Short communication

Dendrometric analysis of *Tamarix africana* L.,species of river and wetlands of the Mediterranean area. Characterisation of biomass

Borja Velázquez Martí[a,*], Juan Ramón Torres Sánchez[a], Ángel Jesús Callejón Ferre[b], Isabel López Cortés[c]

[a] *Departamento de Ingeniería Rural y Agroalimentaria, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain*
[b] *Department of Engineering, University of Almería, Agrifood Campus of International Excellence (CeiA3), s/n, 04120, La Cañada, Almería, Spain*
[c] *Departamento de Producción Vegetal, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain*

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ABSTRACT

A dendrometric and energetic characterisation of *Tamarix africana* L. was carried out in this study. This is an indigenous plant species in the Mediterranean area, and it can survive in semi-arid areas with saline soils and occasional floods. Owing to these characteristics, this species is a good candidate for its use in the restoration of several environments, such as the marshes. This opens up the possibility of improving the management of biomass, which can be used for obtaining economic benefits from its energetic use. For the stems, biomass volume functions were determined from their diameter and length with r^2 of 0.96. For the whole plant, biomass volume functions were determined from the diameter of the projected area in the soil and the height of the plant with r^2 of 0.95. For energetic characterisation, the density, higher heat value, and the composition of this wood were measured in terms of following elements: carbon, nitrogen, hydrogen, sulphur and chlorine, volatiles and ash. The determination of its composition in C allows us to evaluate the CO_2 fixed by the plant during its growth. The average catchment was estimated to be 2.58 kg/plant.

1. Introduction

Biomass is organic, non-fossilised material that exists in a given ecosystem, which consists of both living and non-living beings [1]. Forestry is a scientific discipline that determines whether the biomass of forest species can be used in industrial applications; many techniques have been developed to measure and estimate the commercial viability of biomass. Dendometry is a branch of botany that studies the sizes of plant structures and its mass. Because of stem or main trunk of trees has many industrial applications, measurements were conducted only on these components of trees. However, there are very few systems to quantify the biomass of shrubs. Haase and Haase [2] performed a comprehensive study on riparian shrub species. They developed equations to estimate the biomass of invasive species of Pantanal, Mato Grosso in Brazil. Karunaratne and Asaeda [3] developed different mathematical models. Hall et al. [4] developed the application of Landsat ETM + data, which was used to calculate the biomass of shrubs. Evangelista et al. [5] developed biomass models for *Tamarix ramosissima* in Arkansas River Basin of Southeast Colorado in USA. Velázquez-Martí et al. [6] performed dendometry to characterise five shrub species: *Rosmarinus officinalis* L., *Erica multiflora* L., *Ulex parviflorus* L., *Cistus albidus* L. and *Quercus coccifera* L. The variable “factor of occupation” defines the relation between the apparent volume of bush, which was taken as a figure of revolution, and the actual volume of branches contained in that volume. Greaves et al. [7] estimated the biomass of shrubs in Arctic areas.

Shrub biomass quantification has an enormous importance for the following purposes: i) to evaluate the degree of development of certain species in an ecosystem [8]; ii) to define fire models based on the amount of existing fuel in per unit area; iii) to calculate livestock load that is fed to the species; iv) sequestered CO_2 measurements during the growth phase of shrubby masses; and v) preparation of biofuels from residual materials, which were used for the quantification of available energy.

In this paper, dendrometric techniques were developed for the quantification and characterisation of woody biomass of *Tamarix africana* L. This is a shrub species that belongs to *Tamarix* genus of *Tamaricaceae* family; these shrub species can be found in the riparian zones of western Mediterranean region. This region has humid and sub-saline soils, which is found in sub-saline lands, sands and coastal lagoons as well as along rivers and water currents, fundamentally those that cross marls [9]. *Tamarix africana* L. receives diverse colloquial names, such as taray, tamarix, taraje or tamarisco. This shrub species is distributed in the Iberian Peninsula and Balearic Islands. It usually grows in Mediterranean climate. Oleander (*Nerium oleander* L.), willow (*Salix* spp.) and *Phragmites* spp. are the other shrub species that grow in this region [10]. They are used to fix the margins of rivers and coastal dunes. Stake and layering are the most common methods used to re-produce these shrub species. Seeds are used to further reproduce these shrub species in its natural state; however seasonal flood conditions are conducive for seeds dissemination and growth of shrub species.

The main aim of this research study is to create management tools for saline wetlands near coasts (marshes). The dynamics of these spaces is complex and difficult, and it has been scarcely investigated with dendrometric techniques till date. Moreover, plantations must be either used for environmental restoration or energy production [11]. The influence of the establishment of these plantations on the ecosystem and its effect on the environment must be studied. Therefore, the quantifi-cation and valorization of biomass most be evaluated [12].

The plant of *T. africana* was first described by Jean Louis Marie Poiret in 1789 [13]. This plant received its generic name from Romans. The generic name of this plant was derived from the Tamaris River (currently called Tambro) of Tarraconense; the shrub grows profusely in this region. It is a shrub or a small tree (it is about 3–4 m in height) with long and flexible branches; its bark is reddish-brown in colour. The younger branches are lustrous and hairless, and they become darker with aging. Leaves are very small scale-shaped; these leaves are wi-dened and clamped sharply at the base; their size is in the range of 1.5–3 mm. The leaves of these shrubs are similar to those of cypress. The colour of flowers varies from white to pale pink; these flowers have thick and cylindrical ears. Which have a length of 3–7 cm. Floral bracts are triangular in shape, and they have a capsule that is ovate in shape. These flowers grow in spring and summer [14,15]. Plants of this genus naturally populate marshes and ravines of Mediterranean region [16]. They have the capacity to withstand saline environment [9,14]. Its wood was always appreciated as firewood, so it was used for energy purposes. However, it is necessary to characterise the biomass [17–19] and to determine the productivity of species in these spaces in order to determine whether it is convenient for plantation. This study was conducted on *T. africana* and not on other species of Tamarix, such as *galica* or *canariensis*. This is because *T. africana* is the most re-presentative species in Comunidad Valenciana. This species could be used as a raw material in the production of biofuels after a transfor-mation such as chipping, pelletisation, carbonisation, pyrolysis, gasifi-cation, transesterification, or fermentation to obtain alcohols or biogas [20,21].

2. Materials and methods

Forty plants of *T. africana* were randomly sampled from an agro-forestry plantation, which is located in Marjar dels Moros (Sagunto-Valencia, Spain). The climate in this area is considered BSk according to the climatic classification of Köppen-Geiger. The average temperature is 17.0 °C. August is the hottest month of the year, it has an average temperature of 24.9 °C. January has the lowest average temperature of the year, 10.6 °C. The annual average rainfall is 441 mm. The lowest precipitation is in July, with 11 mm average. The highest precipitation falls in October, with 78 mm average.

This plantation is a qualified clonal bank with a planting frame of 2.5 × 1.5 m; it has a density of 2666 plants per hectare. The plantation was distributed in five rows, each containing 50 plants.

The bushes studied were structured in plants. Plants are defines as a set of woody branched rootstocks, which form a differentiated unit. Each rootstock was formed by the stem and its set of branches. We define "Rod" as each segments of rootstock; the length of the rod is the distance between two consecutive bifurcations. If the rod is terminal, the length of the rod will be extended from the bifurcation to the apex.

Because of the variability in the number of rootstocks in each plant, a systematics-based approach was used to perform measurements in two phases: a dendrometric analysis of all rootstocks of eight selected plants was carried out to obtain functions, which were used to calculate the volume right from the diameter of the base to its length. Subsequently, the volumes of remaining 32 plants were calculated by measuring the diameters and length of each rootstock; measurements were performed by applying the functions obtained in the first step.

2.1. Dendrometric analysis of rootstoks

To determine the volume functions, 26 rods were taken, and diameters were measured every 10 cm. A digital calliper (with resolution of hundredth of a millimeter) was used to measure diameters. A stan-dard flexometer was used to determine length of each rod. Non-circular shape of each section forced to measure two perpendicular diameters; the average diameter was used to calculate volume. We calculated volume of each portion between the two sections by applying the truncated cone formula (1): D is the largest diameter; d is the smallest diameter; and h is the separation of sections. The sum of the volume of all portions was defined as the actual volume of that rod.

$$V_i = \frac{1}{12}\cdot\pi\cdot h(D^2 + d^2 + D\cdot d) \quad (1)$$

A large number of branches were presented in each rootstock. In each bifurcation, the section decreased drastically: the sum of two resulting sections resembled the main rod. The length of rootstock was considered as the distance between the base and the apex of branch with the greatest length (Fig. 1). Each bifurcation was also considered as a new rootstock; the same criteria were used for analysis.

After determining the volume of each rootstock, the form factor of rods (ff_{rods}) and rootstocks ($ff_{rootstock}$) was defined by Equation (2). Cylinder, paraboloid, cone, and neiloid were the different geometrical figures whose basal diameter and length were considered to develop a model [21]. To determine the variability of the data obtained, we determined the mean, standard deviation and coefficient of variation. In addition, multiple regression models were used to analyse and determine the functions of branch volume, from the diameter of its base and length.

$$ff = \frac{\text{Actual volume}}{\text{Volume of the model}} \quad (2)$$

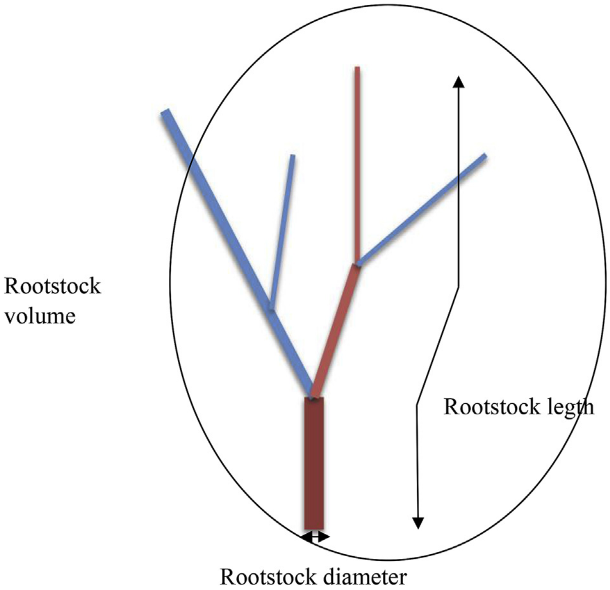

Fig. 1. Criterion for measuring basal diameter and rootstock length.

2.2. Volume analysis of whole plant

After the volume function of rootstocks was determined precisely from the basal diameter and length; these were measured for all the rootstocks of 32 plants. By summing the volume associated with each rootstock, we calculated the total wood volume of each plant.

The diameter of the projection and the dominant height of each bush was measured. An apparent volume was obtained from these parameters by applying the cylinder formula. We investigated the re-lationship between the calculated actual volume of plant and its ap-parent cylindrical volume; the occupation factor was calculated by Equation (3), determining mean and dispersion. Occupation factor was already defined by Velázquez-Martí [6].

$$FO = \frac{\text{Actual volume of the stand}}{\text{Volume of stand model}} \tag{3}$$

In addition, multiple regression models were analysed to obtain volume functions. Using these functions, the volume of the plant was calculated from the diameter of stand and dominant height.

2.3. Physicochemical characterisation of biomass

The analysis of wood was carried out in the Physical Properties and Bioenergy Laboratory of the UPV (Universitat Politècnica de València). The analysed properties were obtained by applying standards presented in Table 1.

A LECO AC500 Calorimeter to determine Higher Heat Value, was used. The LECO TruSpec CHN analyser was used to determine C, N and H in biomass. The LECO TruSpec S analyser was used to determine S in biomass. The Metler Toledo G20 semiautomatic titrator was used to determine Cl.

The dry weight of samples was first determined. To calculate density, samples were introduced in a drying oven, which was operated at a constant temperature of 105 ± 2 °C for 4 h. To determine volume, samples were immersed in a distillation flask; water was flushed into a horizontal tube that was located in the neck of distillation flask. The water level rose in the flask due to displacement; the poured liquid was collected in a container of known weight. Subsequently, volume was calculated from the weight of distilled water collected by applying its density.

3. Results and discussion

3.1. Dendrometric analysis of rootstocks

Table 2 shows statistical description of each variable, which was measured in rods and rootstocks. D_v is the diameter of the base of the rod; L is the length of the rod (the length of the rod was measured between the base and its bifurcation or between two bifurcations); V_v is the volume of the rod; ff_{rods} is the rod form factor, which was obtained by applying cylindrical model to Equation (2). D_r is the diameter of the base of the rootstock; L_r is the length of rootstock (it was measured between the base of rootstock and the termination of longest branch); V_r is the actual volume of rootstock (and branches); and $ff_{rootstock}$ is the factor obtained by applying cylindrical model to Equation (2). ff_{rods} and $ff_{rootstock}$ are different because the actual volume of Equation (2) includes the volume of all branches in $ff_{rootstock,}$ but the actual volume of ff_{rods} only considers the volume between the two nodes.

Table 2 shows the statistics of position, dispersion and form. The coefficients of skewness and standardised kurtosis are particular important because they can be used to determine whether the sample has a normal distribution. The values of these statistical parameters are beyond the range of -2 to $+2$, indicating significant deviations from normality. This would invalidate most statistical procedures, which are usually applied to these data. It was found that all the variables of rootstocks and rods fulfilled the condition of being within this range. The form factors for the model of paraboloid, cone, or neiloid were twice, thrice, and four times of the form factor of cylindrical model [22,23]. It can be seen that the form factor closest to the unit was calculated from the cylindrical model; therefore, it is the figure that best represents the shape of the rod; however, it is necessary to de-termine the highest dispersion.

To obtain volume functions of rootstocks, the mean diameter (cm) and length (cm) were considered as explanatory variables (Fig. 2). Table 3 shows the result of the best fit in a multiple linear regression model, which establishes the relationship between the volume of measured rootstocks (V_r) in cm^3 and independent variables.

By performing ANOVA analysis, we found that *P*-value of the model was less than 0.05; therefore, a statistically significant relationship existed between variables, with a confidence level of more than 95.0%. The R^2 statistic indicates that the model was associated with 95.87% of the variability of branch volume. The root mean square (RMS) value, which is defined as the square root of mean square, was 106.08 cm^3. This value can be used to construct the limits of new observations. The mean absolute error (EMA) was 77.12 cm^3, which is the average value of the waste.

3.2. Analysis of the whole plant

The volume of 40 whole plants was calculated by summing the volumes of each rootstock and with the equation obtained. The cylindrical model was used to calculate the apparent volume by using the average diameter of projection and dominant height. The occupation factor FO was determined with respect to cylindrical model; this parameter describes the relationship between the actual volume of plant, which was formed by wood, and the apparent volume of plant, which was formed by cylinder. The projection diameter and the dominant height of plant were taken into consideration. The values obtained are described in Table 4.

Table 5 shows the fit of an exponential regression model, which is used to describe the relationship between total volume (TV) and the average diameter of projection of plant, represented in Fig. 3.

If logarithms are applied, we can represent this relationship in linear form (Fig. 4).

Table 1
Analysis standards for the characterisation of biomass.

Reference of the standard	Standard title
EN 14778	Solid biofuels – Sampling
EN 14780	Solid biofuels - Methods for sample preparation
EN ISO 18134-3	Solid biofuels - Determination of moisture content - stove drying method. Part 3. Moisture of the sample for general analysis
EN 14918	Solid biofuels - Determination of the calorific value
EN ISO 18122	Solid biofuels - Determination of ash matter content
EN ISO 18123	Solid biofuels - Determination of volatile matter content
EN ISO 16948	Solid biofuels - Determination of total carbon, hydrogen and nitrogen content - Instrumental Methods
EN ISO 16994	Solid biofuels - Determination of total sulphur and chlorine content
EN 15234	Assurance of fuel quality - Solid biofuels
EN ISO 17225-4	Solid biofuels - specifications of fuel and classes - Part 1: General requirements

Table 2
Statistical description of measured variables.

Statistical summary	Dv (cm)	Rods			Rootstocks			
		Lv (cm)	Vv (cm^3)	ff$_{rods}$	Dr (cm)	Lr (cm)	Vr (cm^3)	ff$_{rootstock}$
Count	47	47	47	47	26	26	26	26
Average	1.53	83.83	129.30	0.819	2.48	209.65	561.65	0.91
Standard deviation	0.61	48.67	145.42	0.322	0.98	86.85	500.20	0.337
Minimum	0.62	10.00	3.43	0.289	1.15	50.00	70.23	0.432
Maximum	2.97	190.00	641.85	1.500	4.45	400.00	1973.36	1.500
Rank	2.35	180.00	638.42	1.211	3.30	350.00	1903.14	1.068
Skewness coefficient	1.91	0.90	1.52	0.54	0.85	0.54	2.44	0.92
Standardised Kurtosis	−0.40	−1.13	1.55	−0.81	−0.98	−0.44	1.03	−1.33

$\ln TV = 5.00546 + 1.60241 \cdot D_p$

By performing ANOVA test, we found that *P*-value associated to the model was less than 0.05. Therefore, the relationship between variables was statistically significant, with a confidence level of 95.0%. The R-squared statistic indicates that the model explains 94.44% of variability of TV. The adjusted R-squared statistic was 0.9426, which is more appropriate for comparing models with different number of independent variables. The RMS value shows that the standard deviation of residuals was 0.249862. This value can be used to construct limits of new observations. The mean absolute error (EMA) is 0.19 dm^3, which is the average value of waste.

The logarithmic structure of the equation obtained coincides with allometric equations, which was presented by Montero et al. [24] to determine the biomass of forest trees in Iberian Peninsula.

3.3. Characterisation of biomass

At the moment of cutting, the mean moisture content was 43.11% FW (fresh weight) on a wet basis, and the standard deviation was 1%. If these materials were used as solid fuel, their moisture content must have been lower than 10%. The density of the material with 10% moisture was 1.18 g/mL. The density of the dried material was 0.67 g/mL.

Table 6 shows thermochemical characteristics of *Tamarix africana* L. The standard EN ISO 17225–4 establishes specifications of chips for fuel obtained from forest, plantations and other virgin wood, residues of non-chemically treated wood as well as by-products and waste obtained from wood processing industry (Table 7).

Table 3
Rootstock volume function (including branches) of *Tamarix africana* L.

Equation	R^2	EMA cm^3	RMS cm^3
$Vr = 127.87 \cdot D^2 - 194.9 \cdot D + 140.47$	0.96	77	106

D is the average diameter of the base, which is measured in cm; V$_r$ is the volume of the rootstock and branches, which is measured in cm^3; R^2 is the coefficient of determination; EMA is absolute mean error; and RMS is standard deviation of errors.

Table 4
Occupation factor of *Tamarix africana* L.

	DM (cm)	A (cm)	TV (cm^3)	FO (dm^3/m^3)
No. of measurements	40	40	40	40
Average	2.46	2.99	9366.54	0.61
Standard deviation	0.54	0.38	4610.51	0.18
Minimum	1.02	2.16	513.67	0.28
Maximum	3.51	3.6	16519.0	1.03
Rank	2.49	1.44	16005.3	0.76
Skewness	−0.94	−1.64	−0.48	0.52
Coefficient of kurtosis	1.61	0.82	−0.44	0.23

As it can be seen, chlorine and sulphur contents were higher than required but it was feasible to mix these materials with other elements for their correction and use as a biofuel in the form of a chip. The properties of biomass could be improved by treating it with liquid hot water (LHW) [25,26]. The content of ashes was low.

To determine whether if there are differences between pieces of

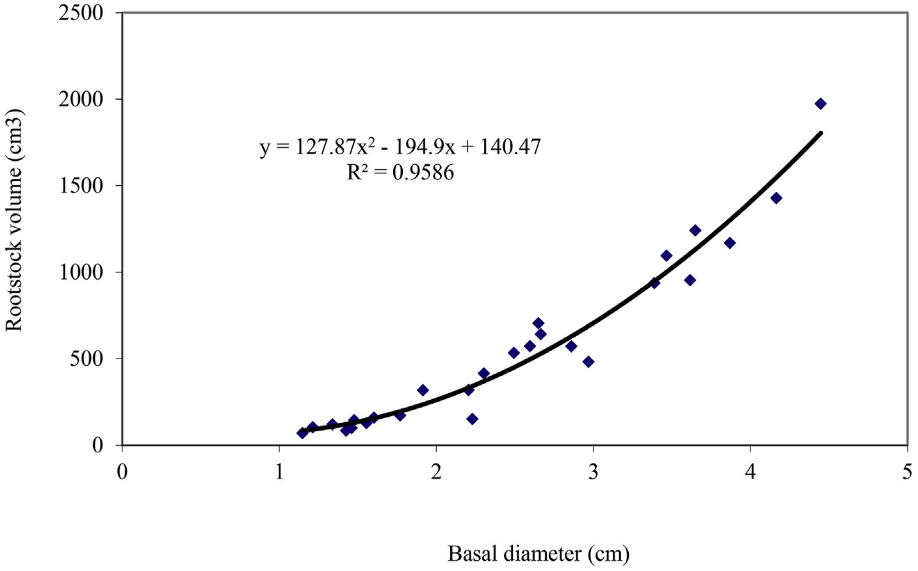

Fig. 2. Relationship between the average basal diameter of the rootstock and the volume of wood (including branches).

Table 5
Stand volume function of *Tamarix africana* L.

Equation	R^2	EMA	RMS
$TV = 149.23 \cdot e^{1.6024 \cdot Dp}$	0.95	0.24	0.19

D_p is the average diameter of the projection of the plant in cm; TV is the actual wood volume (including branches), which is measured in dm^3; R^2 is the coefficient of determination; EMA is absolute mean error; and RMS is standard deviation of errors.

different diameter in terms of higher heat value (Q) and composition, we performed analysis of variance on fines (leaves) and branches for the following distances: 0.25–1 cm, 1–2 cm, 2–3 cm, 3–4 cm, 4–5 cm, and 5–6 cm. Table 8 shows that there are significant differences in the percentage of N, Cl and S. The fines had the highest percentage of these elements, which is obvious due to their photosynthetic function. The highest values of N in fines must be taken into account if these materials are used in the manufacture of pellets, because N content depends on the classification of quality according to EN ISO 17225–4.

Table 9 shows the ratio between wood and fines weight in plants of *Tamarix africana* L. This relationship was used to correct the contents of N and Cl if it is desired that their values do not exceed a certain level.

The CO_2 absorption capacity of species was evaluated from the percentage of C. In this work, the average volume of the whole plant was 9366.54 cm^3. This value was multiplied with dry density 0.6712 g/cm^3, which gives us an average mass of 6286.82 g/plant (6.29 kg/plant) and a captured carbon mass of 2.57 kg/plant. With a higher calorific power of 17.21 MJ/kg on dry basis (Q), the total energy per plant was 108.20 MJ/plant. Therefore, a plantation of 2666 plants per hectare provides 16760 kg of biomass/ha (16.76 t/ha), representing 6.87 t of CO_2 captured per hectare and a stored heat energy of 288451.07 MJ/ha.

This study was carried out on the plantation five years after implanting the samples. This means that for each year, values will be as follows:

- Production: 16760 kg/5 years = 3352.13 kg/ha year
- CO_2: 6.87 t/ha year/5 years = 1.37 kg/ha year
- Heating value: 288451.07 MJ/ha 5 years = 57690.21 MJ/ha year
- Energy power: 57690.21 MJ/ha year = 16025.06 kWh/ha year

The estimated price of biomass was 0.03 €/kWh. The annual income of a plantation, which has these characteristics of energy, would be 480.75 €/year.

4. Conclusions

Tamarix africana L. is a shrub adapted to saline soils in areas with occasional flooding; this plant is resistant to high temperatures and prolonged summer periods, which characterises Mediterranean region. Dendrometric characterisation was conducted on *Tamarix africana* L. to indirectly calculate the available biomass from individual structures and the whole bushes. Simple measurements such as diameter and height of these structures were measured for this purpose. This characterisation was conducted at two levels: branch form factors have been obtained, which show that the geometric figure that best fits the shape of the branch is the cylinder; and volume functions were obtained from regression models to determine the amount of wood in each rod. The allometric equations obtained, density and the elemental analysis, such as the carbon content, allow us:

i) to evaluate the degree of development of certain species in an ecosystem;
ii) to define fire models based on the amount of existing fuel in per unit area;
iii) to calculate livestock load that is fed to the species;
iv) sequestered CO2 measurements during the growth phase of shrubby masses;
v) to quantify whole biomass from volume and density.

Tamarix africana L. can be an alternative energy crop. It has an average higher heat value of 17.21 MJ/kg, ranged between 17 and 19 MJ/kg. This is similar to other forest woods, such as pine or poplar wood. In addition, its density (630 kg/m^3) is higher than those of species, such as pine (500 kg/m^3) and poplar (400 kg/m^3). This is an important factor from a logistic point of view.

The moisture content of cut material is around 43%, so it needs to be dried thoroughly before being used as a biofuel.

The percentages of C, H, N, S and Cl were determined. This is very important because the content, especially the elements of N, S and Cl, were used to determine the quality of biofuels. According to EN ISO 17225–4, the content of chlorine and sulphur were higher than the maximum permissible value. This has a profound negative effect on the quality of wood chips, which are obtained from the forest, plantations and other virgin wood, residues of non-chemically treated wood as well as by-products and wastes obtained from wood processing industry. However, this wood can be used as fuel, if it is mixed with other materials, which have a lower content of these elements. The resultant composite material can be used as a biofuel in the form of chips, briquettes, and industrial pellets. The content of N, S and Cl in tamarix is essential for adapting mixtures with other materials used in the

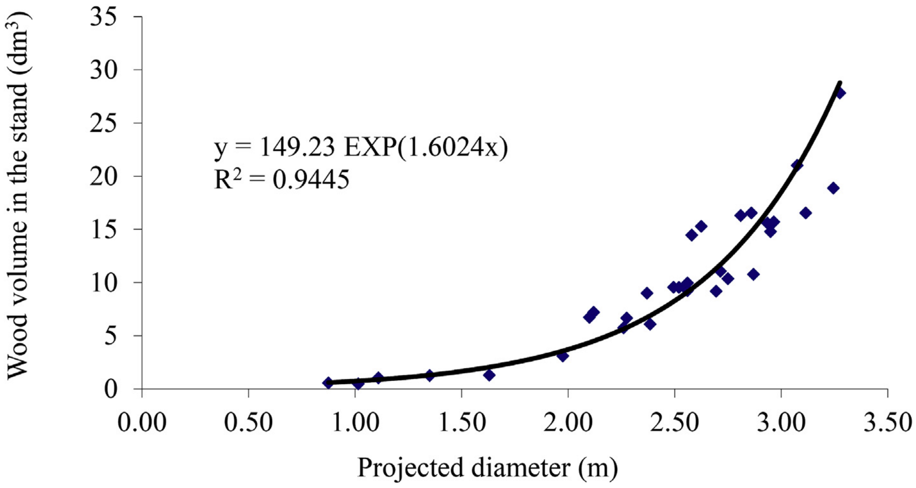

Fig. 3. Relationship between the average diameter of projection and the total volume of the wood of plant.

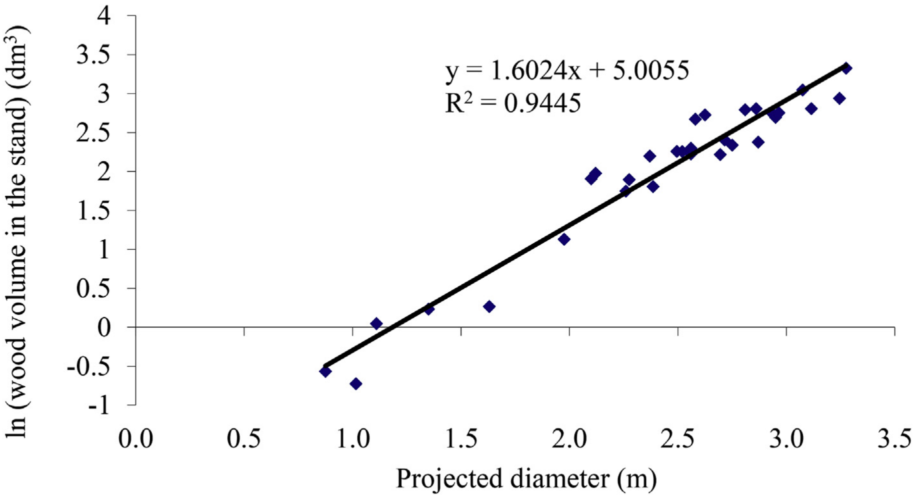

Fig. 4. Relationship between average diameter of projection and ln of total volume of the wood of plant.

Table 6
Thermochemical characteristics of *Tamarix africana L.* wood.

	C (%)	H (%)	N (%)	Cl (%)	S (%)	Q (MJ/kg)	Dry density (g/cm^3)	Density 10% moisture (g/cm^3)	Ash (%)	Volatile (%)
Average	41.79	6.25	1.04	0.18	0.84	17.21	0.67	1.18	1.21	79.2
Standard deviation	1.54	0.16	0.47	0.08	0.22	0.38	0.02	0.02	0.34	1.26
Minimum	40.60	6.04	0.46	0.08	0.47	20.72	0.64	1.14	2.98	73.26
Maximum	42.31	6.66	1.99	0.30	1.25	19.50	0.71	1.22	0.29	84.26
Skewness	1.60	1.29	0.89	0.34	0.85	−0.46	0.83	0.34	0.36	1.58
Coefficient of kurtosis	0.34	1.89	−0.84	−1.19	−0.55	−0.07	−0.81	−0.52	1.36	−1.28

Table 7
Specifications required for wood chips as biofuels according to EN ISO 17225-4.

Parameter	Nomenclature
Ash (%)	A3 < 3%
Higher Heat Value (Q)	Q13 > 13 MJ/kg
Nitrogen (%)	N1.0 < 1.0%
Sulphur (%)	S0.1 < 0.1%
Chlorine (%)	Cl0.05 < 0.05%

Table 8
A comparison in the thermochemical characteristics of different structures of plant.

D	C (%)	H (%)	N (%)	S (%)	Cl (%)	Q (MJ/kg)
Fines	40.80a	6.06a	1.91a	1.188a	0.230 ab	17.42a
0.25–1 cm	43.46a	6.30a	0.89bc	0.604b	0.116c	18.23a
1–2 cm	44.10a	6.32a	0.54bc	0.616b	0.255a	17.93a
2–3 cm	43.96a	6.38a	0.67bc	0.719 ab	0.260a	17.96a
3–4 cm	42.86a	6.27a	0.86bc	0.783 ab	0.179b	18.25a
4–5 cm	41.73a	6.15a	1.28b	0.989a	0.129c	17.66a
5–6 cm	41.96a	6.22a	1.39b	0.862a	0.121c	17.27a

Table 9
Percentages of weight of wood and fines (leaves) *Tamarix africana* L. on dry basis.

	Wood (%)	Fines (%)
Count	14	14
Average	35.51	64.48
Standard deviation	8.98	8.99
Coefficient of variation	25.30%	13.93%
Minimum	23.05	48.71
Maximum	51.28	76.94
Rank	28.22	28.22
Skewness	0.38	−0.38
Coefficient of kurtosis	−1.02	−1.02

manufacture of biofuels.

In order to accurately determine the energy present in plant or any structure, the density and higher heat value can be applied to volume functions. The percentage of C (of 41%), was also applied to determine the captured CO_2. The average catchment was estimated to be 2.58 kg/plant.

The percentage of N and Cl can be also applied to determine the abortion of these elements by roots, to predict nitrogen needs and the chlorine removed of the soil in a desalinization process.

The growth and development of plants was evaluated by dendometric models. These plants were used as landscape. These plants offered protection to river and soil. These plants achieved desalination effect, which was instrumental in managing and conserving wetlands and other natural areas.

This study provides necessary tools to determine the viability of *T. africana* for energy purposes. However, comprehensive research studies have to be carried out to evaluate its profitability as a crop. It is necessary to define the most profitable plantation framework, cultivation techniques, cutting shifts, etc.

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