Research Journal of
Forestry

ISSN 1819-3439

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Forestry 9 (1): 6-21, 2015
ISSN 1819-3439 / DOI: 10.3923/rjf.2015.6.21

Status of Soil Organic Matter of Belezma Cedar Stands Forests Mountains (Northeast of Algeria)

[1]Z. Bensid, [2]T. Halitat, [1]M. Sbih and [1]H. Messaadia
[1]Institute of Agricultural Sciences and Veterinary Science, Department of Agronomy, University Hadj-Lakhdar, Batna, Algeria
[2]University of Ghardaia, Algeria

Corresponding Author: Z. Bensid, Department of Pharmacy, Faculty of Medicine, Driveways Med Boudiaf, Batna, Algeria

ABSTRACT

Apart from the age of forest stands, soil type and climatic factors, the nature of forest cover, the biochemical composition of the litter and the root exudates it produces, may have a decisive impact on the physical, chemical and especially biological characteristics of the soil. However, no study has been reported to precisely examine the effects of forestry vegetation dominated by *Cedrus atlantica* species as compared to deciduous species of *Quercus ilex* on total soil organic matter, the microbial biomass, the light and the heavy fractions in the context of soils of Mediterranean forests, specifically in Belezma forest, Aures region, north-eastern Algeria. The objective of this work is to evaluate the effect of the vegetation of two mono-species site: *Cedrus atlantica*, *Quercus ilex* and mixture species site on the Soil Organic Matter (SOM) parameters such as, Organic Carbon (OC) and Total Nitrogen (TN), Carbon microbial biomass (C_{MB}) and Nitrogen microbial biomass (N_{MB}) of Soil Microbial Biomass (SMB), the carbon and nitrogen of light (LF) and Dense Fraction (DF). In an analysis of 60 woodlands soil, the results showed that different woodland cover site affects the OC content. Indeed, mono specie *Cedrus atlantica* was highly in OC followed by mixed species site and finally by *Quercus ilex* site. The C_{MB} accounted for only 5-15% of OC (average 11%) and 15-31% (average 22%) of TN. The average of C_{MB} of soils under *Cedrus atlantica* was significantly less (7.4%) than soils under *Quercus ilex* and mixed species (15%). Unlike the average of N_{MB} of soils under *Cedrus atlantica* was significantly higher (39%) than soils under *Quercus ilex* and mixed species (20%). The C and N of light fraction of OM was around 2 g kg^{-1} and 190 mg kg^{-1} respectively. The amount of LF of SOM is not affected by different tree species. The amounts of C and N in the dense fractions decreased in soil under *Quercus ilex* and mixed species, 34 and 4% respectively. This results suggested that soil under *Cedrus atlantica* accumulate more SOM, because at higher altitude (lower soil temperature and higher soil moisture) mainly depends on slower decomposition rate despite lower organic matter inputs rate. However, *Quercus ilex* and mixed species are located at lower altitude than *Cedrus atlantica*, this why we found more C and N in dense fraction of SOM. Generally the C/N ratio affects the SOM mineralization, it was found that C/N ratio in dense fractions were highest in soils under *Cedrus atlantica* than other sites.

Key words: Soil organic matter, forest soil, microbial biomass, light fraction, dense fraction

INTRODUCTION

In the mountains of Belezma and Aures region, the area of distribution of the species *Cedrus atlantica* was shrunk in favor to *Quercus ilex* and *Juniperus oxycedrus* that manifest in the form of scrub in Mediterranean regions. This shrinkage has taken place following the great climatic changes that occurred during the Quaternary (Harfouche and Nedjahi, 2003). The difficulties of regeneration of this emblematic tree species in the countries of North Africa were often attributed to topoclimatic and silvicultural constraints (Ezzahiri and Belghazi, 2000) but also anthropogenic (overgrazing, uncontrolled exploitation, illegal logging, forest fires) and defoliating insects and pathogenic fungi (Bentouati and Baritou, 2006). But it is above, climatic factors which were often attributed the causes of the decline of *Cedrus atlantica*. In this type of semi-arid Mediterranean ecosystem, soil moisture, enhanced by high temperatures is the key limiting factor controlling biogeochemical cycles. Indeed, during the season of drought, insufficient water available reduces the growth of plants, litter decomposition and microbial soil respiration (De Giovanbattista *et al.*, 2010). However, the impact of vegetation on soil factors has not been sufficiently expanded. In fact, the only information about the relationship between the vegetation and the substrate (bedrock and soil), indicate poor recovery of trees on marly substrates and low soil water hold capacity because soil texture and their shallow depth are unfavorable to the resumption of trees (Bentouati, 2008). Forest vegetation, produce significant impacts on soil physico-chemical characteristics by producing various types of litter and root exudates. This is way the size and activity of soil microbial communities are regulated (Cheng *et al.*, 2013). In addition, modification of soil physical parameters related to the biological activity of the soil itself depends on many chemical and biochemical parameters, thus the degradation of organic matter (mineralization) seems depend to tree species (Augusto *et al.*, 2002).

Despite of economic importance and for the quality of wood and especially in the environmental area, *Cedrus atlantica* is one last bastion against desertification. Knowledge about the ecological functioning of *Cedrus atlantica* of Belezma and Aures forests (north-east of Algeria) have not been fully explored.

Our standing point hypothesis that shrinkage in the distribution area of a forest species such as *Cedrus atlantica* has occupied this ecosystem for centuries and its replacement by other species such as *Quercus ilex*, apparently, more adapted to soil and climatic conditions, cause disturbances. Fertility is closely linked to the presence of sufficient amounts of Organic Matter (OM) in the soil is considered the key to the sustainability of forest ecosystems. The organic fraction of soil has long been identified as a major component in the maintenance of the key functions of the soil (Annabi *et al.*, 2009) both agricultural soils that forest soils. To ensure sustainability of forest ecosystem, the major challenge would be the maintenance of sufficient level of SOM. The maintaining the quantity and quality of the SOM is essential for the sustainability and restoration of degraded soils. Despite the fact that the SOM is considered the first indicator of soil quality (Sequeira and Alley, 2011), it turned out that the simple measure of the total Soil Organic Matter (SOM) was not sensitive enough to detect changes that occur in soil in the short and medium term. Therefore, the evaluation of the different fractions of SOM could be the better indicators of soil fertility (Gong *et al.*, 2008). Moreover, Kasel and Bennett (2007) and Xu *et al.* (2008) reported that size and activity of the labile pool of SOM (microbial biomass, light fraction extractable organic matter in hot water) which would be most affected.

The objectives of this study were: determining forest vegetation impacts mainly dominated by coniferous species *Cedrus atlantica* and deciduous species *Quercus ilex* on the quantity and quality of SOM, microbial biomass, light and dense fractions of SOM.

MATERIALS AND METHODS

Site description: The present study was conducted in the mountains of Belezma forest located in the Aures region locates at the east of northern Algeria (Fig. 1). This forest is located between

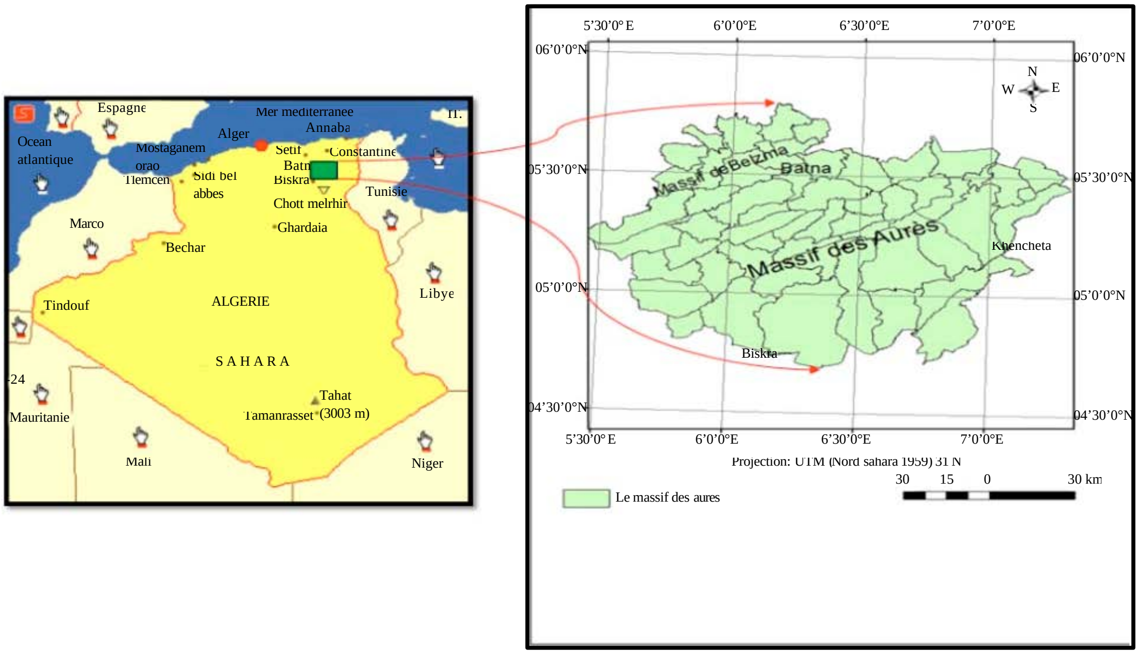

Fig. 1: Location of forest Belezma Mountains (North-eastern Algeria)

latitudes 35°32'40" and 35°37'46" North and longitudes 5°55'10" and 6°10'45" East. Belezma forest integrates into its landscape one of the largest parks of Algeria, it is the Belezma National Park (BNP). The area of Belezma forest was estimated at 61,000 ha of which 26,250 ha constitute the area of the National Park. The main sylvatic dominant formations of Belezma forest consist of mono specie *Cedrus atlantica*, mixed with *Quercus ilex*, or *Cedrus atlantica* mixed with *Ilex auifolium*. Generally, *Quercus ilex* can coexist with *Juniperus phoenicea*, *Juniperus oxycedrus* and *Fraxinus excelsior*.

The structure of the vegetation encountered in Aures and Belezma forest mountains is simple, according Schoenenberger (1970). The vegetation varies an altitudinal gradient which is related to climatic factors such as temperature and humidity. Between northern and southern sides mountains the different belts of vegetation begin appear. From 100-1300 m altitude, the first stage of the vegetation is dominated by *Pinus halepensis*, between 1300-1500 m south side and from 1000-1300 m north side the *Pinus halepensis* is mixed with *Quercus ilex*. Then the stations dominated only by *Quercus ilex* appear between 1500-1600 and 1300-1400 m between the south and north mountains sides, respectively. Between 1600-1800 m and 1400-1600 m altitude, *Cedrus atlantica* starts to appear mixed with *Quercus ilex*. At 1800-2300 m and 1600-1326 m, *Cedrus atlantica* is individualized with monospecific stations. Beyond these altitudes, the cold prevents any form of vegetation, then it is a asylvatique area.

Rainfall in the forest zone of Belezma between the southern and northern slopes ranges between 500-700 mm per year, respectively. At level 1300 and 2100 m, the mean values of the maximum and minimum temperature ranged between 25.9-31.5°C and -4.5 to -0.9°C, respectively. The Bélézma forest is considered as semiarid zone. Sampling sites are located on the mounts of *Tuggurt* (2090 m), *Boumerzoug* (1778 m), *Chellaâla* (1748 m), *Bordjem* (2074 m) and *Tichaou* (2091 m). Plot sizes range from 300 to 500 m^2. A total of sixty soil samples are collected (21 from

Fig. 2: Typical profile of a brown fersiallitic soil of belezma forest

Cedrus atlantica homogenous specie and 20 from *Quercus ilex* homogenous specie and 19 mixture species). Most of the sampled soils are *Rhodoxeralf* (Fig. 2) according to the second edition of US Soil Taxonomy.

Soil sampling methods: At different sampling zones a composite soil samples of at least five randomly collected soil cores were obtained from the surface depth, generally 0 to 25 cm. Soil samples were air dried and ground to pass a 2 mm sieve. Plant roots, gastropod shells, recognizable organic residues >2 mm were removed by hand. For SMB determination the simple are kipped at their Field-moisture and stored in a refrigerator at 4°C.

The soil texture (particle size analysis) has been determined using an international method of Robinson pipette (Baize, 2006). The Soil Water Holding Capacity (SWHC) is estimated by equations of Rawls *et al.* (1982). The Bulk Density (BD) is determined by ring method.

The pH of soil (pH_{H2O}) and KCl (pH_{KCl}) were determined by glass electrodes method in a 2:5 (weight: volume) ratio. The Cationic Exchange Capacity (CEC) was determined by the method with ammonium acetate Metson (1956). The Organic Carbon (OC) was analyzed by Walkley and Black method (Nelson and Sommers, 1982). The procedure for determination organic carbon is based on the wet chemistry technique. This extraction technique is applied cold using the oxidizing agent potassium dichromate in sulfuric acid. The dosage of the excess dichromate is through a Mohr salt solution and determining the difference of volume reacted with the carbon soil. The organic matter was determined by multiplying the organic carbon content by a factor of 2. The amount of soil total nitrogen is determined after Kjeldahl digestion, distillation and titration technique (Bremner and Mulvaney, 1982).

The soil microbial biomass was determined by the fumigation-extraction method (Vance *et al.*, 1987). The carbon content and microbial nitrogen were obtained by the method of

Wu *et al.* (1990) and Brookes *et al.* (1985). Indeed, the following relationships were, respectively applied for carbon and nitrogen microbial biomass:

$$C_{MB} = EC/K_{EC} \text{ and } N_{MB} = EN/K_{EN}$$

OU EC = Organic carbon extracted from fumigated soil-Carbon extracted from non-fumigated

and:

$$\text{Soil } K_{EC} = 0.45$$

(Wu *et al.*, 1990), where, EN is total nitrogen fumigated soil-total Nitrogen non-fumigated soil and K_{EN} = 0.54 (Brookes *et al.*, 1985). The microbial quotient was deduced by calculating the proportion of carbon in the soil microbial biomass (C_{MB}) in soil organic carbon (CO) (microbial Quotient = C_{BM}/CO×100) (Mendham *et al.*, 2002).

Densimetric fraction of SOM: A densimetric fractioning with sodium iodide solution NaI (d = 1.7 g cm^{-3}) was performed to in order to separate the LF (d<1.7 g cm^{-3}) and the DF (d>1.7 g cm^{-3}) (Janzen *et al.*, 1992; Golchin *et al.*, 1994). Each fraction is dried at 60°C for 48 h and then OC and TN are analyzed by CHNOS analyzer (elementar Analysen systeme GmbH-Element analyzer vario EL III).

Statistical analysis: Standard analysis of variance (ANOVA) was used to determine significance between forest litter and different measured variables of SOM. Statistical analysis was performed using XLSTAT 2009. Significant differences were determined between factors using Fisher's Least Significant Difference (LSD) test. A Pearson correlation analysis was also performed.

RESULTS

The initial characteristics of the soil on different sites; *Cedrus atlantica*, *Quercus ilex* and mixed species are given in Table 1. The texture of *Cedrus atlantica*, *Quercus ilex* and mixed species sites

Table 1: Mean Values±Standard Deviations (SD) of the physico-chemical characteristics of soils (0-25 cm) from different forest stands in Bélézma forest

Parameters	Soil particles			Soil density d	Soil water	Soil pH			Cations			
	C	L	S	(g cm^{-3})	content (%)	pH H_2O	pH Kcl	CEC	Ca^{++}	Mg^{++}	K^{+}	Na^{+}
	%								cmol $_{(+)}$ kg^{-1}			
Soils under mono-species												
Cedrus altantica	26.79	30.00	43.17	1.68	27.56	7.27	6.29	59.05	40.12	12.10	5.48	0.61
SD	6.65	10.10	9.18	0.13	4.12	0.27	0.36	1.67	5.12	5.95	2.80	0.01
Quercus ilex	23.80	36.36	39.82	1.70	28.48	7.20	6.48	55.72	40.94	12.05	5.05	0.60
SD	5.82	9.07	7.23	0.11	3.15	0.27	0.42	1.60	4.80	5.45	2.33	0.01
Soils under												
Mixed species	23.62	32.56	43.85	1.68	27.94	7.14	6.67	57.18	36.23	8.00	6.47	0.32
SD	7.58	10.70	8.08	0.12	3.13	0.20	0.22	1.86	5.61	5.93	5.30	0.02

ranged between clay loam sandy and loam sandy clay. Soil density varies between 1.5 to 1.8 g cm^{-3}. In general, the soils are neutral to slightly alcalin in reaction. The soil CEC of all site are ranged from 43-53 $cmol_{(+)}$ kg^{-1}.

The organic C, TN, C_{MB}, N_{MB}, C_{LF}, N_{LF}, C_{DF} and N_{DF} of soil organic matter are presented in Table 2. The total amounts OC on mono species *Cedrus atlantica* are between 43 to 65 g kg^{-1}. However, the amount of OC on *Quercus ilex* site was significantly less, ranged between 33-39 g kg^{-1}. On the mixed species sites the OC values are 43 to 49 g kg^{-1}. The mean value of C/N ratio on *Cedrus atlantica* site was about 16 (Table 2). On the mixed species and *Quercus ilex* specie, the C/N ratio was 62% less than those of *Cedrus atlantica*. Thus indicates that TN content on coniferous was less important than mixed species and *Quercus ilex* specie. The same tendency was observed on the C_{MB}, however, N_{MB} content was more important on *Cedrus atlantica* (mean: 1015 mg kg^{-1}) comparatively to mixed species and *Quercus ilex* specie were the values are 859 and 677 mg kg^{-1}, respectively (Table 2). The proportion of C_{MB} to OC represent 7% on *Cedrus atlantica* however, this proportion was twin for mixed species and *Quercus ilex* specie. The C_{LF} of SOM was about 2 g kg^{-1} for all sites and N_{LF} was about 190 mg kg^{-1}. The C_{DF} of SOM was 25 g kg^{-1} on *Cedrus atlantica* site which represent 45% of total soil OC. In the sites of mixed species and *Quercus ilex* specie this proportion represents 34 and 32%, respectively.

The results showed that different woodland cover site affects the OC content. Indeed, mono specie *Cedrus atlantica* was highly in OC followed by mixed species site and finally by *Quercus ilex* site ($p<0.001$) (Table 3). However, the TN content was more important on mixed species site in comparison to *Quercus ilex* and *Cedrus atlantica*. The same pattern was observed on the content of C_{MB}. The N_{MB} were most pronounced in the soil under *Cedrus atlantica* than on mixed species and *Quercus ilex* sites ($p<0.001$) (Table 3). The ratio of carbon and nitrogen of soil microbial biomass was highly significant ($p<0.001$) for mono specie *Quercus ilex* and mixed species sites. The observed C/N of SMB under *Cedrus atlantica* was half (3.7), this low ratio suggest that soil biomass was dominated by microbial community (Williamson *et al*., 2003). In an analysis of 60 woodlands soil, C_{MB} accounted for only 5-15% of OC (average 11%) and 15-31% (average 22%) of TN. The average of C_{MB} of soils under *Cedrus atlantica* was significantly less (7.4%) than soils under *Quercus ilex* and mixed species (15%). Unlike the average of N_{MB} of soils under *Cedrus atlantica* was significantly higher (39%) than soils under *Quercus ilex* and mixed species (20%). The C and N of light fraction of OM were around 2 g kg^{-1} and 190 mg kg^{-1} respectively. The amount of LF of SOM are not affected by different tree species ($p<0.1$). The average of C_{LF} accounted for only 3.4-5.8% of OC and N_{LF} accounted 4.3-5.4% of TN.). The C/N ratio of LF was about 10.

The separation of LF and DF using 1.7 g cm^{-3} sodium iodide solution, showed that the concentrations of C and N in dense fractions were very highest than in LF. Indeed, the C_{DF} and N_{DF} are tenfold more the C_{LF} and N_{LF}. The average of C_{DF} in soil under *Cedrus atlantica* accounted for 45% of OC and N_{DF} average 6% of TN. The amounts of C and N in the dense fractions decreased in soil under *Quercus ilex* and mixed species 34 and 4% respectively. This results suggested that soil under *Cedrus atlantica* accumulate more SOM, because at higher altitude (lower soil temperature and higher soil moisture) mainly depends on slower decomposition rate despite lower organic matter inputs rate. However, *Quercus ilex* and mixed species are situated at lower altitude than *Cedrus atlantica*, this why we found more C and N in dense fraction of SOM. Generally the C/N ratio affects the SOM mineralization, it was found that C/N ratio in dense fractions were highest in soils under *Cedrus atlantica* than other sites.

Table 2: Mean Values±Standard Deviations of the biological characteristics of the soils (0-25 cm) from different stands Bélézma forest

	Soil Organic Matter (SOM)			Soil Microbial Biomass (SMB)			MB/SOM		Light Fraction (LF)			LF/SOM		Dense fraction (DF)			DF/SOM	
	OC	TN		CMB	NMB		C	N	C	N		C	N	C	N		C	N
Station	-------g kg^{-1}-----		C/N	-----mg kg^{-1}----		C/N	------(%)-----		----mg kg^{-1}----		C/N	-------(%)--------		-----g kg^{-1}----		C/N	------(%)--------	
Soils under mono-species																		
Cedrus altantica	53.35	3.48	15.9	3974	1015	3.78	7.45	39	1908	191	9.89	3.44	5.46	25.16	2.09	12.28	45.5	6.05
SD	5.9	0.34	1.87	444	75	0.44	0.8	1.2	299	34	1.44	0.31	0.49	0.54	0.02	3.20	8.2	0.75
Quercus ilex	35.55	3570	10	5377	677	7.94	15.1	19	2075	193	10.6	5.81	5.41	12.17	1.44	8.91	34.2	4.02
SD	1.5	0.27	0.93	245	50	0.60	0.93	0.9	386	31	2.27	0.85	0.59	0.33	0.02	3.98	9.2	0.34
Soils under																		
Mixed station	45.76	4.25	10	6478	859	7.61	14.1	20	2176	187	11.4	4.75	4.39	14.9	1.77	8.59	32.7	4.17
SD	1.61	0.25	0.67	287	86	0.82	0.32	1.35	260	18	1.71	0.44	0.20	0.096	0.02	1.50	1.8	0.35

Table 3: Summary table of ANOVA soil (0-25 cm) biological variables of different stand of Bélézma forest

Variables	F	Significance
OC	143,01	H
TN	39,03	S
OC/TN	131,22	H
C_{MB}	187,42	H
N_{MB}	271,91	H
C_{MB}/N_{BM}	112,70	H
C_{MB}/OC	65,96	S
N_{MB}/TN	474,68	VH
C_{LF}	3,58	F
N_{LF}	0,22	N
C_{LF}/N_{LF}	3,71	F
C_{LF}/OC	87,71	S
N_{LF}/TN	35,08	S
C_{DF}	72,07	S
N_{DF}	43,64	S
C_{DF}/N_{DF}	8,90	F
C_{DF}/OC	19,42	M
N_{FD}/NT	96,58	S

Sig.: Significance level, VH: Very highly significant, HS: Highly significant, S: Significant, M: Moderately significant, F: Weakly significant and N: Not significant

Relationship among SOM: As mentioned by Gregorich *et al.* (1994) and Carter (2002) the labile SOM is defined by cold-water, hot water, chloroform released and density fraction, it was found that OC were significantly correlated with C_{MB} (r = 0.86) and C_{LF} (r = 0.76), however, the correlation is lower with C_{DF} (r = 0.52) (Fig. 3). The same pattern was observed between TN and N_{MB} (r = 0.92), N_{LF} (r = 0.95***) and N_{DF} (r = 0.78) (Fig. 4). In one hand, these results, the labile fraction of SOM was a major determinant by the amount of microbial biomass (C and N) and the light fraction of SOM (C and N). In the other hand, labile SOM fractions measured in this study show that they partly represent similar organic pool in soil.

Wang *et al.* (2010) measuring four labile soil organic C fractions founded the same significant correlations among this factors and concluded that this labile fraction represent similar C pool. Laik *et al.* (2009) also found a significant relationship between soil microbial biomass C and the light fraction soil organic C in a *calciorthent* after 18 years of afforestation. Some studies showed that soil respiration was correlated with the light fraction soil organic C content, suggesting that light fraction soil organic C was the driving factor in soil respiration (Gregorich *et al.*, 1994; Gregorich and Janzen, 1996; Alvarez and Alvarez, 2000).

The effects of forest vegetation carbon of the light fraction (C_{LF}) and the C_{LF}/N_{LF} ratio were weak significant on N_{LF} SOM (Table 3). Furthermore, as for the C_{LF}/OC and N_{LF}/TN ratios, the effects were significant or moderately significant (Table 3).

Taking into account the highest correlation factors, it is the soils from mixed stand that record the highest relationships between elements of the light fraction C_{LF} and N_{LF} and SOM (OC and TN) on one side and the elements of the microbial biomass (C_{MB} and N_{BM}) on another. In fact, regarding the correlations between C_{LF}, N_{LF} and C_{MB}, N_{MB}, the highest ones were recorded from soil nitrogen N of mixed stand and soil carbon of *Quercus ilex* monospecific stand on the one hand. On the other hand, the less significant correlations between C_{MB} and C_{LF}, N_{MB} and N_{LF} were recorded, respectively from soils of under *Cedrus atalantica* site and *Quercus ilex* site.

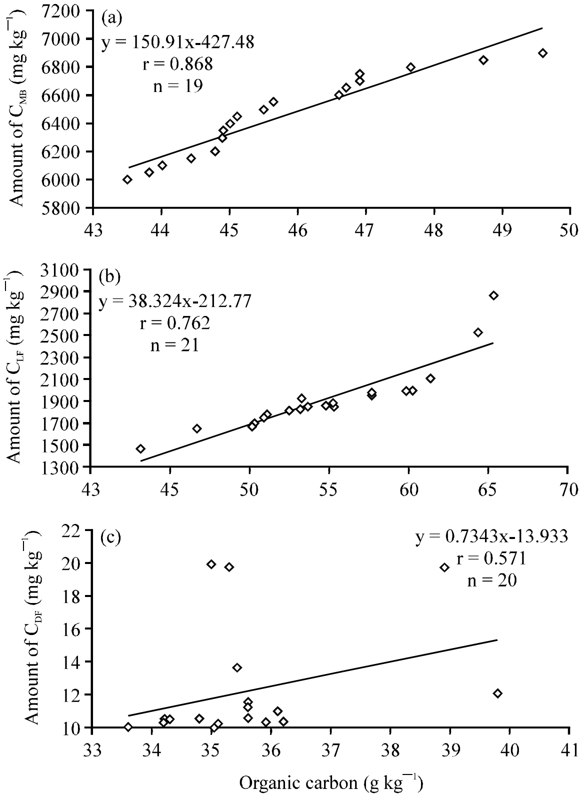

Fig. 3(a-c): Relationship between different fractions of organic carbon of belezma forest soils under monospecies (*Cedrus atlantica* or *Quercus ilex*) and mixed sites

The forest vegetation effect on C and N of heavy fraction, C_{DF} and N_{DF} and N_{DF}/TN ratio, respectively was significant. While the effect on C_{DF}/N_{DF} and C_{DF}/CO ratios have been low and intermediate, respectively (Table 3).

Therefore, significantly higher mean values were recorded in the soils of the *Cedrus atlantica* mono-specie site. While the soil below the mixed stand showed intermediate values and therefore rank second in a descending order. No significant correlation was observed between the dense fraction and the different fractions of organic matter (microbial biomass and light fraction of SOM) in soils of mono-specific or mixed stands of the studied sites except for TN and N_{FD} from mixed stands and *Quercus ilex* mono-specific stands, where a correlation factor r = 0.67 and r = 0.864 were recorded, respectively.

DISCUSSION

Despite the fact that the total SOM is less sensitive to the change in vegetation and land use in forest ecosystems (Gregorich *et al.*, 1994; Laik *et al.*, 2009) than the labile organic matter, our results showed a significant difference between the MO of soils under different stands. Indeed, higher levels of organic carbon were recorded in the soils of *Cedrus atlantica* mono-specific stands, while the weaker stocks are those of the soils collected from *Quercus ilex* mono-specific stands. First, this reflects that it is the soils under *Cedrus atlantica* which are less susceptible to biodegradation and this fact is confirmed by the C/N ratios. Indeed, relatively higher ratios of C/N were recorded

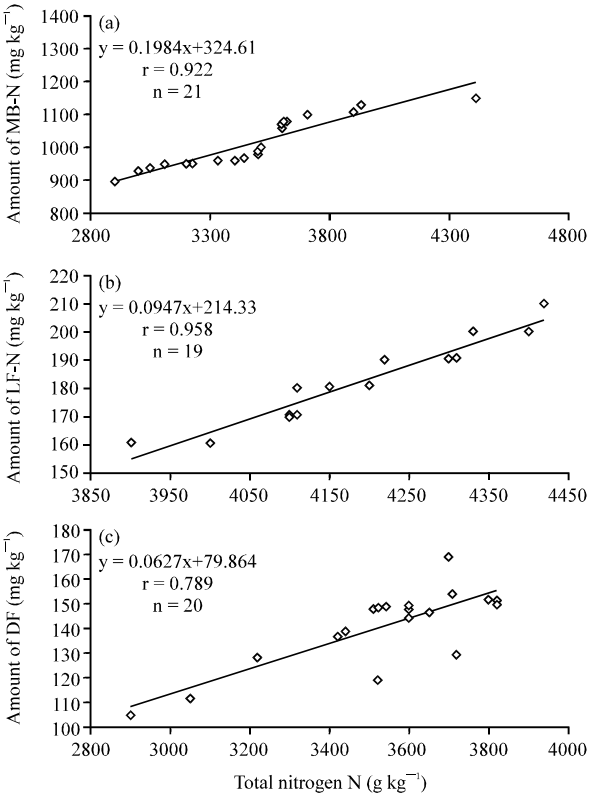

Fig. 4(a-c): Relationship between different fractions of total nitrogen of belezma forest soils under monospecies (*Cedrus atlantica* or *Quercus ilex*) and mixed sites

in soils evolving under *Cedrus atlantica* than under *Quercus ilex*. The changes in the level of the organic carbon stock in soils is the result of the balance between the volume of the contributions of plant materials to the organic pool of soils (or inputs) and the speed of their mineralization by microbial biomass (or outputs) (Annabi *et al*., 2009). This development not only depends on the types of soils and their occupation but also and especially on the nature of the substrate available for microorganisms in the soil. Indeed, the dynamics of decomposition of SOM, therefore its stability which is a form of protection against this decay, much depends on its biochemical composition (Rousk and Baath, 2007). It has long been considered that conifers litter would be much richer than those of deciduous tree species polyphenolic aromatic compounds such as lignin and tannins. By way of comparison, the woods of conifers are therefore richer in vanillic acid, the relatively stable constitutive acid of lignin compared to that of hardwood species (Strukelj *et al*., 2012). The works of Joanisse *et al*. (2007) revealed that the condensed tannins, with very high molecular weight, released by the litter of a shrub of *Kalmia angustifolia* (*Ericacae* sp.) suppress the enzymatic activity of the soil, causing a slowdown in biogeochemical cycling of nutrients. It is now established that tannins, polyphenols aromatic compounds, are endowed with a high ability to form, by precipitation, complex natural polymers such as proteins, amino acids, enzymes, polysaccharides, fatty acids and nucleic acids (Mole and Waterman, 1987). Thus, tannins can have several roles. They may affect the nutrient cycle, they reduce the rate of decomposition and they complexify proteins, are responsible for the toxicity of microbial community and inhibit the enzymatic activity

(Kraus *et al*., 2003). By complexifying proteins, tannins may therefore affect the availability of N (Sjoberg, 2003) through better restraint and decrease in N mineralization (Kraus *et al*., 2003). According to the same authors, tannins act as a carbon source labile leading to an increase of the restraining of N. We contend that this is a fact that we have observed ourselves in the soil sampled from pure stands of *Cedrus atlantica* versus soils sampled in other stands. Given that N is a limiting factor in the decomposition rate of MO. The fact that the C/N ratio of soils under *Cedrus atlantica* is high partially explains the low mineralization of SOM which has resulted in high levels of CO and low in NT in this type of soil.

Microbial biomass: Many factors have often been suggested to explain the effects of vegetation on diversity, composition (Hackl *et al*., 2004), size and activity soil microbial biomass (Cheng *et al*., 2013). However, the most important factor remains the quantity and quality of substrates made through biological impact and root exudates. In our present study and regardless of the nature of the vegetation cover, strong positive and highly. These values suggest that forest sites dominated by the mixed species or those only populated by *Quercus ilex* would be much more beneficial to maintain soil fertility. The soil microbial biomass is also a process agent of SOM and a source of nutrients (specifically N, P and S) (Jenkinson and Ladd, 1981; Tracy and Frank, 1998).

The relative decline in microbial biomass of soils under *Cedrus atlantica* from that of soils under *Quercus ilex* and those evolving in mixed stands were likely to be attributed to the quantitative weakness of residues from this forest species and inhibition of microbial activity under its influence. In fact, Chen and Xu (2005) showed that the nature of the dominant forest cover can have a significant effect on the size and activity of microbial soil populations. These results agree with those found in other contexts (northeastern China) and other tree species by Wang and Wang (2007) in populated secondary natural forests of hardwood species compared to pure conifer plantations of the *Cunninghamia lanceola* specie. Yang *et al*. (2010) found significantly lower values of C and N microbial biomass in soils in pure plantations of larch compared to those found in broadleaved forests. It is unanimously acknowledged that the litter of conifers has inhibitory action against the soil microorganisms (Bauzon *et al*., 1969). This inhibitory effect may be due either to substances of vegetable origin, more or less processed, such as tannins who affect the activity of decomposers considerably (Yadav and Malanson, 2007) or to microbial metabolism (Mangenot, 1980). These results reveal that the microbial microflora, despite its relatively low density, under the influences of the bedding from a coniferous tree such as *Cedrus atlantica* is able to mobilize large N quantities.

The C_{BM}/CO ratio reflects the fraction of total soil organic carbon immobilized in microbial cells. This ratio is an indicator of microbial availability of the organic substrate which explains how microorganisms can use soil carbon to increase and maintain their biomass. This ratio falls sharply when the available MO concentration decreases (Joergensen and Scheu, 1999). Another study reported the degree of contribution of microbial biomass in soil organic carbon (Anderson and Domsch, 1989). In fact, this ratio decreases as the concentration of organic matter available decreases (Brookes *et al*., 1995).

It is indeed, bedding quality, through their biochemical composition (C/N ratio, lignin/nitrogen ratio or phenolic compounds and tannic compounds) that could have a significant effect on soil microbial biomass (Kara *et al*., 2014). The same authors had reported that the microbial biomass in pine bedding was higher than that of pure Beech stands and mixed of both species. They concluded that the pine bedding was much richer in nitrogen and has a relatively lower C/N ratio.

Soil mixed stations through a more diversified production of organic substrate following the mixture of tree species, also enables a better availability of SOM to microorganisms, as has been reported by Wang and Wang (2007).

Light and heavy fractions of SOM: Despite the fact that the bedding is the most important source of C inputs in forest soils (Gosz *et al.*, 1976), these preliminary results suggest that the vegetation type does not significantly affect the light fraction of SOM. At present, it is accepted that SOM is composed of different fractions from the active pool (labile) to the more stable (recalcitrant) through the slow pool (Laik *et al.*, 2009). The LF with a rapid renewal cycle (less than a few decades) and low C/N ratio and low specific density, belongs to the water-soluble organic matter and microbial biomass and to labile pool therefore an asset of the SOM (Hsieh, 1992). It represents a transition pool between the incompletely decomposed and humified organic residue of the MOS (Janzen *et al.*, 1992). Rather, the DF of SOM is a stable pool with a very slow renewal cycle that could reach several thousand years and high C/N ratio and specific density (Campbell *et al.*, 1967). It is its association with the mineral matrix that can prevent the decomposition of this fraction of SOM (Six *et al.*, 2002).

Because of its high lability, as well as microbial biomass and dissolved organic matter, the LF of SOM is often considered one of the most reactive and therefore more sensitive to changes in the mode of use and soil occupation compared the heavy fraction (Gregorich and Janzen, 1996; Six *et al.*, 2002; O'Hara *et al.*, 2006). It can therefore be used as a sensitive and indicator of changes in soil quality (Laik *et al.*, 2009). The forest tree species would also have different impacts on different pools of SOM and on their dynamics (Paul *et al.*, 2002).

In agro-systems, the distribution of the mass of carbon and organic nitrogen between different fractions of SOM are largely influenced by the patterns of use (crops, pastures and forests) and land management practices (Tan *et al.*, 2007) such as crop rotation (Janzen, 1987), plowing (Dalal and Mayer, 1987) and fertilization (Christensen, 1988).

The results obtained by Whalen *et al.* (2000) both for forest and agricultural soils indicate that DF is the main source of potentially mineralizable N while the LF is a potential sink of mineral N. This is in agreement with our results which have shown that the nature of the vegetation had only a minor impact on the carbon and nitrogen of the LF and a more pronounced effect on the DF that is humified organic matter. Boone (1994) who compared two species of forest soils Noah Woods and Wingra Woods with specie of pine and Maple in an agricultural soil-grown corn; that DF would be the main source of nitrogen in mineral coarse textured soils while the LF is a relatively minor source of N in soils of forest soil with more humus. This is despite the fact that Sollins *et al.* (1984) and Shang *et al.* (2014) reported that net mineralization of the soil N mainly depends on the relative amounts of the LF, DF and their C/N ratio. Indeed, these authors demonstrate that in the soils of subtropical forests in southeast China, the major proportion of soil organic carbon was in the heavy fraction and well protected against biodegradation.

The strong correlations explain that the LF is part of the total MO of the soil and it is a source of energy and nutrients for the microbial biomass. This same type of correlation was observed by Janzen *et al.* (1992) and Sollins *et al.* (1984). Indeed, these authors found a strong correlation between the rate of soil respiration and microbial nitrogen with the TN content, suggesting that the LF would be a useful indicator of the MO labile. While the N mineralization was also correlated with LF content, although the correlation was less consistent, probably because the C/N ratio of the LF induces a temporary N immobilization. Sollins *et al.* (1984) report the same conclusions in forest soils and Ohta and Kumada (1978) on volcanic soils.

REFERENCES

Alvarez, R. and C.R. Alvarez, 2000. Soil organic matter pools and their associations with carbon mineralization kinetics. Soil Sci. Soc. Am. J., 64: 184-189.

Anderson, T.H. and K.H. Domsch, 1989. Ratios of microbial biomass carbon to total organic carbon in arable soils. Soil Biol. Biochem., 21: 471-479.

Annabi, M., H. Bahri and K. Latiri, 2009. [Organic status and microbial respiration in Northern Tunisian soils]. Biotechnol. Agronomie Soc. Environ., 13: 401-408, (In French).

Augusto, L., J. Ranger, D. Binkley and A. Rothe, 2002. Impact of several common tree species of European temperate forests on soil fertility. Ann. For. Sci., 60: 233-253.

Baize, D., 2006. Guide of Soil Analyzes in Collection Techniques et Pratiques. 2nd Edn., INRA., Paris, ISBN: 978-2-7380-0892-3, Pages: 266.

Bauzon, D., R. Van Den Driessche and Y. Dommergues, 1969. The litter-effect: 1-Influence *in situ* of the forest litter on some biological characteristics of soils. Oecol. Plant., 4: 99-122.

Bentouati, A. and M. Barritou, 2006. [Reflections on the decline of Atlas cedar aures (Algeria)]. Foret Mediterraneenne, 27: 317-322.

Bentouati, A., 2008. [The situation of the Atlas cedar in the Aures (Algeria)]. Foret Mediterraneenne, 29: 203-208.

Boone, R.D., 1994. Light-fraction soil organic matter: Origin and contribution to net nitrogen mineralization. Soil Biol. Biochem., 26: 1459-1468.

Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-Total. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). ASA and SSSA, Madison, WI., USA., pp: 595-624.

Brookes, P.C., 1995. The use of microbial parameters in monitoring soil pollution by heavy metals. Biol. Fert. Soils, 19: 269-279.

Brookes, P.C., A. Landman, G. Pruden and D.S. Jenkinson, 1985. Chloroform fumigation and the release of soil nitrogen: A rapid direct extraction method to measure microbial biomass nitrogen in soil. Soil Biol. Biochem., 6: 837-842.

Campbell, C.A., E.A. Paul, D.A. Rennie and K.J. McCallum, 1967. Applicability of the carbon-dating method of analysis to soil humus studies. Soil Sci., 104: 217-224.

Carter, M.R., 2002. Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agron. J., 94: 38-47.

Chen, C.R. and Z.H. Xu, 2005. Soil carbon and nitrogen pools and microbial properties in a 6-year-old slash pine plantation of subtropical Australia: Impacts of harvest residue management. For. Ecol. Manage., 206: 237-247.

Cheng, F., X. Peng, P. Zhao, J. Yuan and C. Zhong *et al.*, 2013. Soil microbial biomass, basal respiration and enzyme activity of main forest types in the qinling mountains. PLoS One, Vol. 8. 10.1371/journal.pone.0067353

Christensen, B.T., 1988. Effects of animal manure and mineral fertilizer on the total carbon and nitrogen contents of soil size fractions. Biol. Fertil. Soils, 5: 304-307.

Dalal, R.C. and R.J. Mayer, 1987. Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland.VII. Dynamics of nitrogen mineralization potentials and microbial biomass. Aust. J. Soil Res., 25: 461-472.

De Giovanbattista, D., P. de Angelis, C. Cesaraccio, G. Pellizzaro and P. Duce *et al.*, 2010. Changes of ecosystem functions in a *Mediterranean shrubland* exposed for eight years to prolonged summer droughts. Proceedings of the European Geosciences Union General Assembly Conference, May 2-7, 2010, Vienna, Austria.

Ezzahiri, M. and B. Belghazi, 2000. Synthesis of some results on natural regeneration of Atlas cedar in the Middle Atlas (Morocco). Science et Changements Planetaires/Secheresse, 11: 79-84.

Golchin, A., J.M. Oades, J.O. Skjemstad and P. Clarke, 1994. Soil structure and carbon cycling. Aust. J. Soil Res., 32: 1043-1068.

Gong, W., X.Y. Yan, Z.C. Cai, J.Y. Wang, T.X. Hu, Y.B. Gong and H. Ran, 2008. Effects of long-term fertilization on soil particulate organic carbon and nitrogen in a wheat-maize cropping system. Chin. J. Appl. Ecol., 19: 2375-2381.

Gosz, J.R., G.E. Likens and F.H. Bormann, 1976. Organic matter and nutrient dynamics of the forest and forest floor in the Hubbard Brook forest. Oecologia, 22: 305-320.

Gregorich, E.G. and H.H. Janzen, 1996. Storage of Soil Carbon in the Light Fraction and Macroorganic Matter. In: Structure and Organic Matter Storage in Agricultural Soils, Carter, M.R. and B.A. Stewart (Eds.). CRC Press, Boca Raton, FL., USA., ISBN-13: 9781566700337, pp: 167-190.

Gregorich, E.G., C.M. Monreal, M.R. Carter, D.A. Angers and B.H. Ellert, 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Can. J. Soil Sci., 74: 367-385.

Hackl, E., S. Zechmeister-Boltenstern, L. Bodrossy and A. Sessitsch, 2004. Comparison of diversities and compositions of bacterial populations inhabiting natural forest soils. Applied Environ. Microbiol., 7: 5057-5065.

Harfouche, A. and A. Nedjahi, 2003. Ecological and silvicultural surveys in the cedar forests of Belezma and Aures in search of seed stands and trees more. Rev. Forest. Fr., 2: 113-122.

Hsieh, Y.P., 1992. Pool size and mean age of stable soil organic carbon in cropland. Soil Sci. Am. Soc. J., 56: 460-464.

Janzen, H.H., C.A. Campbell, S.A. Brandt, G.P. Lafond and L. Townley-Smith, 1992. Light-fraction organic matter in soils from long-term crop rotations. Soil Sci. Soc. Am. J., 56: 1799-1806.

Janzen, R.H., 1987. Soil organic matter characteristics after long-term cropping to various spring wheat rotations. Can. J. Soil Sci., 67: 845-856.

Jenkinson, D.S. and J.N. Ladd, 1981. Microbial Biomass in Soil: Measurement and Turnover. In: Soil Biochemistry, Paul, E.A. and J.N. Ladd (Eds.). Marcel Dekker, New York, USA., pp: 415-471.

Joanisse, G.D., R.L. Bradley, C.M. Preston and A.B. Munson, 2007. Soil enzyme inhibition by condensed litter tannins may drive ecosystem structure and processes: The case of *Kalmia angustifolia*. New Phytol., 175: 535-546.

Joergensen, R.G. and S. Scheu, 1999. Depth gradients of microbial and chemical properties in moder soils under beech and spruce. Pedobiologia, 43: 134-144.

Kara, O., I. Bolat, K. Cakiroglu and M. Senturk, 2014. Litter decomposition and microbial biomass in temperate forests in Northwestern Turkey. J. Soil Sci. Plant Nutr., 14: 31-41.

Kasel, S. and L.T. Bennett, 2007. Land-use history, forest conversion and soil organic carbon in pine plantations and native forests of South Eastern Australia. Geoderma, 137: 401-413.

Kraus, T.E.C., R.A. Dahlgren and R.J. Zasoski, 2003. Tannins in nutrient dynamics of forest ecosystems: A review. Plant Soil, 256: 41-66.

Laik, R., K. Kumara, D.K. Das and O.P. Chaturvedi, 2009. Labile soil organic matter pools in a calciorthent after 18 years of afforestation by different plantations. Appied Soil Ecol., 42: 71-78.

Mangenot, F., 1980. [Forest litter: Ecological and pedological significance]. HFF., 32: 339-355.

Mendham, D.S., A.M. O'Connell and T.S. Grove, 2002. Organic matter characteristics under native forest, long-term pasture and recent conversion to *Eucalyptus plantations* in Western Australia: Microbial biomass, soil respiration and permanganate oxidation. Aust. J. Soil Res., 40: 859-872.

Metson, A.J., 1956. Methods of Chemical Analysis for Soil Survey Samples. DSIR, Soil Bureau Bulletin No. 12, New Zealand, pp: 193-204.

Mole, S. and P.G. Waterman, 1987. Tannins as Antifeedants to Mammalian Herbivores: Still an Open Question? In: Allelochemicals: Role in Agriculture and Forestry, Waller, G.R. (Ed.). The Society, New York, USA., ISBN-13: 9780841209923, pp: 572-587.

Nelson, D.W. and L.E. Sommers, 1982. Total Carbon, Organic Carbon and Organic Matter. In: Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties, Wiscosin, A.L. (Ed.). 2nd Edn., ASA and SSSA, Madison, WI., pp: 539-579.

O'Hara, C.P., J. Bauhus and P.J. Smethurst, 2006. Role of light fraction soil organic matter in the phosphorus nutrition of *Eucalyptus globules* seedlings. Plant Soil, 280: 127-134.

Ohta, S. and K. Kumada, 1978. Studies on the humus forms of forest soils: VI. Minerallzation of nitrogen in brown forest soils. Soil Sci. Plant Nutr., 24: 41-54.

Paul, K.I., P.J. Polglase, J.G. Nyakuengama and P.K. Khanna, 2002. Change in soil carbon following afforestation. For. Ecol. Manage., 168: 241-257.

Rawls, W.J., D.L. Brakensiek and K.E. Saxton, 1982. Estimation of soil water properties. Trans. Am. Soc. Agric. Eng., 25: 1316-1320.

Rousk, J. and E. Baath, 2007. Fungal and bacterial growth in soil with plant materials of different C/N ratios. FEMS Microbiol. Ecol., 62: 258-267.

Schoenenberger, A., 1970. Study of the forest cover of the Eastern Aures: Evolutionary trend of the stand. F.A.O. Project Algeria, Constantine, 15, pp: 42.

Sequeira, C.H. and M.M. Alley, 2011. Soil organic matter fractions as indices of soil quality changes. Soil Sci. Soc. Am. J., 75: 1766-1773.

Shang, S., P. Jiang, S.X. Chang, Z. Song, J. Liu and L. Sun, 2014. Soil organic carbon in particle size and density fractionations under four forest vegetation-land use types in subtropical China. Forests, 5: 1391-1408.

Six, J., R.T. Conant, E.A. Paul and K. Paustian, 2002. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant Soil, 241: 155-176.

Sjoberg, G., 2003. Lignin degradation Long-term effects of nitrogen addition on decomposition of forest soil organic matter. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Sollins, P., G. Spycher and C.A. Glassman, 1984. Net nitrogen mineralization from light-and heavy-fraction forest soil organic matter. Soil Biol. Biochem., 16: 31-37.

Strukelj, M., S. Brais, S.A. Quideau and S.W. Oh, 2012. Chemical transformations of deadwood and foliar litter of mixed boreal species during decomposition. Can. J. For. Res., 42: 772-788.

Tan, Z., R. Lal, L. Owens and R.C. Izaurralde, 2007. Distribution of light and heavy fractions of soil organic carbon as related to land use and tillage practice. Soil Tillage Res., 92: 53-59.

Tracy, B.F. and D.A. Frank, 1998. Herbivore influence on soil microbial biomass and nitrogen mineralization in a Northern grassland ecosystem: Yellowstone National Park. Oecologia, 114: 556-562.

Vance, E.D., P.C. Brookes and D.S. Jenkinson, 1987. Microbial biomass measurements in forest soils: The use of the chloroform fumigation-incubation method in strongly acid soils. Soil Biol. Biochem., 19: 697-702.

Wang, Q., S. Wang, G. Xu and B. Fan, 2010. Conversion of secondary broadleaved forest into Chinese fir plantation alters litter production and potential nutrient returns. Plant Ecol., 209: 269-278.

Wang, Q.K. and S.L. Wang, 2007. Soil organic matter under different forest types in Southern China. Geoderma, 142: 349-356.

Whalen, J.K., P.J. Bottomley and D.D. Myrold, 2000. Carbon and nitrogen mineralization from light-and heavy-fraction additions to soil. Soil Biol. Biochem., 32: 1345-1352.

Williamson, J., D. Jones, E. Rowe, J. Healey, R. Bardjett and P. Hobbs, 2003. Soil Functioning in Natural and Planted Woodland on Slate Waste. In: Land Reclamation-Extending Boundaries, Moore, H.M., H.R. Fox and S. Elliott (Eds.). CRC Press, USA., ISBN: 13- 9789058095626, pp: 315-318.

Wu, J., R.G. Joergensen, B. Pommerening, R. Chaussod and P.C. Brookes, 1990. Measurement of soil microbial biomass C by fumigation-extraction: An automated procedure. Soil Biol. Biochem., 22: 1167-1169.

Xu, Z., S. Ward, C. Chen, T. Blumfield, N., Prasolova and J. Liu, 2008. Soil carbon and nutrient pools, microbial properties and gross nitrogen transformations in adjacent natural forest and hoop pine plantations of subtropical Australia. J. Soils Sediments, 8: 99-105.

Yadav, V. and G. Malanson, 2007. Progress in soil organic matter research: Litter decomposition, modelling, monitoring and sequestration. Prog. Phys. Geogr., 31: 131-154.

Yang, K., J.J. Zhu, M. Zhang, Q. Yan and O.J. Sun, 2010. Soil microbial biomass carbon and nitrogen in forest ecosystems of Northeast China: A comparison between natural secondary forest and larch plantation. J. Plant Ecol., 3: 175-182.