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Provisions in NPK elements through litterfall in an oak grove of *Quercus ilex L.* (east Algeria)

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ABSTRACT/RESUME

Abstract: *The main objective of this study is to understand the functioning of oak groves of Quercus ilex L. in the Aurès (eastern Algeria), by estimating the quantities of litter and their contribution of N P K elements.*
The quantities of litter were evaluated over a period of two years (2012 and 2013) in the oak grove of Larbaa (south of the province of Batna) by the installation, under the cover of trees, of a litter trap. The fallen litters were collected monthly, and then analyzed to measure N, P and K contents. Concerning the used statistical methods, nutrient results were subjected to ANOVA Analysis.
The present research revealed that the studied oak grove received 1.3 to 1.55 tons of total litter per hectare and per year. These litters ensured a supply of the soil in mineral elements N, P and K with quantities varied between 53.34 and 60.40 kg / ha. Contributions were dominated by the nitrogen element, supplied in large quantities by oak leaves.On the other hand, the monthly variation in the amount of litter and their NPK contents was significant, whereas the inter-annual variation was not significant.
This study revealed an important part of biogeochemical cycle of nutrients in the oak grove. Because, it highlights the contributions of litterfall inputs, which is considered as natural fertilizer to enrich the forest soil.

I. Introduction

The holm oak, *Quercus ilex* L. occupies a very large part of forest areas in the Mediterranean region, with nearly 2 million ha [1], [2], [3]. In Algeria, the alarming regression of the areas covered by holm oak in few years from 354 000 [4] to 149 000 ha [5] has prompted Algerian researchers to work to better understand the functioning of these oak groves.

For a sustainable management of these oak groves, studies that focus on the productivity of litter and their contribution of biogenic elements are very useful because of these elements present in large quantities in the biogeochemical cycle of nutrients, compared to other sources such as environmental deposits [6], [7], [8], [9], [10].

According to several studies [11], [12], the decrease in soil moisture over the next decades may reach 25% by 2040. This aridity can affect not only the productivity and composition of forests [13], [14], [15], but also the amount of litter dropped and the key processes linked to its fall [16], [17], [18], [19], [3]. Although the holm oak is an intermediate drought tolerant species, several studies have reported that precipitation and water availability are probable causes of differences in the photosynthesis rate and litter production of this forest species [19], [3].

Studies on litter fallout and their NPK nutrient provisions are abundant in the literature worldwide [8], [20], [10], [3], [21]. However, in North Africa this topic of research remains very limited with the exception of a few works [22], [23]. For Algeria, to

our knowledge, no data on nutrient supply through holm oak litter is available.
The main objectives of this study are 1) to quantify the NPK nutrient inputs by litterfall and 2) to assess the monthly and interannual fluctuations of these nutrients (NPK) in an oak grove with *Quercus ilex* L.

II. Materials and methods

The quantities of litter were evaluated in the Larbaa oak grove (35°27'19''N, 6° 22'42''E). It is located at an altitude of 1640 m, on the northern side of the S'gag forest, 28 km south of the town of Batna (Figure 1). The tree ages range from 50 to 90 years.
The vegetation of the studied oak grove consists mainly of *Q.ilex* with a density of 280 trees / ha. The slope from 10 to 18%.
According to the data of the Ain Skhouna Meteorological station located at Batna Airport, the average annual amount of precipitation over 22-year period (1989-2010) was 331.28 mm. Besides, the average temperature was 15.6 ° C for the same period, with a mean of maximal temperatures of 35.57 ° C and a mean of minimal temperatures of 0.06 ° C. In general, the dry period was very important, exceeding five months.

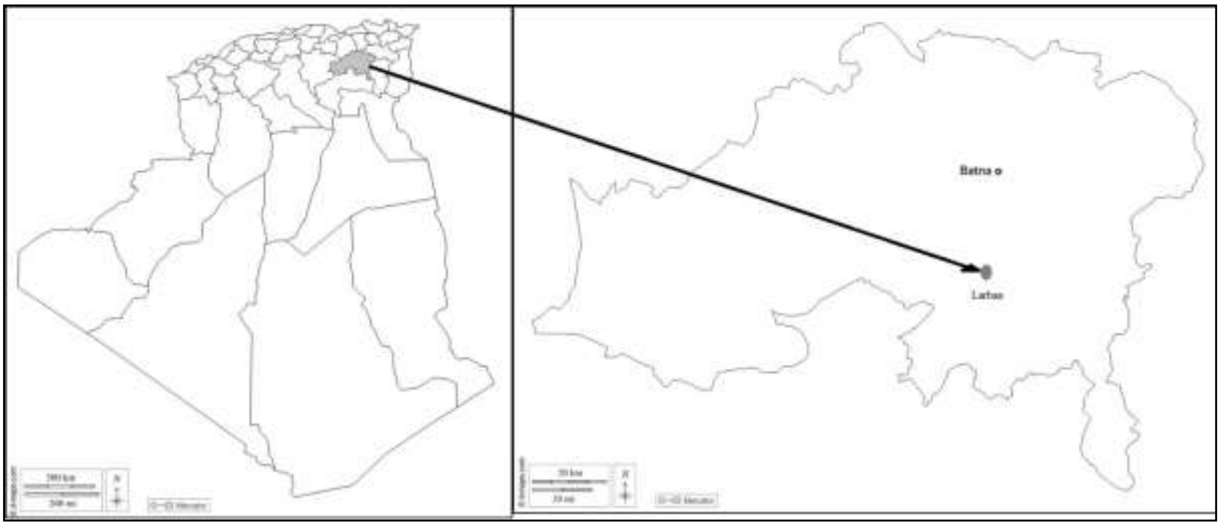

Figure 1. *The location of the study site*

To assess the quantities of litter that fell to the ground, twelve square wooden litter traps, 0.25 m^2 in area and 0.50 m in high, were installed under the tree canopy. The bottom of these collectors is formed by a plastic grid with 2 mm mesh. These collectors were placed on four supports of 0.50 m high and they are randomly spaced from each other 5 to 10 m.
The device used for this study is inspired from many studies [24], [23], [25], [26].
The litter in each litter trap was collected monthly. Then it is separated into three fractions (wood, twigs and bark (BBE), fruits and inflorescences (Fr and In) and leaves of holm oak (Fcv)).
The different fractions of litter brought back were weighed, then kept cool in well-sealed plastic bags (their weightsare known). They were then dried at 105 ° C until a constant weight and then reweighed separately.
After drying, these different fractions are ground until a fine and homogeneous powder is obtained, ready for chemical analyzes.
The quantification of biogenic elements was done by the following methods:
- Total nitrogen by the Kjeldahl method;
- Total phosphorus by spectrophotometer (650 nm);
- Potassium by the flame photometer.

It should be noted that the quantities of N, P and K elements are expressed in kg / ha / year.
Concerning the statistical analysis, nutrient results were subjected to Analysis of Variance (ANOVA) at the 5% error threshold. The software used was SPSS version 10.0.5 (SPSS Inc.). Microsoft Excel was used for obtainingthe histograms relating to the quantities of litter and their nutrient provisions.

III. Results

III.1. Amounts of litter returning to the soil

Our investigation revealed that the studied oak grove received between 1.3 and 1.55 tons of total litter per hectare and per year. On average, the leaf (Fcv) and fruit / inflorescence (Fr / inf) fractions were clearly dominant compared to the litter made up of wood, twigs and bark (BBE) during the two years 2012 and 2013 (Figure 2).
Each of the Fr / inf and Fcv fractions represented more than 40% of the total biomass collected under the canopy in 2012 and 2013 (Figure 2). Their relative contributions are very close in 2012 (40.69 and 40.92%), and slightly divergent in 2013 (44.68 and 42.30% respectively).

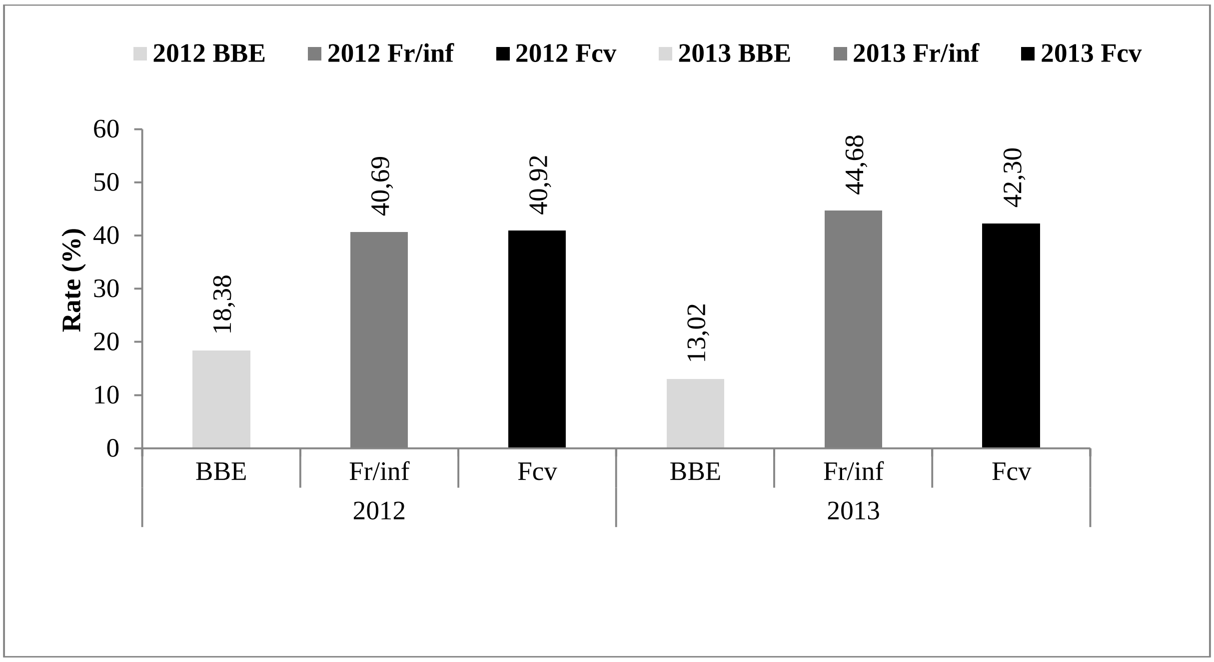

Figure 2. *Average proportions of litterfall fractions in thestudied oak grove*

For the monthly variation in litter fallout, Table 1 revealed a significant difference concerning the amount of litter fall. Besides, Figure 3 shows clearly the two peaks that characterize the litter fall, the first between April and May and the second between October and November. During these two periods combined, the accumulations of litter represent proportions between 53.85 and 57.38% of the annual total of litter fallouts.

Table 1. *Intra-annual variation of total amount of litterfall in the studied oak grove.*

Parameter	**F**	**P**
Total amount of litterfall	14,716	0,000 *

(*) Significant difference when the probability is $p < 0.05$.

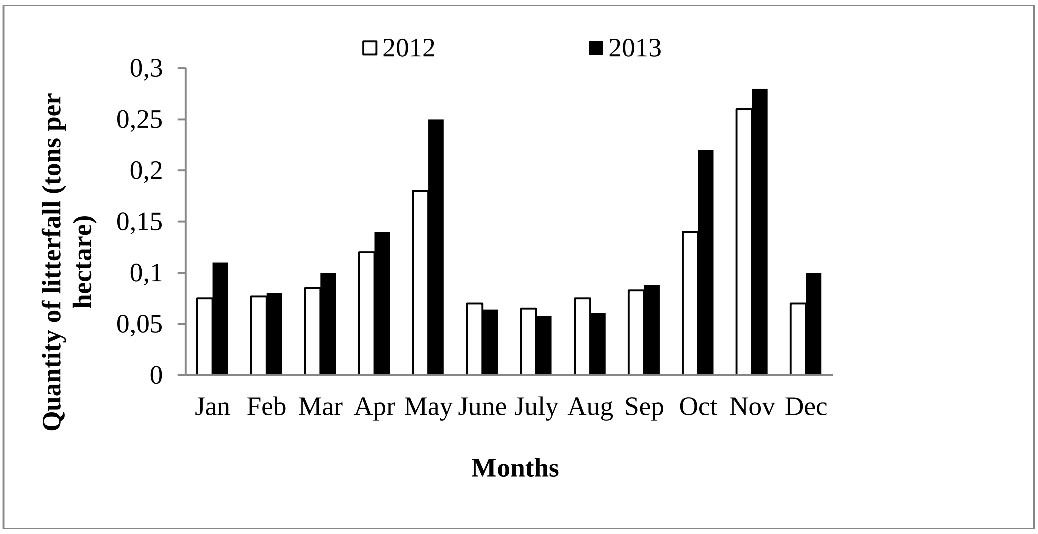

Figure 3. *Monthly variation of litterfall quantities (tons / hectare)*

III.2. NPK content of different litter fractions

In general, ANOVA showed significant difference between fractions in their contents of NPK elements (Table 2). Furthermore, the results of Table 3 show that leaf fraction (Fcv) had the highest nitrogen contents (3.53% of the dry

weight); while the BBE fraction had the lowest one (1.26%).
The same table also reveals on the other hand that the fruit and inflorescence fraction is the richest in K (1.69%) followed by Fcv and BBE. Whereas,the phosphorus contents were practically comparable for the three fractions (0.14 % for the leaf fraction versus 0.17% for the twig branch wood fraction).

Table 2. *ANOVA analysis of NPK contents of different fractions in the studied oak grove.*

Parameters	F	P
Nitrogen	97,730	0,000 *
Phosphorus	55,443	0,000 *
Potassium	50,722	0,000 *

(*) Significant difference when the probability is $p < 0.05$.

Table 3. *Content of NPK elements in different litter fractions.*

Fraction	Content (% Dry Matter)								
	N			P			K		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
Fcv	3,73	3,32	3,53	0,14	0,13	0,14	1,73	1,52	1,63
Fr/In	2,02	1,86	1,94	0,11	0,10	0,11	1,72	1,66	1,69
BBE	1,28	1,23	1,26	0,17	0,16	0,17	0,68	0,59	0,64

III.3. Supply of NPK elements through litterfall

The results of NPK contributions from total litter show that soil mineral enrichment varied somewhat from year to year. Annual provisions were between 53.34 (2012) and 60.40 kg / ha / year (2013). On average, the cover of the oak grove brings 56.87 Kg / ha / year.
The year 2013 appears relatively more productive in N, P and K elements than 2012 (Table 4).

Table 4. *Provisions of NPK elements (in kg / ha / year) via litterfall in the studied oak grove*

Fraction	Element contribution (kg / hectare / year)									
	N			P			K			Total average
	2012	2013	Average	2012	2013	Average	2012	2013	Average	
Fcv	19,60	20,40	20,00	0,76	0,82	0,79	7,74	8,37	8,06	28,85
Fr/In	10,79	13,99	12,39	0,65	0,73	0,69	9,06	12,46	10,76	23,84
BBE	2,99	2,24	2,62	0,39	0,32	0,36	1,36	1,07	1,22	4,19
Total	33,38	36,63	35,01	1,80	1,87	1,84	18,16	21,90	20,03	56,87

The mineral contributions were dominated by nitrogen followed by potassium and finally phosphorus which remains very low. More than 61% of the minerals returned to the soil during the two years of monitoring consist of the element nitrogen. Nitrogen in the litter was mainly localized in leaf fractions (Fcv) and flower inflorescences (Fr and In). The contributions of phosphorus by the litters in the studied oak grove were often low (1.80 to 1.87 kg / ha). Furthermore, Potassium accumulated in the highest proportion in the leaves and inflorescences (Fr / In).
On the other hand, Figure 4 represents the monthly variability of N, P and K provisions in the studied oak forest. The supply of nitrogen and potassium was particularly high in April, May (Spring), a little less in October and November (Autumn) and reduced in summer.
Statistically, the monthly variations were highly significant for all the studied nutrients (Table 5).

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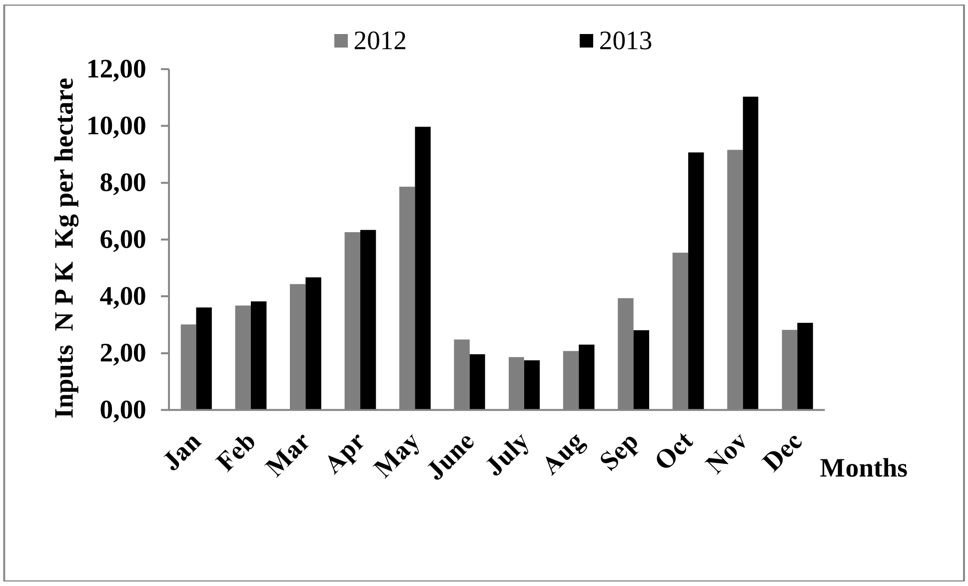

Figure 4. *Monthly variation of inputs NPK (kg / hectare)*

Table 5. *Intra-annual and inter-annual variation of NPK provisions through litterfall of Quercus ilex L.*

	N P K contents	
	F	**P**
Intra-annual variation	33,154	0,000 *
Inter-annual variation	0,060	0,808

(*) Significant difference when the probability is $p < 0.05$.

IV. Discussions

IV.1. Amounts of litter returning to the soil

The quantity of litter found in this study (1.3 to 1.55 tons of total litter / hectare / year) is modest compared to the results found in other research for the same species [27], [28], [29], [20], [30], [23]; which reported quantities of 3-6.94 tons / ha / year). Nevertheless, these researchers evaluated the litter under trees whose height is between 4.5 and 6.3 m and the heights of the trees in our case are only between 3 and 4 meters.

Besides, Bellot et al. [31] reported lower amounts of litter (2.3 tons / ha / year) for oak groves in Spain.

Other studies carried out on *Quercus spp*. have reported average annual quantities that vary between 2.8 and 4.1 [32], [33], [34], [35], [10].

Our results are in concordance with those of [36], [24], wherefor certain years in Spanish oak groves, they found quantities which vary between 1.47 and 1.6 tons / hectare / year.

In a forest ecosystem, most authors agree that the type of stand and its composition, precipitation and temperature govern biomass production, litter fall and its temporal variation [20], [37], [38], [3]. According to Bindzi et al. [26], the litter fall is the consequence of an interaction between environmental factors and endogenous factors whose simultaneous action would cause the early or late fall of leaves, twigs, wood, inflorescences and acorns according to their resilience capacities.

Drought leads, according to several studies, to a drop in productivity [13], [14], [38], [3]. The latter authors estimate that Mediterranean forest ecosystems can undergo a significant decrease in biomass in case of low precipitation and especially high evapotranspiration.

This reduction in holm oak biomass may affect litter amounts. Andivia et al. [19] have previously reported that precipitation and water availability are likely causes of differences in litter production for *Q. ilex* populations.

In addition, Edwards et al. [39] mentioned other factors that influence litter fall like leaf longevity and environmental conditions, including seasonal nutrient flow.

Regarding the distribution of the different litter fractions, our results do not completely agree with previous studies [31], [20], [38], which found for the same species a litter composed of 55.7 to 68% of leaves and from 6.3 to 19% of fruits and inflorescences. The present study revealed contributions which do not exceed 45 % for the fractions of leaves (Fcv) and fruits and inflorescences (Fr / inf).

However, our results remain within the range stated by several works [40], [41], [42], [43], [44] who mentioned that the leaf fraction may vary from 41–98% of total litter).

This divergence of the different litter fractions can be attributed to the influence of weather conditions on the one hand, and to the interannual variability in the production of leaves, inflorescences and acorns. According to Bou et al. [38], years of abundance are often followed by years of low production.

Our results relating to the monthly variation agree with previous studies [20], [45], [23], [38]. They showed that the percentages of fallen leaves have two peaks, the first is between April and May and the second between October and November. For our study, the intra-annual variation can be attributed mainly to the annual precipitation volumes and their time distribution. Rainfall volumes and temperatures determine the intensity of leaf, branch and acorn fall as well as the time of their fall [46], [47], [39], [3]. Several studies have confirmed that holm oak begins during extreme droughts by reducing the leaf area to combat water stress [46], [47], [38]. As for fruits, Bou et al. [38] asserted that the fall of *Q. ilex* acorns is favored by the mechanical effect of rains, while increased rains may promote the final growth of acorns.

IV.2. NPK element content

Compared to the study of Bussotti et al. [20], who found levels between 1.22 and 2.02% for holm oak, the nitrogen concentrations found in our case are higher especially for the leaf fraction (3.52%). This difference can be attributed to the different densities of the trees. Moreover, our results for nitrogen remain close and consistent with the study of Leonardi and Rapp [48] who observed that the N content can reach 3.6% in holm oak litter.

Likewise for the potassium concentrations, they are slightly higher (0.64 to 1.69%) compared to the different studies on holm oak litter [48], [20], which reported levels not exceeding 1.31%. However, the substrate and the climatic conditions surrounding the holm oak were different.

The relative phosphorus concentrations remain low as in other studies [20], [23].

Other factors may explain the different concentrations of nutrients such as the type of vegetation and to the particular climatic and edaphic conditions of the station [25]. In our oak grove, it is believed that drought probably contributed to the increase in nitrogen concentrations, after leaf reduction. Sardans et al. [49] have already mentioned that drought increased the concentrations of nutrients in the leaves of *Q. ilex*.

IV.3. Supply of NPK elements through litterfall

The result found (56.87 Kg / ha / year) is slightly higher compared to those found by other researchers [48], [20], [23] who recorded NPK quantities ranging from 20.52 to 47.5 Kg / ha / year in oak groves of *Q. ilex*. These relatively high nutrient contributions can be attributed, not only to the different climatic conditions and characteristics of the studied forests (density and age), but also to high concentrations of the nitrogen, in particular in the leaf fraction. Furthermore, the amount of the basic elements N, P and K depends on the amount of litter and the content of elements in the woody tissues [50].

Le Gall [51] reported that trees growing on nitrogen-rich soils may have high nitrogen concentrations in their leaves. Besides, the availability of nutrients in the soil influences their concentrations in the leaves and organs of the tree [25]. Other studies have already reported that drought increased nutrient concentrations in the leaves of *Q. ilex* as a result of reduced leaf biomass [49].

The order of importance of the NPK elements revealed by this study is similar to that found for the same species by Leonardi and Rapp [48]; Boulmane et al. [23] and Novák et al. [10].

The rate of nitrogen found in our case, relative to the total NPK is entirely in agreement with the results of Boulmane et al. [23] and Novák et al. [10] who asserted that nitrogen is the most abundant nutrient in holm oak litter (over 61% of total intake). The main supply of nitrogen, which is provided by the leaves of holm oak, means according to Uriarte et al. [52] that the spatial distribution of trees and the structure of the tree crowns play a very important role for the redistribution of nutrients that will return to the forest floor.

Our results relating to the phosphorus input (1.84 kg /ha /year) are lower than those of Boulmane et al. [23] who reported an amount of 3.16 kg / ha / year.

Concerning the K element, it was higher (20.03 Kg / ha / year on average) compared to the amounts found in other studies, which did not exceed 14 kg / ha / year [20], [23].

The temporal variability found in our study is compatible with the results of other holm oak forests [45], [23]. The latter researchers observed a strong monthly and interannual variability in the amounts of NPK elements. These litter contributions are spread over the whole year but the maximum intake was in April, May and September and November. The flow of nutrients varied according to the phenological parameters linked to the leaves, to the reproductive organs and the meteorological factors (storm) which can modify the monthly frequency of litter fallout and consequently NPK provisions [48], [23].

V. Conclusion

The present study brings new data concerning the quantification of holm oak litter and their provisionsin NPK elements during a period of two years in the region of Aurès.

The solid fallout (litter) provides the forest soil with quantities ranging from 1.3 to 1.55 tons / ha of dry matter, mainly composed of the leaves, inflorescences and acorns of holm oak. Most of these organic mattersrecorded in spring and autumn.

The annual contributions of NPK elements were between 53.34 and 60.40 kg / ha / year. The nitrogen was by far the most dominant (over 61% of total intakes).

The quantification of litter and their contributions in other nutrients over much longer periods are desirable to understand the role of holm oak litter in the mineral nutrition of oak groves.

The results of the present study revealed new data about the source that guarantees a large proportion of mineral nutrition of oak trees.These data are very useful in understanding the economy of nutrients of oak grove. The obtained results aim primarily the sustainable management of this oak grove, especially under climate change conditions. Moreover, the aspect related to the mineral demand by oak trees helps forestry engineers to more understanding the nutrient cycling, in order to control the quantities of wood and plant biomass that can be exploited without affecting the fertility of the soil, and consequently reduce the number of forest dieback and preserve the health of trees.

VI. References

1. Bonin, G. 30 ans de recherche forestière en région méditerranéenne. *Forêt Méditerranéenne* 29 (2008) 431-444.
2. Derbal, W.; Zerizer, A.; Gérard, J.; Guibal, D. Caractérisation d'aboutages à entures multiples pour trois essences d'Algérie. *Bois et forêts des tropiques* 325 (2015) 59-70.
3. Liu, D.; Ogaya, R.A.; Abarbeta, A.; Yang, X.; Nuelas, J. Contrasting impacts of continuous moderate drought and episodic severe droughts on the above ground biomass increment and litterfall of three coexisting Mediterranean woody species. *Global Change Biology* 21 (2015) 4196–4209.
4. Letreuch-Belarouci, N. Les reboisements en Algérie et leurs perspectives d'avenir. O.P.U : Algiers, Algeria, 1991; 641 p.
5. El Achi, M. Évaluation des ressources forestières mondiales: Rapport national Algérie. FAO : Rome, Italy, 2010 ; 57 p.
6. Waring, R.H. Estimating forest growth and efficiency in relation to canopy leaf area. *Advances in ecological research* 13 (1983) 327-354.
7. Romane, F. Introduction and objectives. In: Sustainability of Mediterranean ecosystems. Casestudy of the chestnut forest; Romane, F. (Ed.); European Commission: Brussels, Belgium, 1995; Volume 19, pp. 1-5.
8. Santa Régina, I. Biomass estimation and nutrient pools in foor *Quercus pyrenaica* in Sierra de Gata Mountains, Salamanca, Spain. *Forest Ecology and management* 132 (2000) 127-141.
9. Likens, G. E. Biogeochemistry of a forested ecosystem, 3rd ed.; Springer: New York, USA, 2013; 208 p.
10. Novák, J.; Dušek, D.; Slodičák, M. Quantity and quality of litterfall in young oak stands. *Journal of Forest Science* 60 (2014) 219–225.
11. Sabaté, S.; Gracia, C. A.; Sánchez, A. Likely effects of climate change on growth of *Quercus ilex*, *Pinus halepensis*, *Pinus pinaster*, *Pinus sylvestris* and *Fagus sylvatica* forests in the Mediterranean region. *Forest ecology and management* 162 (2002), 23-37.
12. Peñuelas, J.; Filella, I.; Sabate, S. Natural systems: terrestrial ecosystems. In: Report on climate change in Catalonia; Llebot J.E. (Ed.); Institut d'Estudis Catalans: Barcelona, Spain, 2005; pp. 517–553.
13. Ciais, P.; Reichstein, M.; Viovy, N.; Granier, A.; Ogée, J.; Allard, V.; Aubinet, M.; Buchmann, N.; Bernhofer, C.; Carrara, A.; Chevallier, F. Europe-wide reduction in primary productivity caused by the heat and drought in 2003. *Nature* 437 (2005) 529-533.
14. Wu, Z.; Dijkstra, P.; Koch, G. W.; Peñuelas, J.; Hungate, B. A. Responses of terrestrial ecosystems to temperature and precipitation change: A meta-analysis of experimental manipulation. *Global Change Biology* 17 (2011) 927-942.
15. Ivits, E.; Horion, S.; Fensholt, R.; Cherlet, M. Drought footprint on European ecosystems between 1999 and 2010 assessed by remotely sensed vegetation phenology and productivity. *Global Change Biology* 20 (2014) 581-593.
16. Bugmann, H. Sensitivity of forests in the European Alps to future climatic change. *Climate Research* 8 (1997) 35–44.
17. Weber, P.; Bugmann, H.; Fonti, P.; Rigling, A. Using a retrospective dynamic competition index to reconstruct forest succession. *Forest Ecology and Management* 254 (2008) 96-106.
18. Tóth, J.A.; Nagy, P.T.; Krakomperger, Z.; Veres, Z.; Kotroczó, Z.; Kincses, S.; Fekete, I.; Papp, M.; Lajtha, K.: Effect of litter fall on soil nutrient content and pH, and its consequences in view of climate change (síkfokút DIRT project). *Acta Silvatica et Lignaria Hungarica* 7 (2011) 75-86.
19. Andivia Muñoz, E.; Vázquez Piqué, J.; Fernández, M.; Alejano Monge, R. Litter production in Holm oak trees subjected to different pruning intensities in Mediterranean dehesas. *Agroforestry Systems* 87 (2013) 657-666.
20. Bussotti, F.; Borghini, F.; Celesti, C.; Leonzeo, C.; Cozzi, A.; Bettini, D.; Ferretti, M. Leaf shedding, crown condition and element return in two mixed holm oak forest in Tuscaany, central Italy. *Forest and Management* 176 (2003) 273-285.
21. Neumann, M.; Ukonmaanaho, L.; Johnson, J.; Benham, S.; Vesterdal, L.; Novotný, R.; Verstraeten, A.; Lundin, L.; Thimonier, A.; Michopoulos, P.; Hasenauer, H. Quantifying carbon and nutrient input from litterfall in European forests using field observations and modeling. *Global Biogeochemical Cycles* 32 (2018) 784-798.
22. Selmi, R. Différenciation des sols et fonctionnement des écosystèmes forestiers sur grès numédien de kroumerie (Tunisie). Ecologie de subéraie-zeenaie. Doctorate thesis, University of Nancy 1, France, 1985.

23. Boulmane, M.; Halim, M.; Khia, A.; Oubrahim, H.; Abbassi, H.; Amrani, A. Biomasse, minéralomasse et éléments nutritifs retournant au sol dans le *Quercus Ilex* du Moyen Atlas Central Marocain. *Nature et Technologie: Sciences de l'Environnement* 9 (2013) 41 -53.
24. Martin, A.; Gallardo, J.F.; Santa Regina, I. Aboveground litter production and bioelement potential return in an evergreen oak (*Quercus rotundifolia*) woodland near Salamanca (Spain). *Annales des sciences forestières* 53 (1996) 811-818.
25. Jérôme, E.; Pierre, M. J.; Quentin, P. Chute des litières et fertilité des sols sous plantations forestières dans le bassin du Congo : cas de la station I.N.E.R.A/Yangambi en R.D.C. *Journal of Animal and plant Science* 31 (2016) 4843-4861.
26. Bindzi, M.A.M.; Endanga, D.G.H.; Biye, E.H.; Kono, L.D. Variations spatiotemporelles de la chute de litière dans une forêt mixte secondaire mésophile du Cameroun. *World Wide Journal of Multidisiplinary Research and Development* 3 (2017) 10-17.
27. Verdu, A.M.C.; Ferrés, L.; Roda, F.; Terradas, J. Estructuta y funcionalismo de un encinarmontano en el Montseny. *Mediterranéa* 4 (1980) 51–67.
28. Ferrés, L.; Roda, F.; Verdu, A.M.C.; Terradas, J. Circulación de nutrientes en algunos ecosistemas forestales del Montseny (Barcelona). *Mediterránea: Serie de Estudios Biológicos* 7 (1984) 139–166.
29. Rodà, F.; Retana, J.; Gracia, C.A.; Bellot, J. Ecology of Mediterranean evergreen oak forests; Springer: Berlin, Germany, 1999; pp. 1-20.
30. Andivia Muñoz, E.; Alejano Monge, R.; Vázquez Piqué, J. Evolución mensual del desfronde en dos dehesas de *Quercus ilex* subs. ballota de la provincia de Huelva. Influencia de la poda. In 5th Congress of Spanish forestery, Ávila, Spain, May 2009.
31. Bellot, J.; Sánchez, J.R.; Lledó, M.J.; Martínez P.; Escarré A. Litterfall as a measure of primary production in Mediterranean holm-oak forest. *Vegetatio* 99-100 (1992) 69-76.
32. Carlisle, A.; White, A.H.F.; Brown, E.J. Litter fall, leaf production and the effects of defoliation by *Tortrix viridana*in a Sessile Oak (*Quercus petraea*) woodland. *Journal of Ecology* 54 (1966) 65–85.
33. Santa Regina, I. Contribución al estudio de la dinámica de la materiaorgánica y bioelementos en bosques en la Sierra de Béjar. Doctorate thesis, University of Salamanca, Spain, 1987.
34. Carceller, F.; Santa Cecilia, M.; Vallejo, V.; Novo, M. Introducción al ciclo de la materia orgánica en cinco ecosistemas forestales del Moncayo. *Turiaso* 9 (1989) 361–372.
35. Hansen, K.; Vesterdal, L.; Schmidt, I.K.; Gundersen, P.; Sevel, L.; Bastrup-Birk, A.; Pedersen, L.B.; Bille-Hansen, J. Litterfall and nutrient return in five tree species in a common garden experiment. *Forest Ecology and Management* 257 (2009) 2133–2144.
36. Hernandez, I.M.; Gallardo, J.F.; Santa Regina, I. Dynamic of organic matter in forests subject to a Mediterranean semi-arid climate in the Duero basin (Spain): litter production. *Acta Oecologica*13 (1992) 55–65.
37. Lacoste, A.; Salanon, R. Eléments de biogéographie. *Norois* 62 (1969) 270-271.
38. Bou, J.; Caritat, A.; Vilar, L. Litterfall and growth dynamics relationship with the meteorological variability in three forests in the Montseny natural park. *Folia Forestalia Polonica series A* 57 (2015) 145–159.
39. Edwards, W.; Liddell, M.J.; Franks, P.; Nichols, C.; Laurance, S.G.W. Seasonal patterns in rainforest litterfall: Detecting endogenous and environmental influences from long-term sampling. *Austral Ecology* 43 (2018) 225-235.
40. Abelho, M.; Graça, M.A.S. Litter in a first-order stream of a temperate deciduous forest (Margaraça Forest, central Portugal). *Hydrobiologia* 386 (1998) 147–152.
41. Benson, L.J.; Pearson, R.G. Litter inputs to a tropical Australian rainforest stream. *Australian Journal of Ecology* 18 (1993) 377–383.
42. Abelho, M.; Graça, M.A.S. Effects of eucalyptus afforestation on leaf litter dynamics and macroinvertebrate community structure of streams in Central Portugal. *Hydrobiologia* 324 (1996) 195–204.
43. Grigg, A.H.; Mulligan, D.R. Litterfall from two eucalypt woodlands in central Queensland. *Australian Journal of Ecology* 24 (1999) 662–664.
44. Oelbermann, M.; Gordon, A.M. Quantity and quality of autumnal litterfall into a rehabilitated agricultural stream. *Journal EnvironmentalQuality* 29 (2000) 603–611.
45. Makhloufi, M.; Boulmane, M.; Saint-André, L.; Bouillet, J.P.; Abourouh, M.; Ezzahiri, M.; Belghazi, B.; El Harchaoui, H. Tarifs de cubage, modélisation de la biomasse des taillis du chêne vert du Moyen Atlas : cas des iliçaies de Taffechna et Reggada. *Annales de la Recherche Forestière, Maroc* 40 (2008) 123-135.
46. Limousin, J.M. Vulnérabilité du chêne vert (*Quercus ilex* L.) à une augmentation de la sécheresse: Quels ajustements fonctionnels ?. Doctorate thesis, Montpellier SupAgro, France, 2009.
47. Barba, J.; Lloret, F.; Yuste, J.C. Effects of drought-induced forest die-off on litter decomposition. *Plant and Soil* 402 (2016) 91-101.
48. Leonardi, S.; Rapp, M. Retour au sol d'éléments minéraux et d'azote par l'intermédiaire des litières dans un écosystème à *Quercus ilex* L. du monte minardo (Etna). *Flora* 171 (1981) 329-337.
49. Sardans, J.; Penuelas, J.; Ogaya, R. Drought's impact on Ca, Fe, Mg, Mo and S concentration and accumulation patterns in the plants and soil of a Mediterranean evergreen *Quercus ilex* forest. *Biogeochemistry* 87 (2008) 49-69.
50. Rapp, M. Cycle de la matière organique et des éléments minéraux dans quelques écosystèmes méditerranéens : Dynamique saisonnière de deux sols en climat tempéré; C. N. R.S. : Paris VII, France, 1971; 253 p.
51. Le Gall, A.C. Effets des dépôts atmosphériques de soufre et d'azote sur les sols et les eaux douces en France; INERIS : France, 2004; 112 p.
52. Uriarte, M.; Turner, B.; Thompson, J.; Zimmerman, J. Linking spatial patterns of leaf litterfall and soil nutrients in a tropical forest: A neighborhood approach. *Ecological Applications* 25 (2015) 2022–2034.

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