Distribution of soil moisture content and its effect on the potential growth of the over-story species in North-East Chalkidiki

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Abstract

This study deals with the soil moisture distribution and its effect on the potential growth and adaptation of the over-story species in north-east Chalkidiki. These species are: Quercus dalechampii Ten, Quercus conferta Kit, Quercus pubescens Willd, Castanea sativa Mill, Fagus moesiaca Maly-Domin and also Taxus baccata L. in mixed stands with Fagus moesiaca. Samples of soil, 1-2kg per 20cm depth, were taken and the moisture content of each sample was measured in order to determine soil moisture distribution and its contribution to the growth of the forest species. The most important results are: i) available water is influenced by the soil depth. During the summer, at a soil depth of 10cm a significant restriction was observed. ii) the large duration of the dry period in the deep soil layers has less adverse effect on stands growth than in the case of the soil surface layers, due to the fact that the root system mainly spreads out at a soil depth of 40cm iii) in the beginning of the growing season, the soil moisture content is greater than 30% at a soil depth of 60cm, in beech and mixed beech-yew stands, is 10-15% in the Q. pubescens stands and it's more than 30% at a soil depth of 60cm in Q. dalechampii stands.

Key words: Soil moisture content, oak, chestnut, beech, mixed beech-yew, environmental factor, potential growth.

1. Introduction

Soil moisture content is one of the most important ecological factors affecting natural ecosystems. Dafis (1986) determines the importance of soil moisture content in forest ecosystems which depends on the type of forest species present, density, age, altitude, climatic conditions as well as the soil conditions. Smiris (1975), reports that all the physiological functions of the plants depend on normal water supply. Thus, transient water deficiency or surplus diminishes the rate of functions strain and leads to diminishing the plant productivity. Alifragis (1988) and Candler et al. (1989) mention that soil moisture content directly or indirectly influences the recycling of nutrients in the ecosystem. Soil moisture content indirectly influences physical, chemical and biological soil properties such as temperature, ventilation, microbiological soil activity, nutrient uptake capacity and accumulation of toxic substances (Papamichos 1994, Seilopoulos 1991). The temperature and water regimes of the soils, determining the rate of growth of roots in various soil horizons, substantially affect the formation of the root systems as a whole (Bartch 1987, Feil et al. 1988, Korotaev 1988). Many authors, (Koukoura 1989, Aranda et al. 1996), mention that the appearance, support and growth of the forest stand depend on the combination of two important environmental factors: soil moisture content and light radiation.

This research was carried out in the region of Arnea, in the forests of Neohori, Stagira and Olybiada. According to the bioclimatic diagram of Emberger (Tsiontsis and Elias 1996), the area has a Mediterranean subhumid type climate with harsh winters. The mean annual temperature is 12.5°C, the rainfall is 649mm and the relative air humidity is 76%. The study area geologically belongs to the Circum Rodope Zone in the Melissohoriou-Xolomonta entity (Moundrakis 1985). The pedrographical view is composed of: gneiss series –biotite gneiss, mica-schist, biotite granites and the phyllite series- phyllite, orthogneiss, amphibolite, argilic schist.

Most forested areas of Greece are formed by different species of oaks (Quercus sp). The study area is covered by oak forests, with Q. conferta, Q. dalechampii and Q. pubescens, stands of chestnut, beech and mixed stands of beech-yew, occurring mostly in N, NE exposition. Quercus dalechampii forms deciduous oak forests in Italy, the Balkan peninsula, Slovakia, Hungary and Turkey (Athanasiadis 1986). In Greece, this species forms forests mainly in the northern and northeastern areas. Q. dalechampii occurs in small stands as well as in large scale forests. It forms pure stands mostly on sandy-loamy soils which are moister than the soil of pure Q. conferta forests. Quercus conferta forests belong to the Quercetum confertae-cerris vegetation zone, which begins at an altitude of 200-300m and it stretches to the highest 1000-1200m elevations. Physiognomically and floristically, the forest types of these oak species are rather similar. Quercus pubescens forests belong to the submediterranean vegetation zone (Quercetalia pubescentis), mainly to the Ostryo-Carpinion orientalis subzone between 200-300m and 900-1200m elevations (Boratynski et al. 1992). In Greece, this species forms pure and mixed forests mainly on shallow to medium-deep less fertile forest soils. All oak forests were, and still are continue to be, subject to intense human impact, including grazing and management by the forest service as «coppice forests».

The chestnut forests (Castanea sativa) in Greece cover an area of 18.658 ha from 800 to 1000m altitude (Boratynski et al. 1992). In the study area, this species forms mainly coppice forest stands, characterized by normal growing stock. Stands of C. sativa occur mainly in places where the mean annual temperature is between 10-15°C with mild, humid seasons all over the year, on medium to deep, fertile clay-silicic forest soils, avoiding shallow, dry, rich in calcium and poor in potassium forest soils. Beech forests in Greece cover an area of 217.500ha, of which 89.600ha are «coppice forests» and 97.000ha are «high forests» (Moulopoulos 1965). Pure and mixed forests can be found in Cholomontas, Pilio, Ossa, Pieria and Pindos mountains mostly on medium to deep, fertile, rich in moisture forest soils. Taxus baccata occur in small groups as an under-story in beech forests as well as in mixed stands with beech from 400 to 1200m altitude, mostly on medium to wet, fertile forest soils (Boratynski et al. 1992).

3. Research method

3.1. Determination of soil moisture content

Six adjacent Q. conferta, Q. dalechampii, Q. pubescens, Fagus moesiaca, Castanea sativa and Taxus baccata stands were selected. In each of these stands, soil samples 1-2 kg per 20cm depth were collected fortnightly in order to determine the soil moisture content, for the period 1996-1997. The samples were transferred to the laboratory, their weights were obtained and then were oven-dried for 24 hours at 105°C (Smiris 1975).

The soil moisture was measured with the following equation: Yv%=Y1x(BD) where: Yv% is the soil moisture content in a percentage of the soil volume, Y1 is the percentage of soil moisture content in dry weight and BD is the bulk density. After each measuring, a subtraction of stone weights and a correction in the results were made using the Reinhart method according to Table 1 (Hatzistathis 1972). Similarly, the soil moisture was measured in mm using the equation: Yh= Y1x(BD)xH, where: Yh is the soil moisture content in mm and H is the soil depth in m. The available soil water content was estimated with the equation: DY=(Y1-Ym)x(BD) where Ym is the moisture in the permanent wilting point (Smiris 1975).

For the determination of the edaphic constants, field capacity and permanent wilting point, the Richard membrane in pressure 15atm and the Richard pore slab in pressure 1/3 atm were used, respectively. The samples were set for 24 hours on the membrane or pore slab, into a specific ring made from elastic or brass, saturated in water. After that, all the samples were set on the pressure apparatus with the corresponding pressure, for the membrane during 48 hours and for the pore slab during 24 hours. Finally, the weights were obtained and the samples were dried at 105°C for 18-24 hours and then their dry weights were taken. The available soil water content was estimated as the difference between the field capacity and the permanent wilting percentage (Alifragis and Papamichos 1995).

Table 1. Soil moisture estimation using the Reinhart method

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No	No of caps	Weight of caps (gr)	Sample weight with caps		Sample moisture (gr)	Dry weight of soil with stones	Sample moisture before the correction	Dry weight of stones with caps	Dry weight of stones without caps	Moisture of stones	Correct moisture in gr	Correct dry weight of soil without stones	Correct moisture content
			Fresh	Dry									
1	II1												
2	II2												

4. Results

Figure 1 and 2 show the soil moisture content in Q. dalechampii stands during the period of April 1996 to November 1997. According to figure 1, in April 1996, during the expectoration of the leaves, the soil moisture content was 195 mm when the permanent wilting point was at 167 mm. At that period, the soil moisture at a soil depth of 20cm attained 25-30%, restraining 52 mm of soil water when the permanent wilting point at this depth was at 19 mm. A soil moisture increase was observed during May 1996, (at 293 mm), due to the increase of seasonal rainfalls. According to figure 2, soil moisture content at a soil depth of 40cm attained more than 15% and 25-30% at a soil depth of 60cm. During June 1996, after a temporary moisture increase, a steep falling to 229mm was observed, which continued till the end of August 1996, attaining 136mm of soil water. The ecological dry period, when the soil moisture content is around the permanent wilting point, is in July and August 1996, due to the great consumption and evaporation, owed to the continual increase of temperature and minimum percentages of precipitation. During this dry period, according to figure 2, the soil moisture per 20 cm depth was 10-15%, as well as in August 1996. In this period even though the soil moisture content was significantly restricted under the permanent wilting point (figure 1), the summer rains, depending on their intensity, enrich the soil surface for the soil moisture content to fluctuate to 10-15% at each soil depth of 20cm (figure 2). The maximum value in soil moisture content (380mm) appeared during December 1996 (figure 1). After a temporary decrease, a second maximum value in soil moisture content (376mm) appeared during February-March 1997, after the snow melting period (figure 1). Figure 2 indicates that the increase of moisture extended in all the soil depth in the period between February and May 1997, before and during the growing season. This is attributed to the mechanical soil texture. Soils in Q. dalechampii stands, in the study area, are enriched in clay and silt. According to Papamichos and Alifragis (1980), soils which are enriched in clay and silt, show higher nutrient concentrations even though a dramatic increase in available water accumulation is observed. During April-May 1997, a steep falling was observed, which continued till the end of August 1997, attaining 140 mm of soil water when the permanent wilting point was at 167mm (figure 1). When the rainy period began, an increase in soil moisture was also observed, which continued during the winter until the beginning of the growing season.

Figure 3 and 4 show the soil moisture content in Q. conferta stands during the period of April 1996 to November 1997. According to figure 3, in April 1996, at the beginning of the growing season, the soil moisture content was 226mm when the permanent wilting point was at 74mm. A soil moisture increase was observed during May 1996 (242mm), due to the increase of seasonal rainfalls. According to figure 4, soil moisture content was more than 25% at a soil depth of 20 and 40cm. During June 1996, after a temporary moisture increase, a continual falling was observed, which continued during the summer months, attaining 101mm of soil water in August 1996. The reduction is attributed to the great growing activity as well as to the evaporation in soil surface. It is interesting to point out that this soil moisture reduction was observed, with small fluctuations, until October 1996 (figure 4). The maximum value in soil moisture content (240mm) appeared during January 1997 (figure 3), while a fluctuation was observed during the period of February to May 1997, when the moisture content was at 238mm (figure 3).

Figure 1. Soil moisture process in mm in Q. dalechampii stands at a soil depth of 100 cm

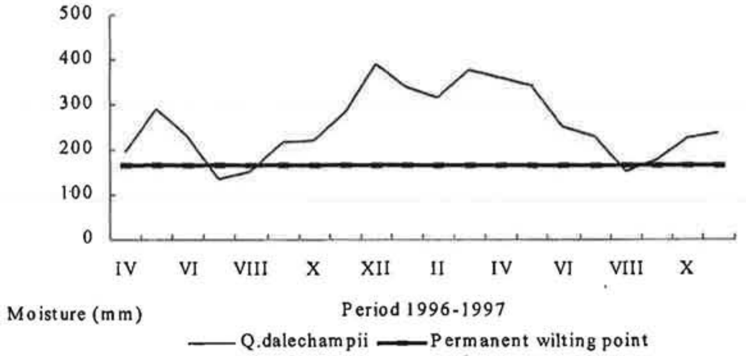


Figure 2. Distribution of soil moisture content in Q. dalechampii stands at a soil depth of 20cm, 40cm, 60cm

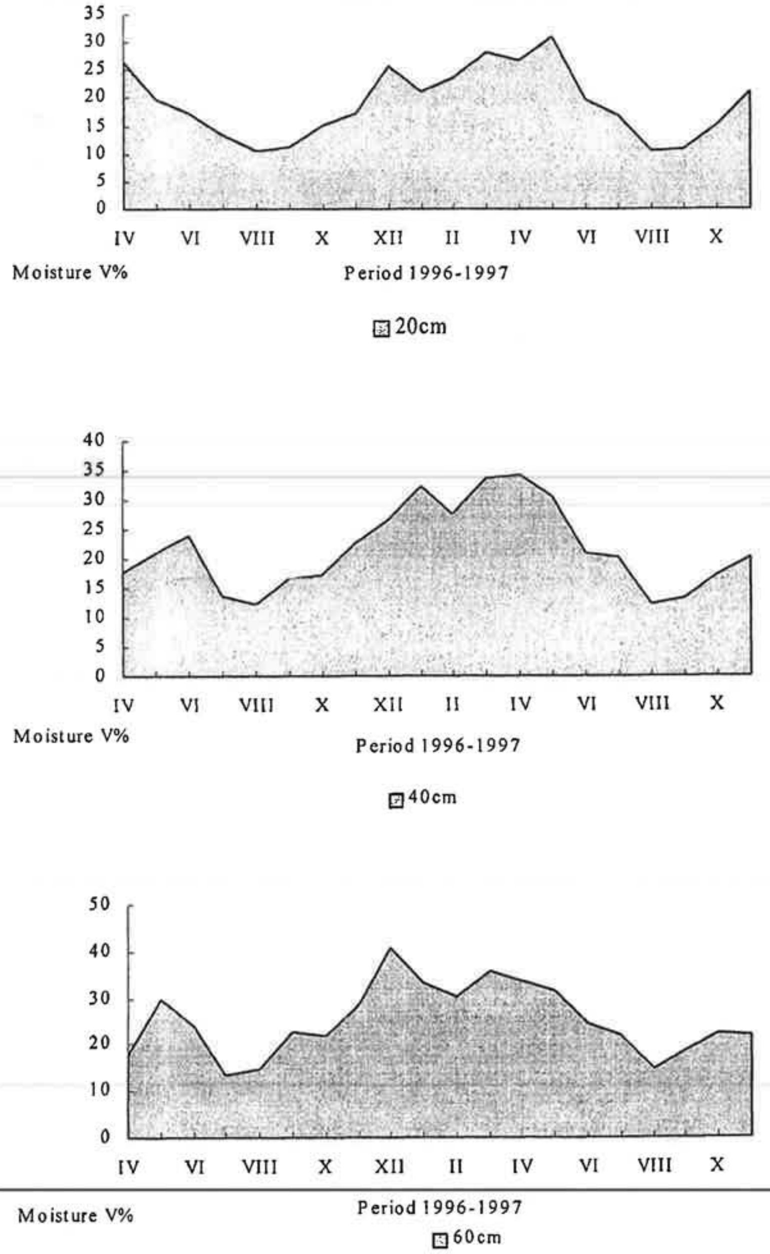


Figure 3. Soil moisture content process in mm in Q. conferta stands at soil depth of 100 cm

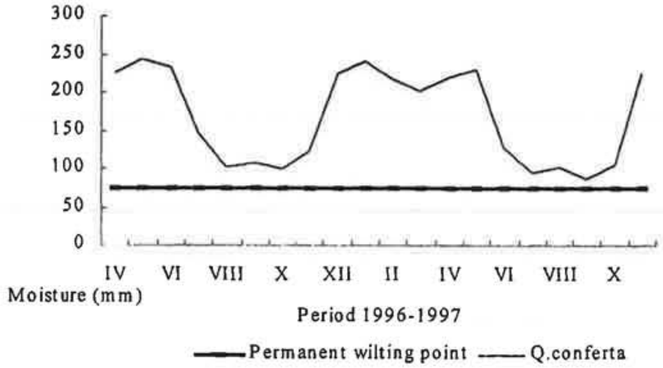
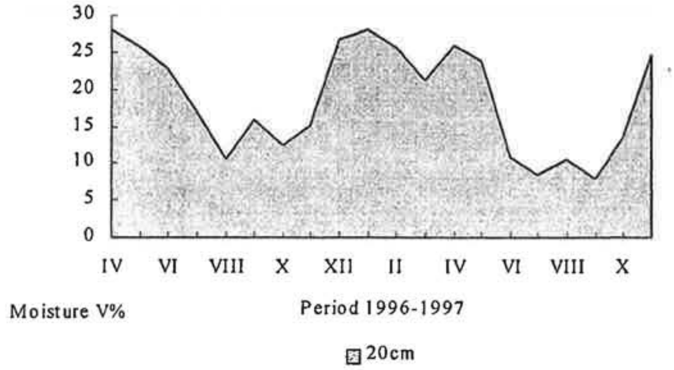
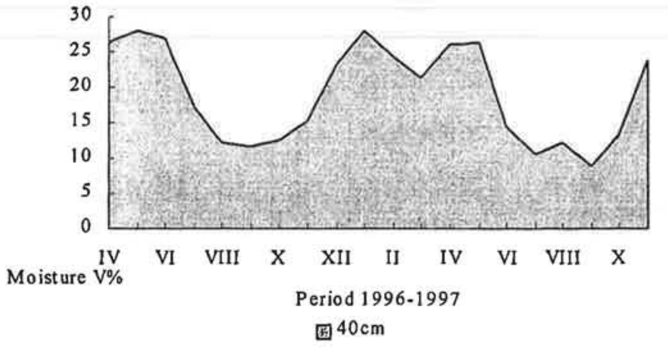


Figure 4. Distribution of soil moisture content in Q. conferta stands at a soil depth of 20cm,40cm,60cm





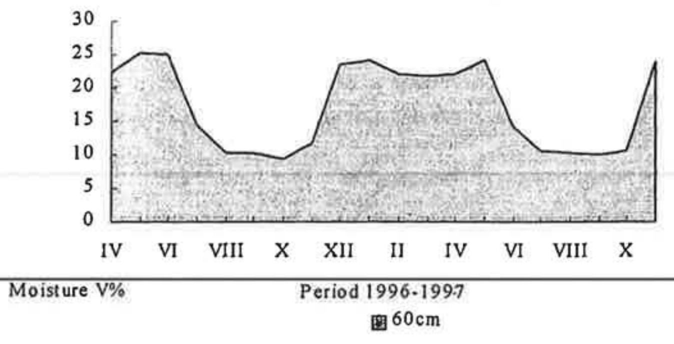


Figure 3. Soil moisture content process in mm in Q. conferta stands at soil depth of 100 cm

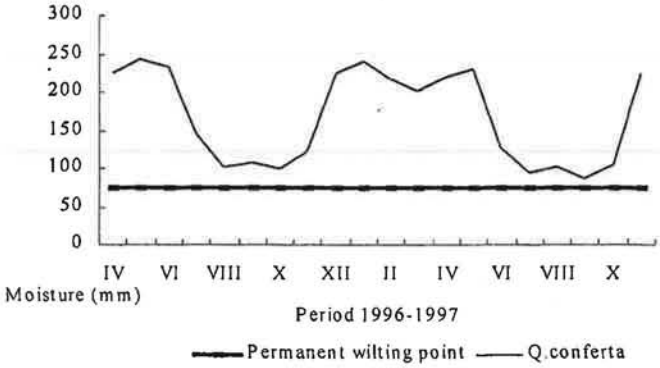
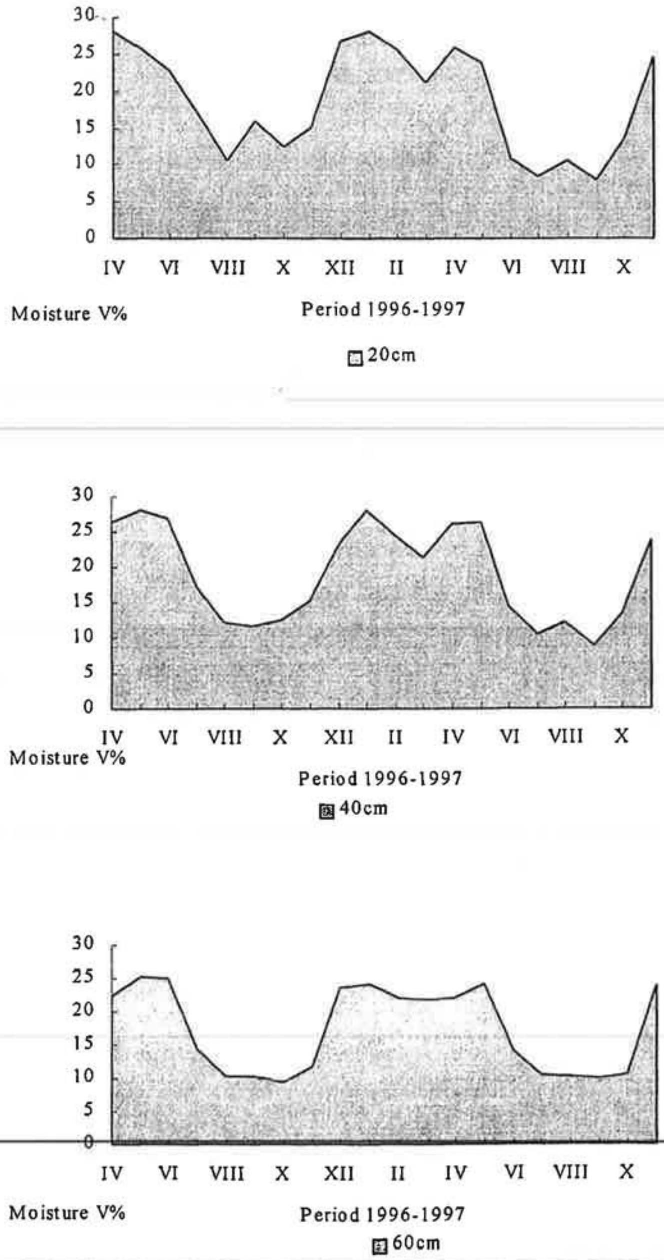


Figure 4. Distribution of soil moisture content in Q. conferta stands at a soil depth of 20cm,40cm,60cm



A steep falling to 128mm was observed during May-June 1997 (figure 3) and in July 1997 the soil moisture content was 74mm. When the rainy period began, an increase in moisture was also observed, which continued during the winter.
Figure 5 and 6 show the soil moisture content in Q. pubescens stands during the period of April 1996 to November 1997. According to the moisture profile (figure 5) in April 1996, the soil moisture content was 105mm and the permanent wilting point was at 28mm. A soil moisture increase was observed during May 1996 (199mm), due to the increase of seasonal rainfalls. In June 1996, after the temporary moisture increase, a steep falling was observed, which continued during the summer months, attaining 22mm in August 1996. The continual water consumption, due to the presence of vegetation, the reduction of precipitation, as well as the intense evaporation in soil surface, lead to a reduction of soil moisture content in the summer months, especially at a soil depth of 20cm (figure 6), which is restricted down to 5% due to the mechanical texture (great amount of sand) and the absence of forest floor (restrictive factor for evaporation). The maximum value in soil moisture content (227mm) appeared during January 1997 (figure 5). After a temporary moisture decrease, a second maximum value in soil moisture content (230mm) appeared during April 1997. In the beginning of the growing season, the continual water consumption lead to a reduction of soil moisture content. During the summer months that reduction was very intense, restraining 12mm, in August 1997. The above result attributed to the great growing activity as well as to the evaporation. When the rainy period began (October 1997) an increase in moisture was observed.

Figure 7 and 8 show the soil moisture content in Castanea sativa stands during the period of April 1996 to November 1997. The maximum value of soil water is observed during April 1996, after snow melting, when the moisture content reached 150 mm and the permanent wilting point was at 28mm (figure 7). This process was maintained until June 1996, restraining 152mm, when the soil moisture at a soil depth of 20cm (in soil surface layer) attained 25-30%, due to the rainfalls which where observed in May 1996 (figure 8). During June 1996, a steep falling to 70mm was observed, which continued during the summer months. That was maintained with small fluctuations until October 1996, due to the different order of rainfall enrichment in soil depth (figure 7). In September 1996, the soil moisture content was 61mm. This is attributed to the significant water consumption of vegetation due to the intense growing season. An increase in soil moisture content was observed with the beginning of the rainfall period. In December 1996, the soil moisture content was at 190mm. The moisture was uniformly divided at all soil depths of 60cm. The first maximum value in moisture content (figure 7) appeared during February 1997 reaching 205mm and this increase continued throughout May 1997 (224mm) due to the seasonal rains which supplied the soil depth with large quantities of water. According to figure 8, soil moisture content attained more than 25% at all depths. A drastic reduction was observed, as expected, the following months. In September 1997 the soil moisture content was 68mm. It is interesting to point out that this reduction was observed, with small fluctuations, until October 1997 (figure 7).

Figure 5. Soil moisture content process in mm in Q. pubescens at a soil depth of 100 cm

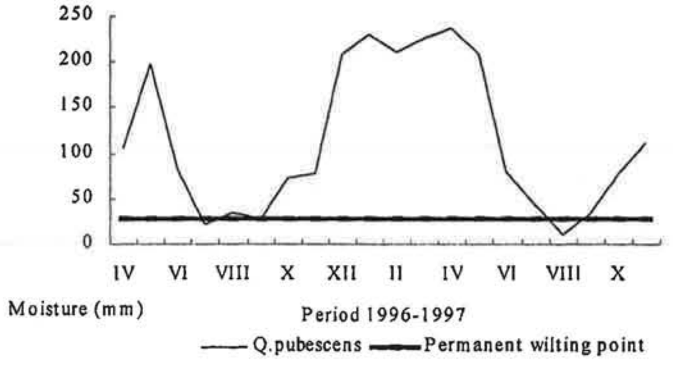


Figure 6. Distribution of soil moisture content in Q. pubescens stands at a soil depth of 20cm,40cm,60cm

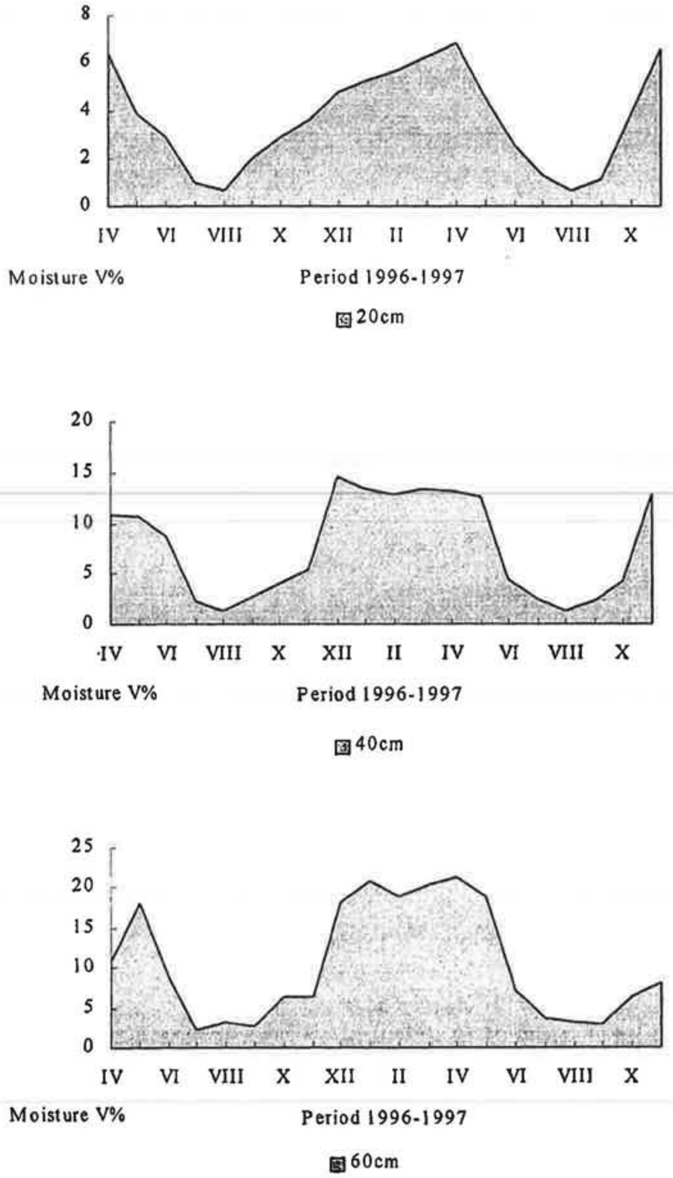


Figure 7. Soil moisture content process in mm in C. sativa at asoil depth of 60cm

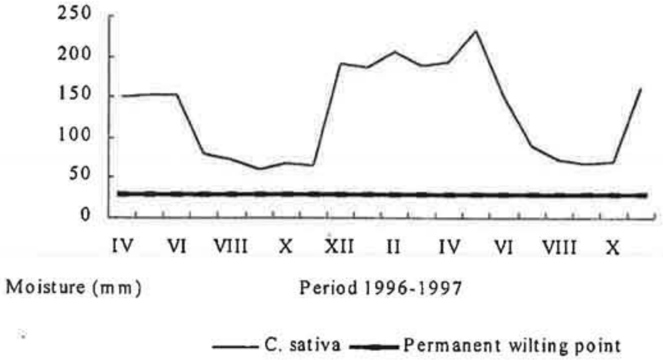


Figure 8. Distribution of soil moisture content in C. sativa stands at a soil depth of 20cm,40cm,60cm

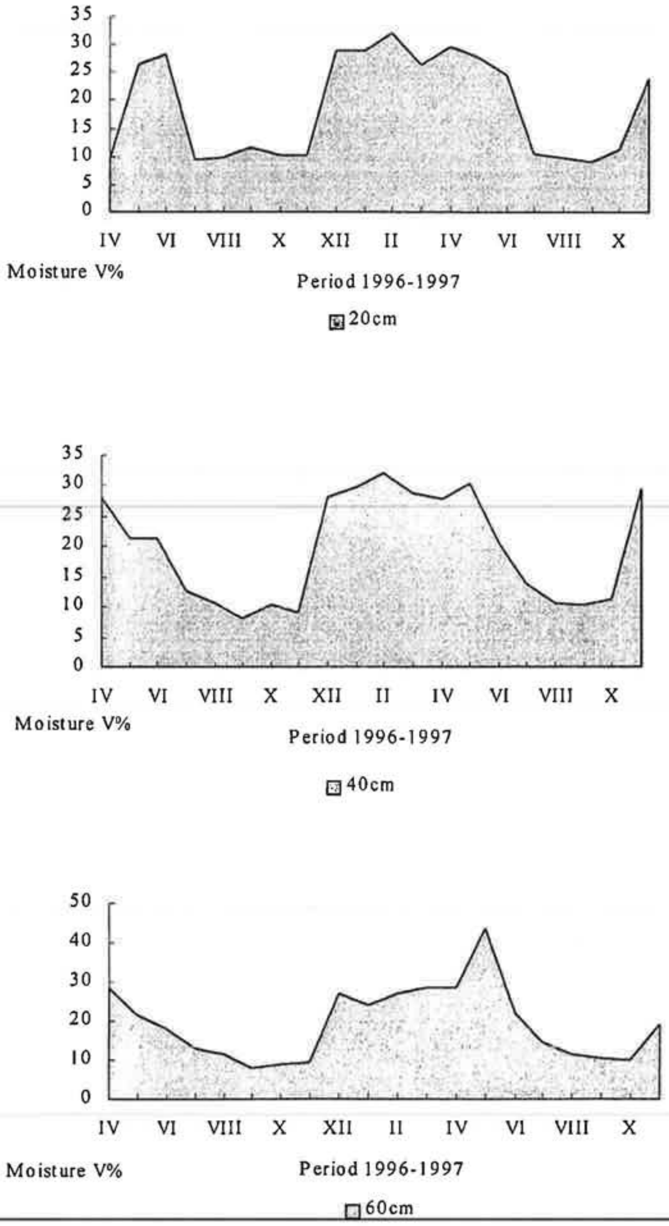


Figure 9 and 10 show the soil moisture content in Fagus moesiaca stands during the period of April 1996 to November 1997. According to figure 9, in April 1996, the soil moisture content was 282mm when the permanent wilting point was at 106mm. This period, the soil moisture at a soil depth of 20cm was greater than 30% (figure 10). At the beginning of the growing season and the expectoration of the leaves, a continual water reduction is observed. That reduction continued till September 1996 (figure 9), attaining 126mm and it is attributed to the great consumption and evaporation, owed to the continual increase of temperature and minimum percentages of precipitation. This moisture reduction process observed is of particular importance for the ecological dry period of August-September. It is well known that the accumulated water in the soil which was observed during November-December 1996, owed to the increase of the rainy period, was continually observed through April 1997 when significant soil soaking was reported. At the beginning of the growing season a moisture restriction (more intense in summer) occurred until the end of August 1997 when the soil moisture content was 128mm.

The distribution process of soil moisture content in mixed beech-yew stands is presented in figures 11 and 12. According to figure 11, in April 1996, the soil moisture content was 220mm when the permanent wilting point was at 36mm. The same period, the soil moisture at a soil depth of 20cm was more than 20% (figure 12). This can be attributed to the influence of the proportion of rainfalls which enrich the soil surface layers. During June 1996, after a temporary moisture increase, a steep falling was observed. In August 1996 the soil moisture content was 110 mm without being restricted down to 36mm (permanent wilting point). The intense reduction of water concentration in the soil surface is attributed to the great growing activity as well as to the evaporation of soil surface. During September 1996, a temporary moisture increase was observed (117mm), owed to the seasonal rainfalls that uniformly enrich the soil depth, attaining 10-15% at each depth of 20cm (figure 12).

In October 1996 the soil moisture was 86mm without falling under the permanent wilting point which could negatively affect the stand productivity. When the rainy period began (in November 1996) a soil moisture increase was also observed. The maximum value in soil moisture content (228mm) appeared during March 1997. After a temporary decrease, a second maximum value (240mm) appeared during May 1997 (figure 11). During June 1997, a steep falling was observed, which continued till the end of September 1997 (92mm). An increase was also observed in October 1997.

Figure 9. Soil moisture content process in mm in F. moesiaca at a soil depth of 100cm

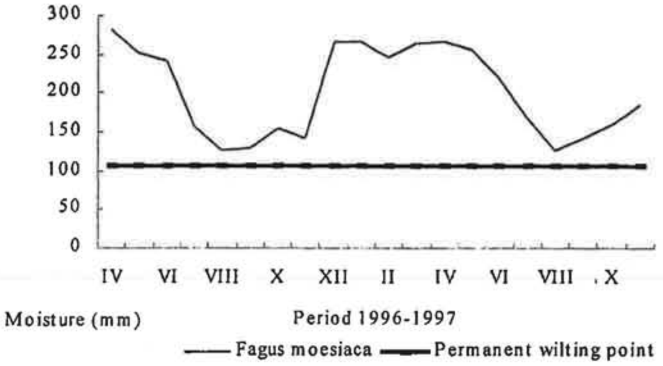


Figure 10. Distribution of soil moisture content in F. moesiaca stands at a soil depth of 20cm,40cm,60cm

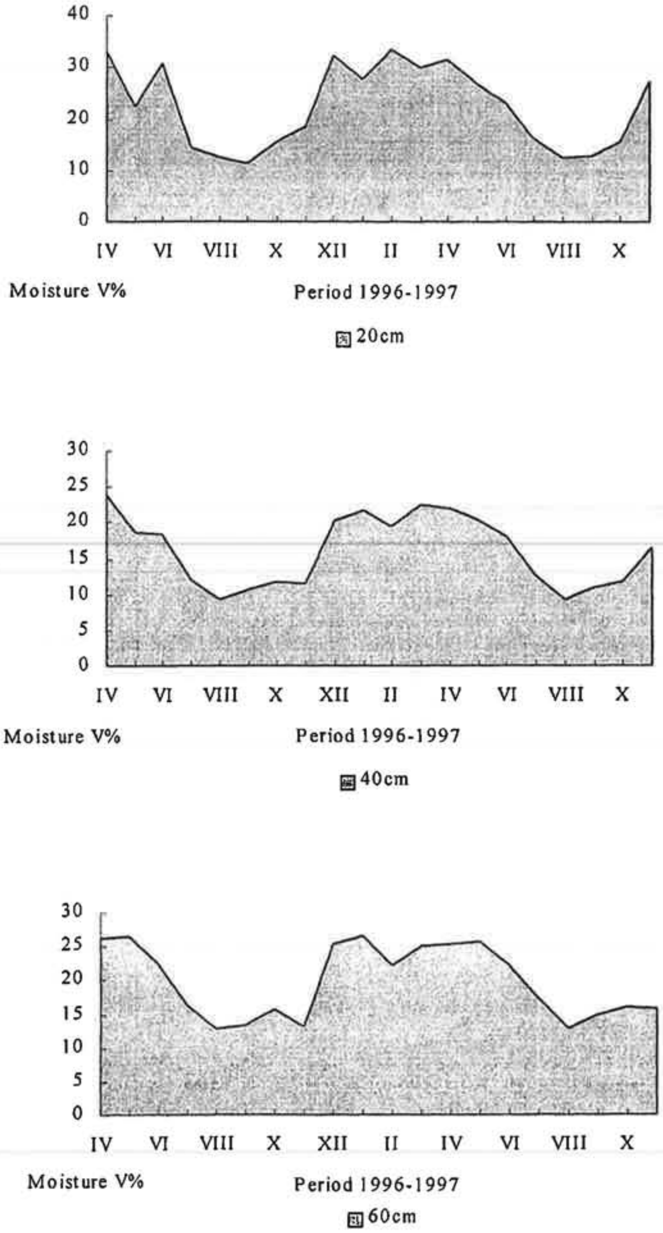


Figure 11. Soil moisture content process in mm in F. moesiaca-T. baccata stands at a soil depth of 100 cm

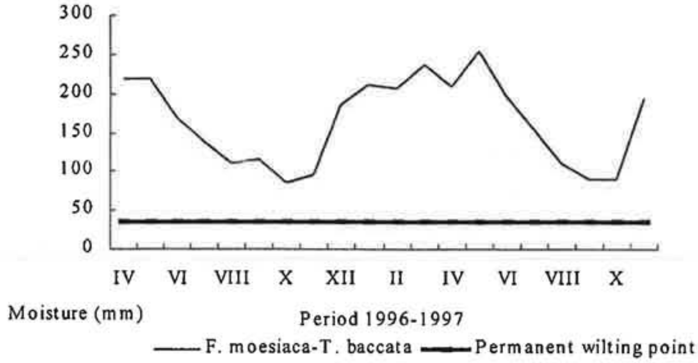
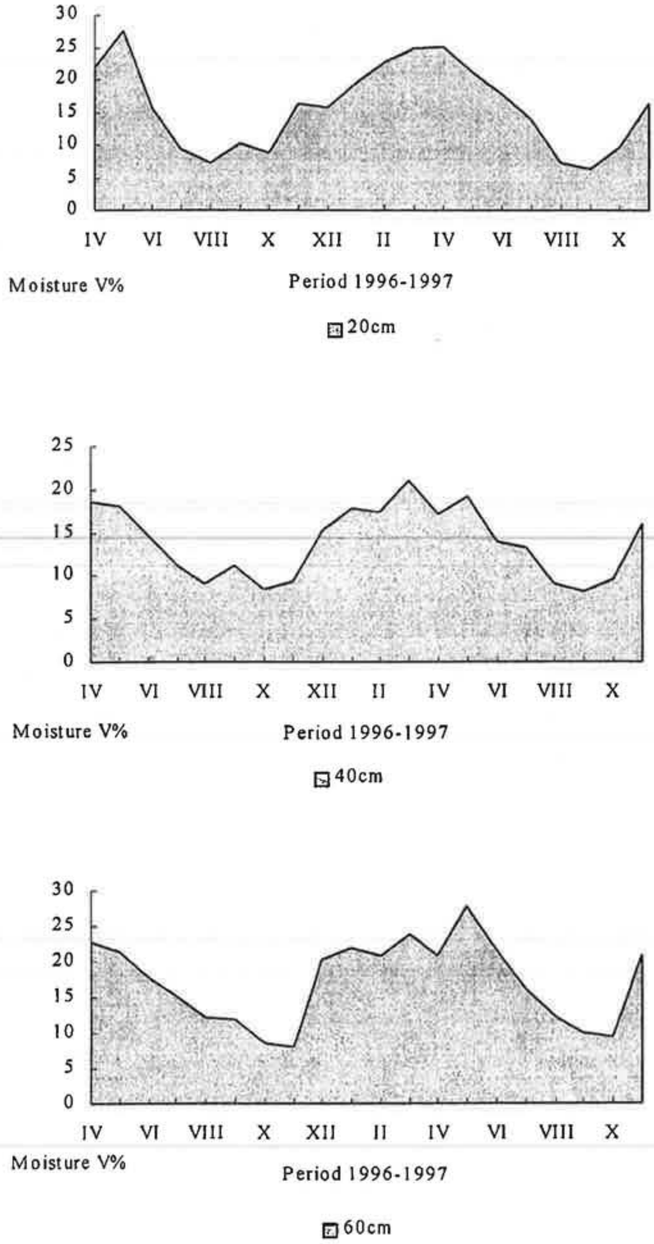


Figure 12. Distribution of soil moisture content in F. moesiaca-T.baccata stands at a soil depth of 20cm,40cm,60cm



5. Discussion

Brais and Camire (1991), Harrison and Shugart (1990), presented the importance of soil moisture content in forest ecosystems, especially into the evergreen broad-leaved zone at lower elevations, where the moisture content is the crucial factor for the forest species survival. Soil moisture is an important component of forest land classification, as it generally influences distribution and production of forest types. Koukoura (1989) and Aranda et al. (1996) mention that water availability is, together with light radiation, a limiting factor in the occurrence, abundance and growth of trees on certain sites. Climatic conditions, as well as soil conditions, are responsible for the soil absorption capacity which determines the percentage of available water in soil (Meriaux 1982).

In the present study, the maximum value in soil moisture content appeared during February-March, after the snow melting period, before and during the growing season. This period, in beech and beech-yew mixed stands, at a soil depth of 60cm, soil moisture content was greater than 20%. On the contrary, in Q. pubescens stands the soil moisture content was nearly 7-15% at each soil depth of 20cm. This attributed to the mechanical texture (great amount of sand) and the absence of forest floor (restrictive factor for evaporation). It is interesting to point out that in Q. dalechampii stands, the soil moisture content attained more than 20% at each soil depth of 20cm, due to the mechanical soil texture. In these stands, soils are enriched in clay and silt which –according to Papamichos and Alifragis (1980)- show higher nutrient concentrations and an increase in available water. The decrease in soil moisture content appeared during the summer months till the end of September or with small fluctuations till October, depending on the climatic conditions and mechanical soil texture. In Q. dalechampii stands a steep falling was observed until the end of August. It is interesting to point out that in all the other species, this soil moisture reduction was observed with small fluctuations until October. It is also interesting to point out that in Q. pubescens stands the continual water consumption leads to a drastic reduction of soil moisture content at a soil depth of 20cm. In this period even though the soil moisture content is significantly restricted especially at a soil surface layer, sometimes besides the permanent wilting point, due to the seasonal rains, the moisture content was nearly 10-15%. The way of absorption, with great amounts of available water, depends on different factors such as particle size texture, bulk density, percentage of stones, percentage of humus and soil depth (Papamichos and Alifragis 1980). According to Papamichos et al. (1979), Papamichos (1994) and Hatzistathis (1991), one of the most important physical soil properties is the depth, which can be easily determined and can provide the mean for absorbing water and nutrients for plants. In the cases where the soil is deep enough, large amount of water accumulates during the rainy season in order to cover the increasing needs for water in the growing season. On the contrary, small soil depth leads to small water absorbing surfaces, permitting the growth of evergreen broad-leaved species. According to Papamichos and Alifragis (1980), although the absorbing soil moisture content is continuously being increased by precipitation, it is however, exhausted during the growing season, due to evapotranspiration.

Hatzistathis (1979) observed that in a reforestation area in Chalkidiki, soil depth was correlated with the drying of seedlings, since this drying was observed in 10-30cm soil depth for Pinus radiata and P. maritima. The same was observed from Papamichos and Alifragis (1980) in the Poligiros (Chalikidiki) reforestations. According to Smiris (1975) in the Holomontas (Chalkidiki) oak stands, a reduction in soil moisture content is observed during July-October, due to irregular supplying of water, owed to its deficiency.

7. Conclusions

- Available water is influenced by the soil depth. During the summer, at a soil depth of 0-10cm (soil surface layer) a restriction in the available water was observed.
- The maximum value in soil moisture is observed during February- March.
- Soil moisture content is influenced indirectly by physical properties in order to increase the absorption activity of plants.
- During February-March (before and during the growing season), the soil moisture content is greater than 30% at a soil depth of 60cm, in beech and mixed beech-yew stands.
- At the same time, the soil moisture content is 10-15% in Q. pubescens stands.
- It is interesting to point out that an increase in water accumulation (>30%) was observed at a soil depth of 60cm in Q. dalechampii stands.
- The duration of the dry period fluctuates between July-August and depends on climatic conditions, structure and soil depth.
- The large duration of the dry period in the deep soil layers has less adverse effect on stands growth than in the case of the soil surface layers, due to the fact that the root system mainly spreads out at a soil depth of 40cm (Blyth and MacLead 1978).

8. References

Alifragis, D. (1988). Soil nutrients in forest ecosystems. Thessaloniki, 4-6.

Alifragis, D. & Papamichos, N. (1995). Description–Sampling and laboratory analysis in forest soil and tissues. Editions Giaxoudi-Giapouli. Thessaloniki, 57-62.

Aranda I., Gil, L. & Pardos, J. (1996). Seasonal water relations of three broad leaved species (Fagus sylvatica L., Quercus petraea Liebl. and Quercus pyrenaica Willd) in a mixed stand in the centre of the Iberian peninsuls. Forest Ecology and Management, 84, 219-229.

Athanasiadis (1986). Forest Botany Trees and Shrubs of the Greek Forests (in Greek), Thessaloniki, pp. 74,129,130,132,134,138,141.

Bartch, N. (1987). Responses of root systems of young Pinus sylvestris and Picea abies plants to water deficits and soil acidity. Canadian Journal Forest Research. 17, 805-812.

Blyth, J. & D. MacLead, D. (1978). The significance of soil variability for forest soil studies in North – East Scotland. Journal of Soil Science, 29, 419-430.

Boratynski, A., Kazimierz, B. & Zielinski, J. (1992). Chorology of trees and shrubs in Greece. Polish Academy of Sciences Institute of Dendrology, pp.44,195,199,258.

Brais, S. & Camire, C. (1991). Keys for soil moisture regime evaluation for northwestern Quebec. Canadian Journal Forest Research, 22, 718-721.

Candler, R., Zech, W. & Alt, H.G. (1989). A comparison of water soluble organic substances in acid soils under beech and spruce in NE-Bavaria. Z. Pflanzenernaehr Bodenk, 152, 61-65.

Dafis, S. (1986). Forest Ecology. Editions Giahoudi-Giapouli. Thessaloniki, 75-80.

Harrison, E.A. & Shugart, H.H. (1990). Evaluating performance of an Appalachian oak forest dynamics model. Vegetatio, 86, 1-13.

Hatzistathis, A. (1972). The influence of deep soil runging in soil moisture and soil fertility and its meaning in reforestation. Doctoral Dissertation. Thessaloniki.

Hatzistathis, A. (1979). Research on drying causes on the reforestation in Chalkidiki. Scientific Anniversary of Forest Department, 22, 55-111.

Hatzistathis, A. (1991). Reforestation – Nurseries. Editions Giaxoudi-Giapouli. Thessaloniki, 16-19.

Feil, W., Kottle, I. & Oberwinkler, F. (1988). The effect of drought on mycorrhizal production and very fine root system of norway spruce under natural and experimental conditions. Plant and Soil, 108, 221-231.

Korotaev, A. (1988). Growth and development of trees. Academic Press. New York and London, 3, 38-47.

Koukoura, Z. (1989). Effects of light intensity on sprouts ability production of Q. coccifera L. Scientific Anniversary of Forest Department, LB/2, 12, 219-230.

Meriaux, S. (1982). Soil and water. In Constituents and properties of soils. Bonneau M. and B. Souchier (Eds). Academic press. London and New York, 306-317.

Moundrakis, D. (1985). Geology of Greece. University Studio Press. Thessaloniki, 50-57.

Moulopoulos, X. (1965). Beech forests in Greece. Part A. Scientific Annals of Forestry Department, 1-88.

Papamichos, N., Alifragis, D. & Seilopoulos, D. (1979). Influence of physiografical and soil properties in growth of spruce. Scientific Anniversary of Forest Department, 22, 5, 133-159.

Papamichos, N. & Alifragis, D. (1980). Reforestation damages due to drying in Poligiro Chalkidiki. Scientific Anniversary of Forestry Department, Vol. KG-No4, 77-106.

Papamichos, N. (1994). Influence of water deficiency in forest growth. Proceedings of 6th Nation Forestry Convention. Xania, 318-326.

Seilopoulos, D. (1991). Influence of forest fires on physical soil properties. Doctoral Dissertation. Scientific Anniversary of Forest Department. Thessaloniki.

Smiris, P. (1975). Distribution and fluctuation of soil moisture content and its influence on thinning in oak stands in Xolomonda Chalkidiki. Scientific Annals of Forest Department, IH, 45 pp.

Tsiontsis, A. & Elias, K. (1996). Data of meteorological station in Arnea Chalkidiki. I. F. R. TH.Thessaloniki.