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INTERCEPTION, THROUGHFALL AND STEMFLOW IN TWO FOREST OF THE "SIERRA DE LA DEMANDA" IN THE PROVINCE OF BURGOS

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RESUMEN.- El balance de agua en dos ecosistemas forestales de la "Sierra de la Demanda", un hayedo climácico (Fagus sylvatica *L.) y un pinar de reforestación* (Pinus sylvestris *L.) en área de potencialidad hayedo, ha sido determinado. La precipitación que alcanza el suelo representa el 61,7% por pluviolavado en el hayedo y el 52,1% en el pinar, el 6,5% y 0,4% por escurrimiento fustal, y el 31 7% y 42,5% por intercepción en hayedo y pinar respectivamente. Estos valores fluctúan mensualmente dependiendo de las características de la lluvia incidente.*

RESUMÉ.- Le bilan de l'eau dans deux ecosystèmes forestiers de la "Sierra de la Demanda", une hetraie climacique (Fagus sylvatica *L.) et une plantation de pin blanc* (Pinus sylvestris *L.) dans une zone de potentialité hetraie a été determiné. La precipitation qu'arrive au sol représente le 61,7 % par l'égouttement dans l'hetraie, et le 52,1 % dans une pinède; le 6,5% et 0,4% par écolulement et le 31,7% et 42,5% par interceptation dans lahetraie et la pinède respectivement. Ces valeurs fluctuent mensuelment en dependant des caractéristiques de la pluie incidente.*

ABSTRACT.- The balance of the water has been investigated in two forest ecosystems of the "Sierra de la Demanda " a climacic beechwood (Fagus sylvatica *L.) and a reafforested plantation of scot pine* (Pinus sylvestris *L.) on land potentially suitable for beech trees. The precipitation reaching the soil represented the 61.7% by throughfall in the beechwood and the 52.1% in the pinewood, the 6. 5 % and 0.4 % by stemflow and 31. 7 % and 42.5 % by interception in beechwood and pinewood respectively. These values fluctuated monthly following the rainfall characteristics.*

Key-words: Throughfall, stemflow, interception, forest ecosystems, Spain.

1. Introduction

An important vector of returning to the ground of mineral elements, apart from fallen leaves, is constitued by rains. Dynamics and balance of water are important parameters in the functioning of forest ecosystems, above all in regions with deficit of water, eventually or usually limitating as it happens in areas with a mediterranean climate, or bordering areas outskirts. It is estimated that if the rainfall represents in general the main source to obtain water in the earthly ecosystems, a certain fraction is quickly eliminated by evaporation of the green covering. In forest ecosystems, this loss is accompanied by a spatial distribution resulting from two ways of percolation through the vegetable covering of the forest; the first one is represented by the throughfall water through the vegetable canopy and the second by the stemflow along the branches and trunk (SANTA REGINA, 1987).

The vegetal covering exerts a considerable influence over the balance of the water above ground by means of two fundamental procedures: the interception of the incident rainfall and the transpiration (RAPP & ROMANE, 1968). Likewise the forest canopy over the chemistry of the rainwater, by the quantities that substracts and by the spatial differences that carries over the water profile of the ground, is a non worthless component of the hydrological cycle (ANDERSON & *al.*, 1976). There are lots of works that deals with the measurement of interception of rain in forest ecosystems and the results are very different. The works by BEALL (1934), WILM (1943), SLAVIK (1962), ROTACHER (1963), RUTTER (1963), PATRIC (1966), SNOCK and GALOUX (1967), AUSSENAC (1968, 1981), BENECKE and MAYER, (1971), AUSSENAC and BOULANGEAT (1980) and MAHENDRAPPA and KINGSTON (1982), are well known.

The aim of this work is to introduce the balance and distribution of the rain water in two forest ecosystems of the "Sierra de la Demanda" in Burgos province.

2. Material and methods

Description of the study area.

The experimental site is located in the Sierra de la Demanda province of Burgos and Logroño (Fig.1). Corologically is located in Carpetano-Ibérico-Leonesa province, Ibérico Soriano section, Demandés subsection. Coordinates: 4" 10′ N, 42" 20′ E.

The beech forest appears broken into small islets occuping 5000 ha at the bottom of valleys and exposition N from 900 to 1600-1700 m height, in contact with forest of *Quercus pyrenaica* that invade them in the lower places.

These meridional beech forest in this marginal situation of the beech represent, as THIEBAUT (1984) points out, a different "breed" to the ones of the Eurosiberian Europe, their great resistence to the summer droughts favours the posible adaptation of this genotype to the characteristics of lots of spanish mountains in future reafforestations.

The beech forest Tres Aguas is a natural forest in full regeneration, with a density of 526 trees/ha, being distributed in 300 young beechs (4-20 cm of diameter) and the rest consisted of adults, reaching in some cases more than 1 m of diameter (Fig. 2), the mean height fluctuates between 20-22 m; their estimated mean age is 50 years. The soil had a wide range of depths, with clay content increasing with depth, and was clasified as Humic Acrisol (F.A.O., 1973).

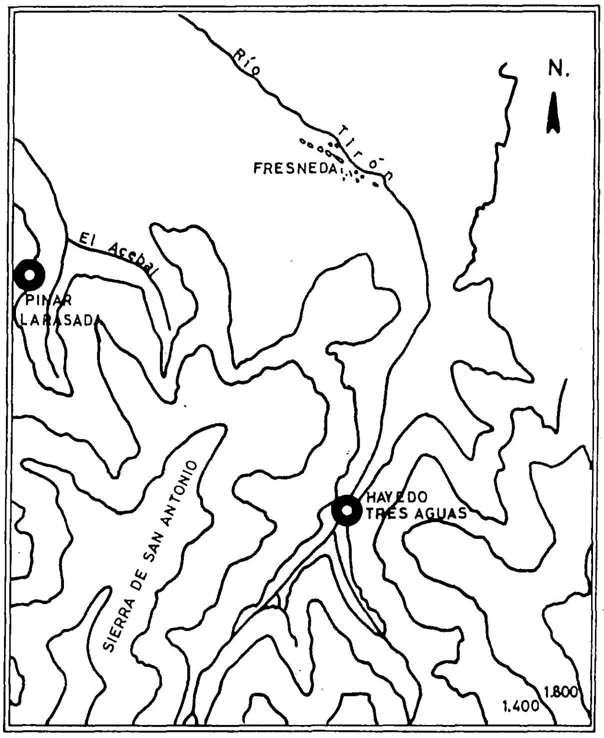

Fig.1. Location of the study site. Situación del área de estudio.

The pine forest La Rasada is a reafforestation of *Pinus sylvestris* made 50 years ago on land suited for beech. The mean tree density was 581 trees/h. with predominance of trees between 30-40 cm. of diameter (292 trees), (Fig.3). Their mean height was approximately 15 m. The soil varied in depth and its clay content was low, with a very acid and desaturated character and was clasified as Humic Cambisol, (F.A.O. 1973).

The climate at the study site is a mild mesomediterranean climate, being submediterranean with increasing elevation (1000 m). The climatologic station of Pradoluengo at the elevation of 960 m, gives an annual mean temperature of 12,4 C, and the annual mean precipitation was 895 mm based on data collected from 1961 to 1980. The annual mean evapotranspiration was 705 mm (345 mm in june, july and august). The average duration of the dry period is two months per year (july and august) during the summer, and the duration of the cold period is six months (+7° C), the mediterranean index is 3.1 (RIVAS MARTÍNEZ, 1987). The termicity index is 195 (RIVAS-MARTÍNEZ, 1987), corresponding to the inferior supramediterranean bioclimatic horizon (RIVAS-MARTÍNEZ, *l.c.*).

Methods

The rainfall were registered during the period 1985-1988 with a totalizer and 3 pluviometers placed in a clearing of the wood near to the parcels of investigation, both in the beech forest and in the pine forest.

The throughfall or traslocation was collected by means of the instalation of 15 pluviometers in each site (S = 213 cm^2, each one) and conducted to plastic vessels.

The stemflow was registered by means of 15 necklaces of sinthasol, in the two parcels, adjusted to the trunk of the tree. This rainfall was conducted through plastic tubes that flow into their respective vessels. The surface of reception, over which is difficult to estimate the contributions of that water, is not easy to delimit, from what the calculus have been delimited estimating the area of a circular crown around the trunk and with a superior ratio, 30 cm bigger than the ratio of the considered tree (MINA, 1967).

In the same way the interception of the rainfalls has been evaluated by means of the following relation:

$I = P - (T + S)$ being,
I = Intercepted rain
P = Incident rainfall
T = Translocation or throughfal
S = Stemflow

It was been employed the statistical method of analysis of varianze: ANOVA comparing in time the water of rainfall, throughfall, and stemflow in the two species considered. Further on the result of that analysis will be indicated.

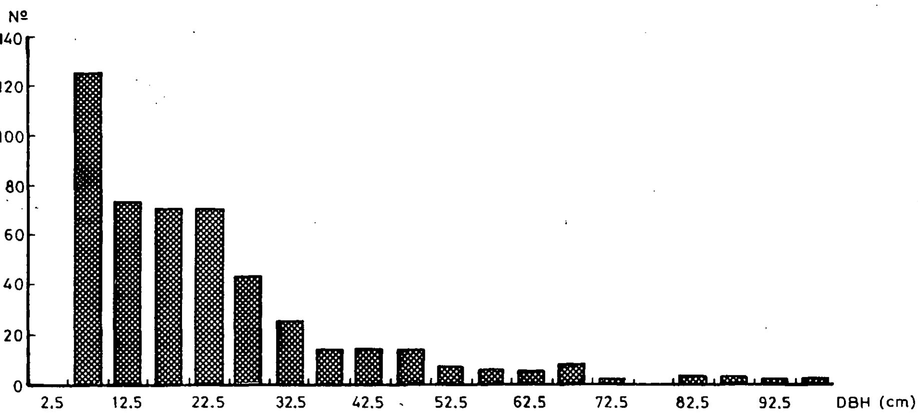

Fig.2. Graphic representation of the number of trees by diametral classes in the beechforest.
Representación gráfica de la distribución del número de árboles por clases de diámetro en el hayedo.

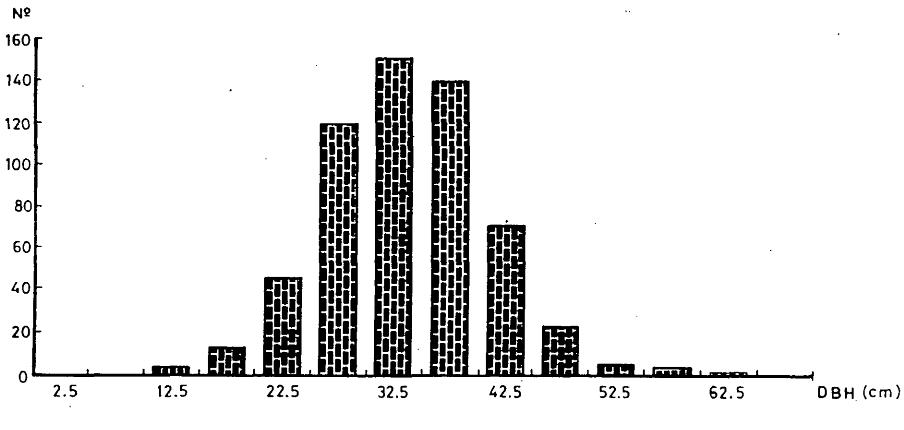

Fig.3. Graphic representation of the number of trees by diametral classes in the pineforest.
Representación gráfica de la distribución del número de árboles por clases de diámetro en el pinar.

3. Results and discussion

The values of rainfall and the percentages of throughfall, stemflow and interception are expressed both by annualities and by seasons in the two forest considered. (Table 1).

The diagram of the monthly mean rainfalls in the study sites (Fig. 4) reveals a similar evolution in beech forest and pine forest being March and April the most rainy months, influenciated these registers by the contribution of snowing, and dry summers, although in many cases can be observed the appearance of wide palls of summer fogs.

It has to be mentioned the pluviometric cycle of 1988 as the most rainy year, and the most dry summer of the three cycles, above most in beech forest (Fig.5). Applying the varianza test to the seasons, significative samples result ($p = 0.005$), but considering each cycle separately such differences can not be appreciated.

If we estimate the throughfall in general, it shows a similar tendency to the incident precipitation in its anual course, as much in the beech forest as in the pine forest (Figs. 6 and 7) and its distribution is coincident in both sites (Fig. 8).

Statistically very significant differences have resulted considering species and cycles, both annuals and monthly. The most important relative values are established in autumn and winter for the beech forest, and winter and spring for the pine forest, indebt mostly to the arboreal species in each determined time.

RAPP AND ROMANE (1968) estimate that the differences in percentage of throughfall among species are a function, mainly, of the intensity and duration of the incident rains. In beech forest AUSSENAC (1975) estimates the 74.8%, NIHLGARD (1970) the 66.2%, BENECKE and MAYER (1971) the 77% and TERRADAS (1984) the 80%. In pine forests of *Pinus sylvestris*, SANTA REGINA *et al.* (1989) indicate the 80%.

The quantities of water that take ground through the stemflow in both ecosystems follow a very different tendency to the course of the incident rainfall. The most elevated values in the beech forest are obtained in autumn (Fig.9), either when the rainfall is heavier or when it is less significative, in 1988 (Table 1). In the pine forest during the first two cycles the same tendency is accomplished (Fig. 6), not in 1988, where the percentage is superior in spring and winter, precisely when the rainfall is higher (Table 1).

If both species are statistically correlationated, we obtain very significant populations ($P = 0.01$), considering both the species and the cycles of rain.

We find in the bibliography considerable variations depending on the morphology, age, management... etc. of the forest. So, in *Pinus sylvestis* AUS-

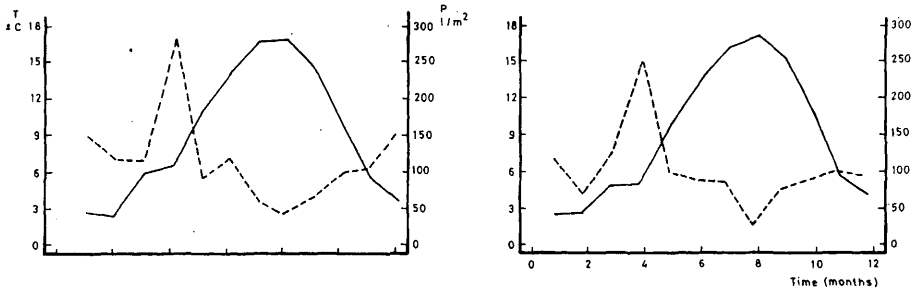

Fig.4. Diagram of the monthly average temperature and pluviometry (1986-88).
Diagrama de la temperatura y pluviosidad medias mensuales (1986-1988)

SENAC (1968) and GASH and MORTON (1978), estimate an average proportion of 1.6%, and SANTA REGINA (1987), depending of the meteorological conditions of every season of the year, obtains 0.6% in March and 22 % in April. In the same way, differences between conifers and decidous trees have been observed (AUSSENAC, 1968), or among the same arboreal communities, but at different ages (DELFS, 1965). These several differences that beside big contributions, others very small are only important when their limited distribution over a small area around the trunk is considered (REYNOLDS and LEYTON, 1963).

The effects of stemflow on the elements of the soil have been found in areas with deposition of acidifying substances (WITTING & NEITE,1985).

In general, in populations of *Fagus sylvatica* bigger quantities of stemflow are estimated, if we compare them with another arboreal populations for example *Picea, Pinus, Larix, Quercus,* and *Betula* (EIDMANN, 1959; CEPEL, 1967; NIHLGARD, 1970).

The water retained by leaves, branches and trunks and returned to the atmosphere by evaporation, constitutes the water of interception. In our study it can be estimated a mean percentage of 31.7 % in beech forest and 42,5 % in pine forest, although big oscilations exist, from 46.4% to 13.6% in beech forest and 66.8% in pine forest (Table 1).

In general the interception decrease with the increment of intensity and duration of the precipitations, so that, as the rains go on, the tops of the trees get saturated with water, what makes the water of the througfall be increased and with it lessen the interception (OYARZUN *et al.* 1985).

AUSSENAC (1968) in *Fagus sylvatica* and *Carpinus betulus* and SCHNOCK & GALOUX (1967) in an holm oak forest have seen a remarkable integration during the period in which the forest maintain the leaves. FORGEAD *et al*

Table 1. Distribution and balance of rainfall. Througfall, stemflow and interception in the two forests.

		1986				1987				1988			
		Rainfall l/m^2	Throug. %	Stemf. %	Interc. %	Rainfall l/m^2	Throug. %	Stemf %	Interc. %	Rainfall l/m^2	Throug. %	Stemf. %	Interc. %
BEECH	SPRING	147.8	66.3	5.7	28.0	460.1	58.8	5.8	35.4	1089.0	51.0	2.6	46.4
	SUMMER	131.4	63.2	5.7	31.2	251.1	64.3	3.4	32.2	88.5	68.2	5.0	26.8
	AUTUMN	300.1	75.9	10.5	13.6	504.1	65.0	8.8	26.2	206.5	57.1	16.3	26.6
	WINTER	233.5	78.5	1.9	19.7	454.5	59.8	4.3	35.9	527.0	64.3	9.1	26.6
PINE	SPRING	222.8	42.3	0.0	57.7	242.4	58.5	0.6	40.9	847.4	59.9	0.5	39.6
	SUMMER	115.8	55.8	0.1	44.2	302.9	48.7	0.5	50.8	156.7	42.9	0.1	56.9
	AUTUMN	255.6	53.0	0.7	46.3	430.8	45.7	0.6	53.7	253.7	32.8	0.4	66.8
	WINTER	206.5	53.2	0.6	46.3	305.3	63.8	0.3	35.9	420.9	57.4	0.6	45.3

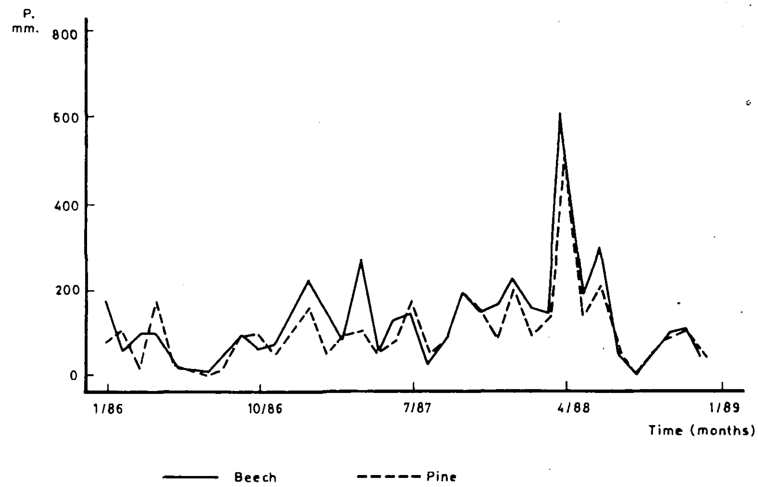

Fig. 5. Monthly variations of incident rainfall in the two sites of experimentation.
Variación mensual de la lluvia incidente en las parcelas experimentales

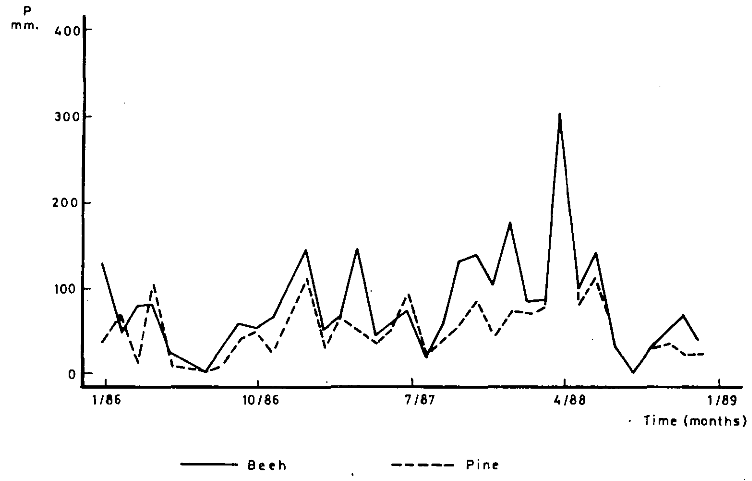

Fig. 6. Monthly variations of throughfall in the two study forests.
Variaciones mensuales de la transcolación en los dos bosques estudiados

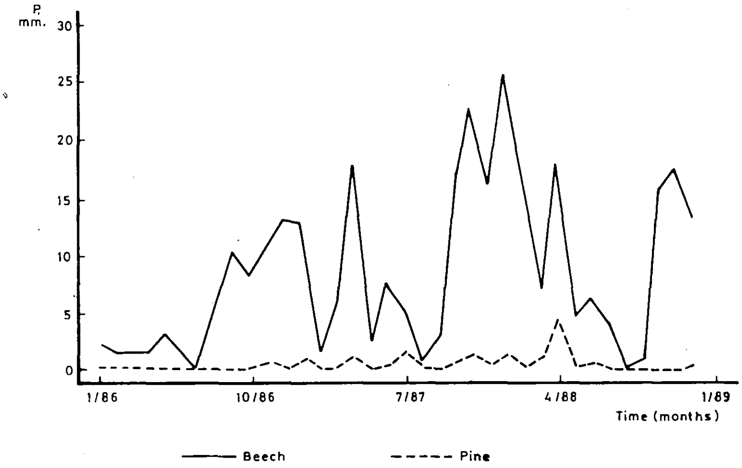

Fig. 7. Monthly variations of stemflow water both in the beechforest and in the pineforest.
Variaciones mensuales del flujo de tronco en el hayedo y en el pinar

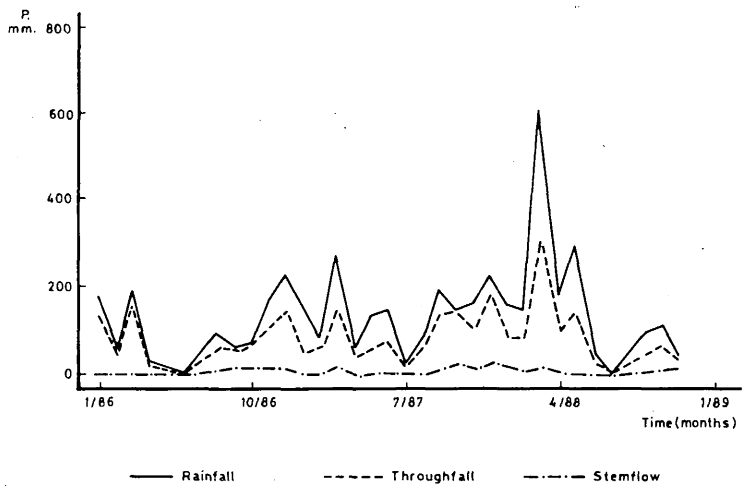

Fig. 8. Monthly variations of rainfall,throughfall and stemflow in the beechforest.
Variaciones mensuales de pluviosidad, transcolación y flujo de tronco en el hayedo.

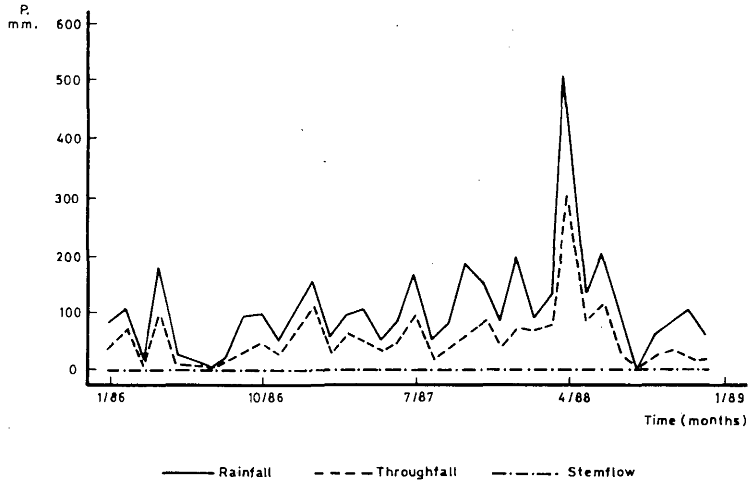

Fig. 9. Monthly variations of rainfall, throughfall and stemflow in the pineforest.
Variaciones mensuales de la pluviosidad, transcolación y flujo de tronco en el pinar.

(1980) in *Fagus sylvatica* have not demonstrated a relation between the rates of interception and phenophases, manifestating more variations in summer and spring, with which they are intercepted in smaller quantities, what can compensate to a great extent the effect of leaves.

Among the results of different authors consulted (CEPEL, 1967; AUSSENAC, 1968; AUSSENAC et BOULANGEAT, 1980; MITSCHERLICH and MOLL, 1970), show that the inteception in the beechwood represent between the 15-25% of the annual precipitations. For a same surface, the conifers are an average bigger that the beech forests; therefore the interception seems to be independent of the age of the population and depends of the structure. FORGEARD *et al.* (1980) estimate in conifers an average between the 42.6%-60.2%.

4. Final considerations

In spite of the two forest to study are relatively near we have obtained different results in relation to the distribution of rainwater in both sites, because of that we know that the specific characteristics of each population have influenced considerably. The fact to emphasize is that, considering the tree vegetative cycles separately, significant differences have not been detected in the two forest ecosystems in as much as to the incident precipitation, although such differences have been established when the throughfall and the stemflow have been considered, both in the period of leaves growth, and in the winter season.

The differences indicated in the water cycle establish a bigger loss in the pinewood in face of a beechwood; therefore their incidence was notable in the nutrient cycling, and we suggest the reafforestation and management of beech forests instead of pinewoods.

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