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# EVALUATION OF THE BIOMASS OF THE GREEN OAK (QUERCUS ROTUNDIFOLIA) OF THE CENTRAL MIDDLE ATLAS: CASE OF THE SOUTH JBEL AOUA FOREST (MOROCCO)

**Mohamed EL MDERSSA**[1+]
**Hassan BENJELLOUN**[2]
**Omar ZENNOUHI**[3]
**Laila NASSIRI**[4]
**Jamal IBIJBIJEN**[5]

[1,3,4,5]*Faculty of Sciences-Moulay Ismail University - B.P. 11201 Zitoune-Meknes, Morocco*
[1]*Email:* elmderssa.enfi@gmail.com
[3]*Email:* omar.zennouhi@gmail.com
[4]*Email:* nassiri_layla@yahoo.fr
[5]*Email:* jamal_ibijbijen@yahoo.fr
[2]*National Forestry Engineering School –Sale-Tabriquet Morocco Couriel, Morocco*
[2]*Email:* benjellounenfi@gmail.com


*(+ Corresponding author)*

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## *ABSTRACT*

The present study is carried out on the green oak forest of Jbel Aoua South, in the Central Middle Atlas. The objective of this work is to estimate the dry biomass of these stands while characterizing this zone in terms of soil and floristic potential. According to the results obtained, the estimated biomass production is 42,70t/ha, based on 30 sample trees using the dimensional analysis method, or an energy equivalent of 192.15$10^{6}$ kcal/ha, which represents a potential income of 3260 to 3586 DH/ha/year. The forage value of the green oak in the forest of Jbel Aoua South is 372 FU/ha. The soil studied is of the para-rendzine carbonate type with a sandy loamy texture, rich in potassium and moderately low in phosphorus.

**Contribution/Originality:** This study is one of the very few studies which have investigated the matter of estimating the forest biomass of green oak forests in Morocco. This reality is leading to a growing interest in carbon sequestration projects based on woody species that store it in their biomass.

## 1. INTRODUCTION

The Green oak occupies an important place in the Mediterranean basin, especially in its western part. This has led some botanists to use its range or that of its related associations to delimit the Mediterranean region [1]. It shows very high potential and adaptability in the Mediterranean climate context [2]. It can survive with a minimum rainfall of 250 mm and withstand thermal extremes of -15°C and +42°C [3, 4]. On the edaphic level, it is indifferent to the chemical nature of the soils except perhaps for the fine swampy silts of podzols which constitute an unfavorable environment.

In Morocco, the target area made one and a half million hectares [5] and extended over a considerable space in the country's forest area. It forms the bottom of the Moroccan forest ornament.

The Green oak forests of the Central Middle Atlas play an essential economic, social and ecological role. They produce large quantities of firewood and constitute a crucial grazing area for pastoralists in this region [6]. In some places, these forests also attract bunches of tourist sites, housing diversified recreation and leisure activities and providing effective soil protection against erosion on sloping land [7].

The Green oak, as an energy and forage resource, has attracted the attention of several researchers. Rondeux [8] considers that knowledge of an ecosystem's energy resources necessarily requires knowledge of biomass.

To ensure the sustainability of the Green oak and taking into account its important contribution in the forage balance of the ecosystems of the Moroccan Middle Atlas, a rational management is necessary; therefore, an evaluation of the biomass potential of this species is essential. The objective of this study is to evaluate Green oak biomass in the forest of Jbel Aoua South by developing biomass tariffs at one and two entrances, estimating biomass in respect of its energetic potentiality, the forage balance in terms of green oak leaf biomass and developing a typology of this region in terms of soil and plant characteristics.

## 2. MATERIALS AND METHODS

The study was conducted in plot 73 of the Jbel Aoua South forest (Figure 1). The geological structure of the area under study is very complicated with numerous repetitions of the middle Lias, limestone and dolomitic layers. Two types of soils are described in the region, namely red fersiallitic soils on limestone and dolomitic limestone and para-rendzine soil on sandy dolomite [9]. The average annual rainfall ranges from 537 mm to 1122 mm and the minimum temperatures from -4.9° C to -1.3°C, and the maximums range from 29.5°C to 32.5°C. The seasonal regime is Winter-Spring-Summer (H.P.A.E). With regard to snow, the studied area records 20 days of snow annually on average and 50 to 100 days of frost as an indication [6].

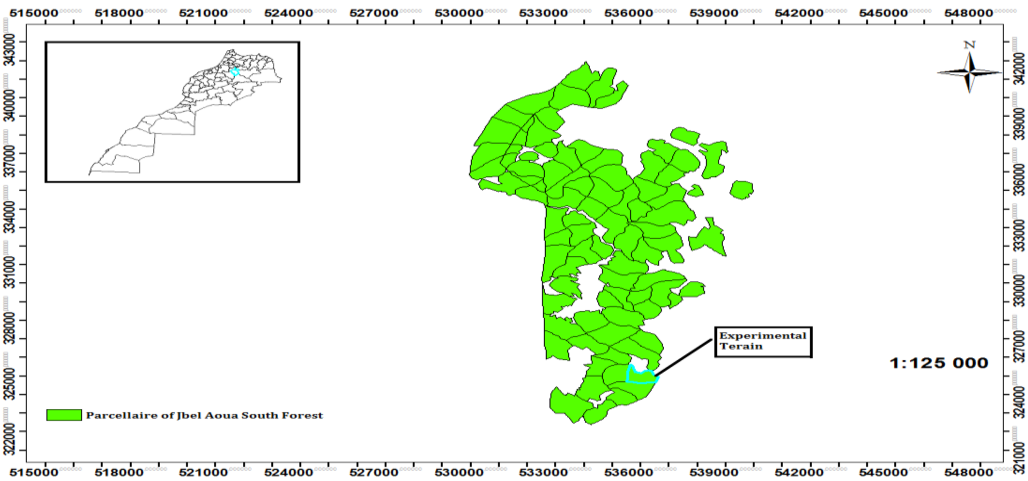


**Figure-1.** Studied area map

Concerning the inventory of the environment and vegetation, data collection was done according to the following steps:

- The transcription of the topo-climate factors of the studied area: Altitude, average slope, exposure, topographic position;
- The elaboration of an exhaustive floristic list of all plant species at the experimental terrain;
- Opening a soil pit for a detailed morphological description of the soil characteristics and taking soil samples (250 g) for physical and chemical analyses in the laboratory.

The Physical and chemical analyses were carried out on:

- Soil grain size: the percentage of clays silts and sands.
- Chemical analysis which concerns the following elements: Nitrogen (N), Carbon (C), C/N ratio, $P_2O_5$, $K_2O$ and percentage of organic substance.

The techniques used for physical and chemical soil analyses are those adopted by the Rabat Forest Research Centre (CRF).

Estimating biomass is a hard operation and often faces two difficulties: one strictly related to the amount of work required to establish individual biomasses, the other concerns the extrapolation of individual results to the entire stand, which implies the felling of a significant number of trees [10].

Based on the work done by Belghazi and Ezzahiri [10] we retained the semi-destructive or dimensional analysis method in the determination of biomass. The method consists of uprooting 30 sample trees weighted by circumference classes. On fallen trees, the measurements taken are:

### Dendrometric Measurements

- Complete inventory of the circumferences at 1.30 m from the ground of all trees inside the experimental terrain;
- Measurements of the circumferences at 1.30 m from the ground and the total heights of the fallen trees;

### Weight Measurements

The different parts of each tree (trunk, branches, and leaves) were separated. Weighing concerns: 

- The total weight of the trunk up to the cutting 5cm of circumference and branches in (Kg) using a spring scale (Poket Balance) with an accuracy of one kilogram (1Kg);
- The total weight of the leaves using an electronic scale with an accuracy of one gram (1g).
- At the end of these weightings, we took a sample:
- At the trunk level, three circles of 2 cm thick washers; one at the base, another at mid-length and one at the cutout 5 cm;
- At the level of the average branch of each tree, a washer of 3 cm thick at mid-length;
- At leaf level, a sample of about 100 grams of each tree.

The washers and leaves sample was put into oven bags in the laboratory and weighed dry.

For the evaluation of the humidity of the various tree components, the dried out weight is used. Indeed, the water content varies according to the seasons and even throughout the day. To determine the dry weight of the samples undertaken, we steamed them for 24 hours at respective temperatures of 105°C for wood and 65°C for leaves [10]. Consequently, the humidity (TH %) and dry weights were calculated according to the following formula:

$$TH\ \% = \frac{PF - PS}{PS}\ 100$$

**TH%:** Humidity of the sample in percent;

**PF:** Fresh sample weight;

**PS:** Dry weight of the same sample.

To determine the plant biomass of forest species, two types of mathematical models were used: single-entry mathematical tariffs and two-entry tariffs.

The models presented below are commonly used to assess forest species biomass [11]:

- **Biomass tariffs at one entrance:**

  $PS = a_0 + a_1\ C$

  $PS = a_0 + a_1\ C^2$

  $PS = a_0 + a_1 C + a_2\ C^2$

  $PS = a_0\ C^{a1}$

- **Biomass tariffs with two entrances:**

  $PS = a_0 + a_1\ H\ C^2$

  $PS = a_0 + a_1\ C + a_2\ H\ C^2$

  $PS = a_0\ C^{a1}\ H^{a2}$

With:

**PS:** dry weight;

**C:** Circumference at 1.30 m from the ground in (cm);

**H:** Shaft height;

**ai (i = 0, 1, 2):** Regression coefficients to be estimated.

The best model is one that meets the following conditions:

- **The coefficient of determination ($R^2$)** which reflects the part of the variation explained by the model, the best model is the one with the highest $R^2$;
- **The residual standard deviation (σr)** which represents the dispersion of residues around the mean, the best model is the one with the smallest σr;
- **FISCHER test (F):** The calculated value of F must be significant, which means that the independent variables explain the dependent variable well [11].
- **Furnival Index (IF):** Any transformation of the explained variable, such as logarithmic transformation, changes the distribution of the residues and the models cannot be directly compared by $R^2$ and σr to judge their quality. Rondeux [8] proposed s an adjustment index based on the concept of maximum likelihood and valid whatever the type of equation used. The best model is the one with the lowest FI.

$$IF = \frac{\sigma r}{[f'(vi)]1/n}$$

**-σr:** Residual standard deviation;

**-f ' (yi):** first derivative of f (yi) relative to y;

**-yi:** dependent variable;

**-n:** number of observations.

If the dependent variable has not undergone any transformation, it is easy to check that this index is equal to the residual standard deviation.

- **Residue analysis** is used to verify the equality of variances, the normality of remains and the absence of auto-correlation of residues. In the conducted study, we tested these assumptions using the graphical method.
- **Durbin-Watson Statistics (index d),** is a statistical test designed to test the autocorrelation/independence of residues in a regression model. According to the Durbin-Watson table, a value below 2 indicates a positive correlation between successive residues and a value above 2 corresponds to a negative correlation between residues. However, a value close to 2 does not reject the hypothesis of independence of the residues [12].

Consequently, the dry biomass of each organ of the tree was estimated by the tariffs used.

Biomass, cultivated or raised by humans, is supposed to renew itself after each use. Biomass is, therefore, a renewable source of energy as long as farming and forestry systems are sustainable and responsible.

Forest biomass is among the most promising energy sources compared to non-renewable energy shortages. The disadvantage of the biomass worth in t/ha is that similar amounts of different biological materials do not necessarily have the same energy value (calorific value). It is thus appropriate to reduce the organic content produced to a common unit which is the calorie (amount of heat required to raise the temperature of one gram of water by 1 degree centigrade).

The conversion table given by Briane [13] and presented in table 01 was used to convert the forest biomass of the green oak stand into energy.

**Table-1.** Calorific value (CP) of some fuels at the experimental terrain of the South of Jbel Aoua. forest

| Fuel | CP en (Kcal/Kg) | CP en (Mj/kg) |
|---|---|---|
| Dry wood | 4500 | 18,8 |
| Dry leaves | 4700 | 19,64 |
| Charcoal of wood | 7000 à 7500 | 29 à 31 |
| Oil | 10000 à 11000 | 42 à 46 |
| Peat | 5000 | 20,9 |
| Pure Carbon | 8100 | 34 |

**Source:** Briane [13]

Moreover, the green oak forests of the Middle Atlas are an essential forage source for the user populations and an indispensable component in the restoration of the agro-sylvo-pastoral balance. Qarro, et al. [14] recommended that the "Arbre-Herbe-Animal" balance is necessary to maintain and develop forest and sylvopastoral resources.
The study of these aspects is based on the estimation of the forage value of the foliar phytomass of the green oak forest of Jbel Aoua South, which is evaluated on the basis of 0.1 UF per kg of dry matter [15].

## 3. RESULTS AND DISCUSSIONS

The statistical study (Figure 2) revealed that the structure of the sample trees is uni-modal and is homothetic to the stand structure.

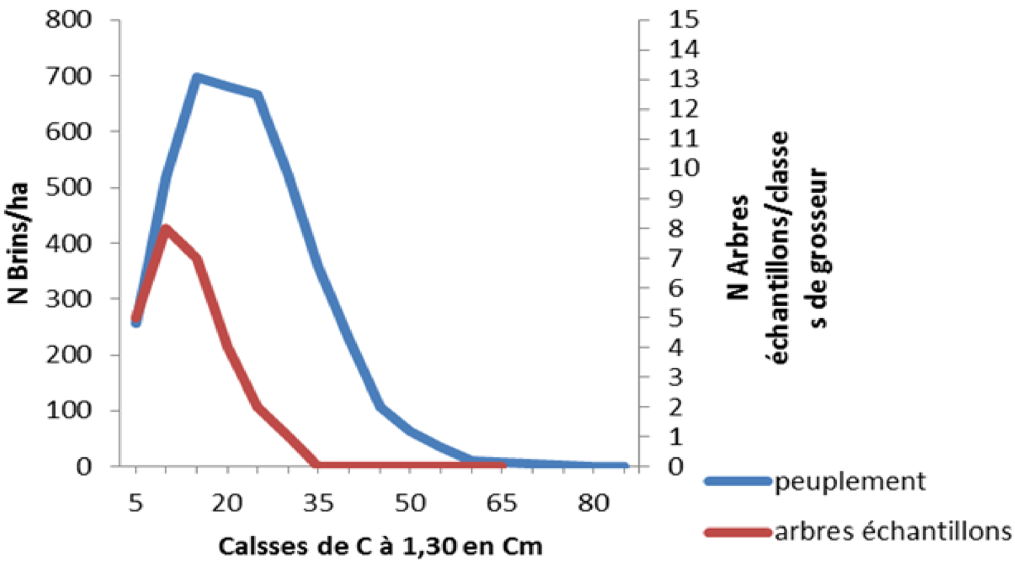


**Figure-2.** Structure of sample trees

The outcomes of the moisture calculation for each tree component are recorded in table 2. Indeed, we notice an increase in humidity from the trunk towards the leaves. Compared to the holm oaks of the Central Plain [16] humidity levels are slightly higher (55.7%, 59.2%, and 70.7% respectively for trunk, branches and leaves).

**Table-2.** Average humidity of each shaft component after steaming

| | Trunk | Branches | Leaves |
|---|---|---|---|
| Steaming temperature (°C) | 105 | 105 | 65 |
| drying time (hours) | 24 | 24 | 24 |
| Average humidity (%) | 56,2 | 63,6 | 72,1 |

The biomass rates at one entry express the relations between the dry weight of the trunk (PSTr), branches (PSB), leaves (PSF) and the whole tree (PST) and the circumference at 1.30 m from the ground (C1.30). The results of the estimation of the models using the linear regression technique and their statistical analysis are shown in table 3.

**Table-3.** Single entry biomass tariffs for sample trees and their statistical analysis

| Component | Adjusted models | $R^2$(%) | Sr | IF | d | F |
|---|---|---|---|---|---|---|
| Whole tree | $PST = -20{,}985 + 1{,}4\ C$ | 90 | 4,97 | 4,97 | 1,41 | 251,98 |
| | $PST = -1{,}413 + 0{,}019\ C^2$ | 94,8 | 3,59 | 3,59 | 1,18 | 506,31 |
| | $PST = -1{,}034 - 0{,}022\ C + 0{,}02\ C^2$ | 95,1 | 3,54 | 3,54 | 1,08 | 262,21 |
| | **$PST = 0{,}0137\ C^{2{,}069}$** | **91,2** | **0,21** | **0,19** | **1,52** | **290,96** |
| Trunk | $PSTr = -20{,}858 + 1{,}162\ C$ | 90,5 | 3,99 | 3,99 | 1,37 | 268,27 |
| | $PSTr = -1{,}635 + 0{,}016\ C^2$ | 92,5 | 3,50 | 3,50 | 1,10 | 258,69 |
| | $PSTr = -3{,}726 + 0{,}124\ C + 0{,}01 C^2$ | 92,8 | 3,55 | 3,55 | 1,12 | 173,73 |
| | **$PSTr = 0{,}00695\ C^{2{,}190}$** | **90,3** | **0,23** | **0,20** | **1,20** | **259,91** |
| Branches | $PSB = -5{,}654 + 0{,}236\ C$ | 64 | 1,88 | 1,88 | 1,46 | 49,84 |
| | $PSB = -2{,}044 + 0{,}003\ C^2$ | 76,6 | 1,49 | 1,49 | 1,63 | 95,76 |
| | **$PSB = 8{,}931 - 0{,}648\ C + 0{,}012\ C^2$** | **91,3** | **0,91** | **0,91** | **2,30** | **153,90** |
| | $PSB = 0{,}00262\ C^{1{,}979}$ | 74,2 | 0,56 | 0,53 | 2,16 | 53,84 |
| Leaves | $PSF = -0{,}68 + 0{,}094\ C$ | 60,9 | 0,81 | 0,81 | 1,39 | 43,58 |
| | $PSF = 0{,}781 + 0{,}001\ C^2$ | 71,2 | 0,68 | 0,68 | 1,41 | 72,55 |
| | **$PSF = 3{,}621 - 0{,}227\ C + 0{,}004\ C^2$** | **81,4** | **0,55** | **0,55** | **1,63** | **64,52** |
| | $PSF = 0{,}00406\ C^{1{,}579}$ | 69,1 | 0,72 | 0,71 | 1,76 | 13,61 |

**$R^2$**: Coefficient of determination
**σr :** Residual standard deviation.
**IF**: Furnival Index.
**d**: Coefficient of DURBIN-WATSON.
**F**: FISCHER value
**PSTr** : Dry weight of trunk in (Kg)
**PSB**: Dry weight of branches in (kg).
**PSF**: Dry weight of leaves in (kg).
**PST**: Dry weight of the whole tree in (kg).
**C**: The circumference at 1.30 m from the ground

By adjusting the above statistical models based on the values of the parameters mentioned in the methodology, for the varied components of the tree, the related outcomes are as follows;

**$PSTr = 0{,}00695\ C^{2{,}190}$** for the trunk ;

**$PSB = 8{,}931 - 0{,}648\ C + 0{,}012\ C^2$** for the branches;

**$PSF = 3{,}621 - 0{,}227\ C + 0{,}004\ C^2$** for the leaves;

**$PST = 0{,}00968\ C^{2{,}133}$** for the whole tree.

For the biomass tariffs with two entrances, they give the dry weight of the whole tree according to the circumference at 1.30 m from the ground and the total height of the tree. These rates are shown in table 4.

**Table-4.** Biomass tariffs with two entries for sample trees and their statistical analysis

| Models | $R^2$(%) | σr | IF | d | F |
|---|---|---|---|---|---|
| $PST = 3{,}245 + 0{,}003\ C^2H$ | 95 | 3,56 | 3,56 | 1,89 | 529,56 |
| **$PST = -0{,}848 + 0{,}349\ C + 0{,}002\ C^2\ H$** | **95,4** | **3,48** | **3,48** | **1,92** | **277,25** |
| $PST = 0{,}0164\ C^{1{,}774}\ H^{0{,}566}$ | 93,5 | 0,18 | 0,17 | 2,26 | 193,36 |

**$R^2$**: Coefficient of determination
**σr :** Residual standard deviation.
**IF**: Furnival Index.
**d**: Coefficient of DURBIN-WATSON.
**F**: FISCHER value
**PSTr** : Dry weight of trunk in (Kg)
**PSB**: Dry weight of branches in (kg).
**PSF**: Dry weight of leaves in (kg).
**PST**: Dry weight of the whole tree in (kg).
**C** : The circumference at 1.30 m from the ground
**H** : The total tree height in (m)

Based on the above statistical criteria, the model judged to be the most efficient of the three models tested is the following:

$$PST= -0,848 + 0,349\ C + 0,002\ C^2\ H$$

The application of the biomass rates used for each organ of the tree, and for the whole tree enabled us to estimate the total dry biomass per hectare. According to table 05, the average total biomass per hectare is about 42.70 t at age 30. The share of each organ (trunk, branches, and leaves) in this biomass is 72.18%, 19.11% and 8.71% respectively.

**Table-5.** Total biomass per hectare per component of tree in (t/ha)

| Component | Biomass in (t/ha) |
|---|---|
| Trunk | 30,82 |
| Branches | 8,16 |
| Leaves | 3,72 |
| Whole tree | 42,70 |

The comparison of biomass values with others obtained in other regions of Morocco showed that except for the forests of Tafchna and Regadda in the Middle Central Atlas [17] the green oak forest of the studied area has considerable biomass potential, compared to other stands of similar ages (Table 06). This can be explained, probably, by the high density of the studied stand as well as by the ecological conditions of the forest of Jbel Aoua South which are more favorable than those of the other Moroccan forests considered.

**Table-6.** Biomass of some holm oak studied in Morocco

| Studied area | author | Biomass (T/ha) and age of holm oak | | | | | |
|---|---|---|---|---|---|---|---|
| | | Trunk | Branches | shoots | Leaves | whole | Age |
| **Central Middle Atlas** (forest of Tafchna) | Boulmane [17] | - | - | - | - | 96 | 30 |
| **Central Middle Atlas** (forest of Regadda) | Boulmane [17] | | | | | 86,4 | 30 |
| **Central Middle Atlas** | Makhloufi [15] | 12,56 | 3,64 | 2,95 | 1,50 | 20,65 | 41 |
| **Eastern Middle Atlas** (experimental terrain of Bab Bou Ider) | Lahmini [18] | 9,93 | 1,49 | 3,09 | 1,99 | 16,50 | 22 |
| **Central Middle Atlas** (experimental terrain of Dayat Aoua) | Moussaoui [19] | -- | -- | -- | -- | 24,30 | 28 |
| **Central plain** (forest of Ait hatem) | Aoid [20] | 13,07 | 7,37 | 2,05 | 1,97 | 24,90 | 32 |
| **Central plain** (experimental terrain of Boukachmir) | Dahane [16] | 24,55 | 14,22 | | 1,47 | 40,24 | 46 |

Similar studies conducted in some holm oak groves around the Mediterranean [21] show that, except for the Oued yagoub massif in Algeria where the biomass is only 9.29 t/ha, holm oak groves on the northern shore of the Mediterranean, particularly in France and Italy (Table 07), have more remarkable biomass of this species (65 to 150 t/ha).

**Table-7.** Biomass of some holm oak studied in the Mediterranean basin

| Author | Studied area | Country | Age | Biomass in t/ha |
|---|---|---|---|---|
| Zitouni [21] | Forest of ouled yagoub | Algeria | 27 | 9,29 |
| Leonardi and Rapp [22] | Mte Minardo | Italy | 31 | 150 |
| Floret [23] | Puéchabon | France | 41 | 65 |
| Miglioreti [11] | Rians | France | 5-30 | 81 |

The estimate of the energy equivalent of green oak biomass in the forest of Jbel Aoua South is given in table 08.

**Table-8.** Energy equivalent of the average biomass of the different components of the holm oak tree

| Component | Biomass (t/ha) | Energy equivalent ($10^6$ kcal/ha) | Equivalent in coal (t/ha) | Equivalent in fuel (l/ha) |
|---|---|---|---|---|
| Trunk | 30,82 | 138,69 | 18,49 à 19,81 | 13 869 à 15 256 |
| Branchs | 8,16 | 36,72 | 4,90 à 5,24 | 3672 à 4039,2 |
| Leaves | 3,72 | 16,74 | 2,23 à 2,39 | 1674 à 1841,4 |
| Whole tree | 42,70 | 192,15 | 25,62 à 27,45 | 19 215 à 21 136,5 |

This table shows that the forest of Jbel Aoua South produces 192.15 $10^6$ Kcal/ha, equivalent to 19215 to 21136.5 l/ha of fuel oil or 120.04 to 132.04 barrels/ha of crude oil, corresponding to a production of 4 to 4.4 barrels/ha/year. If we take into account the current value of a barrel of crude oil which is of the order of 815 DH, this forest can generate a potential income of 3260 to 3586 DH/ha/year.

The contribution to livestock production in forests is generally very important and can greatly exceed wood production. Table 09 represents the forage equivalent of the studied forest. This table shows that this value is relatively high, in comparison to others found by Boulmane [17] in the forests of Tafechna and Reggada in the Middle Central Atlas which are of the order of 221 UF/ha and 259 UF/ha respectively. This improved production could be linked to the favorable climatic conditions in the Ifrane area, which receives more than 1000 mm of rainfall annually, which conditions a favorable water balance in the soil and significant foliation of trees. The high density of the studied stand also contributed to the improvement in this forage value. Moreover, if this production is taken into account, it cannot meet the needs of the plethora of herds that spend more than four months a year in the forest during the dearth period.

**Table-9.** Forage value of pure holm oak from the Jbel Aoua forest

| Leaf biomass (t /ha) | Age (an) | Forage value (UF/ha) |
|---|---|---|
| 3,72 | 30 | 372 |

For more information on the soil studied and to understand its qualities, morphological and physico-chemical characteristics were studied.

**Description of the Station**

- Zone: Middle Central Atlas
- Location: South Jbel Aoua Forest
- Topographic position: High slope
- Parent material: Sandy Dolomite

Natural vegetation (or planting): Young evergreen oak, cedar and juniper oxycedar coppice.

- Vegetation: Association arbuto unedo-quercetum rotundifoliae.
- Slope: 20%.
- Exposure: Northeast (NE)
- Elevation: 1820 m
- Climate: Subhumid to very cold variant
- Land use: Forestry and Pastoral

### 3.1. Morphological Description of the Profile

The morphological description of the profile studied is shown in table 10.

**Table-10.** Morphological description of the soil studied at the level of the experimental terrain of the forest of Jbel Aoua South

| Soil horizon | Depth (Cm) | Description |
|---|---|---|
| L | 6,5-4,5 | Undecomposed litter. The transition is straight and very sharp. |
| F | 4,5-4 | Litter partially decomposed. The transition is straight and very sharp. |
| H | 4-0 | Dark brown (10YR 3/3) when dry, black (10YR 2/1) when wet. The transition is very diffuse. |
| $A_1$ | 0-30 | Dark yellowish brown (10YR 3/4) when dry, very dark brown (10YR 2/2) when wet. The texture is sandy. The structure is quite lumpy. Consistency: no plasticity and poor cohesion. Very porous. Coarse roots are rare, horizontal and oblique, medium roots are rare and without specific orientation, and hairs are medium and without specific orientation. HCL effervescence is low. The transition is strongly undulated and net limit |
| C | 30-70 | Mother rock sandy dolomite. Presence of altered dolomitic rocks. |

**Soil Classification**

- **Class:** Calcimagnetic soil;
- **Under class:** Carbonate with sandy dolomite;
- **Group:** Pararendzine ;
- **Subgroup:** Weakly humiferous.

### 3.2. Soil Physical and Chemical Analysis

The results of the soil physical and chemical analysis are summarized in table 11.

**Table-11.** Soil physical and chemical analysis

| Soil horizon | $P^H$ $H_2O$ | $P^H$ KCl (1 N) | Clay (%) | Silt (%) | | Sand (%) | | M O (%) | C (%) | N (%) | C/N (%) | $P_2O_5$ (ppm) | $K_2O$ (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | F | G | F | G | | | | | | |
| **$A_1$** | 7,68 | 7,36 | 5 | 10 | 32 | 51,8 | 1,2 | 3,05 | 1,79 | 0,20 | 8,95 | 22,41 | 127,8 |
| **C** | 8,03 | 7,87 | 0 | 0 | 15 | 83,3 | 1,7 | 0,55 | 0,32 | 0,03 | 10,7 | 23,49 | 55,6 |

F: Fine G: Gross MO: Organic substance C: Carbon N: Nitrogen

Analysis of this table has indicated that the target soil has a slightly alkaline pH for both A1 and C horizons, indicating good biological activity at both horizons. The Soil grain size analysis pointed out that the soil is rich in sand (53% and 85% respectively for the A1 and C horizons, of which 98% are fine sands and 2% coarse sands for both horizons).

The texture is loamy sandy for the A1 horizon and sandy loam for the C horizon.

The organic matter rate was 3.05% in horizon A1 with a decrease of 82.12% towards horizon C (0.55%). Rendzin or para-rendzin soils are known by a blockage or concentration of organic parts in the A1 surface horizon [24].

The C/N ratio, whose values of 8.95% for the A1 horizon and 10.7% for the C horizon are less than 16, which indicates, according to Bonneau [24] standards, that the mineralization process outweighs the nitrogen N immobilization process.

Meanwhile, while applying these standards, the soil studied is characterized by good potassium fertility and phosphorus poverty in the A1 horizon (respectively 0.33 meq/100g and 0.022 per thousand).

## 4. CONCLUSION

The objective of this work is to evaluate the standing biomass within an experimental terrain installed in the forest of Jbel Aoua South, on an area of one hectare. The results of this study show that:

- The biomass of green oak in this forest is around 42.70 t/ha. This value reflects the good performance of green oak in this forest compared to other green oak forests in Morocco. This biomass of the studied massif can be improved by the application of rational silviculture;

- The energy equivalent of this woody production is 192.15 106 kcal/ha or 25.62 to 27.45 t/ha in coal or 4 to 4.4 barrels/ha/year of crude oil if we take into account the age of the stand (30 years), which represents a potential renewable income of about 3260 to 3586 DH/ha/year ;
- Concerning the forage value of the green oak forest of Jbel Aoua South, which is of the order of 372 UF/ha contributes to covering the forage needs of the grazing livestock in this forest, but it requires a preservation against the uncontrolled practices of delimbing and dehusking, the products of which will be used as supplementary fodder for the livestock. These ill practices lead to the physiological weakening of trees, leading at a long-term to a reduction in density and forest coverage.

Consequently, a regulation of the grazing process in this zone and an organization of the user population of the forest of Jbel Aoua South for a sustainable use of pastoral resources, through the practice of participatory silvicultural pipes (depressing by the population) allow these populations to benefit from the forage units necessary for their herds.

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