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Impact of degradation on the above-ground biomass of plants composing the shrub layer of Djebel Zaghouan

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ABSTRACT: The above-ground shrub biomasses were studied in a degradation sequence of Djebel Zaghouan. The plots of 25 and 400 m^2 each were geolocated with a breakdown into three stages of degradation: degraded, moderately degraded and preserved. Mathematical models were developed for each species to determine the relationships of aboveground biomass as a function of biovolume and crown surface. Regression equations are of different types: logarithmic, power, polynomial, linear and exponential with high coefficient of determination (R2). The highest total phytomass was recorded at station 14 with an average production of 17.48t / ha and a significant degree of recovery of 61.13%. However, the lowest aerial phytomass was recorded in station 22 (0.561t / ha) with a recovery rate of 6%.

KEYWORDS: Biomass, Degradation, Allometric relations, Djebel Zaghouan.

1 INTRODUCTION

Due to its particular geographical location, Tunisia benefits from a very varied range of climates favoring the development of a rich and diverse flora. Indeed, Tunisia is home to more than 2,200 plant species, of which more than 350 are recognized as having medicinal properties (Belghith, 2005).This richness in plant species is undergoing an alarming degradation by permanent overgrazing and continuous overexploitation of forests. In an approach which aims at the rehabilitation as well as the enhancement of natural environments, more specifically the extinct or endangered wild fauna and flora, Tunisia has adopted a strategy based on the creation of national parks and natural reserves. These places are managed by the Directorate General of Forests (DGF) and spread over the entire territory of the country.

Djebel Zaghouan shows an increasingly intense degradation because it is occupied by a large population which has the right of use. This degradation is manifested by holm oaks in a very poor state of development which is caused by the combination of both biotic and abiotic factors (Nsibi et al., 2006). The degraded state of the forest is assessed by retenting various criteria relating to density, vigor of trees and animals and the quality of soil functioning. Degradation is not necessarily a precursor of deforestation; forests can remain degraded for a long time. (Angelsen, 2008).However, in the most severe cases, forest degradation can lead to deforestation (Kamungandu, 2009). The process of degradation of plant formations is complex by the multiplicity of factors in the presence of possible interactions requiring the analysis of these factors (Simula, 2009).

The present study aims to evaluate the aerial shrub phytomass of species falling under each stage of degradation of the Quercus ilex, Pistacia terebinthus.

2 MATERIALS AND METHODS

2.1 CHOICE OF EXPERIMENTAL PLOTS

The prospection of the forest of the Djebel Zaghouan made it possible to choose the zone established from the vegetation map (CRDA Zaghouan, 2007). This vegetation is composed of a group of Quercus ilex, Pistacia terebinthus. For each plot, the geographic coordinates were determined. Each of these plots covers an area of 400m2 (square plots of 20 m side). The projection surfaces of all the shrub species were determined followed by the calculation of the degree of coverage. These plots have been classified into three degradation categories: degraded stage when the degree of coverage is less than 20%, moderately degraded (coverage between 20 and 35%) and preserved stage when this rate exceeds 35%. The plots, numbering 25, were classified according to the degradation categories.

2.2 DETERMINATION OF BIOMASS

The method adopted in the estimation of biomass in this work is that of non-destructive stratification (Etienne, 1989). The floristic composition of the tree layer and the maquis was established from floristic surveys of 400 m2, each, carried out in the 25 plots according to the Braun-Blanquet method (Braun-Blanquet, 1928). This composition varied depending on the station and the stage of degradation.

The measurements of the morphometric parameters of the shrub (large diameter, small diameter and height) were carried out on all individuals of different species in each plot. At each plot, 6 individuals of different sizes (small, medium, large and very large) per species were selected for slaughter. The biovolume of semi-spherical shaped shrubs was estimated from the morphotype function formula following hemispherical:

$$V = \frac{4}{3}\pi h \frac{D_m^2}{4}$$

Where h: is the maximum height and Dm: is the arithmetic mean between the small and the large diameter of the studied shrubs.

2.3 CALCULATION OF DRY WEIGHT AND ESTIMATION OF BIOMASS

The sampled plant material was separated for each species in each plot into two compartments: the stems and the leaves. The weight of leaf and stem samples of each species was determined fresh, then after steaming to constant weight. The drying temperatures were maintained at 70 ° C for 72 hours. We then proceeded to estimate the dry biomass of all individuals of the different species by site. The extent of the study site in the Park was obtained using satellite images where the shades of color are the same.

Fieldwork required the use of a graduated pole to measure height and diameters, a saw for cutting, bags, precision scales to weigh leaves and twigs, a compass and a GPS (Global Positioning System) type Magellan Pro.

The determination of the biomasses of the different plots was obtained by carrying out the applications of three functions including the projection surface, the bio volume and the two parameters together. The formula adopted being:

$$Biomass\,(\text{kg/ha}) = \frac{10000}{400}\sum_{i=1}^{q} nibi$$

Where bi is the equation of species q and ni is the number of individuals of species q

The different equations used to determine the above-ground biomass as a function of the variables (volume, surface of the crown and these two parameters together) were established by choosing individuals of the most representative species. We did not consider individuals whose measurements do not reflect biomass.

Then, the biomasses in the three stages of degradation were deduced. The primary aerial productivities were determined by applying the following formula (Sebei et al., 2008).

2.4 DETERMINATION OF RECOVERY

The coverage of each plot was estimated by proceeding by summing the areas of all the individuals of the species in the plot by assimilating the projection area of the crown of each individual to an ellipse of formula; with a: half of the large diameter and b: half of the small diameter.

3 RESULTS

BIOMASSES OF DIFFERENT SPECIES IN PLOTS OF DIFFERENT DEGRADATION STATES OF DJEBEL ZAGHOUAN

BIOMASS AT THE SCALE OF INDIVIDUALS OF THE SPECIES

The parameters of the height, the small and the large diameter of the shrubs were measured in order to be able to determine their areas and volumes. The minimum, average and maximum values of the various parameters are summarized in Tables 1 and 2.

The data in these tables illustrate a large variability in the biometric values used in this study.

For height, the greatest variability was observed in Pistacia lentiscus with an average value of 1.35 m, ie a biovolume of 810 dm3 and an average total biomass of 4.330 kg of dry matter. The smallest variability was observed in Smilax aspera with an average height of 0.40 m, with a biovolume of 20 dm3 and an average total biomass of 0.033 kg of dry matter.

Regarding the large diameter (D), Pistacia terebinthus also showed the greatest variability with an average value of 0.86 m. On the other hand, the smallest large diameter was recorded in Rhamnus alaternus (0.25 m), i.e. a biovolume of 11 dm3 and an average total biomass of 0.122 kg of dry matter. For the small diameter, the greatest variability was observed in Pinus halepensis with an average value of 0.70 m. Thus, for the smallest variability was observed in Rhamnus alaternus with an average diameter of 0.15 m.

The results presented in Table 5 show that Phillyrea latifolia produced a high average biomass (4.4 kg dry weight subdivided into 0.7 kg of leaves, 3.7 kg of stems and 0.04 kg of twigs). Marrubium vulgare produced the lowest biomass (13.81g dry matter). Other shrub species produced very high total biomasses: Pistasia lentiscus (4330 g), Quercus coccifera (4299 g), Quercus ilex (4115 g), Anagyris foetida (3850g), Pinus halepensis (3846g) and Ceratonia siliqua (3450 g).

In order to better understand the relationships between shrub biomass and occupied biovolume, models were developed for each species studied. The biomass of the samples was calculated using allometric relationships established from data from sample shrubs.

Table 1. Characteristics of height in m, of small and large crown diameters in m, of sampled plants of the 30 species of the shrub layer of Djebel Zaghouan

Species	**N**	**Large diameter**		**Small diameter**		**Height**	
		moy±std	**min-max**	**moy±std**	**min-max**	**moy±std**	**min-max**
P. lentiscus	93	0,86±0,05	0,44-1,80	0,74±0,04	0,40-1,20	1,35±0,07	0,60-2
P. latifolia	125	0,60±0,03	0,29-0,96	0,517±0,03	0,20-0,88	1,05±0,07	0,39-1,5
C. villosa	94	0,43±0,18	0,16-0,98	0,33±0,18	0,10-0,90	0,53±0,17	0,28-1
E. multiflora	54	0,39±0,15	0,2-0,88	0,31±0,13	0,15-0,74	0,44±0,15	0,23-0,94
G. alypum	85	0,44±0,19	0,20-0,91	0,32±0,18	0,1-0,85	0,52±0,20	0,28-0,99
A. mauritanica	20	0,61±0,15	0,25-0,88	0,5±0,2	0,10-0,75	0,68±0,16	0,30-0,95
A. microcarpus	21	0,39±0,20	0,11-0,75	0,32±0,20	0,07-0,71	0,48±0,21	0,21-0,97
T. algeriensis	14	0,31±0,10	0,18-0,58	0,21±0,08	0,11-0,45	0,40±0,11	0,2-0,67
R. alaternus	18	0,25±0,03	0,2-0,35	0,15±0,03	0,10-0,23	0,37±0,05	0,3-0,57
G. tricuspidata	18	0,49±0,19	0,19-0,85	0,39±0,18	0,16-0,78	0,53±0,20	0,20-0,86
P. halepensis	28	0,84±0,34	0,23-1,50	0,70±0,29	0,12-1,30	1,26±0,18	0,90-1,95
A. foetida	10	0,69±0,04	0,40-0,89	0,60±0,04	0,32-0,83	0,78±0,04	0,50-0,96
T. polium	16	0,57±0,23	0,25-0,97	0,48±0,26	0,19-0,89	0,65±0,22	0,38-1
C. siliqua	25	0,80±0,04	0,3-1,2	0,71±0,04	0,25-1	0,95±0,05	0,44-1,5
Q. coccifera	19	0,80±0,04	0,48-1,2	0,69±0,04	0,39-0,96	0,95±0,05	0,66-1,5
R. officinalis	30	0,77±0,12	0,35-0,97	0,68±0,12	0,32-0,86	0,85±0,11	0,46-0,99
O. europea	25	0,49±0,03	0,29-0,95	0,38±0,02	0,21-0,80	0,90±0,04	0,55-1,5
J. oxycedrus	16	0,48±0,24	0,2-0,97	0,37±0,24	0,12-0,85	0,58±0,23	0,30-1
S. aspera	8	0,32±0,07	0,20-0,45	0,21±0,06	0,11-033	0,40±0,10	0,20-0,56
Q. ilex	24	0,69±0,07	0,26-1,5	0,56±0,05	0,13-1,10	0,80±0,07	0,37-1,6
C. salvifolius	18	0,54±0,14	0,30-0,85	0,38±0,15	0,10-0,70	0,48±0,12	0,25-0,70
C. monspeliensis	46	0,41±0,11	0,22-0,80	0,31±0,12	0,16-0,78	0,67±0,15	0,27-1
R. peregrina	24	0,45±0,18	0,22-0,85	0,35±0,20	0,12-0,82	0,53±0,16	0,31-0,88
S. tenacissima	12	0,33±0,13	0,19-0,59	0,22±0,12	0,13-0,54	0,43±0,10	0,30-0,60
H. coronarium	15	0,45±0,12	0,25-0,68	0,35±0,12	0,15-0,57	0,54±0,13	0,30-0,76
G. robertianum	16	0,34±0,33	0,12-1,6	0,21±0,12	0,10-0,60	0,40±0,15	0,24-0,90
A. unedo	15	0,70±0,07	0,31-1,30	0,59±0,06	0,25-1	0,83±0,08	0,47-1,5
M. vulgare	21	0,59±0,21	0,25-0,89	0,51±0,21	0,18-0,85	0,67±0,21	0,30-0,94
P. terbinthus	5	0,93±0,20	0,65-1,75	0,67±0,12	0,56-1,25	1,26±0,18	0,90-1,95
C. azarolus	24	0,60±0,26	0,30-1,30	0,48±0,21	0,24-0,89	1,03±0,34	0,46-1,60

N: the number of individuals of the different species sampled; avg ± std: mean ± standard deviation; min-max: minimum and maximum diameters

The models applied are carried out using a smaller number of individuals per species, in order to have a good fit for the points on the graph and to have significant correlation coefficients.

Table 2. Characteristics of total and compartmental biomasses (g), projection surfaces (m2) and biovolume (m3) (mean standard deviation and minimum maximum values) of the sampled species of Djebel Zaghouan

Espèces	Leaf biomass		Stem biomass		Biomass of twigs		Total biomass		Area		Volume	
	moy±std	Min-max	moy±std	Min-max	moy±std	Min-max	moy±std	Min-max	moy±std	Min-max	moy±std	Min-max
Pistacia lentiscus	1042±102	32-2156	3183±189	1383-5177	104±22	13-645	4330±26	2069-6861	0,54±0,05	0,17-1,69	0,81±0,11	0,103-2,57
Phillyrea latifolia	913±65	241-1567	640±51	66-1385	56±80	7-200	1628±99	365-2542	0,27±0,02	0,04-0,66	0,34±0,04	0,02-0,99
Calicotome villosa	54,12±0,03	9-185	213,00±0,18	26-912	69,00±0,04	12-182	336,00±0,18	91-961	0,14±0,14	0,015-0,692	0,09±0,14	0,005-0,69
Erica multiflora	53,12±0,02	9-103	167,29±0,19	17-764	40,51±0,03	6-167	260,93±0,19	58-838	0,11±0,10	0,028-0,49	0,06±0,1	0,007-0,44
Globularia alypum	19,03±0,02	10-121	57,87±0,20	17-689	100,64±0,02	4-111	177,53±0,20	85-714	0,14±0,14	0,01-0,60	0,10±0,14	0,005-0,60
Ampelodes mamauritanica	24,87±0,02	2-94	-	-	-	-	24,87±0,02	2-94	0,26±0,12	0,01-0,51	0,19±0,11	0,005-0,49
Asphodelus microcarpus	29,36±0,02	7-94	8,31±0,20	4-13	-	-	37,68±0,02	14-103	0,13±0,13	0,006-0,41	0,09±0,12	0,001-0,38
Thymus algeriensis	39,56±0,02	9-84	91,87±0,01	11-457	44,37±0,03	1-102	175,00±0,11	37-487	0,05±0,04	0,01-0,204	0,02±0,03	0,003-0,13
Rhamnus alaternus	20,00±0,02	3-89	82,09±0,024	48-148	20,000±0,007	7-39	122,00±0,03	64-215	0,03±0,011	0,015-0,063	0,011±0,005	0,004-0,025
Genista tricuspidata	30,50±0,02	6-73	183,00±0,15	27-646	51,40±0,04	15-167	265,77±0,15	96-683	0,17±0,14	0,023±0,52	0,118±0,120	0,004-0,39
Pinus halepensis	678±74	12-1591	3117±290	147-5510	52±06	10-119	3846±25	1216-6149	0,52±0,07	0,02-1,42	0,64±0,12	0,007-2,35
Anagyris foetida	692±13	86-1312	3090±24	1513-3926	68±80	3-96	3850±23	2074-5083	0,34±0,04	0,10-0,58	0,29±0,05	0,05-0,56
Teucrium polium	31,72±0,03	11-94	2698±213	1134-4612	52±50	13±92	3450±237	1666-5924	0,49±0,05	0,06-0,94	0,52±0,07	0,03-1,41
Ceratonia siliqua	700±94	175-1952	139,23±0,21	27-815	49,63±0,02	13-111	276,45±0,26	122-1203	0,48±0,27	0,02-1,02	0,55±0,45	0,007-1,84
Quercus coccifera	601±11	182-2534	3548±18	2467-4895	151±40	25-760	4299±17	304-5777	0,46±0,05	0,14-0,9	0,49±0,08	0,09-1,35
Rosmarinus officinalis	35,88±0,03	15-143	40,96±0,04	11-187	4,69±0,02	1-87	81,53±0,05	37-274	0,42±0,12	0,08-0,64	0,37±0,14	0,04-0,64
Olea europea	504±41	255-1094	1043±01	400-2603	15±30	4-63	1561±107	952-3102	0,16±0,02	0,04-0,59	0,17±0,03	0,02-0,89
Juniperus oxycedrus	45,33±0,02	12-93	178,72±0,19	16-578	22,38±0,02	2-85	246,44±0,18	70-603	0,18±0,19	0,02-0,64	0,14±0,19	0,007-0,64
Smilax aspera	0,023±0,028	7-82	9,4±0,0	05-12	-	-	32,800±0,029	14-93	0,05±0,02	0,01-0,11	0,02±0,01	0,003-0,06
Quercus ilex	1012±87	336-1964	3048±216	385-5155	56±70	18-152	4115±0,22	2319-6160	0,38±0,07	0,03-1,2	0,42±0,11	0,01-1,86
Cistus salvifolius	2,54±0,02	1-84	32,8±0,1	23-447	23,95±0,01	1-46	59,29±0,11	42-490	0,17±0,11	0,03-0,46	0,09±0,08	0,01-0,39
Cistus monspeliensis	33,88±0,02	7-143	158,00±0,14	21-612	9,360±0,024	1-167	201,24±0,14	42-640	0,11±0,08	0,02-0,48	0,08±0,08	0,01-0,44
Rubia peregrina	24,5±0,02	7-82	5,7±0,0	1-22	-	-	30,29±0,02	11-86	0,15±0,14	0,027-0,54	0,10±0,13	0,009-0,48
Stipa tenacissima	20,58±0,01	10-71	2,4±0,00	01-4	-	-	22,98±0,01	12-75	0,06±0,07	0,01-0,25	0,034±0,044	0,005-0,15
Hedysarum coronarium	15±0,003	11-19	17,6±0,0	5-36	-	-	33,40±0,01	16-54	0,13±0,12	0,02-0,30	0,08±0,06	0,008-0,23
Geranium robertianum	7,55±0,00	2-19	6,72±0,002	2-13	-	-	14,270±0,006	7-32	0,08±0,17	0,009-0,7	0,05±0,15	0,002-0,67
Arbutus unedo	691±71	93-1107	3700±32	170-5902	38±08	7-87	4429±30	2866-6920	0,38±0,07	0,06-1	0,40±0,11	0,03-1,41
Marrubium vulgare	3,31±0,01	1-88	10,50±0,27	3-87	-	-	13,81±0,40	5-37	0,27±0,18	0,03-0,59	0,22±0,18	0,01-0,55
Pistacia terbinthus	700±133	392-1120	2645±348	1734-3837	82±13	48-128	2527±281	1831-3501	1,13±0,24	0,28-1,71	2,18±0,70	0,34-4,59
Crataegus azarolus	512±67	108-1578	1850±146	581-3349	61±80	12-162	2423±159	851-3814	0,25±0,04	0,06-0,79	0,32±0,07	0,03-1,27

The relationships between the volume of shrubs and their aboveground biomass are of the following types:

a) logarithmic for P. lentiscus, Q. ilex, O. europaea, P. halepensis, C. salviifolius, A. unedo, T. algeriensis, Q. coccifera, C. azarolus and S. aspera (Figure 1a);

b) potency for P. latifolia, C.villosa, H. coranarium and T. polium (Figure 1c);

c) polynomial for R. alaternus, A. mauritanica, A. microcapus, M. vulgare, S. tenacissima and G. tricuspidata (Figure 1b);

d) linear for E. multiflora, C. monspeliensis, G. alypum, R. peregrina, P. terebinthus, G. robertianum and J. oxycedrus (Figure 1b);

e) exponential for C. siliqua and R. officinalis (Figure 1c);

The relationship between the projection surface of shrubs and their aboveground biomass are of the type:

f) logarithmic for P. lentiscus, Q. ilex, O. europaea, P. halepensis, C. salviifolius, A. unedo, T. algeriensis, Q. coccifera, C. azarolus and S. aspera (Figure 1a);

g) potency for P. latifolia, C. vilosa, H. coranarium and T. polium (Figure 1c);

h) polynomial for E. multiflora, C. monspeliensis, R. alaternus, A. mauritanica, A. microcapus, M. vulgare, S. tenacissima, R. peregrina, G. tricuspidata and P. terebinthus (Figure 1b);

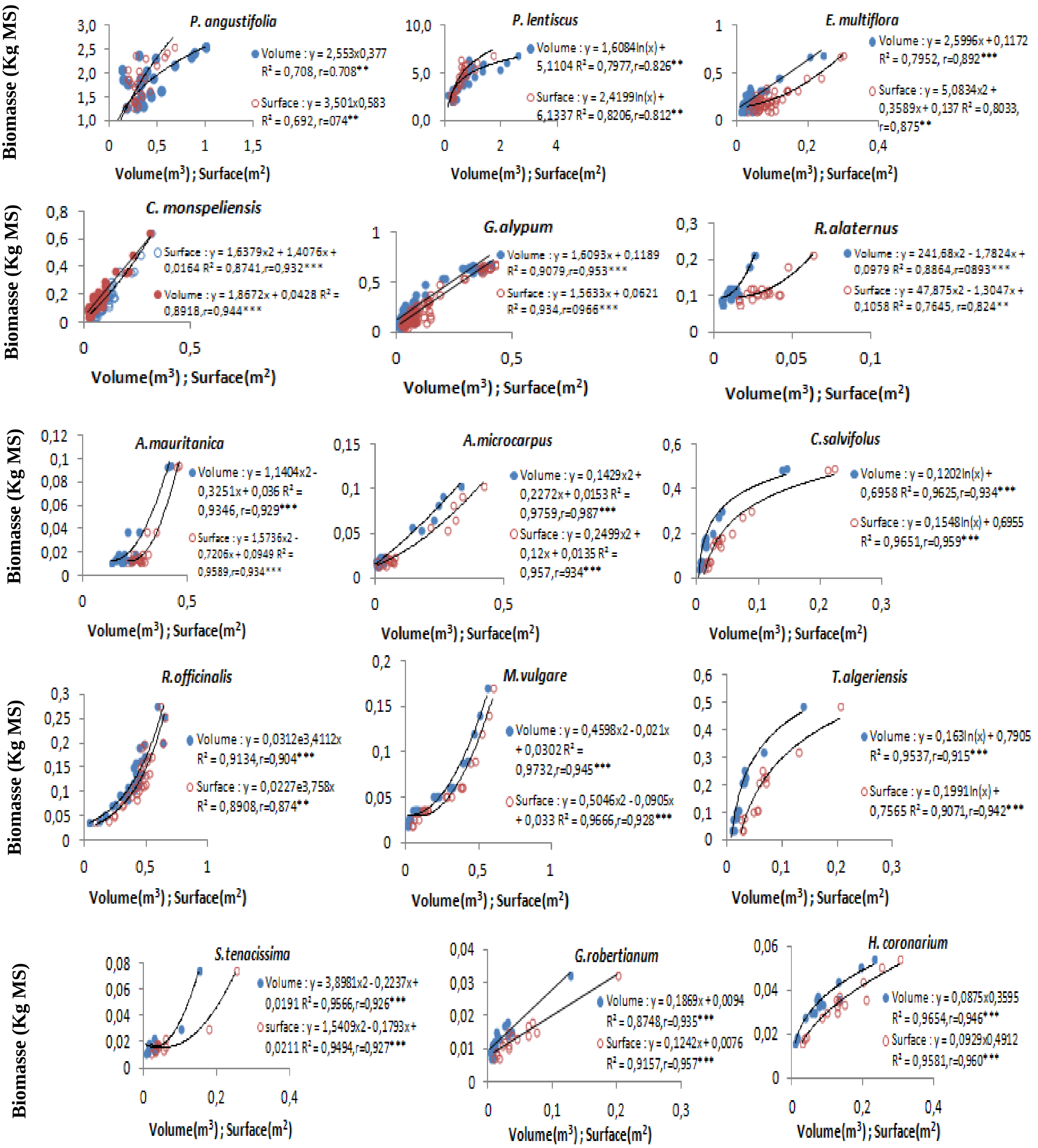
i) linear for G. alypum, G. robertianum and J. oxycedrus (Figure 1b);

j) exponential for C. siliqua and R. officinalis (Figure 1c).

The logarithmic and exponential relationships are the same for the projection area and biovolume variables of the same species. On the other hand, the other linear polynomial and power relations are not applied for the same species.

The results also show highly significant coefficients of determination.

Indeed, at the level of total biomass as a function of volume (m3), the highest coeffecient was that of the species P. terebinthus (0.997), followed by A. microcapus and T. polium (0.975) and the smaller is observed for P. halepensis (0.355) and C. siliqua (0.377). The other species represent R2 between 0.708 and 0.973 (Figure 1). The results of the above-ground biomass as a function of the projection surface (m2) show the highest coefficient of determination for P. terebinthus (0.978) and J. oxycedrus (0.976). In contrast, C. siliqua, P. halepensis and Q. ilex exhibited R2 of 0.315, 0.342 and 0.457, respectively. The remaining species show R2 between 0.692 and 0.966 (Figure 1).


Biomasse (Kg MS)
P. angustifolia
Volume : y = 2,553x0,377 R² = 0,708, r=0.708**
Surface : y = 3,501x0,583 R² = 0,692, r=074**
3,0
2,5
2,0
1,5
1,0
0
0,5
1
1,5
Volume(m³) ; Surface(m²)
P. lentiscus
Volume : y = 1,6084ln(x) + 5,1104 R² = 0,7977,r=0.826**
Surface : y = 2,4199ln(x) + 6,1337 R² = 0,8206,r=0.812**
10,0
5,0
0,0
0
2
4
Volume(m³) ; Surface(m²)
E. multiflora
Volume : y = 2,5996x + 0,1172 R² = 0,7952, r=0,892***
Surface : y = 5,0834x2 + 0,3589x + 0,137 R² = 0,8033, r=0,875**
1
0,5
0
0
0,2
0,4
Volume(m³) ; Surface(m²)
Biomasse (Kg MS)
C. monspeliensis
Surface : y = 1,6379x2 + 1,4076x + 0,0164 R² = 0,8741,r=0,932***
Volume : y = 1,8672x + 0,0428 R² = 0,8918,r=0,944***
0,8
0,6
0,4
0,2
0
0
0,5
Volume(m³) ; Surface(m²)
G.alypum
Volume : y = 1,6093x + 0,1189 R² = 0,9079,r=0,953***
Surface : y = 1,5633x + 0,0621 R² = 0,934,r=0966***
1
0,5
0
0
0,5
Volume(m³) ; Surface(m²)
R.alaternus
Volume : y = 241,68x2 - 1,7824x + 0,0979 R² = 0,8864,r=0893***
Surface : y = 47,875x2 - 1,3047x + 0,1058 R² = 0,7645, r=0,824**
0,3
0,2
0,1
0
0
0,05
0,1
Volume(m³) ; Surface(m²)
Biomasse (Kg MS)
A.mauritanica
Volume : y = 1,1404x2 - 0,3251x + 0,036 R² = 0,9346, r=0,929***
Surface : y = 1,5736x2 - 0,7206x + 0,0949 R² = 0,9589,r=0,934***
0,12
0,1
0,08
0,06
0,04
0,02
0
0
0,5
Volume(m³) ; Surface(m²)
A.microcarpus
Volume : y = 0,1429x2 + 0,2272x + 0,0153 R² = 0,9759,r=0,987***
Surface : y = 0,2499x2 + 0,12x + 0,0135 R² = 0,957,r=934***
0,15
0,1
0,05
0
0
0,5
Volume(m³) ; Surface(m²)
C.salvifolus
Volume : y = 0,1202ln(x) + 0,6958 R² = 0,9625,r=0,934***
Surface : y = 0,1548ln(x) + 0,6955 R² = 0,9651,r=0,959***
0,6
0,4
0,2
0
0
0,1
0,2
0,3
Volume(m³) ; Surface(m²)
Biomasse (Kg MS)
R.officinalis
Volume : y = 0,0312e3,4112x R² = 0,9134,r=0,904***
Surface : y = 0,0227e3,758x R² = 0,8908,r=0,874**
0,3
0,25
0,2
0,15
0,1
0,05
0
0
0,5
1
Volume(m³) ; Surface(m²)
M.vulgare
Volume : y = 0,4598x2 - 0,021x + 0,0302 R² = 0,9732,r=0,945***
Surface : y = 0,5046x2 - 0,0905x + 0,033 R² = 0,9666,r=0,928***
0,2
0,15
0,1
0,05
0
0
0,5
1
Volume(m³) ; Surface(m²)
T.algeriensis
Volume : y = 0,163ln(x) + 0,7905 R² = 0,9537,r=0,915***
Surface : y = 0,1991ln(x) + 0,7565 R² = 0,9071,r=0,942***
0,6
0,5
0,4
0,3
0,2
0,1
0
0
0,1
0,2
0,3
Volume(m³) ; Surface(m²)
Biomasse (Kg MS)
S.tenacissima
Volume : y = 3,8981x2 - 0,2237x + 0,0191 R² = 0,9566,r=0,926***
surface : y = 1,5409x2 - 0,1793x + 0,0211 R² = 0,9494,r=0,927***
0,08
0,06
0,04
0,02
0
0
0,2
0,4
Volume(m³) ; Surface(m²)
G.robertianum
Volume : y = 0,1869x + 0,0094 R² = 0,8748,r=0,935***
Surface : y = 0,1242x + 0,0076 R² = 0,9157,r=0,957***
0,04
0,03
0,02
0,01
0
0
0,1
0,2
0,3
Volume(m³) ; Surface(m²)
H. coronarium
Volume : y = 0,0875x0,3595 R² = 0,9654,r=0,946***
Surface : y = 0,0929x0,4912 R² = 0,9581,r=0,960***
0,06
0,04
0,02
0
0
0,2
0,4
Volume(m³) ; Surface(m²)

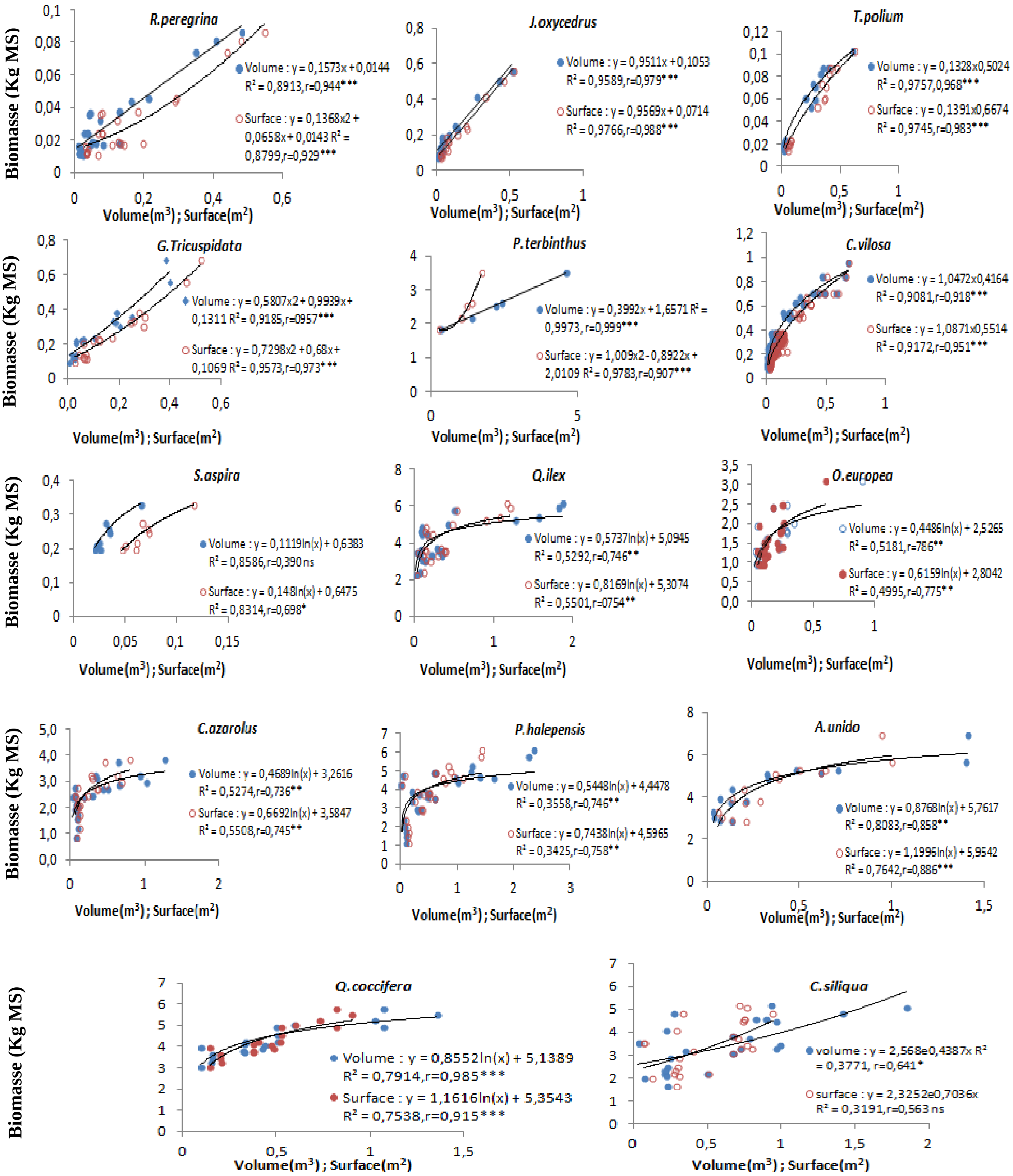


Fig. 1. Relations between total production and projection area, volume of species studied

The ellipsoid surface (S) and the volume (V) on the one hand and the above-ground biomass on the other hand are closely related. The surface of the crown and the volume are explanatory variables of the individual biomass of shrubs. By comparing the two elliptical and spherical shapes; the latter seems to be the best for the species studied because it incorporates an additional parameter (height). The shape that one assimilates to the shrub is a factor which can influence the total production of above-ground biomass. The allometric equations giving the biomass as a function of the volume vary according to the species. With the exception of Smilax aspera where the correlation coefficient between biomass and projection area / volume is highly significant, all other species have very highly significant coefficients. The coefficients of determination are the lowest by taking the untransformed data and where we have linear relations in the form: y = a1S + a2V + a0. The function established by the biomass regression model as a function of the combined volume / area parameters is not significant for Smilax aspera. The functions of Ceratonia siliqua and Pistacia terebinthus are highly significant and very highly significant for the other 26 species.

The equations were determined on untransformed data. The relationships between the above-ground biomass, the biovolume (V) and the projection surface (S) were represented by regression equations with very variable coefficient of determination (R2) (Table 4). The coefficients of determination R2 are of the order of 0.9 for 8 species and 0.404 for Ceratonia siliqua. The significance of the coefficients a0, a1 and a2 of the equations is very high for Calicotome villosa. The majority of functions have at least one non-significant coefficient (Table 3). This adjustment allows less significant variations in biomass than the other two adjustments depending on the area and the biovolume separately.

Table 3. Regression models for biomass (Y) as a function of volume (V) and projection surface (S) of the shrub species studied in Djebel Zaghouan

Espèces	Modèles de régression	Signification des coefficients de la fonction y=a0S + a1V + a2	N	R2	S	r'	R-MSE
Pistacia lentiscus	Y=1,044S+1,373V+2,65	1,044NS, 1,373NS, 2,65***	29	0,686	0,562, 0,147, 0,000	0,828	0,813
Phillyrea latifolia	Y=3,887S-0,637V+0,771	3,887NS, 0,637NS, 0,771**	31	0,579	0,190, 0,721, 0,002	0,761	0,372
Erica multiflora	Y=0,412S+2,062V+ 0,102	0,412NS, 2,062**, 0,102***	54	0,798	0,449, 0,007, 0,000	0,893	0,056
Calicotome villosa	Y=2,550S-1,395V+0,113	2,550***, -1,395***, 0,113***	94	0,930	0,000, 0,000, 0,000	0,964	0,050
Cistus monspeliensis	Y=0,195S+1,680V+0,037	0,195NS, 1,680**, 0,037NS	46	0,892	0,734, 0,004, 0,066	0,944	0,040
Globularia alypum	Y=1,701S-0,146V+ 0,057	1,701***, -0,146NS, 0,057***	85	0,934	0, 000, 0,641, 0,000	0,967	0,051
Ceratonia siliqua	Y=-0,019S+1,516V+ 2,627	-0,019NS, 1,516NS, 2,627***	25	0,404	0,990, 0,105, 0,000	0,636	0,874
Quercus ilex	Y=2,822S-0,306V+3,181	2,822NS, -0,306NS, 3,181***	24	0,581	0,288, 0,850, 0,000	0,762	0,738
Rhamnus alaternus	Y=-0,715S+6,804V+0,0589	-0,715NS, 6,804**, 0,0589***	18	0,803	0,483, 0,008, 0,000	0,896	0,015
Ampelodesma mauritanica	Y=0,244S+0,099V-0,067	0,244NS, 0,099NS, -0,067**	20	0,874	0,241, 0,580, 0,007	0,942	0,009
Olea europea	Y=-0,165S+2,459V+1,173	-0,165NS, 2,459NS, 1,173***	25	0,618	0,967, 0,344, 0,000	0,786	0,345
Crataegus azaroulus	Y=6,973S-2,700V+1,546	6,973NS, -2,700NS, 1,546**	23	0,564	0,327, 0,530, 0,002	0,751	0,516
Asphodelus microcarpus	Y=-0,156S+0,458V+0,458	-0,156*, 0,458***, 0,018***	21	0,980	0,036, 0,000, 0,000	0,990	0,004
Smilax Aspera	Y=-0,272S+0,5126V+0,021	-0,272NS, 0,5126NS, 0,021*	8	0,507	0,437, 0,334, 0,030	0,712	0,002
Pinus halpensis	Y=2,486S+0,006V+2,534	2,486NS, 0,006NS, 2,534***	27	0,575	0,319, 0,9975, 0,000	0,758	0,872
Cistus salviifoilus	Y=7,012S-7,368V+0,005	7,012***, -7,368***, 0,005NS	18	0,969	0,000, 0,000, 0,771	0,984	0,025
Rosmarinus officinalis	Y=-0,755S+1,048V+0,054	-0,755*, 1,048***, 0,054NS	30	0,853	0,015, 0,000, 0,077	0,924	0,023
Marrubum vulgare	Y=-0,4016S+0,620V+0,036	-0,4016*, 0,620**, 0,031**	21	0,917	0,035, 0,003, 0,002	0,957	0,012
Arbutus unedo	Y=4,707S-0,823V+2,960	4,707NS, -0,823NS, 2,960***	15	0,789	0,111, 0,654, 0,000	0,888	0,582
Thymus alageriensis	Y=3,414S-1,414V-0,001	3,414*, -1,414NS, -0,001NS	14	0,892	0,039, 0,512, 0,976	0,944	0,045
Stipa tenacissima	Y=0,197S+0,044V+0,008	0,197NS, 0,044NS, 0,008NS	12	0,858	0,758, 0,965, 0,353	0,927	0,007
Geranium robertianum	Y=0,235S-0,172V+0,006	0,235**, -0,172NS, 0,006***	16	0,928	0,009, 0,167, 0,000	0,963	0,002
Hedysarum coronarium	Y=0,168S-0,044V+0,014	0,168NS, -0,044NS, 0,014**	15	0,923	0,055, 0,661, 0,001	0,961	0,003
Rubia perigrina	Y=-0,027S+0,188V+0,015	-0,028NS, 0,188*, 0,015****	24	0,892	0,071, 0,029, 0,000	0,944	0,008
Quercus coccifera	Y=2,738S+0,176V+2,941	2,738NS, 0,176NS, 2,941***	19	0,838	0,071, 0,846, 0,000	0,916	0,328
Juniperus oxycedrus	Y=0,970S-0,014V+0,071	0,970**, -0,014NS, 0,071***	16	0,977	0,008, 0,966, 0,000	0,988	0,025
Teucrium polium	Y=0,148S+0,013V+0,012	0,148**, 0,013NS, 0,012**	16	0,966	0,006, 0,794, 0,002	0,983	0,006
Genista tricuspidata	Y=1,269S-0,270V+0,072	1,270**, -0,270NS, 0,072**	18	0,949	0,007, 0,584, 0,003	0,974	0,038
Pistacia terebinthus	Y=-0,100S+0,431V+1,702	-0,100NS, 0,431**, 1,702**	5	0,999	0,346, 0,004, 0,001	0,999	0,034

*R2: Coefficient of determination; s: Residual standard deviation; r ': Correlation coefficient between measured Y and calculated Y; n: number of individuals; R-MSE: Mean squared error. NS: not significant, *: α = 0.05, **: α = 0.01, ***: α = 0.001.*

3.1 BIOMASSES OF SPECIES DETERMINED AT PLOT SCALE

The results relating to the variation in the coverage rate (in each 400 m² plot) of vegetation in the 25 stations are shown in Table 4.

Table 4. Aerial phytomasses as a function of volume, area and as a function of the combined parameters (volume / area) determined at the level of the Djebel Zaghouan study stations

Stations	Recouvrement (%)	BV (t/ha)	BS (t/ha)	BVS (t/ha)	Surface représentative des sites (ha)
1	40,03	6,388	7,219	6,903	
12	37,07	6,685	6,621	6,547	98,04
4	51,62	5,496	5,6171	5,695	
10	36,19	9,952	10,494	10,235	85,71
6	35,88	10,784	10,932	10,721	
11	36,53	10,409	8,6735	8,689	
18	36,52	12,41	12,703	12,706	82,71
14	61,13	13,014	17,48	17,559	
15	52,76	7,674	7,891	7,861	
19	46,66	10,223	10,681	10,893	
20	61,11	10,776	10,534	10,886	111,49
Moyenne	45,05	9,437	9,895	9,881	Total: 377,95
(M. pondérée)	(44,25)	(8,973)	(9,414)	(9,374)	(45%)
2	20,23	4,289	4,334	4,68	
17	23,84	8,217	8,325	8,2	
23	25,25	4,84	4,698	4,852	110,94
5	25,18	3,441	3,289	3,448	
9	22,28	6,731	7,001	7,022	125,38
Moyenne	23,36	5,503	5,529	5,64	Total: 236,32
(M. pondérée)	(23,44)	(5,412)	(5,445)	(5,552)	(28%)
3	12,37	2,918	2,989	2,992	
16	10,98	1,695	1,616	1,616	
22	6,04	0,583	0,561	0,603	
24	6,11	1,476	1,464	1,463	
25	7,03	1,355	1,486	1,442	89,5
7	18,7	3,373	3,272	3,142	
8	15,76	2,512	2,684	2,468	
13	15,56	2,109	2,06	2,167	
21	13,58	3,171	2,988	3,131	139,71
Moyenne	11,79	2,132	2,125	2,113	Total: 229,21
(M. pondérée)	(13,01)	(2,328)	(2,311)	(2,296)	(27%)

BV: biomass as a function of volume; BS: biomass as a function of the surface; BVS: biomass as a function of volume and surface; M. Weighted: Weighted Average

The recovery rates vary from 6.04 (degraded plot) to 61.13% (plot in good condition). The 9 degraded plots (S3, S7, S8, S13, S16, S21, S22, S24 and S25) show recovery rates of less than 20% with an average rate of 11.79%. These are sites characterized by very degraded vegetation producing low biomass and stunted shrubs. The coverage rates of moderately degraded sites (5 plots: S2, S5, S9, S17 and S23) are between 20 and 35% with an average rate of 23.36%. This stage is characterized by plants of medium vigor. Eleven plots kept (S1, S4, S6, S10, S11, S12, S14, S15, S18, S19 and S20) have recovery rates greater than 35% with an average rate of 45.05%. Their vigorous shrubs produce the highest biomasses.

Table 4 gives the surfaces occupied by the different stages of degradation. It follows that the degraded stage represents 27% of the surface area of the group, that moderately degraded 28% and the preserved stage 45%.

The values of the total aerial phytomass calculated from the allometric equations of three models (biomass as a function of volume (Bv), biomass as a function of area (Bs) and biomass as a function of the two parameters (Bvs) show that this variation n It is not important for the same degadation stage (Table 5). It should be noted that the aerial biomasses of the different shrub, under-shrub and herbaceous species are variable and the phytomasses per hectare are not high, all degradation trends combined. Indeed, the difference between stages in good condition and degraded is 7t DM ha-1 (Table 5); this demonstrates a degradation due to overgrazing affecting all stages without exception.

Table 5. The aerial phytomasses of shrubs obtained by including the surface, volume and surface / volume parameters in a degradation sequence of the grouping of Quercus ilex and Pistacia lentiscus of Djebel Zaghouan

Biomasse	**Placettes**					
	ND	% Variation	MD	% Variation	D	% Variation
BS (tMS ha-1)	9,895±3,310a	34	5,529±2,069b	37	2,124±0,913c	43
BV (tMS ha-1)	9,437±2,502a	27	5,503±1,939b	35	2,132±0,936c	44
BVS (tMS ha-1)	9,881±1,013a	10	5,640±0,861b	15	2,114±0,298c	14

The values in the same row with the same letters are not significantly different at the 5% level. ND: not degraded; MD: moderately degraded; D: degraded. BV: biomass as a function of volume; BS: biomass as a function of area; BVS: biomass as a function of volume and surface.

The biomasses in conserved (ND) and moderately degraded (MD) plots show lower percentages of variation than those in degraded plots (10 to 37% versus 14 to 43%, respectively). The highest variability's are recorded in degraded sites with 44% for biomasses as a function of volume.

Fig. 2 illustrates the equations of the overhead shrub biomass obtained by including the surface, volume and surface / volume variables as a function of the coverage of the strata which are of the power type. The relationship between these two parameters is highly significant (p <0.001).

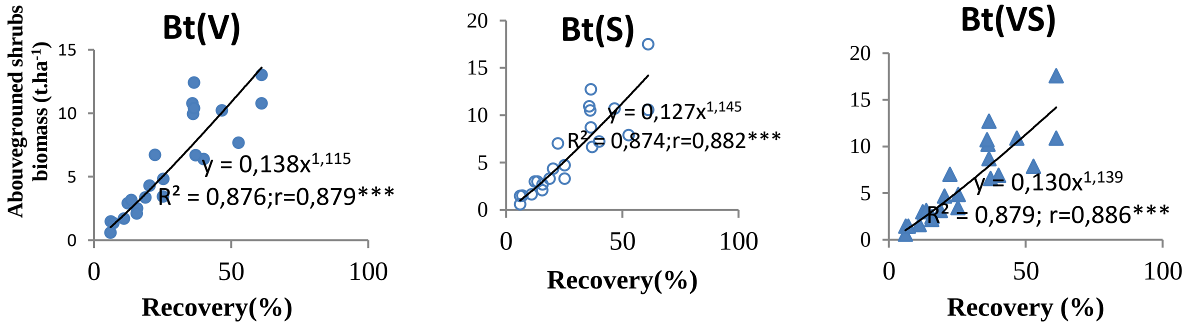


Fig. 2. Above-ground biomass of shrubs from 25 stations as a function of the recovery of the degradation sequence of Djebel Zaghouan National Park. (a): biomass obtained by the Bt (v) biovolume; (b): biomass obtained by the projection surface of the Bt (s) crowns; (c): biomass as a function of the volume and the area together Bt (vs). ***: α = 0.001

The effect of degradation is reflected in a significant link between the biomass and the cover. This fact is well corroborated with the data in Table 8 where the percentage variation varies from 27-34% in the plots in good condition to 43-44% in the degraded ones. In degraded plots, the biomass depends on the coverage but when the coverage exceeds 35% (plot in good condition), the biomass remains unchanged. Figure 2 attests that the cover turns out to be a qualitative criterion for the state of degradation of stands in the shrub layer.

Table 6 shows the aerial productivities as a function of volume, of projection surface and as a function of volume and surface in a degradation sequence of the group of in Quercus ilex, Pistacia terebinthus of the Zaghouan. These productivities differ significantly from one site to another depending on the state of degradation and show a continuous decline along the degradation sequence. The highest total aerial productivities were observed in the conserved site (450 kg DM ha-1 year-1 and

429 kg DM ha-1 year-1) for the models: productivity as a function of volume (Pv) and productivity in function of the projection surface (PS). The lowest productivity is recorded in the degraded site (97 kg DM ha-1 year-1).

Table 6. Aerial productivity of the shrubs obtained by including the surface, volume and surface / volume parameters in a degradation sequence of the group of to Quercus ilex, Pistacia terebinthus of Djebel de Zaghouan

Productivités	**Stadiums**		
	ND	MD	D
PS (kg MS ha- 1 an-1)	449,78±150,45a	251,34±94,05b	96,59±41,52c
PV (kg MS ha- 1 an-1)	428,97 ±113,70a	250,16±88,13b	96,95±42,54c
PVS (kg MS ha- 1 an-1)	449,15±46,03a	256,38±39,12b	96,08±13,55c

The values in the same row with the same letters are not significantly different at the 5% level. ND: undegraded stage; MD: moderately degraded stage; D: degraded stage. PV: productivity determined from the biovolume; PS: productivity obtained by the crown projection surface parameter; PVS: productivity as a function of volume and surface.

4 DISCUSSION

The biomass of the samples was calculated using allometric relationships established from data from sample shrubs. To do this, six representative individuals of each species at the study station were slaughtered. The regression equation obtained for the species was applied to all individuals. The total above-ground biomass can be determined from the ellipsoid surface using linear and polynomial allometric relationships. Baudin (1985) indicates that the regression equation makes it possible to obtain a good appreciation of phytomasses as a function of volumes. The variation in the number of individuals sampled by species (Table 1 and 2) can be explained by the heterogeneity of the floristic composition of the stations studied and also by the size of the station which was 400 m2 for this study. The size of the plot was rather variable (between 100 m2 and 10,000 m2), taking into account the structure and distribution of the species studied (Blanco and Navarro, 2006). Suganoma et al. (2006) chose a fixed but larger plot size (1000 m2). Likewise, Navar et al. (2004) worked on samples of 20 shrubs per species in a plot with an area of 1000 m2.

The growing aerial phytomass of the studied species has also been modeled in numerous studies (Etienne, 1989; Blanco and Navarro, 2003; Sebei et al., 2008). The number of individual samples used per species varied according to the authors. Blanco and Navarro (2003) used 50 individuals of Calycotome villosa, 40 of Cistus monspeliensis, 35 of Phillyrea latifolia, 30 of Pistacia lentiscus and 20 of Rosmarinus officinalis. Paton et al. (1998) employed 21 individuals of Cistus salvifolius

In this work, some species did not reach a sufficient number of observations, which is of the order of 10 (According to Blanco et al., 2003). This insufficient number of individuals is partly due to the low dominance of these species in the stations studied. Comparison of the regression equations developed in this study with those of other studies (Navar et al. 2004, 2006; Blanco and Navarro, 2003; Castro et al., 1996; Sebei et al, 2001, 2004, 2008; Laamouri et al. al., 2002; Wang, 2006; Armand et al., 1993; Montes et al., 2000) reflected a difference in the type of equation used. Thus, in this study most of the equations used are of linear type.

In this work, the individuals of the studied species were assimilated to an apparent biovolume, then a relationship was established between this independent variable and the total aerial phytomass on the stand. This technique is frequently used in the study of the phytomass of shrubs (Sebei et al., 2008; Snowdon et al., 2000; Blanco et al., 2003; Etienne, 1989). In similar work by Cruzado and Soalleiro (2011), the elliptical morphotype was adopted. Johanaton (2004) and Montes et al. (2000,1999) used the cylindrical morphotype for all species studied. Finally, Laamouri et al. (2002) assimilated the volume occupied by the shrub to a regular parallelepiped. Another technique different from that of the biovolume, and which could give similar results in the modeling of the growing aerial phytomass, according to the diameter of the stem (Sampio et al., 2009; Wang, 2005). With this technique, there is no need to define the morphotype beforehand and only one equation can be developed in order to estimate the total aerial phytomass standing or a component of this phytomass for a species that exhibits different morphotypes. Regarding the comparison of results from each regression method, this study showed that overall, the regression gave the best fit with high coefficients of determination. In this study, the coefficients of determination R2 varied between 0.5 and 1. In the study by Blanco and Navarro (2003), these coefficients of determination varied, R2 varied between 0.751 and 0.989. Laamouri et al. (2002) reported R2 coefficients greater than 0.7.

This difference can be explained above all by the number of individuals sampled by species and also by the study sites with individuals that show great variability in size and aerial phytomass on the ground.

The results of the total above-ground biomass showed a great variability in the biomass values which can be attributed to the age of the shrubs. Sebei et al. (2004) showed a strong increase in the increase in biomass with the age of plants. The variation in biomass distribution may also be due to organ size and with species (Sebei et al., 2001). Thus, Benzyane and Khatouri (1991), Cabanettes and Rapp (1978) have shown that for a medium-sized branch, the leaves retain a biomass of 7% in cork oak and pinion pine and 6% in the argan tree. This variability would be due to the density, climatic and edaphic characteristics of the site (Lemée, 1978; El Mokni et al., 2009). The low number of individuals of the species could also influence the biomass (El Mokni et al., 2009). Estimating the dry matter production of a plant community is still difficult and imprecise.

The evaluation of the compartmental (stems, leaves and twigs) and total productivities of the Quercus ilex and Pistacia lentiscus grouping of the Zaghouan National Park according to the state of degradation of the sites showed that the productivities differ significantly (p <0, 05) from one site to another depending on the state of degradation.

In the present study, the average productivity was estimated by dividing the biomass by the lifespan of the maquis of the Djebel Zaghouan forest, estimated at 20 years.

The total productivity in our plots was estimated at 96.59 to 449.78 kg DM ha-1 yr-1 (Table 8). Sebei et al. (2008) showed that the annual phytomass of the scrub of the Ain Snoussi forest during the age period of 78-87 was approximately 2702.476 kg DM ha-1 yr-1. This value is considerably higher than what we found in our study. Indeed, the low productivity observed in our study could be attributed to the low useful water reserve of the soil and / or to the poor fertility of this site (Bouchon, 1974; Sebei et al., 2004). It may also be due to the seasonal poor distribution of precipitation in Djebel Zaghouan. By evaluating the above-ground and below-ground phytomasses of trees and the above-ground phytomass of cork oak (Quercus suber) shrubs in Ain Snoussi, Sebei et al. (2008) found low phytomass values compared to those found in Spain. They attributed the good phytomass production obtained by them to the humid climate and the good seasonal distribution of precipitation in the study area. On the other hand, our values are clearly higher than those of trees aged 58 and 166 years, whose annual phytomass was estimated at 19.743 and 27.790 kg DM ha-1.year-1 respectively (Sebei et al., 2008).

It is also noted that the productivity of the stems is markedly increased between the site in good condition and the degraded site at the expense of the other organs.The productivities of plant species register decreasing values according to the sequence of degradation. The differences could be attributed to the intrinsic characters and the abundance of the species at each site, to the characteristics of the sites (degradation) but also to the fertility of the site. Indeed, Sebei et al. (2004; 2008) have shown that in a forest ecosystem of Kroumirie the stored phytomass depends mainly on the type of forest and its age. Degraded plots were characterized by an increase in the number of puny individuals of the species. These modifications could be a consequence of overgrazing following the reduction of vigorous shrubs (Sebei et al., 2001; 2004) which has led to a decrease in the biomass produced in this site, and therefore the drop in aerial productivity.

5 CONCLUSION

The non-destructive techniques used to assess aerial phytomass at the individual and plot scales give a very interesting assessment.

The biometric values retained (height, small and large crown diameters) are explanatory variables of the individual biomasses of the shrub species in the plots studied. The regression equations relating the growing aerial phytomass to the apparent volume and to the crown surface and to these two parameters taken together have shown a strong relationship. Individual aerial phytomasses varied significantly from species to species and from plot to plot. The variation of the phytomass at the level of the preserved stage is lower in comparison with the stations of Kroumirie, which attests to a degradation by a high overgrazing. This state of vegetation encourages more vigilance and more rigorous conservation of all environments of Djebel Zaghouan.

The degree of cover is strongly correlated with above-ground biomass at the plot scale. This degree of recovery and the above-ground biomass are explanatory parameters of the degradation stage. The biomasses obtained by these three models do not differ if we limit ourselves to a well-determined degradation stage, hence the reliability of these adjustments of the equations. In the 25 study plots, the above-ground biomasses differ according to the stage of degradation. In degraded sites (recovery rate: R <20%), the biomasses record very low and variable values, hence defending is necessary. In moderately degraded stations (20% <R <35%), the plants show average vigor with a biomass equivalent to half that of the conserved site. Stations in good condition (recovery rate R> 35%) show better healthier plants with a different phytosociological composition from those in the degradation stages.

The primary productivities of these media vary according to the degradation sequence. Primary productivity in the conserved site remains low (0.5t.ha-1.year-1) compared to what was reported in the Kroumirie-Mogod region. The degradation of the environment marked these productivities even more.

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