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ECODENDROMETRIC STUDY OF STONE PINE (*Pinus pinea* L.) IN THE REGION OF MOSTAGANEM (WESTERN ALGERIA)

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Abstract

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The evaluation and monitoring of forest species provide a fundamental source of information for the implementation of effective and adapted conservation strategies for these species. The present study aims to determine the ecodendrometric characterisation of even-aged stone pine stands in the region of Mostaganem (western Algeria). Seventy-two temporary plots (1,151 trees) of circular shape with a surface area of (4–6 a) were installed according to age and density in stands that were as regular as possible. These plots were subjected to a complete dendrometric inventory (total height, crown diameter, circumference at 1.3 m, age, etc.) and an ecological description (soil depth, altitude, aspect and slope). It was found that this species is characterised by a regular structure forming young populations. Relationships between parameters such as mean total height/mean circumference, mean crown diameter/diameter at 1.3 m and basal area/mean crown diameter were very positive and significant. The ecodendrometric data was processed by a multivariate principal component analysis, which revealed the effect of altitude, especially soil depth, on stone pine production.

Key words: stone pine, dendrometric inventory, ecological factors, production, western Algeria.

Introduction

Stone pine (*Pinus pinea*), recognisable by its open umbrella-like habit, is an atypical Mediterranean species. Its total area worldwide is estimated at 700,000 ha (Mutke et al., 2012). Its range extends from Portugal to Syria and along some Black Sea coastal areas. It can be found pure or mixed with maritime pine (*Pinus pinaster* Ait), some *Juniperus* species (Barbeito, 2009), and with cork oak (*Quercus suber* L.) (Cabannes, 2015). This species has been used since ancient times for its economic importance as a source of timber, firewood, bark, resin and edible pine nuts. In addition, the stone pine provides important ecological, landscape and recreational services due to its ability to grow on continental and coastal dunes. Indeed, it has been widely used for soil erosion control.

In Algeria, the stone pine is found in the form of reforestation in different regions (coastal, sublittoral and others). These plantations have shown that the adaptation and acclimatisation potential of this species is capable of colonising such difficult environments.

However, the stone pine in Algeria remains poorly known. Few scientific studies are currently available on the growth and the environments preferred by this species.

The objective of this study is to estimate the productivity of stone pine while identifying the different relevant dendrometric characteristics and to determine the ecological factors that influence this productivity. To this end, we undertook this research on the growth of old reforestation stands of the species in the region of Mostaganem in northwestern Algeria. The artificial stands that are the subject of the present work extend from the coastal dunes of Stidia to the hacel of Bel (Agboub forest).

Material and methods

Study area

The region of Mostaganem, with a surface area of 2,269 km^2, is located in the northwest of Algeria. It extends geographically between the meridians 0°8’ west and 0°46› east and between latitudes 36°29› and 35°37› north. It is bordered to the north and northwest by the Mediterranean Sea, with a coastline of around 120 km, to the east by the wilaya of Chleff, to the south by the wilayas of Mascara and Relizane and to the west by the wilaya of Oran (Fig. 1).

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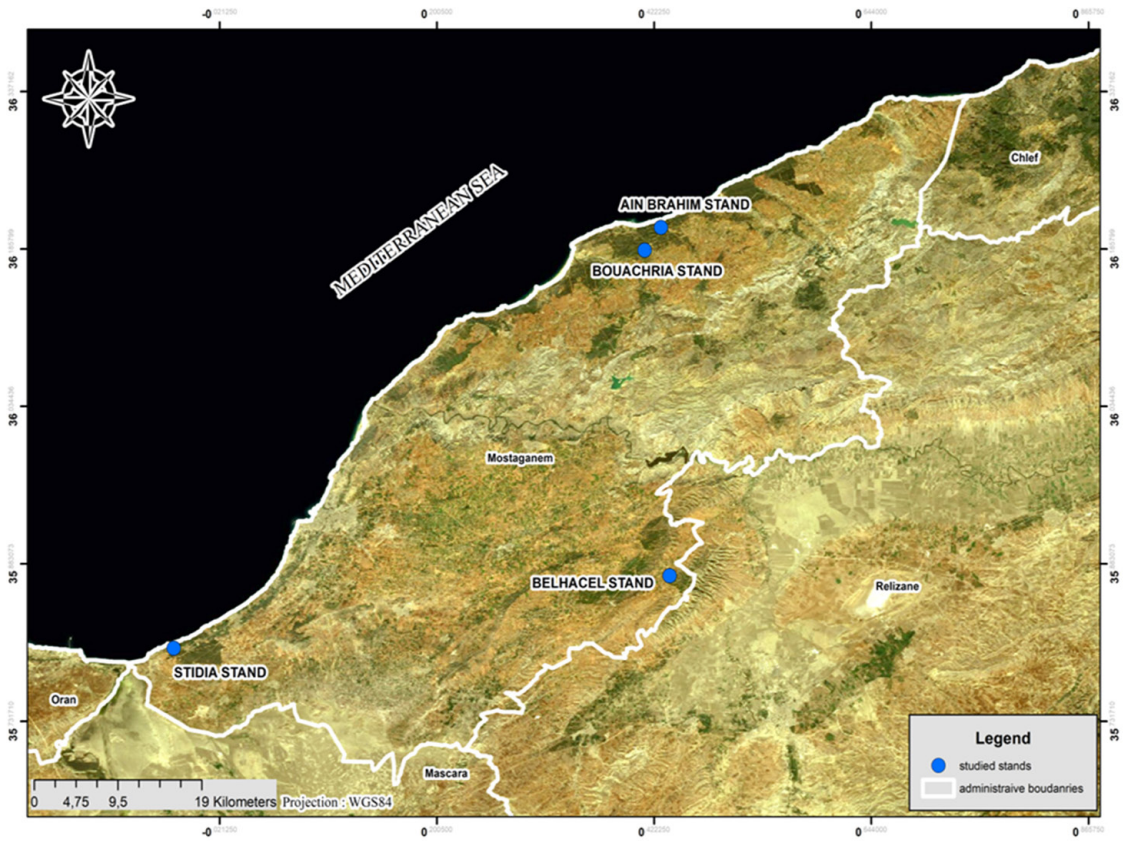


Fig 1. Location of the study area.

Stone pine occupies more than 4,480 ha of the total area of Algeria (N.F.I, 2017), all of which are artificial plantations. The most important stands in western Algeria are located in the Mostaganem region. The present study covered all stone pine plantations in the Mostaganem region, which occupied a total area of about 407 ha. Stone pine has been used for reforestation in the Mostaganem region since the French colonisation to fight against soil erosion in Bel hacel and Bouchria. The success of these first plantations encouraged foresters to use this species to provide vegetation cover for the coastal dunes of Stidia and Ain Brahim since 1972 (N.F.I, 2017) (Fig. 1).

The type of climate in our study area is Mediterranean, belonging to the semi-arid bioclimatic stage with a cool winter, with irregular and low rainfall (on average, around 360 mm/year). There are two contrasting periods, one wet and cold the other dry and hot. Summer rainfall is often torrential and temperatures vary greatly, the difference between the average maximum (M) and minimum (m) temperatures is between 15 and 25 °C. January and February are the coldest months of the year and July and August are the hottest. The dry season generally starts in April and lasts until October (NMO, 2020).

Dendrometric inventory and plot characterisation

According to Rondeux (1993), carrying out a forest inventory is often a very important issue in forest management. For reasons of time and budget, it is appropriate or necessary to use sampling. The heterogeneity and diversity of the facies imposed a random stratification of the sampling. The criteria used for the installation of our plots were topographical characteristics (slopes, exposure and altitude), stand density (number of trees per unit area) and the condition of the stand. A total of 72 temporary plots (4–6 a) were sampled throughout the studied stone pine stands. All plots were ecologically characterised and a complete dendrometric inventory was carried out.

Dendrometric measurements

The total height of the tree is defined as the distance from the base of the tree to its terminal bud. However, in the case of trees with a tabular or rounded shape, the height is taken at the limit of the last twig of the crown. This measurement was made with the Blum-Leiss for all trees in each plot.

The circumference at 1.3 m from the ground was measured with a tape measure for all pre-countable trees in the plot with a circumference of more than 22 cm. The minimum circumference at which production is estimated is 22 cm, regardless of the use of the wood. Trees smaller than this size will simply not be included in the estimate for softwood. This circumference is called the smallwood circumference.

The diameter was measured with a decameter, taking into account the horizontal projection of the crown. Rondeux (1993) indicates that the further the projected area is from a circle, the more diameters should be measured.

In the case of n radii r, the area of the horizontal projection hp results from the following root mean square:

$$p = \pi \sum_{i=1}^{n} ri^2 /n,$$

from which the average crown diameter (CD) is deduced:

$$CD = \frac{\sqrt{4\,hp}}{\pi} = 2\sqrt{\sum_{i=1}^{n} ri^2 /n}\ .$$

For the height of the crown, the first large living branch is considered to be the base of the crown.

For more precision in the age, the trees are drilled with a Pressler auger driven into the heart of the trees at 1.3 m from the ground and the annual rings are counted. The number of rings gives the age of the tree; for a better estimate of this variable, it is useful to add 5 years to the number obtained to compensate for the 30 cm of stump. Dominant trees should be healthy, with no external pathological signs.

Measurement of transformed variables

After collecting data in the field on a total of 72 plots in stands that were as regular as possible, the dendrometric productivity variables were calculated for each plot (Alder, 1980). These variables are as follows:

- number of stems per hectare (*N*/ha),
- average stand circumference (Cm),
- dominant stand circumference (Cdom),
- average total stand height (Hm),
- total dominant stand height (Hdom),
- stand basal area (*G*),
- average basal area ($\bar{g}$) and
- tree diameter of average basal area ($d\bar{g}$).

Number of stems per hectare:
This is obtained by dividing the total number of living trees on the plot by the total plot area.

$$N/H = n/S,$$

where *n* is the number of trees in the plot and *S* is the area of the plot.

Average total stand height (Hm) and dominant height (Hdom):
Average total stand height represent the average height of all trees in the plot.

$$Hm = \frac{\sum_{i=1}^{n} Hi}{n}.$$

where Hi is the total height of the trees and *n* is the number of trees in the plot.

Based on the most commonly accepted standards (Hummel, 1955; Hengst, 1958; Hamilton, 1975; Rondeux, 1993; Wouters, Lorent, 2001), the dominant stand height is considered to be the average of the 100 largest trees per hectare.

$$Hdom = (h1 + h2 + \ldots h100)/100$$

In the case of a plot with an area of 0.06 ha, the dominant height corresponds to

$$Hdom = \sum_{i=1}^{n} Hi\ /6.$$

Basal area (G):
The basal area of a stand is the sum of basal areas of all the trees in the stand. The unit of basal area is, therefore, expressed in square metres. In order to be able to compare measurements, this value is reduced to the hectare. In the present work, the formula applied for the calculation of basal area is as follows:

$$G = \frac{1}{4\pi} \sum_{i=1}^{n} C^2\ /S.$$

where *C* is the circumference of the tree (m) and *S* is the plot area in hectare.

Average basal area ($\bar{g}$) and diameter of the average basal area tree ($d\bar{g}$):
Average basal area is obtained by dividing the basal area of the stand (*G*) by the number of stems per hectare (*N*):

$$\bar{g} = G/N.$$

Diameter of the average basal area tree is the root mean square of the diameters, obtained by dividing the sum of the squared diameters by the number of trees in the plot and taking the square root of the result.

$$d\bar{g} = \sqrt{\sum_{i=1}^{n} di^2 /n} \text{ or } d\bar{g} = \sqrt{4\bar{g}/\pi}\ .$$

Ecological characteristics of the plots

The main station, topographical and pedological characteristics recorded to define the study stations can be abstracted as follows:
altitude: measured with an altimeter;
slope: determined by a clinometer;
exposition: oriented by means of a compass and
soil depth: determined by a soil auger.

Multivariate analysis of ecodendrometric data

In the framework of this approach, a relationship between the different dendrometric variables and the ecological variables of the sample plots is established. This is based on a Principal Component Analysis (PCA) performed with the Statistical Package for the Social Sciences (SPSS) software. The numerical variables (ecodendrometric variables) are shown in a circle of correlations of the PCA.

Results

Dendrometric and ecological characteristics of the sampled plots

The dendrometric and ecological characteristics of the different plots studied are summarised in Table 1.

Table 1. Dendrometric and ecological characteristics of the different plots studied.

Characteristics	Minimum	Maximum	Mean	Coefficient of variation (%)
Dendrometric data				
Average circumference at 1.30 m Cm (cm)	43.17	60	86.19	34.58
Dominant circumference at 1.30 m Cdom (cm)	61.5	195.66	111.65	29.87
Average total height Hm (m)	5.32	12.72	8.79	24.7
Dominant height Hdom (m)	6.25	14.5	11.05	21.17
Average crown diameter CDA (m)	2.82	16.42	6.88	42.44
Âge (years)	42	100	67.5	24.9
Number of stems per hectare (*N*/ha)	183.33	900	375.88	51.7
Basal area *G* (m^2/ha)	9.22	42.43	19.98	33.66
Average basal area $\bar{g}$ (m^2)	0.51	3.63	1.33	51.21
Tree diameter of average basal area $d\bar{g}$ (cm)	80.58	214.98	126.84	23.7
Ecological data				
Altitude (m)	32	372	170.66	75.97
Slope (%)	03	27	8.51	61.71
Soil depth (m)	0.1	0.85	0.33	58.98
Exposition	Southeast 2.77%	North 31.94%		

The values of the coefficient of variation (CV; ratio between standard deviation and mean) showed a certain homogeneity between the different dendrometric measurements.

For the CV values of the dendrometric characteristics, the highest value was that of the number of stems per hectare (*N*/ha) with 51.7%. On the other hand, the CV value of the dominant height was the lowest at 21.7%.

There were significant differences between the ecological conditions of the sample plots. This heterogeneity is confirmed by the CV, which is more or less important for the different ecological measures (CV values >58%). The latter gives a good idea of the adaptation potential of the species studied.

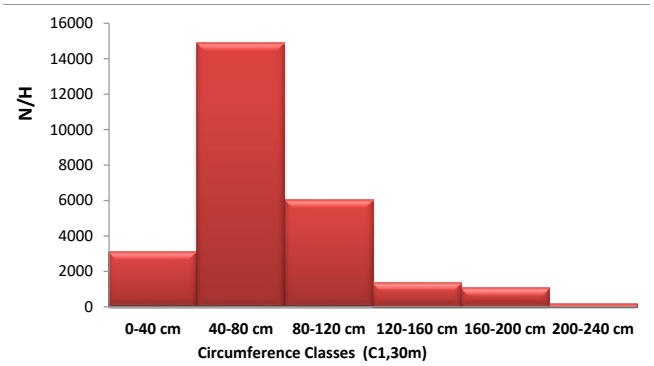


Fig. 2. Frequency histogram of stone pine according to circumference classes ($C_{1.30\ m}$).

Overall stand structure

When all the stems that can be counted in a stand are grouped by size category, a frequency distribution is defined. This is of great interest in forest management because it is an expression of the stand structure. It also reflects the reaction of the stand to growth conditions and silvicultural operations (Barbeito, 2009). Fig. 2 shows the distribution of the number of stems by circumference categories at 1.3 m of stone pine in the study area.

Indeed, the structure of the stands in the study area was regular and consisted of several even-aged stands. The majority of the stands were made up of trees belonging to the second (40–80 cm) and third (80–120 cm) circumference classes, thus forming young stands. The other classes were poorly represented, with a deficit of large trees (200–240 cm circumference) (Fig. 2).

Relationship between total height and circumference at 1.3 m

According to Sabatia and Burkhart (2013), measurements of heights and girths at breast height of forest stands are also useful for making management decisions and planning activities such as thinning, harvesting or improvement operations. Generally, height–circumference or height–diameter relationships are applied to even-aged stands and can be based not only on linear functions (Johnson, 1949; Sanchez et al., 2003), but also on non-linear functions (Huang et al., 1992).

The unique relationship between the average total height and the average circumference of the plots is well illustrated in Fig. 3. The total tree height and the mean total height of the plots studied were equally distributed on both sides of the polynomial trend line. These results are confirmed by the high value of the coefficient of determination (R^2), which ranges from 0.85 to 0.95 for the relationship (total height–circumference at 1.3 m) of all trees and the relationship (mean total height–mean circumference) of the surveyed plots, respectively (Fig. 3).

Relationship between CD and diameter at 1.3 m

The crown of a tree represents its growth and development potential (Bechtold et al., 2002). The crown dimensions of the tree,

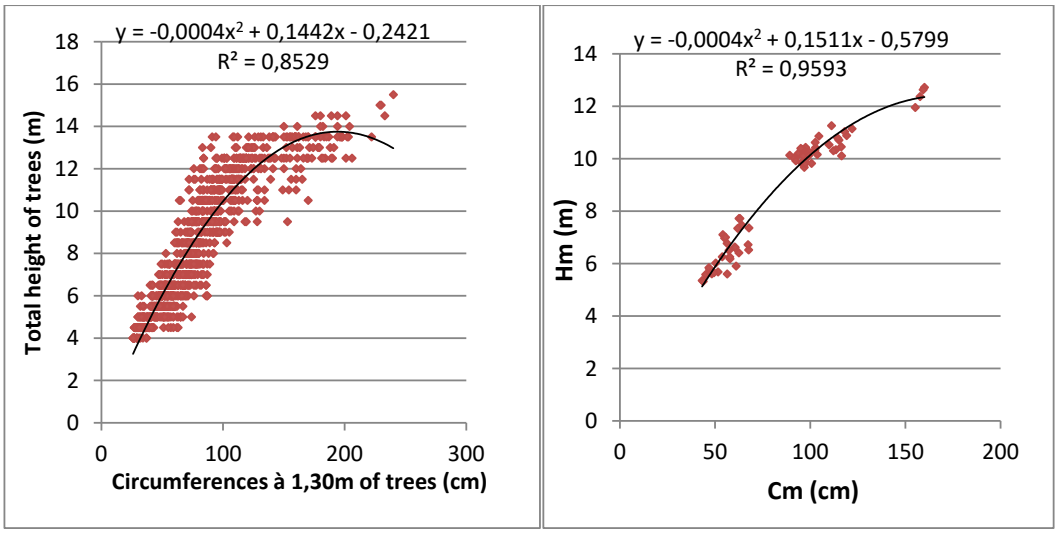


Fig. 3. Evolution of total height as a function of circumference at 1.30 m of the plots studied.

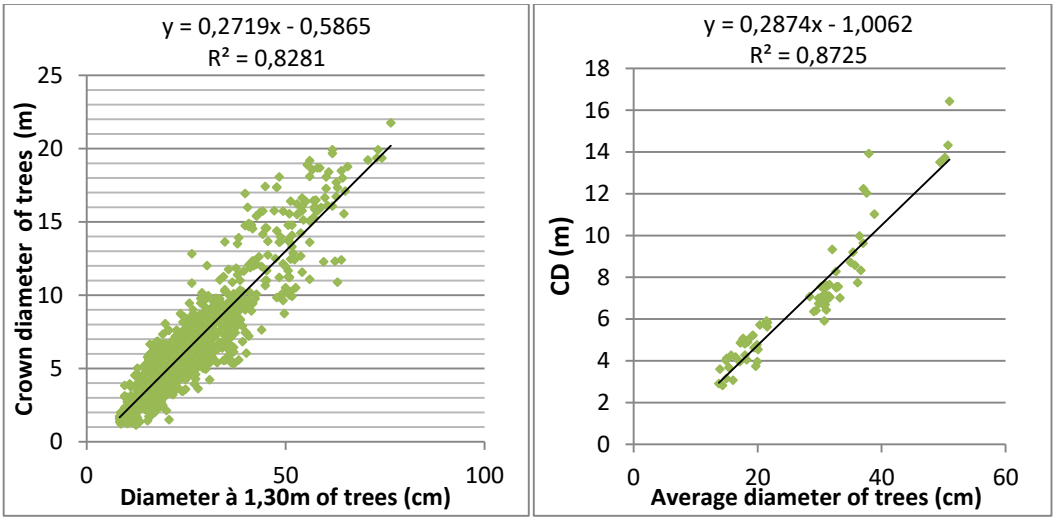


Fig. 4. Relationship between crown diameter and diameter at 1.30 m, and the relationship between average crown diameter and average diameter at 1.30 m of the plots studied.

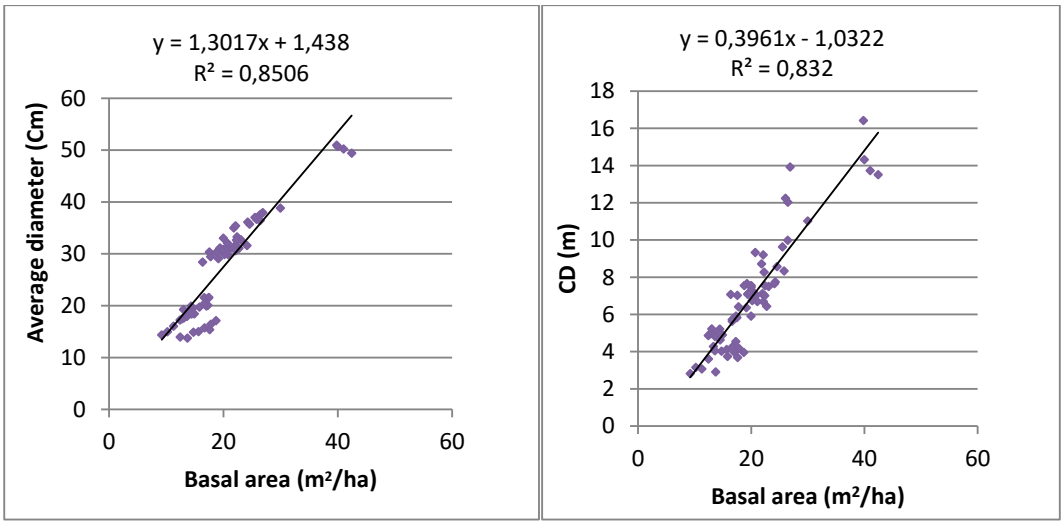


Fig. 5. Relationship between basal area/average diameter at 1.30 m and basal area/average crown diameter of the plots studied.

Table 2. Correlation matrix between dendrometric and ecological variables.

Correlation	Age (years)	Hm (m)	Hdom (m)	Cm (cm)	Cdom (cm)	CDA (m)	G (m^2/ha)	Altitude (m)	Slope (%)	Soil depth (m)	Exposition
Age (years)	1.000	0.943	0.907	0.953	0.942	0.886	0.831	0.592	0.331	0.797	0.126
Hm (m)	0.943	1.000	0.931	0.954	0.931	0.838	0.810	0.748	0.397	0.777	0.110
Hdom (m)	0.907	0.931	1.000	0.860	0.855	0.762	0.698	0.648	0.314	0.764	0.094
Cm (cm)	0.953	0.954	0.860	1.000	0.984	0.934	0.922	0.665	0.398	0.799	0.105
Cdom (cm)	0.942	0.931	0.855	0.984	1.000	0.926	0.927	0.627	0.381	0.776	0.092
CDA (m)	0.886	0.838	0.762	0.934	0.926	1.000	0.912	0.459	0.307	0.795	0.081
G (m^2/ha)	0.831	0.810	0.698	0.922	0.927	0.912	1.000	0.519	0.369	0.724	0.052
Altitude (m)	0.592	0.748	0.648	0.665	0.627	0.459	0.519	1.000	0.579	0.458	0.142
Slope (%)	0.331	0.397	0.314	0.398	0.381	0.307	0.369	0.579	1.000	0.165	-0.071
Soil depth (m)	0.797	0.777	0.764	0.799	0.776	0.795	0.724	0.458	0.165	1.000	0.227
Exposition	0.126	0.110	0.094	0.105	0.092	0.081	0.052	0.142	-0.071	0.227	1.000

Note: CDA- average crown diameter.

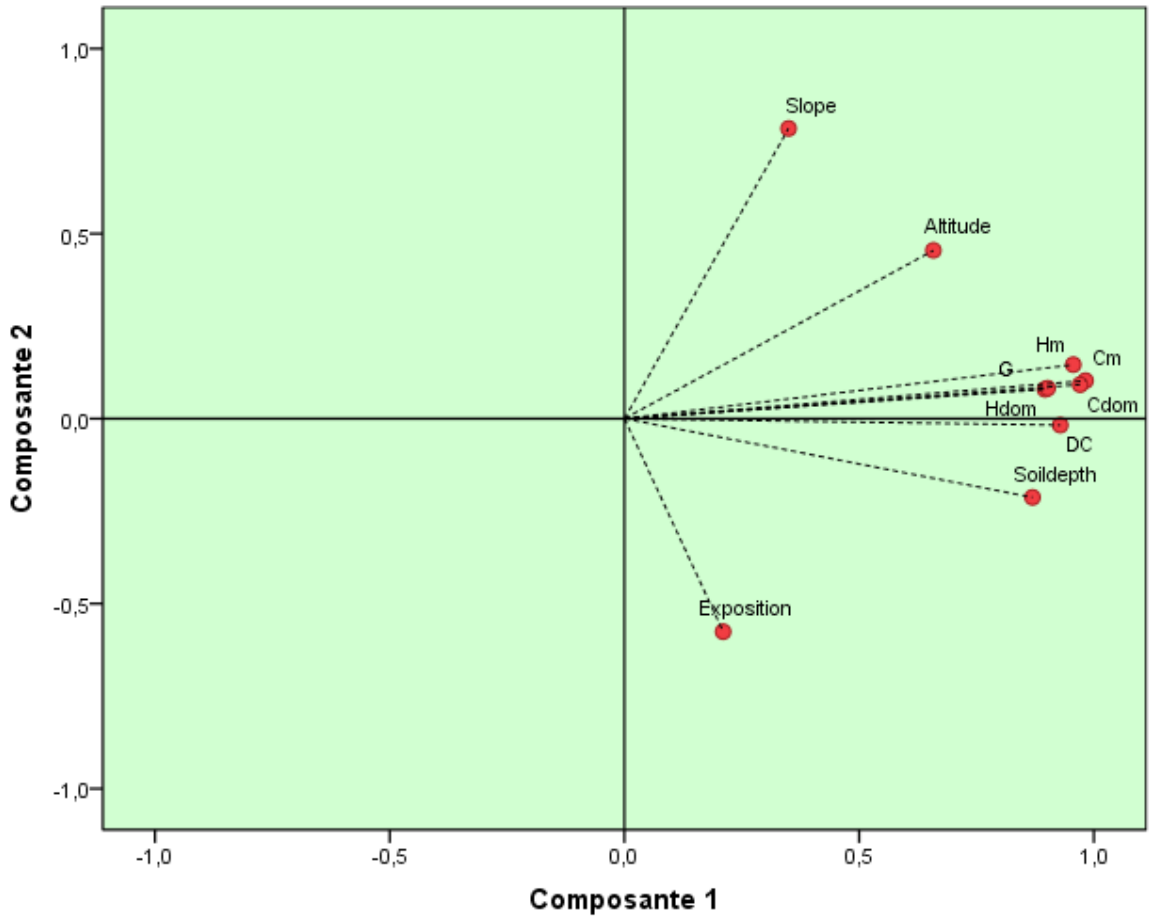


Fig. 6. Correlation circle showing the degree of correlation between dendrometric and ecological variables.

in particular, the horizontal dimension, radius or diameter, were well correlated with the diameter at 1.3 m of the tree. The CD/diameter at 1.3 m relationship is particularly useful for determining crown competition factors (Krajicek et al., 1961; Vezina, 1963; Strub et al., 1975), stand density (Dawkins, 1963; Roberts, Ross, 1965; Minckler, Gingrich, 1970; Goelz, 1996), tree growth and tree and stand volume (Minor, 1951; Bonnor, 1968; Gering, May, 1995).

Fig. 4 shows the relationship between CD and diameter at 1.3 m of all trees studied, as well as the relationship between average CD and average diameter at 1.3 m of the different plots in the study area.

The linear fit between CD and diameter at breast height showed the relationships (Fig. 4), with high coefficients of determination (R^2), which ranged from 0.82 for the relationship between CD and diameter at breast height to 0.87 for the relationship between average CD and average diameter at breast height of the plots studied (Fig. 4).

Relationship between basal area and the two parameters, diameter at 1.3 m and CD

Basal area is one of the most important characteristics in the study of forest stands. Monitoring this parameter over time provides a precise index of the productivity of a plot via the growth in tree diameter. Burrows et al. (2002) reported that the relationship between these two could be used to facilitate biomass estimation since basal area can be quickly measured. Due to its simplicity and convenience, basal area is a very often mentioned criterion used to define the fullness of a forest stand (Rondeux, 1993). A correlation between basal area and the two diameters, diameter at 1.3 m and CD can be expected.

The graphical presentation in Fig. 5 shows a positive correlation between basal area and growth in diameter at 1.3 m from the trunk and in CD, which are good indicators of the productivity of forest sites where high coefficients of determination (R^2) of 0.85 and 0.83, respectively, are recorded.

Influence of ecological factors on the growth and productivity of stone pine

Understanding how forest stands function is an essential preoccupation in forest ecology. The sustainable management of these stands depends on the level of knowledge acquired about their functioning. The aim of our approach is to estimate the productivity of stone pine, which is represented by dendrometric characteristics, and to determine the ecological factors that influence this productivity. In this context, we tried to relate ecological factors (soil depth, altitude, exposition and slope) with dendrometric characteristics for each plot.

Table 2 shows the correlation matrix between the 11 variables. Principal component 1 alone explains 99% of the variance, indicating the degree of redundancy between the variables (Fig. 6).

Fig. 6 and Table 2 show a positive correlation between all dendrometric characteristics and ecological factors. The correlation between soil depth and dendrometric characteristics is very high. The correlation between the latter and the altitude is also high, although somewhat lower. On the other hand, there is little correlation between the dendrometric variables and the two variables, exposition and slope.

The influence of soil depth on the dendrometric parameters is remarkable. This indicates that stone pine develops well in deep soils. In addition, the positive correlation between soil depth and average circumference is the highest compared to the other parameters.

The effect of altitude on the dendrometric characteristics is significant, as it can be seen that the correlation is positive and important between the latter and the average height. The stands studied are located between 31 and 373 m of altitude, where we observe that the species studied finds its preferential conditions at altitudes more or less superior to 95 m.

From Table 2 and Fig. 6, it can be seen that slope has no significant effect on the productivity of stone pine, meaning that it is not a relevant factor in the productivity of the species studied.

In the study area, it can be seen that there is no relationship between exposition and dendrometric parameters. The northern exposition dominates the study area representing 31% of the plots.

Discussion

The analysis of the results of different dendrometric parameters for the region of Mostaganem showed that the stands studied are regular. This regularity is characterised by the distribution of the number of stems per circumference category at 1.3 m.

The evolution of the total height as a function of the circumference at 1.3 m of the plots studied confirms the unique relationship between these two parameters. The relationships between CD/diameter at 1.3 m and mean CD/mean diameter at 1.3 m of the plots studied are characterised by high coefficients of determination (above 0.8).

The correlations between basal area and both diameters, notably diameter at 1.3 m and CD, are positive and significant.

These relationships between dendrometric characteristics are good indicators of productivity for the stands studied.

In order to gain a better understanding of the productivity of stone pine, we used the results of the PCA. In this multivariate analysis, the dendrometric characteristics are gathered according to the ecological factors (quality of the plots studied).

According to the results obtained, the dendrometric parameters and the ecological factors are positively correlated with each other. This correlation is confirmed by principal component 1, which alone explains 99% of the variance.

The PCA showed that the soil depth parameter has a strong influence on the productivity of stone pine, especially on the average circumference of the plots studied. Moreover, the altitude is also responsible for this productivity, as it was noticed that the plots located at an altitude above 95 m are the most productive, especially in height and circumference.

The lack of influence of slope on the dendrometric parameters is probably due to the fact that 68% of the plots studied are characterised by a slope class of less than or equal to 8%; this class is relatively flat and corresponds to plains, alluvial terraces and structural flats. The remaining 32% of the plots have a more or less accentuated topography with a slope class of 8%–27%, representing the piedmonts, glacis and hills.

In the study area, there is no relationship between exposition and dendrometric parameters, as the majority of the plots are exposed to the north (31.94% of the plots), northeast (20.83% of the plots) and northwest (19.44% of the plots).

In recent years, fires have been the most serious threat to the forest wealth in Algeria, in general, and in the west of the country, in particular, but other problems such as overgrazing and illicit felling are also present. In view of this situation, it is necessary to implement a sustainable strategy for the conservation and protection of stone pine stands, which should be based on the following actions:

- placed under protection – surface reserved for the rejuvenation of the forest stands;
- sylvopastoralism – which is the use of forests as a grazing area for livestock; but if it is not controlled, grazing becomes

a factor of regression and risk through browsing of regeneration;

- reforestation works – reforestation work is necessary for the reconstitution of degraded ecosystems. This degradation is very advanced in the region of Mostaganem, especially in the coastal areas (Mostari et al., 2021). The stone pine deserves a more advanced place in the reforestation programmes in Algeria because of its ecological importance (fixing of coastal dunes, fight against erosion, etc) on the one hand and economic importance (wood, edible pine nuts, etc) on the other hand and
- preventive silviculture – the objective of this action is to obtain a composition and structure of the stands that will counteract the spread of fire and limit the damage caused to trees.

Conclusion

In this research, we analysed the dendrometric and ecological characteristics of even-aged stone pine stands in the region of Mostaganem (western Algeria), based on 72 temporary sample plots (1,151 trees).

The lack of studies in this field on this species in Algeria led us to elaborate a complete dendrometric inventory and ecological description and to analyse the significant relationships between the most important parameters in the study of forest stands in order to better reflect the potential of the stone pine in western Algeria. The results obtained show the existence of very positive and significant relationships between parameters such as average total height/average circumference, average CD/diameter at 1.3 m and basal area/average CD.

Finally, the analysis of the elaborated data of the dendrometric characteristics according to the ecological factors, taken into consideration, on the basis of the PCA, highlighted the significant differences in the soil depth factor and the altitude factor in contrast to the slope and exposition factor.

References

Alder, D. (1980). *Estimation of volumes and growth of forest stands. Vol.2: Production studies and forecasts*. Forest 22/2, Rome, FAO. http://www.fao.org/3/a-ap354f.pdf.

Barbeito, I.S. (2009). *Structure and natural regeneration in Iberian Pine forests implications for management*. Thesis, Universidad Politecnica de Madrid. https://oa.upm.es/7201/.

Bechtold, W.A., Mielke, M.E. & Zarnoch S.J. (2002). Comparison of field methods and models to estimate mean crown diameter. North. *J. Appl. For.*, 19, 177–182. https://www.fs.usda.gov/treesearch/pubs/5208.

Bonnor, G.M. (1968). Stem diameter estimates from crown width and tree height. *Commonwealth Forestry Review*, 47, 8–13. https://www.jstor.org/stable/42603649.

Burrows, W.H. (2002). Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. *Global Change Biology*, 8, 769–784. DOI: 10.1046/j.1365-2486.2002.00515.x.

Cabannes, B. (2015). The stone pine, an opportunity for Provençal forests. *Mediterranean Forest*, 12.

Dawkins, H.C. (1963). Crown diameters: their relation to bole diameter in tropical forest trees. *Commonwealth Forestry Review*, 42, 318–333. https://www.jstor.org/stable/42603453.

Gering, L.R. & May, D.M. (1995). The relationship of diameter at breast height and crown diameter for four species groups in Hardin County, Tennessee. *South J. Appl. For*., 19, 177–181. https://www.fs.usda.gov/treesearch/pubs/3156.

Goelz, J.C.G. (1996). Open-grown crown radius of eleven bottomland hardwood species: prediction and use in assessing stochng. *South J. Appl. For.,* 20, 156–161.

Hamilton, G.J. (1975). *Forest mensuration handbook*. Forestry Commission Booklet No. 39. London: HMSO.

Hengst, E. (1958). The yield management of pine in eastern Thuringia. *Arch. Forstwes*., 7, 653–702.

Huang, S., Titus, S.J. & Wiens D.P. (1992). Comparison of nonlinear height-diameter functions for major Alberta tree species. *Can. J. For. Res*., 22(9), 1297–1304. DOI: 10.1139/x92-172.

Hummel, F.C. (1955). *The volume-basal area line*. Forest Record No. 24. London: Forestry Commission.

Johnson, N.L. (1949). Bivariate distributions based on simple translation systems. *Biometrika,* 36(3–4), 297–304. https://www.jstor.org/stable/i315416.

Krajicek, J.E., Brinkman, K.A. & Gingrich S.F. (1961). Crown competition-a measure of density. *For. Sci*., 7, 35–42. https://www.cabi.org/ISC/abstract/19610604908.

Minckler, L.S. & Gingrich S.F. (1970). *Relation of crown width to tree diameter in some upland hardwood stands of southern Illinois*. USDA Forest Serv. Res. Note NC99, St. Paul. https://www.fs.usda.gov/treesearch/pubs/11156.

Minor, C.O. (1951). Stern-crown diameter relationships in southern pine. *J. For*., 49, 490–493.

Mostari, A., Benabdeli, K. & Ferah T. (2021). Assessment of the impact of urbanisation on agricultural and forest areas in the coastal zone of Mostaganem (western Algeria). *Ekológia (Bratislava)*, 40(3), 230–239. DOI: 10.2478/eko-2021-0025.

Mutke, S., Calama, R., Gonzalez-Martínez, S.C., Montero, G. & Gordo F.J. (2012). Mediterranean Stone Pine: Botany and Horticulture. In J. Janick (Ed.), *Horticultural reviews* (pp. 153–201). Hoboken: Wiley-Blackwell.

N.F.I. (2017). National forest inventory. General characteristics of Stone pine.

N.M.O. (2020). National Meteorological Office. Meteorological data (35 year period).

Roberts, E.G. & Ross R.D. (1965). Crown area of freegrowing loblolly pine and its apparent independence of age and site. *J. For*., 63, 462–463.

Rondeux, J. (1993). *The measurement of trees and forest stands*. Gembloux: Les Presses Agronomiques.

Sabatia, C. & Burkhart H.E. (2013). Height and Diameter Relationships and Distributions in Loblolly Pine Stands of Enhanced Genetic Material. *For. Sci*., 59(3), 278–289. https://www.proquest.com/scholarly-journals/height-diameter-relationships-distributions/docview/1445273569/se-2.

Sanchez, C.A.L., Javier, G.V. & Fernando C.D. (2003). A height-diameter model for *Pinus radiata* D. Don in Galicia (Northwest Spain). *Annals of Forest Science,* 60(3), 237–245. DOI: 10.1051/forest:2003015.

Strub, M.R., Vasey, R.B. & Burkhart H.E. (1975). Comparison of diameter growth and crown competition factor in loblolly pine plantations. *For. Sci*., 21, 427–431. https://www.academia.edu/22950080/.

Vezina, P.E. (1963). More about the 'crown competition factor'. *Forestry Chronology*, 39, 313–317. https://pubs.cif-ifc.org/doi/10.5558/tfc39313-3.

Wouters, P. & Lorent V. (2001). The cubing of standing trees on foot. *Royal Forestry Society of Belgium SLVA*, 6, 1–8.