VARIATION OF THROUGHFALL, STEMFLOW AND INTERCEPTION OF RAINFALL IN A *Quercus ilex* L. COPPICE

BENHIZIA Toufik[(1,2,*)], OUDJEHIH Bachir[(1)], LEBBAL Salim[(2)]

[(1)]*Department of Agronomy, University Hadj Lakhdar, Batna 1, Algeria*
[(2)]*Department of Agronomy, Faculty of Natural and Life Sciences,*
University Abbas Laghrour, Khenchela, Algeria
E-mail: toufikbenhizia@yahoo.fr

Abstract.- *Rainfall partitioning by vegetation plays an important role affecting the water balance at local scale due to the control that vegetation canopies exert by modifying both evaporation and the redistribution of precipitation in different fractions of throughfall, stemflow and interception loss. These fractions have been evaluated during three years in an evergreen oak coppice in the eastern Algeria using specific collection devices. The results revealed that the mean rate of throughfall was 66.30% of the open field precipitation (gross rainfall). Stemflow represented on average a very small fraction (7.13% of open field precipitation), whereas the interception loss was relatively high (26.46% of the open field precipitation). The use of linear regressions showed strong correlations between open field precipitation and different fractions of water (stemflow, throughfall and interception loss) at the studied station.*

VARIATION DE L'EGOUTTEMENT, ECOULEMENT ET INTERCEPTION DES PLUIES DANS UN TALLIS A *Quercus ilex* L.

Résumé.- *La répartition des précipitations par la végétation joue un rôle important dans le bilan hydrique à l'échelle locale en raison du contrôle exercé par les couvertures végétales en modifiant l'évaporation et la redistribution des précipitations dans différentes fractions d'écoulement, d'égouttement et d'interception. Ces fractions ont été évaluées pendant trois ans dans un taillis de chêne vert dans l'est de l'Algérie à l'aide de dispositifs de collecte spécifiques. Les résultats ont révélé que le taux moyen d'égouttement était de 66,30% des précipitations (précipitations incidentes). L'écoulement représentait en moyenne une très petite fraction (7,13% des précipitations), tandis que la perte d'interception était relativement élevée (26,46% des précipitations). L'utilisation de régressions linéaires a montré de fortes corrélations entre les précipitations et les différentes fractions d'eau (égouttement, écoulement et perte d'interception) dans la station étudiée.*

Introduction

The Mediterranean forest consists mainly of evergreen oak (*Quercus ilex* L.) coppices [1]. It is difficult to give a statistic of its distribution sometimes mixed and often much degraded [2]. Nevertheless, it ranks third among the main species of Algerian forests after Aleppo pine (*Pinus halepensis* Mill.) and cork oak (*Q. suber*) [3]. In remote areas, these forests are permanently subject to strong anthropogenic pressure [4,5]. Furthermore, the Algerian forest is strongly conditioned by a climate where drought is a factor that slows down its evolution [6-9]. The last four decades are characterized by recurrent droughts in Algeria [4]. The study of NEDJRAOUI and BÉDRANI [10] showed clearly a decrease of 18 to 27% in the open field precipitation (gross rainfall) in the steppe area over a period of

almost a century (1907-2003). In the Aurès (east of Algeria), the effect of continentality is felt; open field precipitation decreases and temperatures rises, which constitute an ecological factor limiting the productivity of forests or crops, and adaptation is possible only for the species having the faculty to resist extreme conditions [9].

In forest ecosystems, rainfall is partitioned by forest canopies into throughfall, stemflow, and interception loss [11]. The throughfall part crosses the crowns of trees, whereas the stemflow part flows through the trunks of the trees and the interception part is lost either by saturation of crowns and tree trunks either by evaporation [12].

The importance of rainfall for populations and natural ecosystems [13,14] and the poor availability of water in a semi-arid climate highlighted the utility for water managers to estimate rainfall arriving to soil by stemflow and throughfall [15,16] as well as an understanding of the distribution of open field precipitation in different fractions, which is the first interaction between the water cycle and the forest [17,18], in order to develop strategic plans for the selection of tree species for reforestation and control of soil erosion.

The interception of precipitation was described by several studies carried out in different countries under different forest covers [19,20]. Data on rain interception by evergreen oak are virtually non-existent for Algeria, except the study of BENHIZIA *et al.* (2018) on a forest of tall trees [21]. Thus, the purpose of this study is to quantify the temporal variations of open field precipitation, stemflow, throughfall and interception loss in a *Q. ilex* coppice located in Aurès, in order to establish models for the prediction of different fractions of water.

1.- Materials and methods

1.1.- Study site

Our work concerns a *Q. ilex* coppice in Marconna in the region of Aurès (east Algeria). The Marconna coppice (39° 32'N and 4° 25'E) is located at an altitude of 1310 m on the northern side of the S'gag forest, 12 km south of the town of Batna. Its vegetation has experienced several successive fires and consists of evergreen (holm) oak, *Q. ilex* L. of 25 to 40 years of age, associated with variable densities of *Pistacia atlantica* Desf., *Stipa tenacissima* L., *Ampelodesma mauritanica* (Poir.) Dur. and Schinz, *Globularia alypum* L. and *Rosmarinus officinalis* L. The density of the forest is 370 stems ha^{-1}. The average height of the trees is 3 meters with a Leaf Area Index of 1.

1.2.- Experimental design

The protocol used was inspired from the studies of GASH *et al.* (1995) [22], DUMAS (2009) [23] and LIMOUSIN *et al.* (2008) [12], because of its advantages such as the taking into account of the stemflow along the trunks.

Throughfall water was collected manually under 25 trees, using 4 plastic containers installed randomly under the crown of each tree. Thus, 100 containers were used in total. To reach within 10% of the population mean, 12–26 individual funnels are necessary [24]. The used containers have the shape of inverted cone, provided with a lid whose lower conical portion is pierced with small holes to minimize evaporation. Each container was fixed to 4-foot metal supports, so that the tank was 20 cm from the ground. The receiving

surface of a container was 0.049 m²; whereas the overall collection area was 4.9 m², which is considered sufficient [25]. The quantities of water collected are measured with a test tube. LLORENS and DOMINGO (2007) [26] mentioned in their review that throughfall is frequently measured manually by 3 to 163 emptied stationary funnels and the total collecting area in all studies varied between 0.03 and 14.5 m^2.

The quantities of the open field precipitation were evaluated by placing 10 containers, similar to those of throughfall, randomly distributed in a bare ground zone, about 10 m away from the canopy.

Stemflow water was collected by devices sealed securely around the trunks of 12 trees, with plastic clamps rendered watertight with mastic. The collectors were slightly inclined to allow the connection of their lowest point, which facilitates the rapid transfer of the collected water to a can. The upper openings of the collectors were covered to prevent the entry of direct and throughfall water. Stemflow volume was converted back to depth equivalent at the tree scale by dividing stemflow volume by total canopy area [27].

Water quantities (open field precipitation, throughfall and stemflow) were measured from January 2011 to December 2013, as soon as possible after the rain.

The volumes of collected water are converted into mm by the formula:

$$P \text{ (mm)} = 10 \text{ x } \frac{V}{S} \text{ [28]}$$

Knowing that: S = receiving area in cm² and V = volume of water collected in cm^3. The quantity of intercepted water, expressed in mm, was estimated by the formula:

$$I \text{ (mm)} = P - (TF + SF) \text{ [23]}$$

With: I = interception loss, P = open field precipitation, TF = throughfall, SF = stemflow.

1.3.- Data analysis

Precipitation, throughfall, stemflow and interception loss are subjected to ANOVA one way analysis, using the 10th version of SPSS software. While the predicted models of the studied parameters (TF, SF and I) were obtained by linear regressions with MS-Excel 2007.

2.- Results

2.1.- Precipitations (*P*)

2.1.1.- Inter-annual and intra-annual variations

During the study period between 2011 and 2013, the amount of open field precipitation P collected varies from year to year and from month to month (fig. 1-3). ANOVA analysis showed a significant difference of annual precipitation (tab. I). The year 2011 was the rainiest (469.1 mm). While the year 2012 was the least rainy (223.9 mm).

Table I.- ANOVA analysis for the inter-annual and intra-annual variations of open field precipitation, throughfall, stemflow and interception

	P	TF	SF	I
Interannual variations	0.006*	0.006*	0.197	0.126
Intraannual variations 2011	0.033*	0.046*	0.052	0.003*
Intraannual variations 2012	0.112	0.197	0.592	0.036*
Intraannual variations 2013	0.137	0.142	0.398	0.094

* Significant difference at $P < 0.05$

On the other hand, the ANOVA analysis revealed no significant differences in open field precipitation between the months during 2012 and 2013 (tab. I). However, the driest months were July and August, while the months of April, September and October were often the most watered (fig. 1-3).

2.1.2.- Frequencies of the different precipitation classes

During the study period (2011-2013), the *Q. ilex* coppice in Marconna received about 469, 224 and 290 mm of open field precipitation, spread over 110, 84 and 87 days with precipitation respectively (tab. II).

Table II.- Distribution of recorded open field precipitation in quantity classes during the study period

Daily rains	2011			2012			2013		
	Frequency	Cumulative precipitation		Frequency	Cumulative precipitation		Frequency	Cumulative precipitation	
	Days	mm	%	Days	mm	%	Days	mm	%
]0-2 mm]	59	66.8	14.24	48	53.6	23.94	43	54.3	18.75
]2-4 mm]	18	50.8	10.83	24	62.2	27.78	18	50.7	17.51
]4-6 mm]	13	67.7	14.43	5	24.2	10.81	15	72.9	25.17
]6-8 mm]	5	37.3	7.95	3	20.8	9.29	7	46.9	16.19
] 8-10 mm]	5	44.1	9.40	0	0	0.00	0	0	0.00
]10-60 mm]	10	202.4	43.15	4	63.1	28.18	4	64.8	22.38
Total	110	469.1	100	84	223.9	100	87	289.6	100

The daily precipitation recorded during the present study is between 0.3 and 50.8 mm.

The results of precipitation classification and their frequencies in ranges from 0 to 60 mm are shown in Table II. The number of days during which the collected precipitation was less than 4 mm represent a high percentage (> 70%) of the total precipitation days.

3.2.- Throughfall (TF)

The number of days with precipitation, which really launched throughfall, varied from year to year. It was 78 days for the year 2011, 52 days for the year 2012 and 62 days for the year 2013. Also, it was noticed that the percentages of the collected TF change according to the years and the months (fig. 1-3). At a year scale, the statistical analysis of

TF revealed a significant difference (tab. I). The year 2011 recorded the highest value of TF in relation to open field precipitation ($\bar{x}$ = 0.92 mm). Conversely, 2012 was characterized by the lowest TF ($\bar{x}$ = 0.35 mm).

On a monthly scale, ANOVA confirmed a significant difference only for 2011 (tab. I). The month of July recorded the lowest TF during the study period.
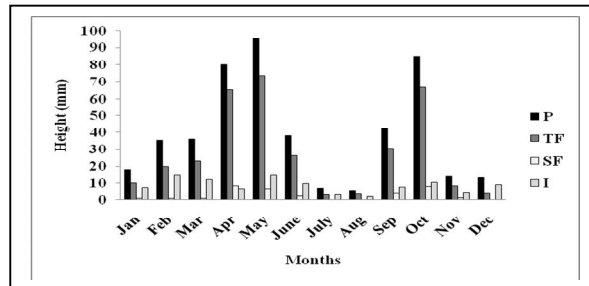

Figure 1.- Open field precipitation (P), throughfall (TF), stemflow (SF) and interception loss (I) (mm) in the oak coppice of Marconna (Algeria) in 2011
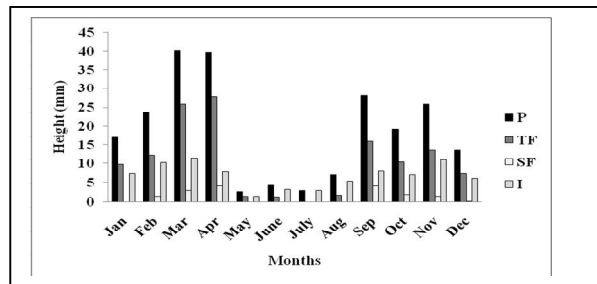

Figure 2.- Open field precipitation (P), throughfall (TF), stemflow (SF) and interception loss (I) (mm) in the oak coppice of Marconna (Algeria) in 2012
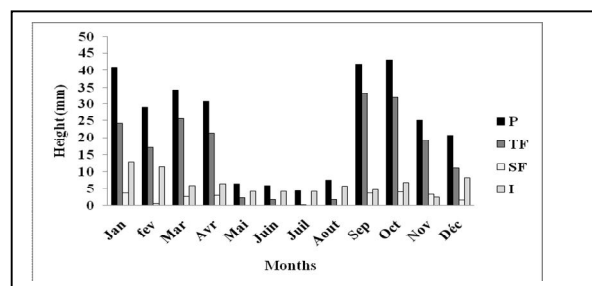

Figure 3.- Open field precipitation (P), throughfall (TF), stemflow (SF) and interception loss (I) (mm) in the oak coppice of Marconna (Algeria) in 2013

2.3.- Stemflow (SF)

The number of days with precipitation that caused SF is low. It was between 11 and 27 days / year. Overall, SF represented an average of 7.13% of the open field precipitation for the studied site. In addition, it varied according to years and months (fig. 1-3). The year 2011 recorded the highest percentage of SF compared to open field precipitation ($\bar{x}$ = 0.09 mm), although ANOVA did not reveal a significant difference (tab. I). On the other hand, 2012 was characterized by the weakest SF ($\bar{x}$ = 0.04 mm), with its total absence during months May, June, July and August.

By comparing the monthly SF, ANOVA did not report a significant difference (tab. I). In months of July and August, we noted no volumes of SF (fig. 1-3).

2.4.- Interception loss (I)

Table I shows that the monthly fluctuation in interception loss was very high. In general, the highest I rates were reported during the months of July and August (> 80% of open field precipitation on average) (fig. 1-3).

There is an oscillation in the percentages of rain intercepted by years and months (fig. 5). The I reached its maximum value in July 2012 (100% of open field precipitation). The precipitation lost through interception is considerable. They represent about 26.46% of the open field precipitation received. In 2011 and 2013, the interception loss 102 and 77.4 mm, representing 21.74 and 26.74% of the open field precipitation, respectively. In 2012, this I rate was increased to reach 36% of the open field precipitation (which represents 80.6 mm).

2.5.- Relationship between open field precipitation and throughfall

During the period from 2011 to 2013, the TF according to the P follows the relations exposed on figure 4. There was a strong positive correlation between P and TF water volumes collected after rainfall has fallen (R^2 varied between 0.98 and 0.99).
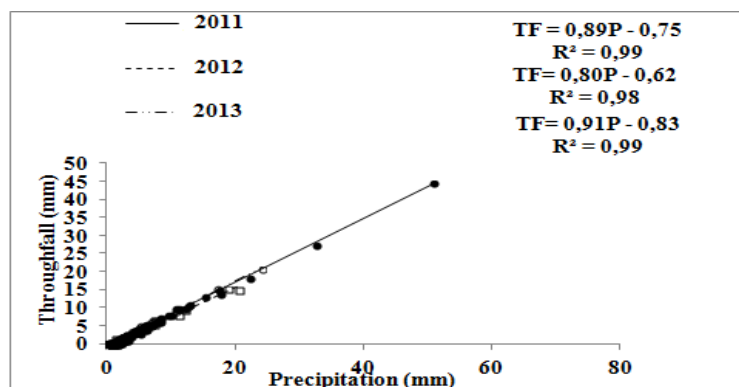

Figure 4.- Throughfall (mm) according to the open field precipitation (mm) in the years from 2011 to 2013

3.6.- Relationship between open field precipitation and stemflow

Figure 5 shows linear regression lines that are adjusted to a cloud of points of the SF water, as a function of P, following the equations presented in the same figure. The SF was positively correlated with P (R^2 varied between 0.79 and 0.90). The results suggest that low P induces a low SF volumes.

Using the equations presented on the Figure 5, we can deduce that the stemflow in the studied coppice starts from 2.82 mm of precipitations.
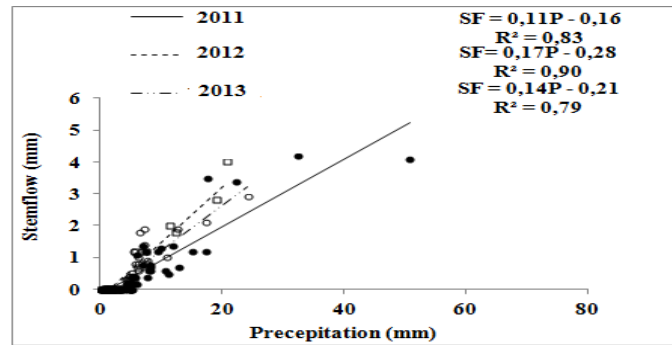
Figure 5.- Stemflow (mm) depending on open field precipitation (mm)
in the years from 2011 to 2013

3.7.- Relationship between open field precipitation and interception loss

The rain intercepted according to the P follows the equations mentioned on Figure 6. I was negatively correlated with P (R^2 varied between 0.01 and 0.12).
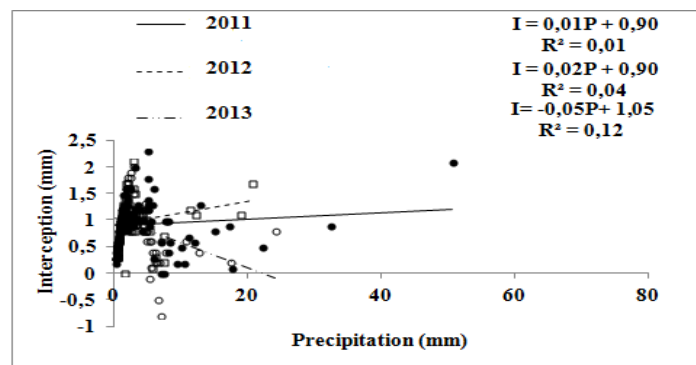

Figure 6.- Interception loss rate (% open field precipitation) depending
on open field precipitation (mm) in the years from 2011 to 2013

3.- Discussion

3.1.- Precipitation (P)

The inter-annual variability of open field precipitation (P) is important in the studied oak coppice. Similarly, other studies found significant interannual variability of rains in northern Algeria including the Aurès region over many years [29,30]. Besides, the P in the years 2012 and 2013 (223 and 290 mm respectively) was less than the mean annual precipitation of the region (331 mm) during a period of 22 years according to the meteorological station of Ain Skhouna (Batna).

Redistribution of rainfall into TF, SF, and I in forest ecosystems depends on P characteristics, meteorological conditions and forest structure [11]. Evergreen oak ensures the conservation and regulation of water flow through its mobilization and storage especially in side basins and fragile environments [31].

3.2.- Throughfall (TF)

TF rates in this study are considered relatively low (66.30% of open field precipitation on average) in comparison to the study of LLORENS and DOMINGO (2007)

[26], which reported TF percentages between 63.8 and 77.8% in different European countries of the Mediterranean, accompanied with annual rainfall quantities between 478 and 1275 mm. The low TF in our case is attributed to the low annual rainfall (between 223.9 and 469.1 mm year^{-1}), and their distribution over time.

Thus, the number of days with low rainfall (< 4 mm) was very important, which affects the number of TF and SF days, and therefore the amount of water that reaches the forest floor. The change in rainfall regime in semi-arid climate led to the increase of the frequency of rains less than 5 mm [32]. SADEGHI *et al*. (2016) recorded low rates of TF for limited daily precipitation [33]. Moreover, DUMAS (2009) reported little or no water that flows through the canopy during low rains [23].

On the other hand, the low TF found during the summer period can be attributed to warm winds (Sirocco) and high temperatures [34,4] causing important evaporation.

TF volumes were correlated positively to P amounts. This result is similar to that of BAHMANI *et al*. (2012) which found TF increased with higher P [11].

Using the equations presented on the Figure 4, it can be deduced that throughfall in the Marconna coppice starts when precipitations are between 1.02 and 1.13 mm. The comparison of these results with those obtained in the forest of tall trees of Hamla [21], showed that a green oak coppice requires smaller volumes of P to launch the TF.

3.3.- Stemflow (SF)

SF rates measured in this study (7.10% on average) were in agreement with the study of LIMOUSIN *et al*. (2008) [12], which have shown that these rates can reach 10% of the P. Nevertheless, COMIN *et al*. (1987) estimated the SF rate to be greater than 13% in sites that accumulate precipitation exceeding 560 mm/ year [35].

The SF rate is influenced mainly by the quantity of daily open field precipitation. In the present study, the number of days with precipitation less than 4 mm constituted an important percentage of the total number of rainy days (> 70%). Similarly, the rainfall class between 0 and 2.5 mm led to zero SF rate under some forest covers [33]. Furthermore, other factors such as the thick and rough bark of the evergreen oak, angle of the branches insertion [36], and the wind may influence the SF rate. Species with high SF rates are characterized by branched roots [37].

In this study, SF rates were correlated positively to P amounts. The months with the lowest P (July and August), recorded zero SF volumes.

3.4.- Interception loss (I)

Estimation of I is required by forest researchers because of the fact that the estimation of I plays an important role for permanent soil water, and it saves a considerable amount of time and effort for the watershed planner [38]. The I rate found in this study is considerable (26.46% of the open field precipitation on average) compared to other studies conducted on I in a *Quercus ilex* coppice. CARLYLE-MOSES *et al*. (2004) [39] for example, reported an interception loss rate that did not exceed 15% in the same kind of coppice.

The low height of the trees and the precipitation pattern seem to be the main factors that caused high I for the Marconna coppice, where low daily open field precipitation (< 4 mm) characterized the rainfall regime in this region. Similarly, numerous authors have confirmed that the small amounts of daily rainfall contribute to the increase of I rates [22,32,40]. Moreover, other factors may influence significantly the I rate such as solar radiation [41], tree population density [42] and foliar index [43].

Several authors [44-46] point out that precipitation deficit may result from a decrease in the frequency of heavy precipitation. Then, according to them, from forestry and hydrological point of view, the decrease in the frequency of heavy precipitation and the distribution of precipitation within the rainy season are important data, especially for the evaluation of the rainfall interception loss by a cover forest.

It should be noted that, during the period of our study, the evergreen oak undergrowth received on average only 240 mm. This small amount may be among the probable causes of the low natural germination, low growth and productivity of the evergreen oak. In such natural conditions surrounding this oak tree, including those related to water and mineral availability, holm oak continues to adapt morphologically and reiterates that it is robust even in a climate change.

Conclusion

This study in a *Q. ilex* coppice allowed obtaining new data of the rainfall interception loss of the Aurès region (Algeria). Between 2011 and 2013, it is concluded that the daily open field precipitation in the Aurès was predominantly less than 4 mm. The amount of annual open field precipitation recorded ranged from 223.9 to 469.1 mm spread over 84 to 110 days year^{-1}.

The proportion of water reaching the soil directly and by throughfall was low. It was on average 66.30% of open field precipitation and shared over a maximum of 78 days year^{-1}.

As for the fraction of the water which reaches the ground by stemflow, it represented on average 7.13% only of the total open field precipitation, distributed over a period not exceeding 27 days year^{-1}. This very low quantity of water, which reaches the ground close to the trunks of trees, might contribute to the low productivity of the evergreen oak in the Aurès.

The annual precipitation lost through interception was relatively high. On average, it accounted for 26.46% of the total precipitation received.

The variation of open field precipitation, throughfall and interception loss was important over time, especially between years.

The study of the relationship between the different measured parameters showed strong positive correlations between open field precipitation and throughfall and stemflow rates, while interception loss was negatively correlated with precipitation.

The prediction models can be used to estimate the amount of water entering the forest floor either by throughfall or stemflow in *Q. ilex* coppices in the Aurès, and then to apprehend the interception loss.

References

[1].- Bonin G., 2008.- 30 ans de recherche forestière en région méditerranéenne. Forêt Méditerranéenne, 29(4): 431-444.

[2].- Haichour R., 2009.- Stress thermique et limite ecologique du chêne vert en Algérie. Magister dessertation, Department of Bilogy, University of Constantine, Constantine, 180p.

[3].- Dilem A., 1995.- Etude de quelques propriétés du bois de chêne vert (*Quercus ilex*) dans la région d' El -Hassasna (Saida- Algérie). Forêt Méditerranéenne, 16(1): 74-78.

[4].- Chermat S., Djellouli Y. et Gharzouli R., 2013.- Dynamique régressive de la végétation des hautes plaines Sétifiennes: Erosion de la diversité floristique du Djebel Youssef (Algérie*).* Terre Vie-Rev. Ecol., 68 (1): 85-100.

[5].- Chermat S., Gharzouli R. et Djellouli Y., 2016.- Phytodynamique des groupements steppiques de Djebel Zdimm en Algérie Nord-Orientale. Ecologia mediterranea, 42(1): 51-63.

[6].- Quezel P., Tomaseilli R. et Morandini R., 1976.- Forêts et maquis méditerranéens: Ecologie, conservation et aménagement. UNESCO, 84p.

[7].- Quezel P., 2000.- Réflexion sur l'évolution de la flore et de la végétation au Maghreb méditerranéen. Ibis Press, Paris, 117p.

[8].- Missoumi A., Mederbal K., et Abdelli K., 2002.- Apport des SIG dans la prévention et la lutte contre les incendies de forêt: Stratégie de prévention des incendies dans les forêts d'Europe du Sud. Collection Actes éditions, 368p.

[9].- Belkaid H., 2016.- Analyse spatiale et environnementale du risque d'incendie de forêt en Algérie: Cas de la Kabylie maritime. Doctorate dissertation, University Nice Sophia Antipolis, 306p.

[10].- Nedjraoui D. et Bédrani S., 2008.- La désertification dans les steppes algériennes: Causes, impacts et actions de lutte. Vertigo, 8(1): 1-15.

[11].- Hosseini Ghaleh Bahmani S. M., Attarod P., Bayramzadeh V., Ahmadi M. T. and Radmehr A., 2012.- Throughfall, stemflow, and rainfall interception in a natural pure forest of chestnut-leaved oak (*Quercus castaneifolia* C.A. Mey.) in the Caspian forest of Iran. Annals of Forest Research, 55(2): 197-206.

[12].- Limousin J. M., Rambal S., Ourcival J.-M. and Richard J., 2008.- Modelling rainfall interception in a Mediterranean *Quercus ilex* ecosystem: Lesson from a throughfall

exclusion experiment. Journal of Hydrology, 357: 57-66.

[13].- Ghassemi-Golezani K ., Bakhshi J., and Dalil B., 2015.- Rate and duration of seed filling and yield of soybean affected by water andradiation deficits. Acta agriculturae Slovenica, 105(2): 225-232.

[14].- Bodian A., Ndiaye O. et Dacosta H., 2016.- Evolution des caractéristiques des pluies journalières dans le bassin versant du fleuve Sénégal: Avant et après rupture. Hydrological Sciences Journal, 61(5): 905-913.

[15].- Crabtree R.W., and Trudgill S.T., 1985.- Hillslope hydrochemistry and stream response onwooded, permeable bedrock: the role of stemflow. Journal of Hydrology, 80(1-2): 161-178.

[16].- Tromble J.M., 1988.- Water interception by two arid land shrubs. Journal of Arid Environments, 15(2): 65-70.

[17].- Keim R.F. and Skaugset A.E., 2003.- Modelling effects of forest canopies on slope stability. Hydrological Processes, 17(7): 1457-1467.

[18].- Tsiko C. T., Makurira H., Gerrits A.M.J. and Savenije H.H.G. 2012.- Measuring forest floorand canopy interception in a savannah ecosystem. Physics and Chemistry of the Earth, 47: 122-127.

[19].- Jackson N.A., 2000.- Measured and modeled rainfall interception loss from an agroforestry system in Kenya. Agricultural and Forest Meteorology, 100(4): 323-336.

[20].- Šraj M., Brilly M. and Mikoš M., 2008.- Rainfall interception by tow deciduous Mediterranean forests contrasting stature in Slovenia. Agricultural and Forest Meteorology, 148(1): 121-134.

[21].- Benhizia T., Oudjehih B., et Lebbal S., 2018. Variation de l'interception des précipitations dans une chênaie à *Quercus ilex* L. des Aurès (Est algérien). Ecologia Mediterranea, 44(1): 97-108.

[22].- Gash J. H. C., Lloyd C. R. and Lachoud G., 1995. Estimating sparse forest rainfall interception with an analytical model. Journal of Hydrology, 170(1-4): 79-86.

[23].- Dumas D., 2009.- Estimation de l'influence de la couverture forestière sur la pluie en montagne exemple du massif de chartreuse. Revue Forestière Française, 60(6): 711-726.

[24].- Bleeker A., Draaijers G., Van Der Veen D., Erisman J. W., Möls H., Fonteijn P. and Geusebroek M., 2003.- Field intercomparison of throughfall measurements performed within the framework of the Pan European intensive monitoring program of EU/ICP Forest. Environmental Pollution, 125(2): 123-138.

[25].- Rodrigo A. and Avila A., 2001.- Influence of sampling size in the estimation of mean throughfall in two Mediterranean holm oak forests. Journal of Hydrology,

243(3): 216-227.

[26].- Llorens P. and Domingo F., 2007.- Rainfall partitioning by vegetation under Mediterranean conditions. A review of studies in Europe. Journal of Hydrology, 335(1): 37-54.

[27].- Siegert C. M. and Levia D. F., 2014.- Seasonal and meteorological effects on differential stemflow funneling ratios for two deciduous tree species. Journal of Hydrology, 519: 446-454.

[28].- Vialard-Goudou A. et Richard C., 1956.- Etude pluviométrique, physico-chimique et économique des eaux de pluie à Saigon (1950-1954). L'Agronomie Tropicale, 11(1): 74-92.

[29].- Smadhi D., 2011.- Régionalisation et modélisation agro climatique en céréaliculture pluviale. Doctoral dissertation, ENSA, Algiers, 180p.

[30].- Meddi M. and Toumi S., 2013.- Study of the interannual rainfall variability innorthern Algeria. Revue LJEE, 23: 40-59.

[31].- Nasrallah Y., 2014.- Caractérisation de la variable morphologique de 21 provenances algériennes de chêne vert: Evolution de leur adaptation écologique dans la région semi –aride de Saida. Doctoral dissertation, ENSA Algiers, 213p.

[32].- Attarod P., Sadeghi S. M. M., Pypker T. G., Bagheri H., Bagheri M., and Bayramzadeh V., 2015.- Needle-leaved trees impacts on rainfall interception and canopy storage capacity in an arid environment. New Forests, 46(3): 339-355.

[33].- Sadeghi S. M. M., Attarod P., Van Stan J. T. and Pypker T. G., 2016.- The importance of considering rainfall partitioning in afforestation initiatives in semiarid climates: A comparison of common planted tree species in Tehran, Iran. Science of the Total Environment, 568: 845-855.

[34].- Emberger L., 1938.- Les arbres au Maroc et comment les connaitre. Paris, Larousse, 314p.

[35].- Comin M. P., Escarré A., Gracia C. A., Liedo M. J., Rabella R., Savé R. and Terradas J., 1987.- Water use by *Quercus ilex* in forests near Barcelona, Spain. In J. D. Tenhunen, F. M. Catarino, O. L. Lange and W. C Oechel (Eds.), *Plant reponsetostress,* Springer, Berlin, Pp 259-266.

[36].- Aussenac G., 1970.- Action du couvert forestier sur la distribution au sol des précipitations. Annales des Sciences Forestieres, 27(4): 383-399.

[37].- Aussenac G. et Boulanget C., 1980.- Interception des précipitations et évapotranspiration réelle dans des peuplements de feuillu (*Fagus silvatica* L.) et les résineux (*Pseudotsuga menziesii* (Mirb) Franco). Annales des Sciences Forestières, 37(2): 91-107.

[38].- Yurtseven I. and Zengin M., 2013.- Neural network modelling of rainfall

interception in four different forest stands. Annals of Forest Research, 56(2): 351-362.

[39].- Carlyle-Moses D. E., Laureano J. S. F. and Price A. G., 2004.- Throughfall and throughfall spatial variability in Madrean oak forest communities of northeastern Mexico. Journal of Hydrology, 297(1-4): 124-135.

[40].- Van Stan J. T., Gutmann E.D., Lewis E. S. and Gay T. E., 2016.- Modeling rainfall interception loss for an epiphyte-laden *Quercus virginiana* forest using reformulated static- and variable-storage Gash analytical models. Journal of Hydrometeorology, 17(7): 1985-1997.

[41].- Linhoss A. C. and Siegert C. M., 2016.- A comparison of five forest interception models using global sensitivity and uncertainty analysis. Journal of Hydrology, 538: 109-116.

[42].- Bryant M. L. Bhat S. and Jacobs J. M. 2005.- Measurements and modeling of throughfallvariability for five forest communities in the southeastern US. Journal of Hydrology, 312(1-4): 95-108.

[43].- Deguchi A., Hattori S. and Park H. T., 2006.- The influence of seasonal changes in canopy structure on interception loss: Application of the revised Gash model. Journal of Hydrology, 318: 80-102.

[44].- Sadeghi S. M. M., Attarod P. and Pypker T. G., 2015.- Differences in rainfall interception during the growing and non-growing seasons in a *Fraxinus rotundifolia* Mill. plantation located in a semiarid climate. Journal of Agricultural Science and Technology, 17(1), 145-156.

[45].- Bodian A., Ndiaye O. et Dacosta H., 2016.- Evolution des caractéristiques des pluies journalières dans le bassin versant du fleuve Sénégal: Avant et après rupture. Hydrological Sciences Journal, 61(5), 905-913.

[46].- Lempereur M., Limousin J. M., Guibal F., Ourcival J. M., Rambal S., Ruffault J. and Mouillot F., 2017.- Recent climate hiatus revealed dual control by temperature and drought on the stem growth of Mediterranean *Quercus ilex*. Global Change Biology, 23(1): 42-55.