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Aerial biomass of the laburnum (*Cytisus triflorus* L'Hérit.) in the rangelands of the Moroccan Rif

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Abstract
In the Moroccan Rif, the aboveground biomass of the forage shrub "*Cytisus triflorus*", very appreciated by the livestock, has been assessed, based on dendrometric and weight data of 36 shrubs. Simple and multiple regressions were applied to the data in order to estimate the woody and foliar biomasses in this species. The data analysis allows us to conclude that (i) the estimation of the dry biomass of strands can be performed from their diameter to the stump shrub and the length of the single strand; (ii) the assessment of the dry biomass of shrubs can be performed from their maximum height and the average diameter; (iii) the best obtained models for the strands and the shrubs are in allometry, adjusting the best of data biomass; and (iv) the total estimated production of *C. triflorus* is 148.1 kg DM.ha^{-1}, distributed by reason of 96.3 Dry Mass.ha^{-1} of woody biomass and 51.83 kg DM.ha^{-1} of foliar biomass. *C. triflorus* is subjected to a pastoral overload in all the natural ranges of the Rif. Pastoral pressure has a significantly depressive effect on the total biomass production of the shrub.

Keywords: *Cytisus triflorus*, Forager shrub, Anthropogenic action, Multiple regression, Morocco.

Introduction

The *Cytisus triflorus* is a legume shrub of 1 to 2 m, located mainly in the western part of the Rif. In this region, the shrub is characterized by its large palatability in the face of the livestock and by its importance on the phytosociological Plan (Benabid, 1984). In fact, it is inserted in the *Cytiso triflflori-Quercetum canariensis* association (Benabid, 1982). The grouping is mesomediterranean (altitude from 900 to 1400 m) and located on a substrate siliceous or sandstone of the western Rif under humid and perhumid bioclimate. The *C. triflorus* associates with the zen oak (*Quercus canariensis*) on thick soils, and tauzin oak (*Q. pyrenaica*) on slightly thick soils.

During the last ten years, the soil of the West-Center Moroccan Rif region was radically degraded because of the strong anthropogenic pressure, land clearing and frequent forest fires caused for the benefit of the cannabis culture. The *C. triflorus* as a legume forage shrub has traditionally played a fundamental role in the maintenance and sustainability of the plant cover of the soils in the Rif. In addition, it's the preferred food of the goats in the region.

In order to assess this anthropogenic action on the *C. triflorus* and to know the conditions of survival of this pastoral resource, this study proposes to (i) establish estimating models of the above-ground biomass of the strands and shrubs by non-destructive indirect measure, and (ii) to study the effect of the pastoral pressure on the production of the *C. triflorus*.

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Materials and methods

Study area

The study area is located in the Rif, of Morocco (Figure 1), and covers Bab Berred, Kourt and Khezana forests, which are mountainous hinterland parts of the Mediterranean coastline. The climate is typically Mediterranean along the coastline with a mild winter (10 to 12 °C) and moderately watered, doubled in a hot and dry summer (24 to 26 °C). In the reliefs of the back-country, precipitation can reach a maximum of more than 1,000 mm per year with snow and cool temperatures in winter, and with a bioclimatic wet atmosphere. The substrate is schistose or sandy-schistose.

The forest vegetation is diversified: young forest of tauzin oak, young coppice green oak (*Q. rotundifolia*), adult understory of tauzin oak (*Q. pyrenaica*) on shale-sandstone substrate, moderately dense matorral of green oak, matorral of tauzin oak, adult understory of cork oak (*Q. suber*) in altitude on shale-sandstone substrate, and adult understory of cork oak with green oak on shale substrate.

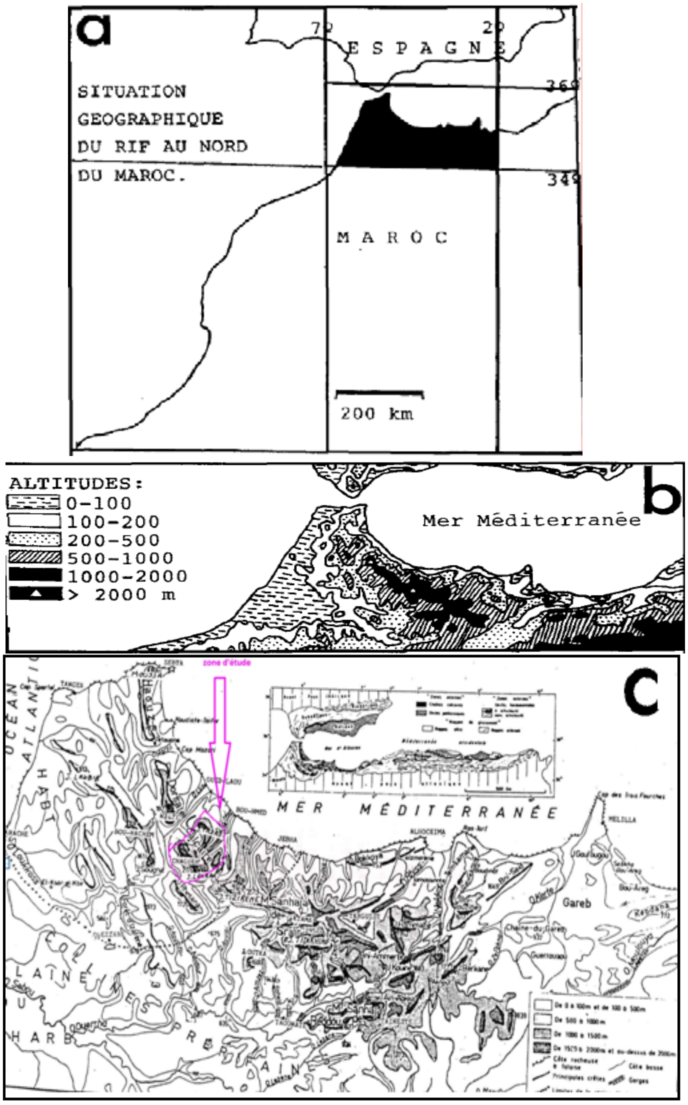

Figure 1. Location of the Rif in northern Morocco (Taiqui, 1997). **a**, Location of the Rif in the Northern Morocco; **b**, Simplified representation hypsometric levels in the Northern Morocco; **c**, General map of the Rif. Geographic situation of Tanghaya-Kourt-Bab Berred forest massif (Maurer, 1968).

Sampling strategy

The exploration of the three forests: Bab Berred (MAMVAGEF-RIF/AGROFOREST, 1997a), Kourt and Khezana (MAMVAGEF-RIF/AGROFOREST, 1997b), has allowed us to identify 3 types of locations (Table 1), combinations of the four variables: spontaneous C. triflorus, type of vegetation trees, nature of the substrate, and pastoral charge.

In each of the 3 locations studied, three square plots (corresponding to 3 replicates) of 100 m² each has been installed in a random manner according to a device in a block.

Animal charge

The animal charge of the rangelands is determined according to the method of Sarson & Salmon (1976) (in Projet Parcours, 1978).

Two types of animal charge are determined. The balance charge (CE) defined on the basis of the forage production of all resources and the needs of the livestock. This charge is equal to the size of the cattle (Small Livestock Unit) that can graze per hectare without damaging the pastoral potential of the concerned area and thus, ensure its continuity. The real charge (CR) determined in function of the apparent charge (CA), and the residence time "TS" (number of days of actual grazing):

$$CR = \frac{CA \times TS}{365}$$

The CA is obtained by dividing the number of livestock (Small Livestock Unit) observed on the ground for a time "t", by the grazed area (ha).

Table 1. Characterization of the study sites and sampled shrubs. **A**, Green, tauzin and cork oaks; **B**, Green and tauzin oaks; **C**, Green and cork oaks; **CE**, Balance charge; **CR**, Real charge; **Gr**, Stoneware; **LU.ha^{-1}**, Small Livestock Unit per hectare (RGA, 1996); **Nb.**, Number of shrubs; **S**, Spontaneous; **Sc**, Schist**;** **TS**, Number of grazing days (Ministry of Agriculture, Province of Chefchaouen). ***Location** numbers are extracted from the plot description cards (MAMVA-GEF-RIF/AGROFOEST, 1997a & 1997b): 27, Fifi-Sraib; 53, Khezana; and 72, Bab Taliouent-Aazayeb.

Location*	*C. triflorus*	Animal charge (LU.ha^{-1})	TS (days)	CR (LU.ha^{-1})	CE (LU.ha^{-1})	Tree vegetation	Substrate	Area (ha)	Dondrometric measures (Nb.)	Biomass cutting (Nb.)	Chopped strands	Shrubs.ha^{-1}
53	S	8.99	265	6.53	0.34	A	Gr-Sc	151.2	12	12	20	290
72	S	5.54	265	4.02	0.56	B	Gr-Sc	282	9	9	22	400
27	S	2.55	305	2.13	1.22	C	Sc	112.2	15	15	39	610

For a not overloaded rangeland, the real charge is less than the balance one. In the case of an overloaded rangeland, the real charge is greater than the balance one.

Biomass method

The assessment method of the biomass by non-destructive stratification (Etienne, 1989) has been retained. It is followed by an indirect estimation of the biomass from some established regressions on the cut strands samples.

The measures of morphological parameters (maximum diameter, orthogonal diameter, maximum height, and number of strands and their basal diameter), and the total aerial phytomass carried out on 36 shrubs.

At the level of the plots, individuals are arranged in a class of volume. The phytovolume (V) or overcrowding volume (Etienne et al., 1991) has been calculated by multiplying the area of the projection of the shrub by its maximum height (h_m) or the height of the master-strand according to Cabanette (1989):

$$V = \pi \times R^2 \times h_m$$

R, arithmetic average radius of the shrub (Etienne, 1989).

Six classes of volume are calculated in each plot, taking into account the average volume (V_m) of shrubs and the gap-type (б) (Ludwig et al., 1975; Molinero, 1983):

- Class 1: volume < V_m - б
- Class 2: V_m - б < volume < V_m - (б/2)
- Class 3: V_m - (б/2) < volume < V_m
- Class 4: V_m < volume < V_m + (б/2)
- Class 5: V_m + (б/2) < volume < V_m + б
- Class 6: volume > V_m + б

In table 2 are presented the volume of classes by location and plot**.**

No more three individuals per volumes class have been selected to carry out the biomass cuts, integrating the representativeness of shrub shape and size (Cabral & West, 1986). To avoid the slaughter of individuals, we recoursed to a stratification of the shrub (Etienne, 1989), and only a part of the tuft was sampled: for each stump, the different strands were grouped into strata, each composed of similar strands by their basal diameter and the density of their foliage. In each of the strata, two strands at most have been collected.

Table 2. Classes of the volume of shrubs in the sampling plots of study stations. **V**, Volume; **Vm**, Average volume; **Б**, Standard deviation. ***Locations:** 27, Fifi-Sraib; 53, Khezana; 72, Bab Taliouent-Aazayeb.

Locations*	Plots	Shrubs / plot	Number of the volume classes / plot					
			Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
53 V_m=0.026 m^3 Б= 0.019 m^3	 1 2 3	 3 6 3	V<0.007 1 1 0	[0.007-0.017[0 4 0	[0.017-0.026[0 1 2	[0.026-0.036[0 0 0	[0.036-0.045[0 0 0	V>0.045 2 0 1
72 V_m=1.578 m^3 Б=0.959 m^3	 1 2 3	 4 2 3	V<0.618 2 0 0	[0.618-1.098[0 0 2	[1.098-1.578[1 0 0	[1.578-2.058[0 0 0	[2.058-2.537[0 2 0	V>2.537 1 0 1
27 V_m=1.477 m^3 Б=0.876 m^3	 1 2 3	 4 6 5	V<0.602 1 3 1	[0.602-1.039[0 0 0	[1.039-1.477[1 1 2	[1.477-1.915[0 0 0	[1.915-2.353[2 1 0	V>2.353 2 1 2

The cut is carried out at the end of the development cycle of *C. triflorus* about mid-July. In fact, the biomass of the shrub at this stage is stationary at all the locations because it is the fruiting stage, where the biomass production of the current year ends until the recovery in the good season at beginning of March of the following year. The two similar strands of the same class are cut simultaneously.

Dry mass method

The weights are carried out with a closely 1/10 (g) accuracy. After having cut the strands, the different components of each strand are separated, and each component has been the subject of a special study:

- Strands with diameter ≤ 1.5 cm (soft wood) are measured at the fresh state, and a sample is collected, weighed and then parboiled up to constant weight.
- Strands with diameter > 1.5 cm (hard wood) are charged in the ridges and weighed *in situ* to determine the fresh weight, and three washers have been collected at different levels: at the base, mid-length and at the cutting 1.5 cm (Auclair & Métayer, 1980); these are weighed and then put in bags and steamed in the laboratory to determine the dry mass.
- Leafs obtained from strands are weighed completely fresh, and a sample of 50 g, accurately measured *in situ*, is selected for drying.

The samples collected in the field have been placed in an oven up to constant weight. The drying temperatures were maintained at 105°C for the woody component and 70°C for leafs in order to avoid losses of nitrogen that volatilizes at high temperatures (Reidacker, 1968). The mean dry mass of the two strands of the same stratum of similar strands is used to calculate the total dry weight of the shrub, having a number of strata and correspondent strands.

Biomass assessment

The calculation of the dry biomass per hectare in the studied area is carried out according to Bakkali et al. (2000, 2002).

Dry biomass per hectare is estimated in the study area from the average density of shrubs per hectare. At the plot scale, we count the number of shrubs (N) in "n" plots of 10 m*10 m each, chosen randomly. The average number of shrubs per plot of 100 m^2 is then "$\frac{N}{n}$", which is an average density of shrubs per hectare of "$\frac{N}{n \times 100}$". Then, the number of shrubs per hectare and their average biomass per plot allow an estimation of the actual biomass per hectare.

Modeling

In the forestry literature, there are a large number of models explaining the relationship between the weight and tree characteristics. In this study, the two categories of models expressed below have been adjusted:

- Polynomial models:

$$DMi = a_0 + a_1\, x\, p$$

$$DMi = a_0 + a_1\, x\, p^2$$

$$DMi = a_0 + a_1\, x\, p + a_2\, x\, p^2$$

- Allometric models:

$$DMi = a_0\, x\, p^{a_1}$$

a_0, a_1 and a_2, regression coefficients; DM, Dry mass; i, refers to the nature of the component [wood (B), leaves (F) or both of them (T)]; p, measurable dendrometric parameter (basal diameter of the strand, length of the strand, average diameter of the shrub, average height of the shrub).

The choice of the best model was based on a rigorous statistical analysis, based on the values of coefficients of determination (R^2) and correlation (R).

Results

Above-ground biomass Prediction

Strands Biomass

The equations relating the components dry weight of the strand of *C. triflorus* studied to the basal diameter (D) and the strand length (L) are of the allometric form (Figures 2-9).

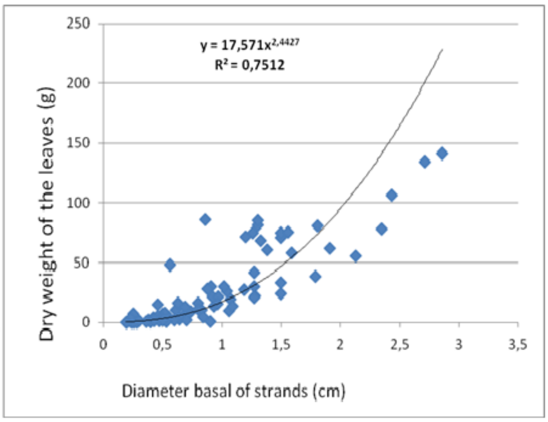

Figure 2. Trend curve of leaves dry weight according to the basal strand diameter in *C. triflorus*.

Modeling of the biomass's strands and shrubs

Before performing the estimation of the shrub aboveground biomass, different models have been previously tested on the strands to establish regressions by using the basal diameter as a dendrometric parameter.

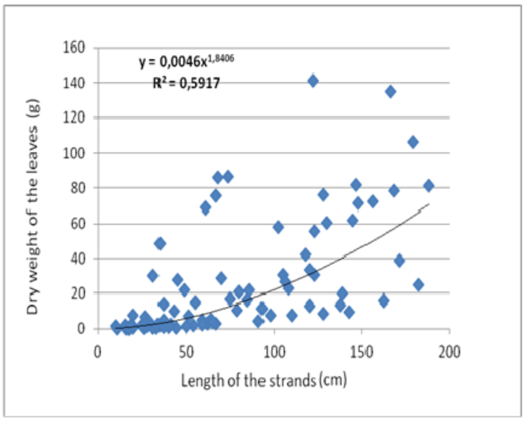

Figure 3. Trend curve of leaves dry weight according to the strands length in *C. triflorus*.

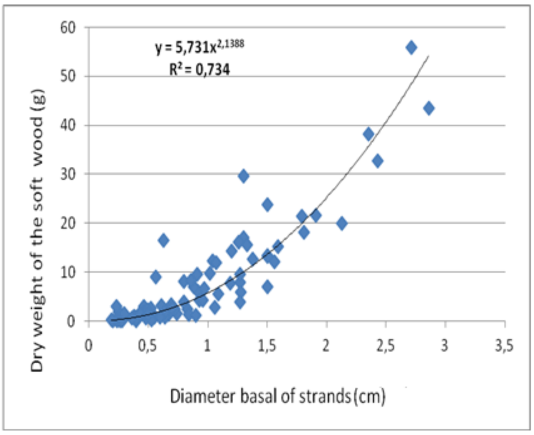

Figure 4. Trend curve of soft wood dry weight depending on the basal diameter of strands in *C. triflorus*.

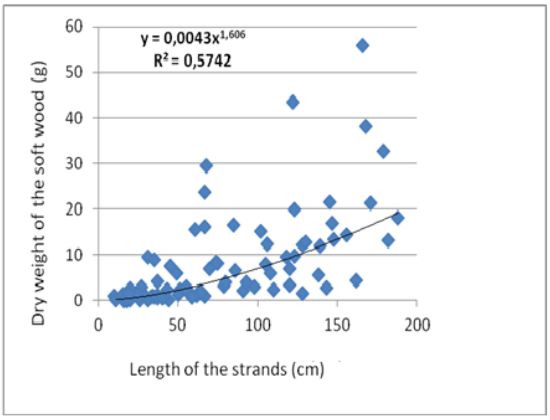

Figure 5. Trend curve of soft wood dry weight depending on the length of strands in *C. triflorus*.

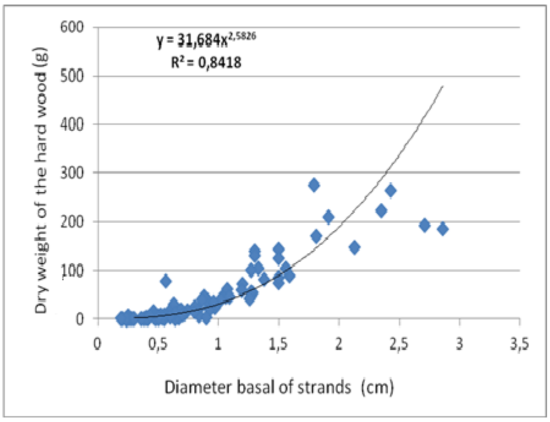

Figure 6. Trend curve of hard wood dry weight according to the basal diameter of strands in *C. triflorus*.

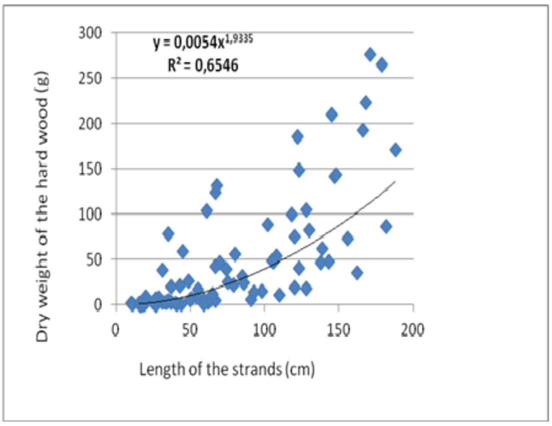

Figure 7. Trend curve of hard wood dry weight according to the length of strands in *C. triflorus*.

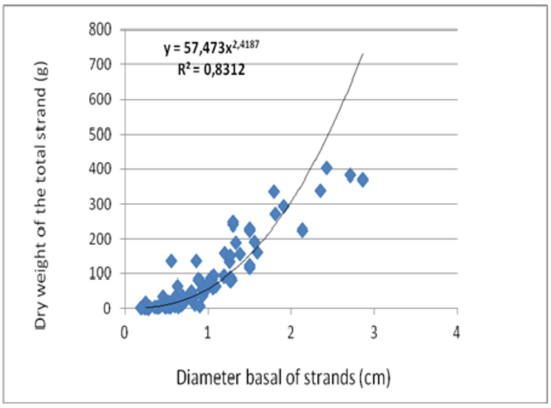

Figure 8. Trend curve of total dry weight depending on the basal diameter of *C. triflorus* strands.

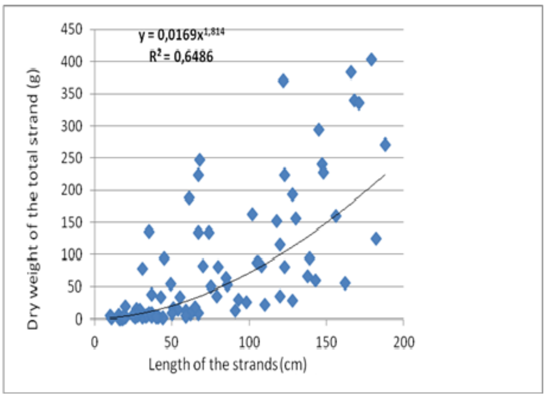

Figure 9. Trend curve of total dry weight according to the length of *C. triflorus* strands.

Table 3 contains the selected adjustment models and the precision criteria considered when evaluating the biomass of the components of the sampled strands.

Shrubs biomass

We also established relations between averages diameter (AD) and height (AH) of the shrub, and the dry weight of its components. The equations retained are of allometric form (Figures 10-17).

Table 4 includes the adjustment models selected as well as the precision criteria for the evaluation of components biomass in the sampled shrubs.

Table 3. Rates of components biomass of single strands. **DMhW**, dry mass of hard wood; **DML**, dry mass of leaves; **DMsW**, dry mass of soft wood; **R**, Coefficient of correlation; **R²**, Coefficient of determination; **TDM**, total dry mass.

Component	Number of strands	Strand characteristics	Model	R²	R
Leaf	87	Basal diameter	$DML = 17.57x^{2.442}$	0.75	0.87
		Length	$DML = 0.004x^{1.840}$	0.59	0.77
Soft wood	87	Basal diameter	$DMsW = 5.731x^{2.138}$	0.73	0.85
		Length	$DMsW = 0.004x^{1.606}$	0.57	0.75
Hard wood	87	Basal diameter	$DMhW = 31.68x^{2.582}$	0.84	0.92
		Length	$DMhW = 0.005x^{1.933}$	0.65	0.81
Total	87	Basal diameter	$TDM = 57.47x^{2.418}$	0.83	0.91
		Length	$TDM = 0.016x^{1.814}$	0.65	0.81

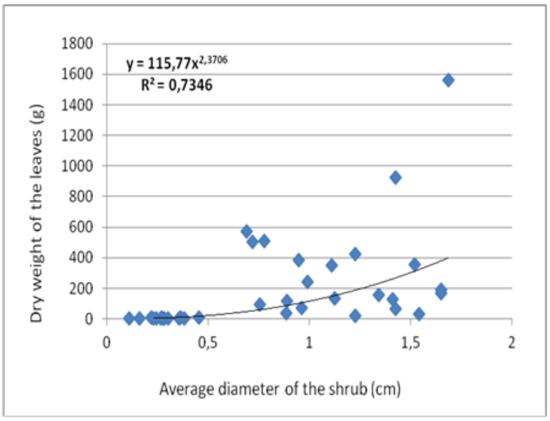

Figure 10. Trend curve of leaves total dry weight according to the average diameter of *C. triflorus* shrubs.

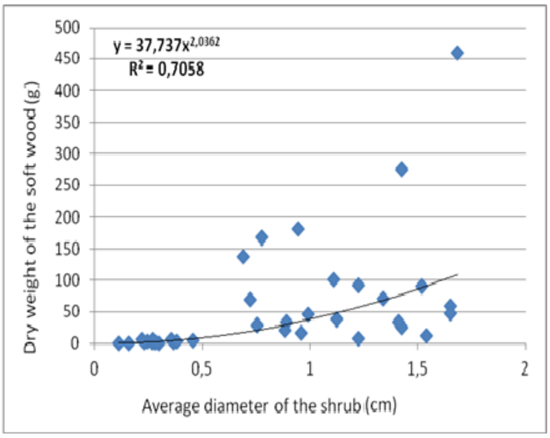

Figure 12: Trend curve of the total dry weight of the soft wood depending on the average diameter of *C. triflorus* shrubs.

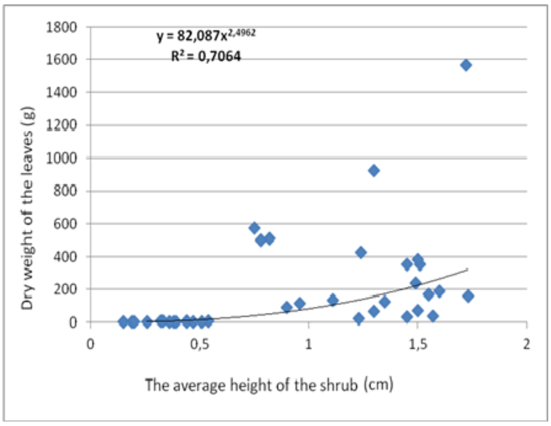

Figure 11: Trend curve of leaves total dry weight according to the average height of *C. triflorus* shrubs.

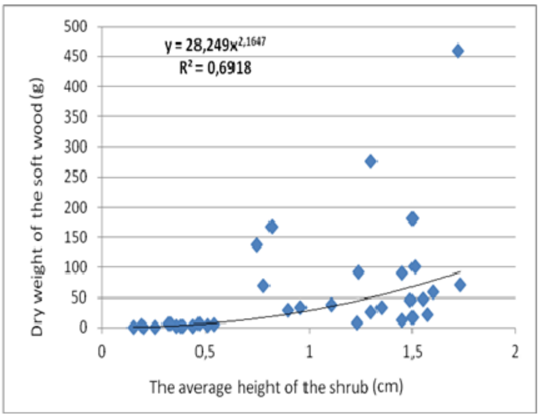

Figure 13: Trend curve of the total dry weight of the soft wood depending on the average height of *C. triflorus* shrubs.

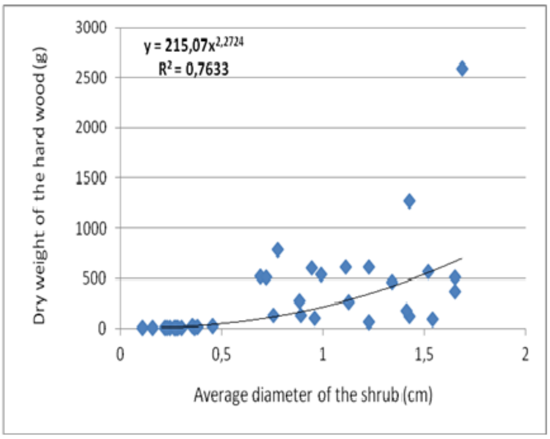

Figure 14. Trend curve of the total dry weight of the hard wood according to the average diameter of *C. triflorus* shrubs.

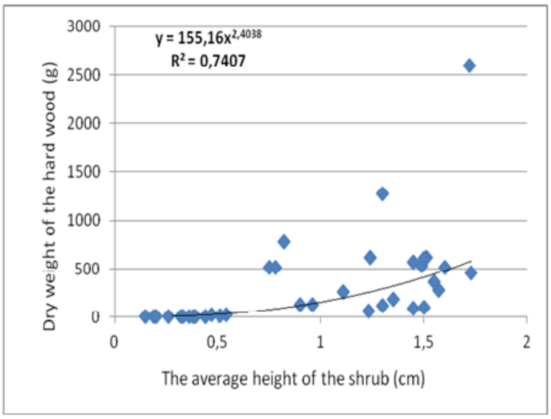

Figure 15. Trend curve of the total dry weight of the hard wood according to the average height of *C. triflorus* shrubs.

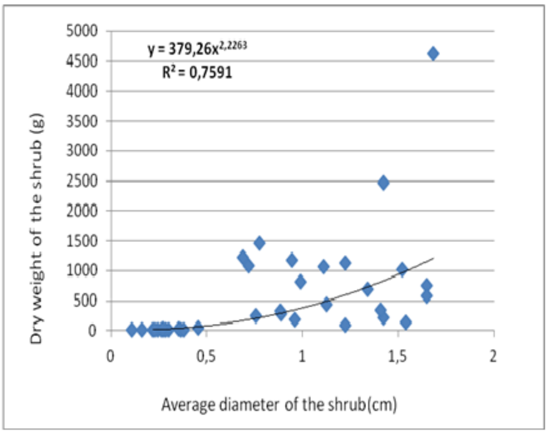

Figure 16. Trend curve of the total dry weight of both leaves and wood depending on the average diameter of *C. triflorus* shrubs.

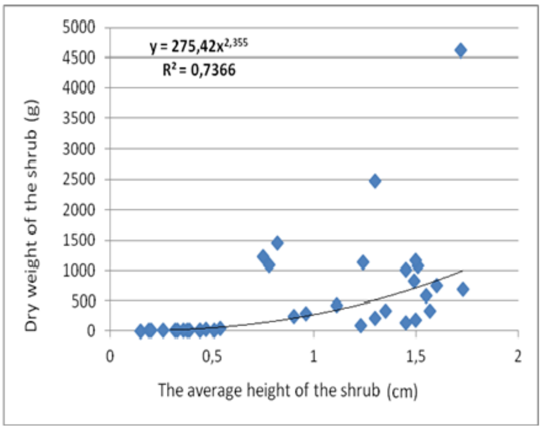

Figure 17. Trend curve of the total dry weight of both leaves and wood depending on the average height of *C. triflorus* shrubs.

Average production of biomass

Applying the rates of individual biomas to the whole of all plots allows the determination of the dry biomass per plot. The dry biomass per hectare is obtained by a linear extrapolation of the results obtained by a plot. In each plot, the aboveground phytomass of each shrub is calculated from the rates of biomass. The average phytomass of the plot is then obtained. For the 9 plots of 3 locations studied, the average value of the phytomass is calculated for the plot area, ie. 100 m², and then reported to the hectare.

As well the average production in the biomass of *C. triflorus* from the Moroccan Rif is of the order of 148.13 kg of Dry Matter (DM) per hectare. By category of aerial component, the mean dry mass is 96.30 and 51.83 kg $DM.ha^{-1}$ for the wood and leaves in the same order (Tables 1 and 5). We noted likewise large difference in biomass production between the three locations.

Effects of the pastoral pressure on *C. triflorus* aboveground biomass

In all plots, the real animal charge was higher than the balance one (Tables 1 and 5), so there is a very high pastoral pressure in this forest area, especially in Plots 72 (Bab Taliouent-Aazayeb forest) and 53 (Khezana forest), with a very high overgrazing coefficient: 86.07% and 94.79 respectively. Which explains the low biomass of *C. triflorus* in these plots, especially the 53 one, where the overgrazing coefficient approaches 100%. While, the phytomass of *C. triflorus* is higher in the parcel 27 (Fifi-Sraib forest), where the overgrazing coefficient equals 42.72%.

Table 4. Rates of biomass components in *C. triflorus* shrubs. **DMhW**, dry mass of hard wood; **DML**, dry mass of leaves; **DMsW**, dry mass of soft wood; **R**, Coefficient of correlation; **R²**, Coefficient of determination; **TDM**, total dry mass.

Component	Number of shrubs	Shrub characteristics	Model	R²	R
Leaf	36	Basal diameter	DML= $115.7x^{2.370}$	0.73	0.85
		Average height	DML= $82.08x^{2.496}$	0.71	0.84
Soft wood	36	Basal diameter	DMsW= $37.73x^{2.036}$	0.70	0.84
		Average height	DMsW= $28.24x^{2.164}$	0.69	0.83
Hard wood	36	Basal diameter	DMhW= $215.0x^{2.272}$	0.76	0.87
		Average height	DMhW= $155.1x^{2.403}$	0.74	0.86
Total	36	Basal diameter	TDM= $379.2x^{2.226}$	0.76	0.87
		Average height	TDM=$275.4x^{2.355}$	0.74	0.86

Table 5. Above-ground phytomass per hectare in *C. triflorus*. **A**, Green, tauzin and cork oaks; **B**, Green and tauzin oaks; **C**, Green and cork oaks; **DM**, Dray Matter. ***Location** (See Table 1).

Location*	Coefficient of overgrazing (%)	Aboveground phytomass (kg DM.ha^{-1})				
		Total	Leaves	Wood		
				Subtotal	Soft	Hard
53	94.79	3.08 C	0.70 C	2.39 C	0.52 C	1.87 C
72	86.07	44.35 B	10.79 B	33.56 B	3.96 B	29.60 B
27	42.72	281.06 A	101.21 A	179.85 A	28.20 A	151.65 A
Weighted average		148.13	51.83	96.30	14.78	81.52

In the parcel 27, where pastoral pressure is 2.13 LU.ha^{-1}, the phytomass of *C. triflorus* is significantly higher than that observed elsewhere. In the parcel 53, the high pastoral pressure (6.53 LU.ha^{-1}) would be responsible for the very low biomass of *C. triflorus*. In this forest, the overgrazing coefficient reaches 94.79 %, and the balance charge (0.34 LU.ha^{-1}) is largely exceeded because of an extensive grazing.

Discussion

Generally, we note that there is a very high correlation between the dry weight and basal diameter for all of the components of the strands studied, because their coefficients of determination (R^2) all exceed 73% (0.73 ≤ R2 ≤ 0.84) and their coefficients of correlation are between 0.85 and 0.92. We also note that the correlation between the dry weight of the components of the strands and their length is a good because their coefficients of determination is higher than 57% ($0.57 \leq R^2 \leq 0.65$) and their coefficients of correlation are between 0.75 and 0.81.

We also note that there is a good correlation between the dry weight and the average diameter for all of the components of the shrubs studied, because their coefficients of determination (R^2) all exceed 70% (0.70≤ R2≤0.76) and their coefficients of correlation are between 0.84 and 0.87. The relationship between the average height of the shrub and the dry weight of its components presents a good correlation because their coefficients of determination (R^2) is higher than 69% ($0.69 \leq R2 \leq 0.74$) and their coefficients of correlation are between 0.83 and 0.86.

The correlations between the different strand components and basal diameter, and the different shrub components with the average diameter are more significant when compared to the correlations between the different strand components and length, and the different shrub components with the average height. This can be explained by the specific characteristics of this species which grows rather in width (recovery) that in height.

The aboveground biomass (148.13 kg $DM.ha^{-1}$ of the *C. triflorus* in the Moroccan Rif is generally very low, compared to Etienne et al. (1991) in the same species from the Esterel massif (France), Bakkali et al. (2002) in *Argyrocytisus battandieri* from the Middle Atlas (Morocco). According to the work of Baudin (1985) led in the Esterel massif, the maquis of *Cytisus* spp. and *Calycotome* spp. constitute a group with a low index of phytomass. An intensive impact on *Cytisus* stand accelerates its degradation, because of the quick biomass accumulation in the first year, and then decreases gradually (Rousseau & Loiseau, 1982; Etienne et al, 1991).

Most Mediterranean woody species are consumed by livestock; *Cytisus* spp. is one of the most popular species (Bourbouze, 1980; Le Houérou, 1980). The traditional operating system of the Rif mountain area is based on the existence of an important goat population, conducted extensively in the forest, paired with an ancient practice of shifting cultivation requiring to dispose of new land culture. The clearing for the cannabis culture of the Kif and cutting for firewood represent nearly 90 % of the deforestation process (Grovel, 1996).

Conclusion

In the Moroccan Rif, the aboveground biomass of *C. triflorus*, a forage shrub very appreciated by the livestock, has been apprehended from shrub dendrometric data, allowing simple and multiple regressions have to estimate woody and foliar biomasses in this species.

The estimation of strands dry biomass can be performed from their diameter and length of the single strand. The assessment of shrubs dry biomass can be performed from their maximum height and average diameter. The best models obtained for strands and shrubs are allometric, adjusting more to the biomass data.

The *C. triflorus* from the Moroccan Rif is subjected to a very strong anthropic action threatening it of disappearance, and the following recommendations would be urgently needed for the conservatory management of this sylvo-pastoral resource:

- decrease the pastoral charge in forests, in intensive and extensive range locations, by reducing the number of heads of cattle;
- Sow and disseminate scarified seeds of *C. triflorus*, on siliceous substrate in the locations with strong shrubs degradation, and protect and monitor for at least 10 years;
- and stop the clearing of land for the cannabis culture, and wood cutting for heating.

However, these recommendations, among others, can only be achieved by mutual agreement with farmers and pastoralists on the basis of a clearly defined organization system.

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