeper layers of soil, significantly (P < 0.01) (Table 2 and Fig. 4). The greatest value of cation exchange capacity (CEC) resulted in small gap, closed canopy and gap edge position and beneath layers of soil. Significantly statistical differences (P < 0.01) were considered for this character (Table 2 and Fig. 5).

Compare mean of total nitrogen in the gap size indicated that large and very large gaps had the higher amounts (P < 0.01) than in the small and medium gaps. Gap center position and upper layer of soil had the greatest value of this character in comparison to the other positions and depth (Table 2 and Fig. 6). As can be seen in Table 2 and Fig. 7, the available P was significantly (P < 0.01) greater in medium gaps, gap center position and the 0 – 15 cm depth than in the other treatments. Medium gaps, gap center with gap edge position and the first soil depth devoted in the highest amounts (P < 0.01) of available K (Table 2 and Fig. 8), whereas the maximum available Ca (P < 0.01) was detected in medium gap, gap center position and soil upper layers (Table 2 and Fig. 9).

Gap sizes, position and soil depths were significantly (P < 0.01) different in terms of nitrogen mineralization. As Table 2 and Fig. 10 shows, its maximum values were detected in very large gaps, gap center position and soil upper layers. The similar results was observed in soil microbial respiration as the greatest values (P < 0.01) devoted in very large and large gaps, gap center position and upper layers of soil (Table 2 and Fig. 11). Earthworm density showed descending trend from small gap to very large and significantly statistical differences (P < 0.01) were detected (Table 2 and Fig. 12). The assemblage of earthworms was more in closed canopy (P < 0.01) and 30 – 45 cm depth (P < 0.05) than in the other position and depths (Table 2 and Fig. 12). Earthworm different biomass was found in gap area classes, positions and soil layers depending on earthworm density changes. Biomass decreased (P < 0.01) towards the greater areas of canopy openings (Table 2 and Fig. 13). Closed canopy position and soil deeper layers devoted in the greatest value (P < 0.01) of earthworm biomass (Table 2 and Fig. 13).

Table 2. Three - way analysis of soil properties in gap different areas, positions and soil depths.

Soil chara-cter	Variables source	F - Value
pH	Gap area	199.67**
	Gap position	964.59**
	Soil depth	3.39*
	Gap area × Gap position	54.63**
	Gap area × Soil depth	0.05 ns
	Gap position × Soil depth	0.20 ns
	Gap area × Gap position × Soil depth	0.05 ns
Organic matter (%)	Gap area	211.19**
	Gap position	1064.95**
	Soil depth	94.09**
	Gap area × Gap position	50.88 **
	Gap area × Soil depth	0.72 ns
	Gap position × Soil depth	0.42 ns
	Gap area × Gap position × Soil depth	0.45 ns
Organic carbon (%)	Gap area	209.45**
	Gap position	1063.77**
	Soil depth	92.65**
	Gap area × Gap position	50.50**
	Gap area × Soil depth	0.74 ns
	Gap position × Soil depth	0.43 ns
	Gap area × Gap position × Soil depth	0.43 ns
Carbon to nitrogen ratio	Gap area	13.35**
	Gap position	176.26**
	Soil depth	130.45**
	Gap area × Gap position	5.69**
	Gap area × Soil depth	0.58 ns
	Gap position × Soil depth	2.30 ns
	Gap area × Gap position × Soil depth	0.44 ns
CEC (cmol (+) kg-1)	Gap area	8.27**
	Gap position	9.54**
	Soil depth	16.92**
	Gap area × Gap position	5.32**
	Gap area × Soil depth	1.00 ns
	Gap position × Soil depth	20.78**
	Gap area × Gap position × Soil depth	1.16 ns
Total nitrogen (%)	Gap area	68.29**
	Gap position	526.92**
	Soil depth	211.74**
	Gap area × Gap position	24.40**
	Gap area × Soil depth	0.48 ns
	Gap position × Soil depth	1.89 ns
	Gap area × Gap position × Soil depth	0.50 ns
Ava…	Gap area	32.69**
	Gap position	20.36**
	Soil depth	5.54**
	Gap area × Gap position	3.67**
	Gap area × Soil depth	0.06 ns
	Gap position × Soil depth	0.14 ns
	Gap area × Gap position × Soil depth	0.20 ns
Available K (mg/kg)	Gap area	14.88**
	Gap position	5.42**
	Soil depth	4.80**
	Gap area × Gap position	1.54 ns
	Gap area × Soil depth	0.05 ns
	Gap position × Soil depth	0.07 ns
	Gap area × Gap position × Soil depth	0.03 ns
Available Ca (mg/kg)	Gap area	12.26**
	Gap position	34.63**
	Soil depth	24.92**
	Gap area × Gap position	11.48**
	Gap area × Soil depth	0.17 ns
	Gap position × Soil depth	0.07 ns
	Gap area × Gap position × Soil depth	0.17 ns
Nitrogen mineralization (mg N kg^{-1} soil)	Gap area	20.56**
	Gap position	181.27**
	Soil depth	49.41**
	Gap area × Gap position	9.02**
	Gap area × Soil depth	0.92 ns
	Gap position × Soil depth	0.90 ns
	Gap area × Gap position × Soil depth	1.85*
Soil microbial respiration (mg co_2-c/gr	Gap area	52.04**
	Gap position	453.32**
	Soil depth	180.16**
	Gap area × Gap position	23.23**
	Gap area × Soil depth	0.43 ns
	Gap position × Soil depth	1.38 ns
	Gap area × Gap position × Soil depth	0.58 ns
Earthworm density (number/m^2)	Gap area	28.70**
	Gap position	66.72**
	Soil depth	4.31**
	Gap area × Gap position	2.89**
	Gap area × Soil depth	1.10 ns
	Gap position × Soil depth	1.16 ns
	Gap area × Gap position × Soil depth	1.79 ns
Eartworm biomass (mg/m^2)	Gap area	26.78**
	Gap position	69.85**
	Soil depth	5.23**
	Gap area × Gap position	2.86*
	Gap area × Soil depth	0.77 ns
	Gap position × Soil depth	1.81 ns
	Gap area × Gap position × Soil depth	1.60 ns

** Different is significant at the 0.01 level. *Different is significant at the 0.05 level. (ns): Non significant differences ($P > 0.05$).

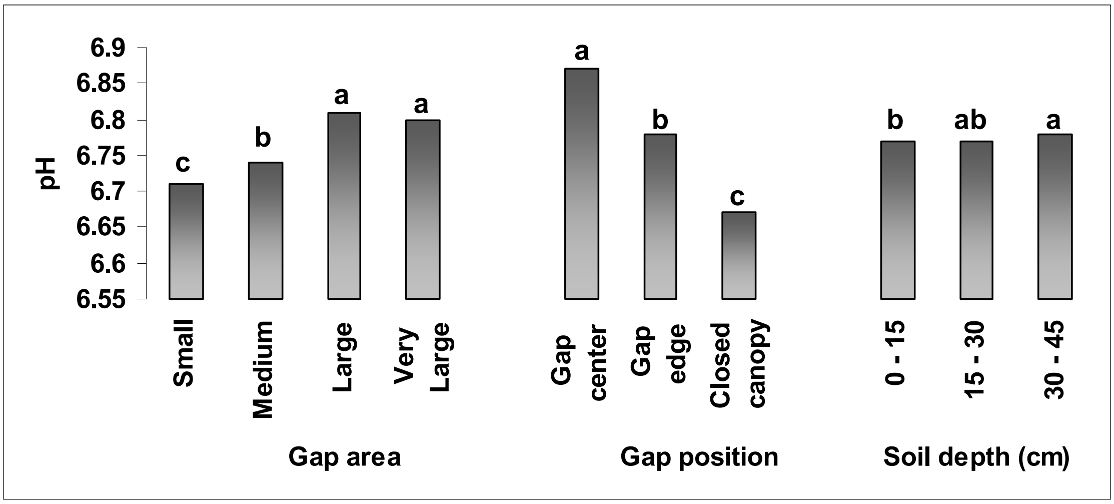

Fig. 1. Mean of soil pH in gap different areas, gap positions and soil depth

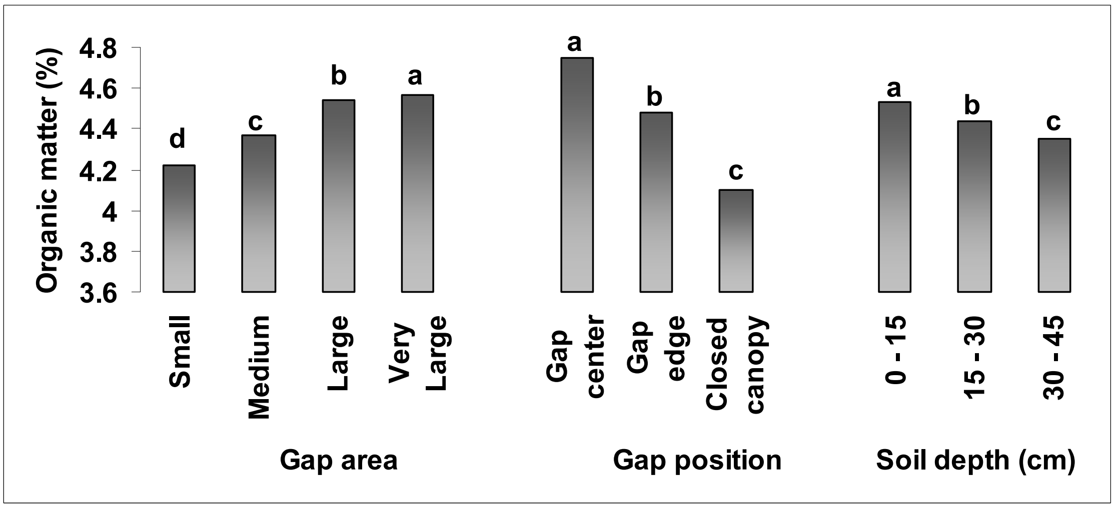

Fig. 2. Mean of soil organic matter in gap different areas, gap positions and soil depth

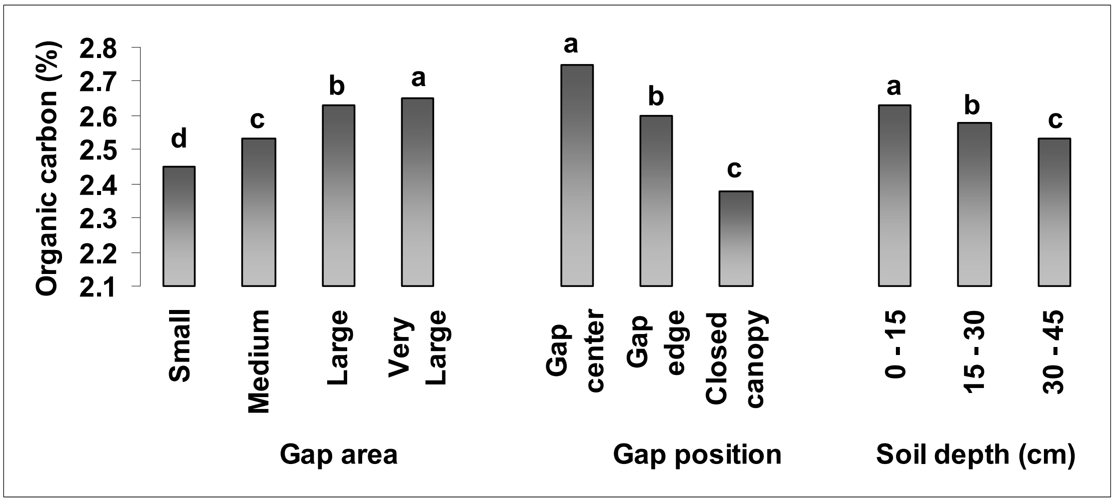

Fig. 3. Mean of soil organic carbon in gap different areas, gap positions and soil depth

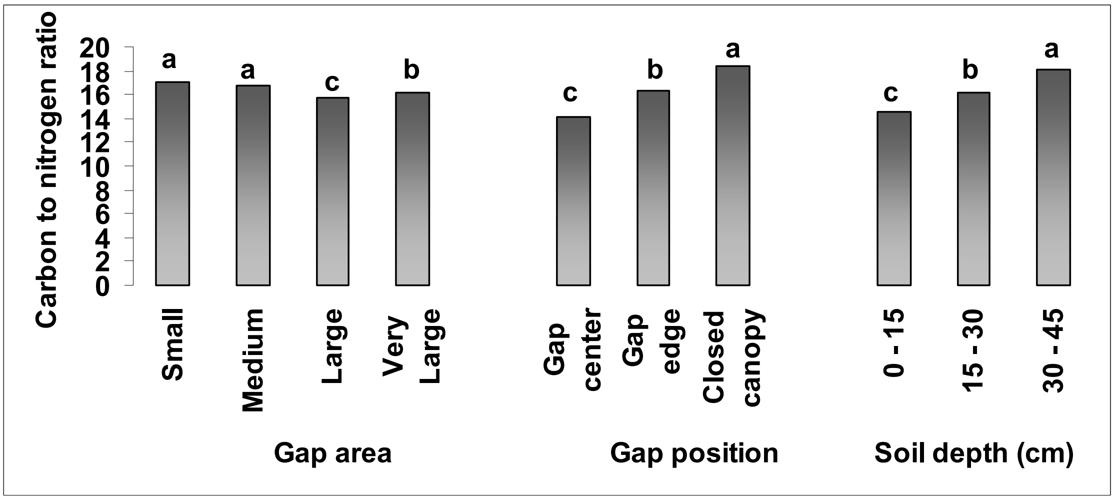

Fig. 4. Mean of soil C/N ratio in gap different areas, gap positions and soil depth

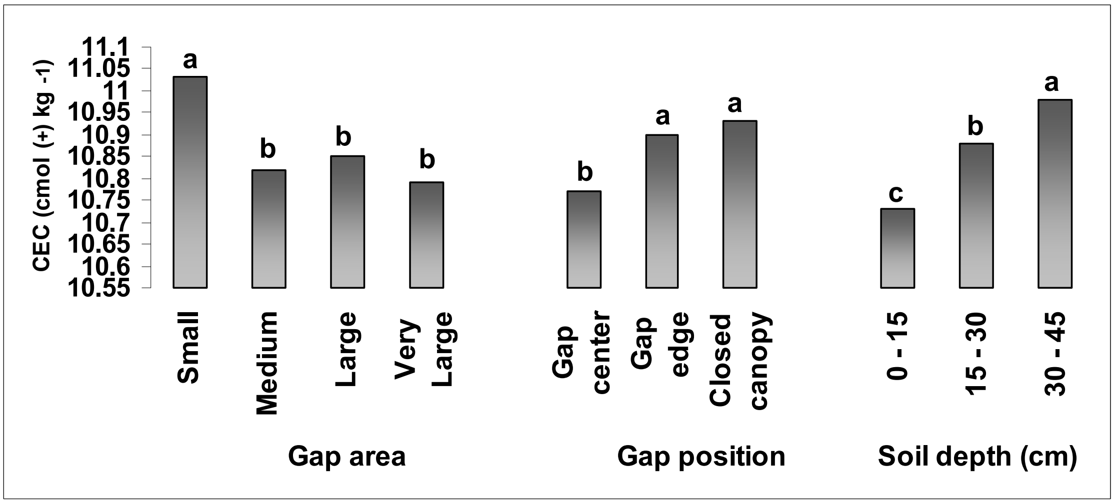

Fig. 5. Mean of soil CEC in gap different areas, gap positions and soil depth

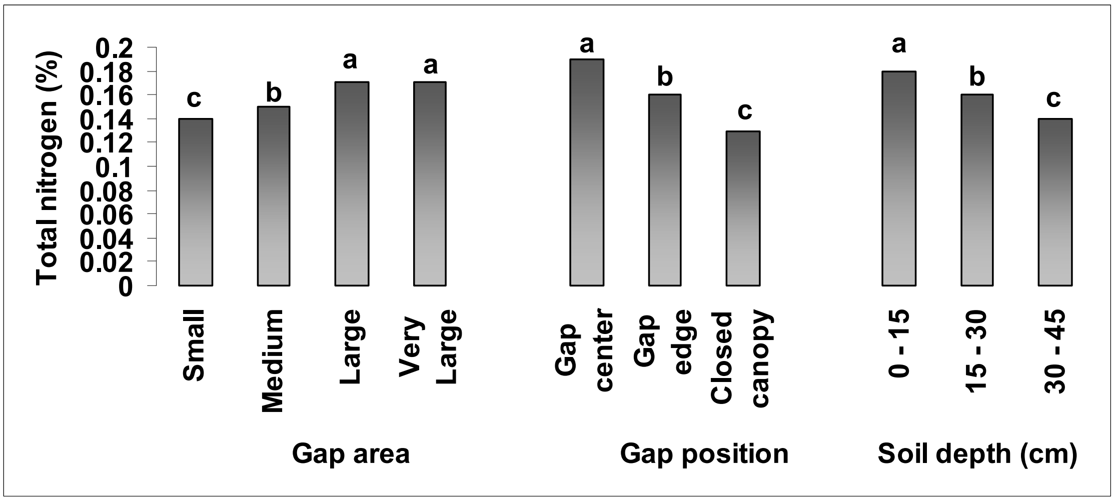

Fig. 6. Mean of soil total nitrogen in gap different areas, gap positions and soil depth

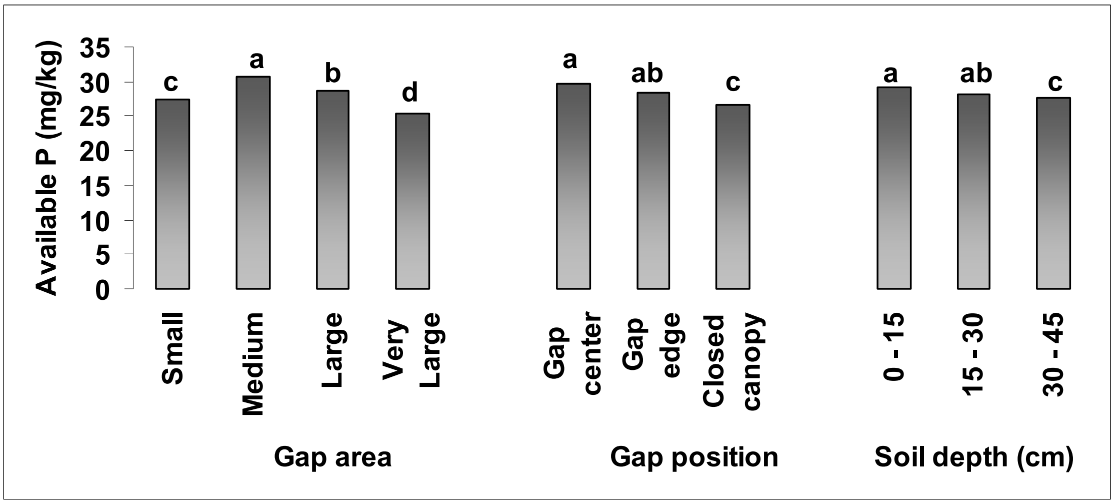

Fig. 7. Mean of soil available P in gap different areas, gap positions and soil depth

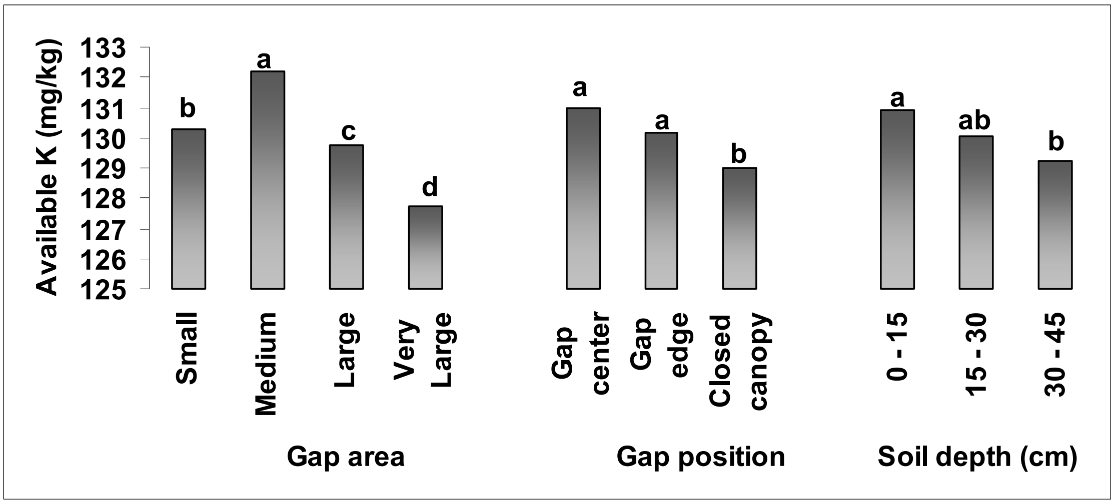

Fig. 8. Mean of soil available K in gap different areas, gap positions and soil depth

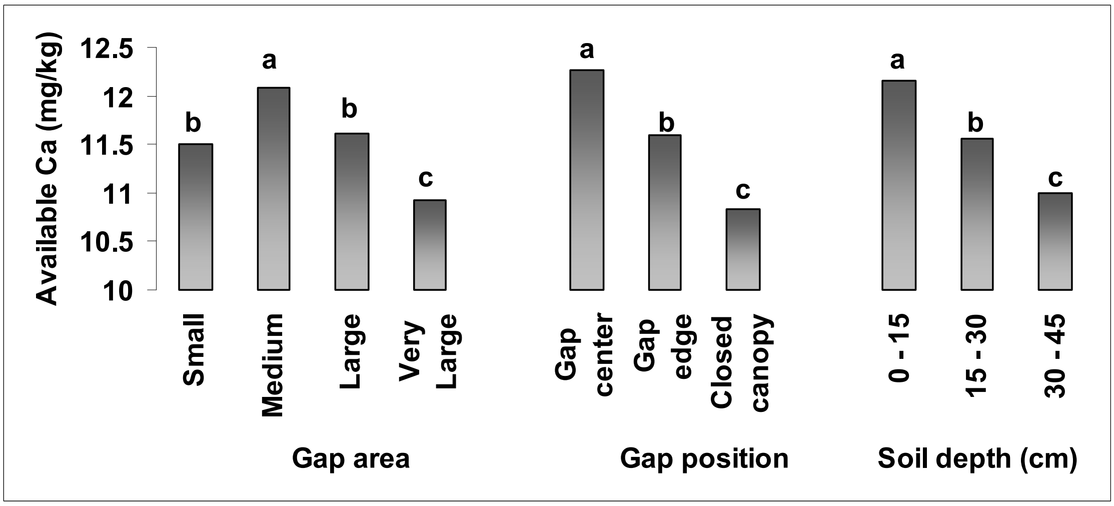

Fig. 9. Mean of soil available Ca in gap different areas, gap positions and soil depth

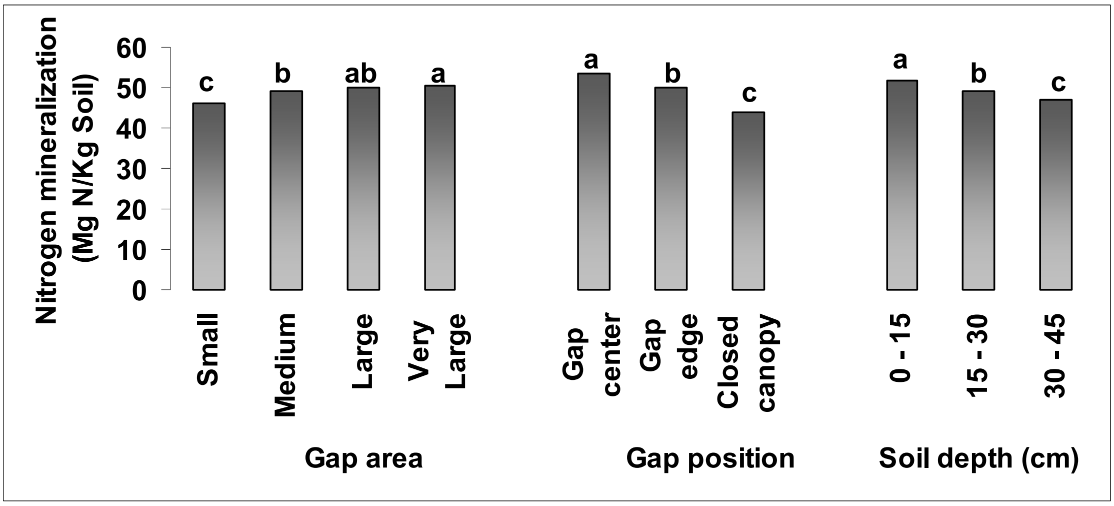

Fig. 10. Mean of nitrogen mineralization in gap different areas, gap positions and soil depth

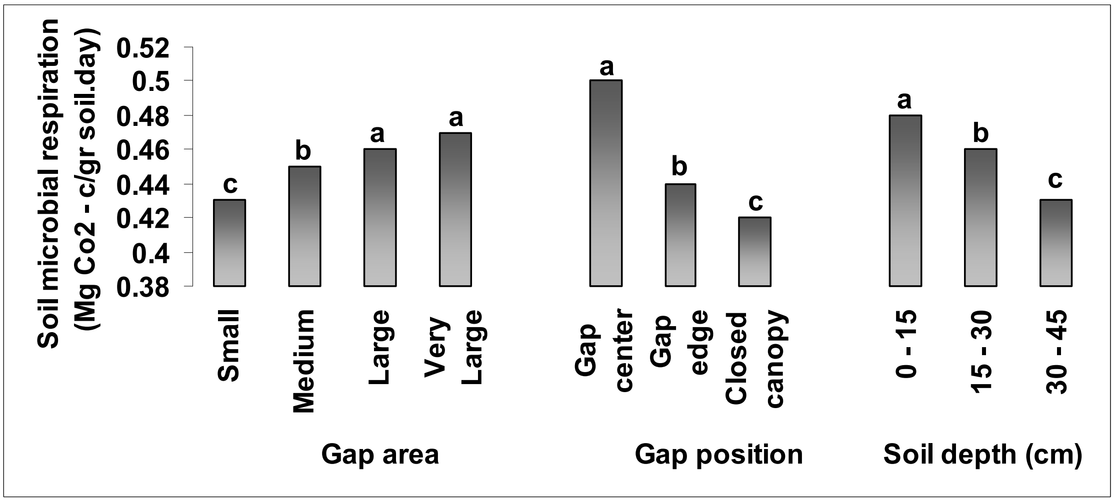

Fig. 11. Mean of soil microbial respiration in gap different areas, gap positions and soil depth

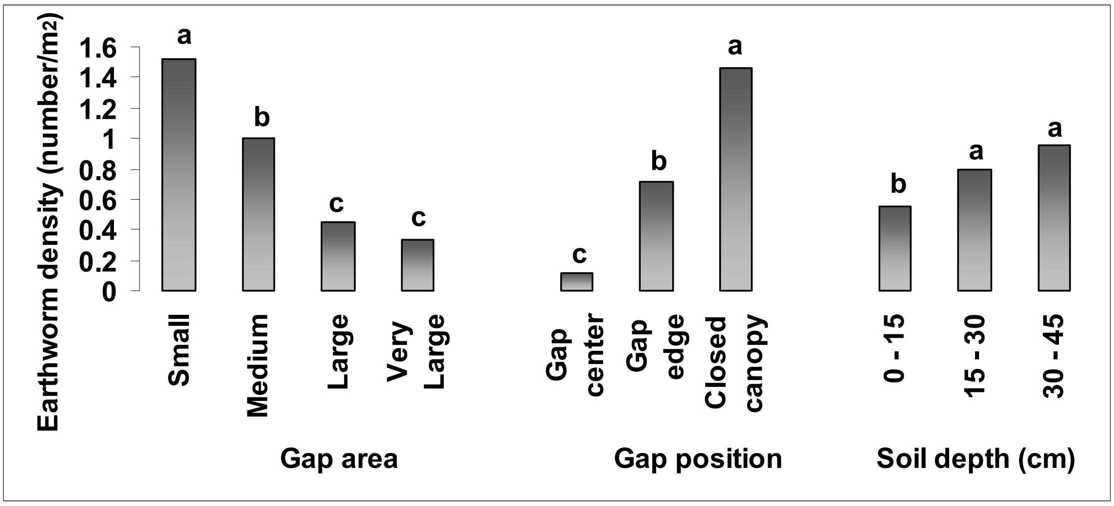

Fig. 12. Mean of earthworm density in gap different areas, gap positions and soil depth

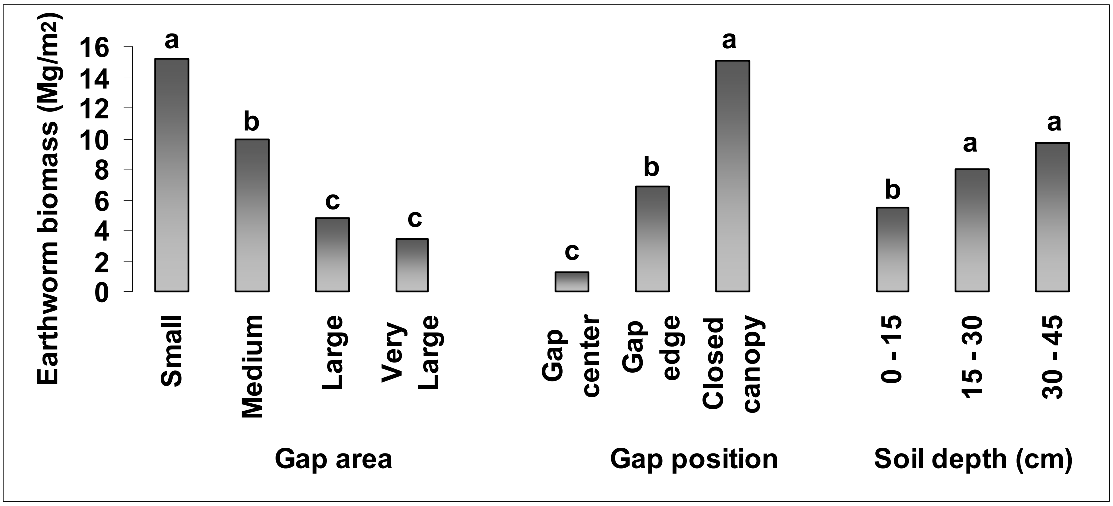

Fig. 13. Mean of earthworm biomass in gap different areas, gap positions and soil depth

Discussion

Soil pH. The result is indicating that large and very large gaps, gap center and 30 - 45 cm depth had greater pH than in the other gap size, position and depths. Soil acidification often occurs with NO^{3-} leaching and nitrification (GUNDERSEN & RASMUSSEN, 1990); thus, it is unlikely gap disturbance have a role in acidification of these forest soils through $NO3^{-}$ leaching or increased nitrification (GUNDERSEN & RASMUSSEN, 1990). Small gaps tended to have lower amounts of soil pH that can be related to presence complexes of sustain organic acids as in gaps with more openings these complexes are leaching from soil upper layers. Thus, gap larger areas tended to have higher pH. Similar status can be considered in different positions of gaps as in gap center leaching of acid complexes more occurred and soil pH is increased. SCHARENBROCH & BOCKHEIM (2007) detected no significant differences in soil pH character for gap different areas. SCHARENBROCH & BOCKHEIM (2008) studied the soil pH amounts in different positions of gaps. Theirs research result is indicating soil pH had no significant differences among gap center, gap edge and closed canopy. Soil pH higher amounts in soil deeper layers can be related to lower values of organic matter in soil beneath depths as inversely relation found between these characters (NOURBAKHSH *et al.*, 2003; YASREBI *et al.*, 2003).

Organic matter and carbon. The highest values of these characters found in very large gaps, gap center and soil upper layers and significant differences were considered. Density and particle size separations isolate district soil organic matter pools for relating stabilization and turnover of carbon in soil (ELLIOT & CAMBARDELLA, 1991; GREGORICH & ELLERT, 1993; SIX *et al.*, 2002). Soil organic matter associated with silt and clay particles are considerably more recalcitrant, with turnover times ranging from 400 to 1000 years (JENKINSON & RAYNER, 1977; PARTON *et al.*, 1988; BUYANOVSKY *et al.*, 1994). Soil microbial biomass is a mediator of carbon turnover (PAUL & JUMA, 1981) and is essential as both a flow and source of plant nutrients (SINGH *et al.*, 1989). The microbial biomass reflects long term quantitative and qualitative carbon inputs in soil (MCGILL *et al.*, 1986; INSAM & DOMSCH, 1988). In this research by reason presence of clay higher amounts in soil texture (result is unpublished) and microbes assemblage and density (with considering microbial respiration values), the organic matter amounts were more considerable in large gaps. Soil upper layers had more organic matter contents regarding near to litter sources and plant residuals. However, gap dynamics may be important in explaining discrepancies in theories suggesting old growth forests are inconsequential carbon sinks (for example, ODUM, 1969, 1985) or are actively accumulating carbon (BUCHMANN &

SCHULZE, 1999; ZHOU *et al.*, 2006). SCHARENBROCH & BOCKHEIM (2007) reported the canopy gaps effects on soil organic matter character was non significant.

Total nitrogen. The most values of total nitrogen found in gap large, gap center and soil upper layers. RITTER *et al.* (2005) also found that soil solution nitrate concentrations and nitrate losses were increased as a result of forest gaps. In Rocky Mountain coniferous forests, PARSONS *et al.* (1994a, b) found that the removal 15 - 30 trees together represented a threshold above which significant losses of available nitrogen to groundwater may be incurred. Of course, in this research the similar status can be occurred with formation of more opening areas. Many researchers (PRESCOTT *et al.*, 2003; RITTER *et al.*, 2005) observed the non significant effects gap different areas on soil nitrogen character. SCHARENBROCH & BOCKHEIM (2008) claimed that canopy gaps are susceptible to nitrogen leaching less, thus the amounts of this character is less in opening areas soil than in closed canopy. Changes in nitrogen uptake, microclimate (e. g., increased radiation, temperature and moisture), and substrate associated with gaps effect significant influence on forest nitrogen dynamics. In general, increased organic matter decomposition and nitrogen mineralization and reduced root nitrogen uptake tends to favour leaching of inorganic nitrogen in gaps relative to the undisturbed closed forest (e. g., MLADENOFF, 1987; PARSONS *et al.*, 1994a; 1994b; BRUMME, 1995; ZHANG & ZAK, 1995; DENSLOW *et al.*, 1998). The indicators that have been used to indicate N -saturation include increased N deposition (JOHNSON & LINDBERG, 1992), increased nitrogen mineralization and nitrification (FOSTER *et al.*, 1989), high soil nitrogen accumulation with decreased soil C/N ratios (MCNULTY *et al.*, 1991; ABER, 1992), and increased NO^{3-}/NH^{4+} ratios in drainage waters (HEDIN *et al.*, 1995). Clear - cut studies suggest the peak nitrogen loss period to be 2 to 3 after the cutting with a return to pre - cut levels after 5 years (GUNDERSEN *et al.*, 2006). Although minimal, SCHARENBROCH & BOCKHEIM (2008) results show that nitrogen loss in these gaps, 6 - 9 years old, is significant relative to the closed forest. Likewise, PRESCOTT *et al.* (2003) found gaps in Canadian spruce - fir forests still had significant nitrogen loss 7 years after disturbance. RITTER & VESTERDAL (2006) claimed that nitrogen concentration in growth season is more in within gaps than to closed canopy. In present study similar results detected pay attention to this research carried out in summer season. But, it is assumed that nitrogen losses will occurred after removal of the forest cover on large areas. Plant diversity and regeneration in the gap was vigorously growing and the nitrogen demand of young trees is relatively high until canopy closure. Thus, reduction of nitrogen concentration at this site can be strongly effected in use by plants as a significant part of ecosystem nitrogen pool must be accumulated in the living biomass (MILLER, 1981). RITTER & VESTERDAL (2006) mentioned that it takes a long time for a reduction in solution nitrogen concentration to take place when regeneration in the gap develops slowly. A similar conclusion was also reached by BARTSCH (2000) for gaps in a German beech forest. In RITTER & VESTERDAL (2006) research, an increase in nitrogen concentration in the gaps in ALS Nqreeskov and Rude forest in the second year after gap formation indicates a delay in response to the disturbance. Increased nitrogen concentration in the gaps may partly be attributed to a lack of nitrogen uptake by regeneration or ground vegetation in the early years after gap formation, as also found by KNIGHT *et al.* (1991). Therefore, in our study after 3 - 4 years of gaps formation wasn't enough time for nitrogen uptake by regeneration and vegetation. RITTER & VESTERDAL (2006) also pointed in the advanced regeneration in the seventh year after gap formation was still not enough to reduce nitrogen concentrations significantly. We suspect that a long time is need to reduction of nitrogen concentrations in within gaps, significantly.

Carbon to nitrogen ratio. The highest value of this character detected in small and medium gaps, closed canopy position and the third depth. With considering the greatest amounts nitrogen observed in large, very large gaps and soil upper layers, thus greater C/N ratio found in small gap and soil deeper layer depending to carbon and nitrogen amounts.

Cation exchange capacity (CEC). This character was significantly greater in small gap, closed canopy and the third depth. Clay percent content in soil texture can be effective on cation exchange capacity amounts. The highest value of clay was detected in small gap, closed canopy position and deeper layers of soil (result is unpublished). Thus, cation exchange capacity increased in these treatments following more clay presence. SCHARENBROCH & BOCKHEIM (2007) resulted that gap positions (gap center, gap edge and closed canopy) had non significant effects on cation exchange capacity value. But, fewer amounts were observed in gaps than to closed canopy.

Available P, K and Ca. Medium gaps, gap center and upper soil had the greatest amounts of base cations. In general, solar radiation will increased with increasing of canopy opening areas that is due to accelerating decomposition of litters. But if the opening be very large, decrease in base cations in gaps is likely a result of leaching losses. SCHARENBROCH & BOCKHEIM (2007) reported the leaching is the most important reason for decrease of base cations in within gaps. Their results suggest an increased nutrient leaching potential as a result of relatively large (300 - 2000 m^2) gaps in old growth northern hardwood - hemlock forests. The results of current research is indicating that base cations leaching potential increased with expanding of canopy opening areas from medium to large; thus soil is poor of nutrient elements in large canopy gaps. This important should be considered in forest management and trees marking for utilization to prevent of gaps formation with large opening areas. Furthermore, plant diversity will increased with increasing of opening areas in canopy gaps (SHURE et al., 2006) that is observed in study area, also. On the other hand, nutrient retention is dependent upon the balance between inputs (atmospheric deposition, gas adsorption/fixation), transformations (mineral weathering, mineralization of soil organic matter), and outputs (soil leaching and volatilization) (BRUIJNZEEL, 1991; LESACK & MELACK, 1996). Canopies tend to enhance nutrient concentrations of incident precipitation (PARKER, 1983; LINDBERG & OWNES, 1993). There is a strong negative relation in nutrient elements with the amounts of precipitation. Total nutrient deposition, on the other hand, is positively related to precipitation amounts (PARKER, 1983). Therefore, leaching potential of soil nutrient will increased with expanding canopy gaps. Removal of canopy cover is generally known to increase water drainage and stream flow. This is reported from thinning, clear -fallings and gap formation (e.g. KNIGHT *et al.*, 1991; LESCH & SCOTT, 1997) and is also supported by the present study. In a study in a heterogeneous forest with mixed tree species, ZIRLEWAGEN & VON WILPERT (2001) emphasised the role of small - scale structural variation. They found crown interception to be a main factor reducing water fluxes, while crown gaps increased water fluxes. These effects were enhanced by variable root densities and thus water uptake. An influence of the forest structure (canopy, roots), tree sizes, species composition, soil properties and soil solution chemistry was reported in other studies (KOCH & MATZNER, 1993; BEIER, 1998), and hyrcanian forests of Iran are characterized by high variability in most of these parameters.

Nitrogen mineralization. The maximum values of nitrogen mineralization observed in very large gaps, gap center and 0 - 15 cm depth. Decomposition and mineralization tend to increase where smaller, non-occluded substrates that are low in resistant compounds (e.g., lignin), and high in available nitrogen are present (i.e., C/N ratio) (WAGNER & WOLF, 1998). Through the loss of canopy trees and subsequent alteration of the existing vegetation dynamics (e.g., BUSING & WHITE, 1997;

WEBSTER & LORIMER, 2002), gaps likely also impact the microbial substrate. Through top - down trophic interactions, gaps alter the soil environment and substrate for microbial - mediated processes. In current study, carbon and nitrogen amounts created a condition that is due to increasing of nitrogen mineralization in mentioned treatments. However, organic matter decomposition and nutrient mineralization may be greater in gaps than in the closed forest (MLADENOFF, 1987; PARSONS *et al.*, 1994a, b; ZHANG & ZAK, 1995; BRUMME, 1995; DENSLOW *et al.*, 1998) that is according to results of this research. SCHARENBROCH & BOCKHEIM (2007) resulted that nitrogen mineralization was significantly greater in gap center and edge positions in compare to closed canopy. BAUHUS (1996) found that nitrogen mineralization decreased with time in gaps relative to the forests, and hypothesized that mineralizable substrate had been depleted under gap conditions. Of course, the decrease of nitrogen mineralization is predicted in this research also. But, this decrease isn't logical by reason of substrate depleting. Because of with considering presence of deciduous broad leaved trees (leaf litter fall) in studied ecosystem, very much litters gathered in forest floor every year that are as pool of nutrition elements for mineralization. But, reduction of nitrogen mineralization is related to decreasing intensity solar radiation within gaps with gradual closing of opening areas in along time. RITTER & VESTERDAL (2006) pointed that gap disturbance is due to increasing of nitrogen mineralization in forest ecosystems that is according to this research. It was found the impacts on nitrogen mineralization decreased from the forest floor to the upper mineral soil by reason decreasing of substrate content to soil deeper layers.

Microbial respiration. This character was significantly greater in very large gaps, gap center and 0 -15 cm depth. Microbial processes are regulated by a variety of substrate and environmental conditions. Microbial activity generally increases with adequate soil moisture and aeration, warmer soil temperatures (optimum of 30 – 45°C), and a near - neutral soil pH to allow for diverse active microbial populations (WAGNER & WOLF, 1998). It is imagined that these conditions are more appropriate in very large gaps, gap center position and soil upper layers in site area that is due to gathering of different microbes and increasing of soil microbial respiration amounts. The effects gaps have on microclimate are important as solar radiation, soil moisture, and soil temperature have direct impacts on soil microbial processes (WAGNER & WOLF, 1998). SCHARENBROCH & BOCKHEIM (2007) recognized that gaps modify soil resources and create an appropriate condition for microbes different activity that is confirming results of current study. In contrast, gaps can also adversely affect microbial activity and biomass through dramatic temperature increases (ZHANG & ZAK, 1995; ARUNCHALAM *et al.*, 1996). Of course, greater microbial respiration in gap location in compare to closed canopy is indicating appropriate condition for activity of microbes. BAUHUS & BARTSCH (1995) and also SCHARENBROCH & BOCKHEIM (2007) observed that microbial activity increased in gaps, likely due to microclimate changes. In addition, gap microbial activity is negatively impacted as a result of decreased substrate availability. They believed that gap edges may represent regions of optimal microclimate and substrate availability for microbial - mediated processes. But, in current study pay attention to presence of broad leaved trees, the shortage of substrate isn't visible and microclimate condition is appropriate for microbe's activity within gaps. Thus, we suspect that within gap (especially gap center) has more appropriate conditions for different microbes activities as microbial respiration was increased in this position. BAUHUS & BARTSCH (1995) found leaf litter fall in gaps to be 75% of the adjacent closed beech forest. Although, litters mass is fewer in within gap than in closed canopy, but intensity solar radiation is greater in within gap that is due to more accelerate decomposition of litters. Thus, greater available nutrient elements are gathered in within gap that can be used by microbes. Disturbances influence the microbial community locally through microclimate change (MCGILL *et al.*, 1986; INSAM *et al.*, 1989), and temperature and moisture are positively correlated with microbial activity (BUNNELL et al., 1977). The soil microbial biomass responds more quickly to disturbance than does the amount of organic matter in the soil (INSAM & DOMSCH, 1988) thus, it can be more sensitive index in disturbances of forest ecosystems (ANDERSON & DOMSCH, 1989). BAUHUS (1996) found a substantial decrease in microbial biomass in the gap center compared to gap edge and found equal microbial biomass in the forest and gap edge. The other research showed that with gap disturbance it is expected that soil bacteria will increase and fungi decrease (BRADY & WEIL, 2002; COLEMAN *et al.*, 2004).

Earthworm density and biomass. These characters were significantly greater in small gaps, closed canopy position and soil lower layers. The most important effective factors can be soil higher moisture and lower temperature in small gaps (SALEH RASTIN, 1978). Almost, 80 to 90 % of earthworms live weight is water, thus soil moisture is essential for their life and will kill them (SALEH RASTIN, 1978). Furthermore, soil moisture amounts have descending trend with increasing of canopy gaps but soil temperature has ascending trend (SCHARENBROCH & BOCKHEIM, 2007). Thus, earthworm density and biomass is decreased with increasing of canopy cover opening areas by reason of soil moisture reduction and increase of temperature. As similar, closed canopy position has greater soil moisture and less temperature in compare to the other positions. Therefore, this position created more appropriate condition for gathering of earthworms. Gap edge has medium condition for assemblage of earthworms than to gap center and closed canopy. In general, low moisture and high temperature created fatal conditions for earthworms (NACHTERGALE *et al.*, 2002) in gap center. Earthworms (especially endogeic) are able to migration more beneath layers and avoid of soil drought, especially in summer season (HALE & HOST, 2005). Thus, earthworms were gathered in soil lower layers in this research with considering weather heating in growth season (summer).

Conclusion

Forest gaps irregularly affect the availability degree of materials and micro region resources, soil and the site. The existence of the above - mentioned factors are changeable in time and place. The purpose of the present study was recognizing the appropriate way in forest management that prevents the wasting of materials and sources in forest ecosystems. So, it is clear that using the gaps in medium area is an appropriate guideline to maintain the balance in cycle of food materials and the climatic factors of temperature, moisture and transmittance light especially in temperate ecosystems. In conclusion, within the range of gap sizes included in this study, results have shown that gap size is effective on soil chemical and biochemical. However, on the basis of the results, we believe that the creation of medium gaps (200 - 400 m^2) may be important from an ecosystem perspective representing the appropriate management procedures for an adequate conservation of ecological functions, capable to preserve soil properties and favour beech natural regeneration. Since this study was not replicated across a range of site types, we cannot generalize our conclusion. We hope that these results will be tested in a replicated study to determine whether they are general. We believe that such a study in different natural forest could be conducted using the set of measurements and the analytical tools we have presented.

References

ABER J. D. 1992. Nitrogen cycling and nitrogen saturation in temperate forest ecosystems. - *Trends Ecological Evolution*, 7: 220–223.

ALLEF K. 1995. Estimating of soil respiration. - In: Alef, K., P. Nannipieri (Eds.). *Methods in soil microbiology and biochemistry,* Academic Press, New York, pp. 464–470.

ALLISON L. E. 1975. Organic carbon. - In: Black, C. A. (Ed.), *Methods of soil analysis.* American Society of Agronomy, Part 2, Madison, WI, pp. 1367–1378.

ANDERSON T. H., K. H. DOMSCH. 1989. Ratios of microbial biomass carbon to total organic carbon in arable soils. - *Soil Biology & Biochemistry,* 21: 471–479.

ANONYMOUS. 2002. *Aghozchal Forest Management Planning (district 3).* Organization of Forest and Rangelands and Watershed Management, Islamic Republic of Iran, 328 p. (In Persian).

ARUNCHALAM, A., K. MAITHANI, H. PANDEY, R. TRIPATHI. 1996. The impacts of disturbance on detrital dynamics and soil microbial biomass of a *Pinus kesiya* forest in north – east India. - *Forest Ecology & Management,* 88: 273-282.

BARTSCH N. 2000. Element release in beech (*Fagus sylvatica* L.) forest gaps. - *Water Air Soil Pollution,* 122: 3–16.

BAUHUS J., N. BARTSCH. 1995. Mechanisms for carbon and nutrient release and retention in beech forest gaps. - *Plant Soil,* 22: 168–169.

BAUHUS J. 1996. C and N mineralization in an acid forest soil along a gap - stand gradient. - *Soil Biology & Biochemistry,* 28: 923-932.

BEIER C. 1998. Water and element fluxes calculated in a sandy forest sol taking spatial variability into account. - *Forest Ecology & Management,* 101: 269–280.

BOWER C. A., R. F. REITEMEIER. M. FIREMAN. 1952. Exchangeable cation analysis of saline and alkali soils. - *Soil Sciences,* 73(4): 251–261.

BRADY N. C., R. R. WEIL. 2002. *The nature and properties of soils. 13ed.* New Jersey, USA, Prentice Hall, 436 p.

BREMER J. M. 1965. Inorganic forms of nitrogen. In: Black, C. A. (Ed.), *Methods of soil analysis,* Part 2. Chemical and microbiological properties. American Society of Agronomy, Madison, WI, pp. 1191–1205.

BREMER J. M., C. S. MULVANEY. 1982. Nitrogen - total. In: Page, A.L., Miller, R.H., Keeney, R.R. (Eds.), *Methods of Soil Analysis,* Part 2. Second ed. American Society of Agronomy, Madison, WI, pp. 595 – 624.

BRUIJNZEEL L. A. 1991. Nutrient input - output budgets of tropical forest ecosystems: a review. - *Journal of Tropical Ecology,* 7: 1–24.

BRUMME R. 1995. Mechanisms of carbon and nutrient release and retention in beech forest gaps. - *Plant Soil,* 168–169: 593–600.

BUCHMAN N., E. SCHULZE. 1999. Net CO_2 and H_2O fluxes of terrestrial ecosystems. - *Global Biogeochem. Cycles,* 13: 751–760.

BUNNELL F. L., D. E. TAIT, P. W. FLANAGAN, K. VAN CLEVE. 1977. Microbial respiration and substrate weight loss: A general model of the influences of abiotic variables. - *Soil Biology & Biochemistry,* 9: 33–40.

BUSING R. T., P. S. WHITE. 1997. Species diversity and small-scale disturbance in an old - growth temperate forest: A consideration of gap partitioning concepts. - *Oikos*, 78: 562–568.

BUYANOVSKY G. A., M. ASLAM, G. WAGNER. 1994. Carbon turnover in soil physical fractions. - *Soil Sciences Society American Journal,* 58: 1167–1173.

COLEMAN, D. C., D. A. CROSSLEY, P. F. HENDRIX. 2004. *Fundamentals of soil ecology.* 2 ed. San Diego, CA, USA, Elsevier Academic Press, 456 p.

DENSLOW J. S., A. M. ELLISON, R. E. SANFORD. 1998. Tree fall gap size effects on above - and below - ground processes in a tropical wet forest. - *Journal of Ecology,* 86: 597-609.

EDWARDS C. A., P. J. BOHLEN. 1996. *Biology and Ecology of Earthworms,* 3rd. Chapman and Hall, London, 426 p.

ELLIOT E. T., C. A. CAMBARDELLA. 1991. Physical separation of soil organic matter. - *Agriculture & Ecosystem Environmental,* 34: 407–419.

FOSTER N. W., J. A. NICOLSON P. W. HAZLETT. 1989. Temporal variation in nitrate and nutrient cations in drainage waters from a deciduous forest. – *J. Environ Qual.,* 18: 238–244.

GRAY A. N., T. A. SPIES, M. J. EASTER. 2002. Microclimate and soil moisture responses to gap formation in coastal Douglas – fir forests. - *Canadian Journal of Forest Research,* 32: 332–343.

GREGORICH E. G., B. H. ELLERT. 1993. Light fraction and macro organic matter in mineral soils. In: Carter M. (Eds.) *Soil sampling and methods of analysis.* Boca Raton, FL, Lewis Publishers, CRC Press Inc. pp. 397–407.

GUNDERSEN P., L. RASMUSSEN. 1990. Nitrification in forest soils: effects of nitrogen deposition on soil acidification and aluminium release. – *Rev. Environ. Contam. Toxicol.,* 13: 1-45.

GUNDERSEN P., I. SCHEMIDT, K. RAULUND – RAMUSSEN. 2006. Leaching of nitrate from temperate forests – effects of air pollution and forest management. - *Environ Rev.,* 14: 1–57.

HALE, C., E. HOST. 2005. *Assessing the impacts of European earthworm invasions in beech-maple hardwood and aspen- fir boreal forests of the western Great Lakes region.* National park service Great Lakes inventory and monitoring network report GLKN / 2005 / 11, 35 p.

HEDIN L. O., J. J. ARMESTO, A. H. JOHNSON. 1995. Patterns of nutrient loss from unpolluted, old-growth temperate forests: evaluation of biogeochemical theory. - *Ecology,* 76: 493–509.

HOLEKSA J. 2003. Relationship between field – layer vegetation and canopy openings in a Carpathian subalpine spruce forest. - *Plant Ecology,* 168: 57–67.

HOMER C. D., P. F. PRATT. 1961. *Methods of Analysis for Soils, Plants and Waters.* University of California, Agricultural Sciences Publications, Berkeley, CA, 309 p.

INSAM H., KH. DOMSCH. 1988. Relationship between soil organic carbon and microbial biomass on chronosequences of reclamation sites. – *Microb. Ecology,* 15: 177– 188.

INSAM H., D. PARKINSON, KH. DOMSCH. 1989. Influence of macroclimate on soil microbial biomass. - *Soil Biology & Biochemistry,* 21: 211–221.

JENKINSON D. S., J. H. RAYNER. 1977. The turnover of soil organic matter in some of the Roth Amsted classical experiments. - *Soil Sciences,* 123: 298–305.

JENNY H. 1994. *Factors of soil formation. A system of quantitative pedology.* Dover Publications, Inc. New York, USA.

JOHNSON D. W., S. E. LINDBERG. 1992. *Atmospheric deposition and forest nutrient cycling.* - Ecological Studies Series 91, Springer - Verlag, New York.

JONASOVA M., E. VAVROVA, P. CUDLIN. 2010. Western Carpathian Mountain spruce forest after a windthrow: Natural regeneration in cleared and uncleared areas. - *Forest Ecology & Management,* 259: 1127-1134.

KATHKE S., H. BRUELHEIDE. 2010. Interaction of gap age and microsite type for the regeneration of *Picea abies*. - *Forest Ecology & Management,* 259: 1597–1605.

KNIGHT D. H., J. B. YAVITT, G. D. JOYCE. 1991. Water and nitrogen outflow from lodge pole pine forest after two levels of tree mortality. - *Forest Ecology & Management,* 46: 215–225.

KOCH A. S., E. MATZNER. 1993. Heterogeneity of soil and soil solution chemistry under Norway spruce (*Picea abies* L. Karst) and European beech (*Fagus sylvatica* L.) as influenced by distance form the stem basis. - *Plant Soil,* 151: 227–237.

KWIT C., W. J. PLATT. 2003. Disturbance history influences regeneration of non – pioneer understory trees. - *Ecology,* 84(10): 2575–2581.

LESACK L. F., J. M. MELACK. 1996. Mass balance of major solutes in rainforest catchments in the Central Amazon: implications for nutrient budgets in tropical rainforests. - *Biogeochemistry,* 32: 115–142.

LESCH W., D. F. SCOTT. 1997. The response in water yield to the thinning of *Pinus radiata*, *Pinus patula* and *Eucalyptus* *grandis* plantations. - *Forest Ecology & Management,* 99: 295–307.

LINDBERG S. E., J. G. OWENS. 1993. Through fall studies of deposition to forest edges and gaps in montane ecosystems. - *Biogeochemistry,* 19: 173–194.

MARVIE MOHADJER M. R. 2007. *Silviculture.* Tehran University Publications, 387 p. (In Persian).

MCGILL W. B., K. CANNON, J. A. ROBERTSON, F. D. COOK. 1986. Dynamics of soil microbial biomass and water soluble organic C in Breton L after 50 years of cropping to two rotations. - *Canadian Journal of Soil Sciences,* 66: 1–19.

MCCARTHY J. 2001. Gap dynamics of forest trees: A review with particular attention to boreal forests. - *Environ. Rev.,* 9: 1–59.

MCNULTY S. G., J. D. ABER, R. D. BOONE. 1991. Spatial changes in forest floor and foliar chemistry of spruce-fir forests across New England. - *Biogeochemistry,* 14: 13–29.

MILLER H. G. 1981. Forest fertilization: Some guiding concepts. - *Forestry,* 54: 157-167.

MLADENOFF D. J. 1987. Dynamics of nitrogen mineralization and nitrification in hemlock and hardwood tree fall gaps. - *Ecology,* 68: 1171–1180.

MOSADEGH A. 2000. *Silviculture.* Tehran University Publications, 481 p. (In Persian).

MUSCOLO A., M. SIADARI, R. MERCURIO. 2007. Influence of gap size on organic matter decomposition, microbial biomass and nutrient cycle in Calabrian pine (*Pinus laricio*, Poiret) stands. - *Forest Ecology & Management,* 242: 412–418.

NACHTARGALE L., K. CHEKIERE, A. SCHRIJVER, B. MUYS, S. LUSSAERT, N. LUST. 2002. Earthworm biomass and species diversity in windthrow sites of a temperate lowland forest. - *Pedobiologia,* 46: 440–451.

NOURBAKHSH F., A. JALALIAN, H. SHARIATMADARI. 2003. Estimating of soil CEC using of soil physico - chemical characteristics. - *Agriculture and Natural Resources Sciences Journal of Esfahan,* 3: 107–117 (In Persian).

ODUM E. 1969. The strategy of ecosystem development. - *Bioscience,* 164: 262–270.

ODUM E. 1985. Trends in stressed ecosystems. - *Bioscience,* 35:419–422.

PARKER G. 1983. Through fall and stem flow in the forest nutrient cycle. - *Advance Ecology Research,* 13: 57–133.

PARSONS W. F. J., D. H. KNIGHT. S. L. MILLER. 1994a. Root gap dynamics and forest disturbance theory in lodge pole pine forests: nitrogen transformations in gaps of different size. - *Ecological Appl.*, 4: 354–362.

PARSONS W. F. J., D. H. KNIGHT, S. L. MILLER. 1994b. Root gap dynamics in lodge pole pine forests: ectomycorrhizal and nonmycorrhizal fine root activity after experimental gap formation. - *Canadian Journal of Forest Research,* 24: 1531–1538.

PARTON W. J., D. S. SCHIMEL, C. V. COLE, D. S. OJIMA. 1988. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. - *Soil Sciences Society American Journal,* 51: 1173–1179.

PAUL E. A., N. G. JUMA. 1981. Mineralization and immobilization of soil nitrogen by microorganisms. In: Clark FE, Roswell T, (Eds.), *Terrestrial nitrogen cycles.* Ecological Bulletins 33, Stockholm, pp. 179–195.

PRESCOTT C. E., G. D. HOPE, L. L. BLEVINS. 2003. Effect of gap size on litter decomposition and soil nitrate concentrations in a high - elevation spruce - fir forest. - *Canadian Journal of Forest Research,* 33: 2210–2220.

RAHMANI R., H. ZARE MAIVAN. 2004. Investigation diversity and structure of soil invertebrate in relation to beech, hornbeam and oak – hornbeam forest types. - *Natural Resources Journal of Iran,* 56: 425–437 (In Persian).

RESANEH Y., M. H. MOSHTAGH, P. SALEHI. 2001. Quantitative and qualitative study of north forests. – In: *Nation seminar of management and sustainable development of north forests,* Ramsar, Iran, August 2000, Jehad – e Agriculture Ministry, Forests and Ranges Organization. Press. Vol. 1, pp. 55–79.

RITTER E., L. VESTERDAL. 2006. Gap formation in Danish beech (*Fagus sylvatica*) forests of low management intensity: soil moisture and nitrate in soil solution. - *European Journal of Forest Research,* 125: 139–150.

RITTER E., M. STARR, L. VESTERDAL. 2005. Losses of nitrate from gaps of different sizes in a managed beech (*Fagus sylvatica*) forest. - *Canadian Journal of Forest Research,* 45: 308–319.

ROBERTSON G., D. COLEMAN, C. BLEDSOE, P. SOLLINS. 1999. *Standard soil method for long – term ecological research.* Oxford University Press, Oxford, 462 p.

RUNKLE J. R. 1992. *Guidelines and sample protocol for sampling forest gaps.* U. S. For. Serv. Gen. Tech. Rep. PNW – GTR – 283.

SALEH RASTIN N. 1978. *Soil biology,* Tehran University Publications, 213 p. (In Persian).

SAMONIL P., L. ANTOLIK, M. SVOBODA, D. ADAM. 2009. Dynamics of windthrow events in a natural fir – beech forest in the Carpathian Mountains. - *Forest Ecology & Management,* 257: 1148-1156.

SCHARENBROCH B. C., J. G. BOCKHEIM. 2007. Impacts of forest gaps on soil properties and processes in old growth northern hardwood – hemlock forests. - *Plant and Soil,* 294: 219-233.

SCHARENBROCH B. C., J. G. BOCKHEIM. 2008. The effects of gap disturbance on nitrogen cycling and retention in late – successional northern hardwood – hemlock forests. - *Biogeochemistry,* 87: 231–245.

SHURE D. J., D. L. PHILLIPS, P. E. BOSTICK. 2006. Gap size and succession in cutover southern Appalachian forests: an 18 year study of vegetation dynamics. - *Plant Ecology,* 185: 299-318.

SINGH J. S., A. S. RAGHUBANSHI, R. S. SINGH, S. L. SRIVASRASTA. 1989. Microbial biomass acts as a source of plant nutrients in dry tropical forests and savanna. - *Nature,* 338: 449–500.

SIX J., T. CONTANT, E. PAUL, K. PAUSTIAN. 2002. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. - *Plant Soil,* 241: 155–176.

WAGNER GH., D. C. WOLF. 1998. Carbon transformations and soil organic matter formation. - In: Sylvia D (Ed.) *Principles and applications of soil microbiology,* Prentice Hall, New Jersey, USA, 564 p.

WEBSTER C. R., C. G. LORIMER. 2002. Single-tree versus group selection in hemlock-hardwood forests: are smaller openings less productive? – *Can. J. For Res.* 32: 591–604.

YASREBI J., N. A. KARIMIAN, M. MAFTON, A. ABTAHI, A. RONAGHI, M. T. ASAD. 2003. Distribution of nitrogen status in lime soils planted in Fars province and theirs with soil characteristics. - *Agriculture and Natural Resources Sciences Journal of Esfahan,* 7: 39–51 (In Persian).

ZHANG Q., J. C. ZAK. 1995. Effects of gap size on litter decomposition and microbial activity in a subtropical forest. - *Ecology,* 76: 2196–2204.

ZHOU G., S. LIU, Z. LI, D. ZHANG, X. TANG, C. ZHOU, J. YAN, J. MO. 2006. Old - growth forests can accumulate carbon in soils. - *Science,* 314: 1417.

ZIRLEWAGEN D., K. VON WILPERT. 2001. Modeling water and ion fluxes in a highly structured, mixed - species stand. - *Forest Ecology & Management,* 143: 27–37.

Received: 17.07.2010
Accepted: 18.10.2010