

# Diagnostic of Atlas cedar in the forest of Djebel El Ouahch (north-eastern Algeria)

## Author's Details:

M. Rached-Kanouni<sup>1</sup>, A. Hade<sup>2</sup>, A. Boukhelifa<sup>3</sup>, R. Megoura<sup>4</sup>, D. Alatou<sup>5</sup>

<sup>1, 2, 3, 5</sup> Laboratory of development and valorisation of plant genetic resources. Department of Biology and Vegetal Ecology, Faculty of Natural sciences and Life, University Constantine 1, Algeria

<sup>4</sup> Forest Conservation, Constantine, Algeria **Malika Rached-Kanouni** (Corresponding author)

## Abstract

Results from Atlas cedar (*Cedrus atlantica* Manetti) located in the forest of Djebel El Ouahch (north-eastern Algeria) are presented. Dieback and dendrometric parameters (height, diameter, circumference and basal area) are analysed in four stations (S1, S2, S3: Biological Reserve and S4: Kef Lekhel). There are significant differences between stations on survival and the dendrometric parameters. The Atlas cedar of Kef Lekhel is chosen as having the best performances for future afforestation programmes.

**Key words:** Atlas cedar, decline, dendrometric parameters, Djebel El Ouahch

## 1. Introduction

Naturally distributed in the northern African mountain ranges from Morocco (Rif and Atlas) and Algeria (Atlas), the Atlas cedar is an essence that has always attracted significant interest by its many forest qualities: maintaining a biological balance, low flammability, its production of quality wood, and a remarkable aesthetic port (Toth, 1980; M'Hirit, 1994). Outside the natural range, it has been used for afforestation in Mediterranean climates zones (Steinmetz, 1986), mainly in Europe (France, Italy and Spain) with a planting area of 20.000-30.000 ha. The total cedar forest area in Morocco is 132.000 ha and is unequally distributed between the Rif (16.000 ha) and Atlas (116.000 ha), in Algeria the area is about 25.000 ha.

The Atlas cedar can reach 50 m height and 1.50 m DBH. The species is light demanding and cannot stand too much cold and long winters, withstanding summer droughts only when the year precipitation exceeds the 800 mm. Cedar needs siliceous soils, while the carbonatic ones are tolerated when deep and in sufficiently rainy stations. The specie's optimum is located in elevations from 1400 m to 2 000 m a.s.l., with rainfalls from 900 to 1500 mm per year. The young tree has a slender and elegant bearing, as adult shows an expanded crown, without showing the tabular crown typical of the Lebanon cedar, from which it is also differentiated by shorter needles. Bark is light grayish, smooth and brilliant till about 25 years, and then it cracks in small scales (Brunetti *and al.*, 2001). The needles are 15-20 mm long, the cones are green, upright, 8 cm long and with a diameter of about 7.5 cm, then smaller than the Lebanon cedar ones. Mature cones are brown. Seeds are oval and flat, 10-12 mm long, with a 2 cm long wing. The plantula has from 7 to 10 cotyledons.

Although it has relatively wide tolerances with regard to climate and soil type, Atlas cedar is threatened by climatic change, particularly by the projected temperature increase, which will alter soil-water availability and plant evapotranspiration (Cheddadi *and al.*, 2009; Et-tob *and al.*, 2009).

Since the early 1980, severe droughts have been related to Atlas cedar decline and mortality (Bentouati, 2008; Mokrim, 2009; Allen *and al.*, 2010), mainly in the drier mountainous areas near the Sahara (Chenchouni *and al.*, 2008). In addition to these hypothesized climate-driven factors, human perturbation by overgrazing, logging, pruning of lower branches for livestock winter fodder and firewood has led to soil erosion and degradation of the remaining historic forest, resulting in a loss of natural vegetation cover Barbero *and al.*, 1990). Moreover, crown defoliation by processionary caterpillars (*Thaumetopoea bonjeani* and *T. pityocampa*), cedar bark stripping by Barbary Macaques (*Macaca sylvanus*), and damage by cedar bark beetles (*Phaenops marmottani*) seem to have exacerbated the recent Atlas cedar decline (Camperio Ciani *and al.*, 2001).

In some places, the Atlas cedar mortality appears to take place on dry sites (Chenchouni *and al.*, 2008; Et-tobi *and al.*, 2009), affecting mainly old trees. Drought-induced mortality of large trees, as well as the selective logging, pruning and pollarding of these big individuals, trigger the replacement of the original canopy trees by new individuals (Oliver *and Larson*, 1990; Veblen, 1992; Ferris-Kaan *and al.*, 1998). Because altered conditions of light and soil moisture are expected in the gaps caused by tree mortality or logging, compared to canopy conditions, other species with different resource requirements could undergo successful recruitment, with major implications for community biodiversity and dynamics (Condit, 1998; Slik, 2004; Suarez and Kitzberger, 2008; Kelly, *and Goulden*, 2008; Galiano, 2010). Consistent with this scenario, changes in the regeneration pattern of the natural vegetation associated with high

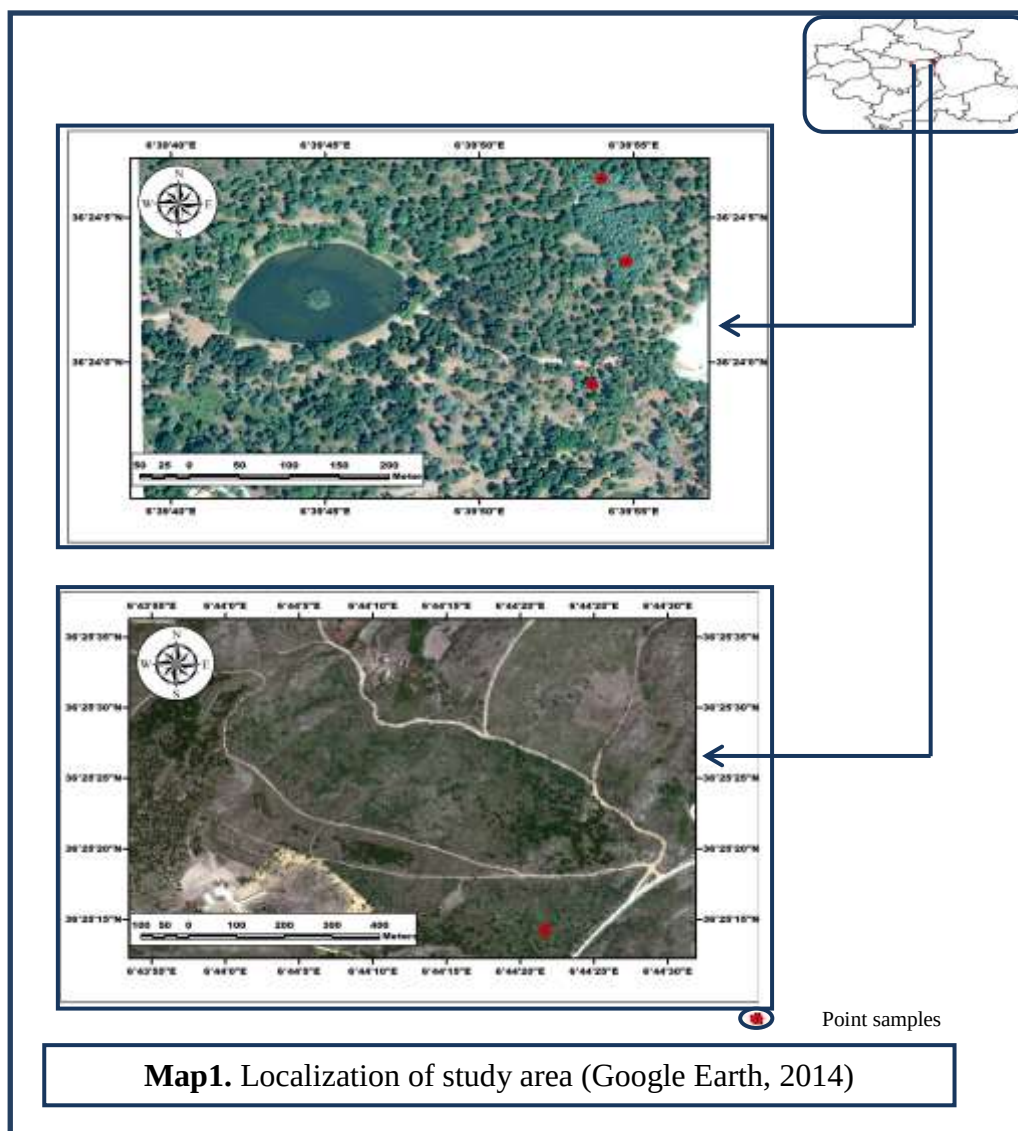
mortality rates of Atlas cedar or intense human perturbation may promote shifts in species composition in these forests (Linares *and al.*, 2011).

Cedar of Djebel El Ouahch's forest (north-eastern Algeria), is currently in the process of decay under the action of a multitude of deterioration factors (recurrent drought, overgrazing, lack of silvicultural treatment), that constantly to weigh heavily on its sustainability and inducing is a real ecological pandemic, slow ecocide. The decline affecting the cedar forest in recent years that require that one is interested in order to try to highlight the deterioration factors for developing a strategy for the preservation of this heritage. Knowing that the affected trees are part of the biological reserve of El Djebel el Ouahch; it is essential to include the study in this framework to reinforce the concept of endangered species.

## 2. Materiel and methods

### 2.1. Presentation of the study area

Our study area is located in Djebel El Ouahch forest which it is located 20 km from Constantine city (east-Algeria). It is located between longitude ( $X_1$ :  $6^{\circ}39'4''E$ ,  $X_2$ :  $6^{\circ}44'30''E$ ) and latitude ( $Y_1$ :  $36^{\circ}24'5''N$ ,  $Y_2$ :  $36^{\circ}25'15''N$ ) (Map 1).



## 2.2. Choice of stations, sampling and data acquisition

### 2.2.1. Choice of stations

Djebel El Ouahch's forest is characterized by topographic variability, edaphic, geological and flora. This multitude of physical factors has created many microclimatic conditions where a difference to the stand level. The choice of stations was dictated by two key imperatives: the station must be uniform in terms of density and being in a "forest atmosphere" (Rathgeber *and al.*, 2004); also, the chosen site must be understood as a ranger station, homogeneous on topographic climatic, edaphic plans and provides the same industry during their period of development.

### 2.2.2. Sampling method

The chosen method is based on a subjective sampling oriented since the purpose of our study is the identification of standing trees by the change in altitude. The samples are taken at three sites in the Biological Reserve (S1, S2 and S3) and Kef Lekhel (site S4) (Table 1).

**Table 1.** Inventory description of stations.

| Station            |    | Altitude (m) | Description                                                           |
|--------------------|----|--------------|-----------------------------------------------------------------------|
| Biological Reserve | S1 | 930          | Atlas cedar + Underwood low density (Diss, Spiny Calycotome, Juniper) |
|                    | S2 | 940          | Atlas cedar + few feet of Fir Numidia                                 |
|                    | S3 | 950          | Atlas cedar few + feet of Aleppo pine                                 |
| Kef Lekhel         | S4 | 1183         | Atlas cedar                                                           |

### 2.2.3. Dendrometric data

Dendrometric data collection inventory and description of the stands are a prerequisite for any successful forest management and silvicultural planning (Huart *and al.*, 2004). We are interested in achieving this inventory to highlight the structure, stand density and the difference of perspective development for each station. The structure of the stand is defined as the manner in which these are arranged dendrometric variables (Stewart and Roustide, 1974).

The tree inventory was conducted in each plot. Dendrometric measurements are:

- The diameter (D) at 1.30 m is estimated using calipers;
- The circumference (C) at 1.30 m is estimated with a tape measure;
- The total tree height (H) measured with the "Smartphone". The Swedish unit is, recommended in this type of study requiring maximum precision; the permissible error is negligible with direct readings that require no calculation. The measurement accuracy depends on the quality of the inclinometer of Apps and stability with which the device is held.
- The basal area of a stand is the area of all cross sections of trunks, 1.30 m tall, and the trees on one hectare of forest. It is expressed in m<sup>2</sup>/ha. It should be noted that all dendrometric characteristics were measured on four stations of cedar (10 repetitions per feature per station). The matrix of data obtained by the site and dimensions (n × p) with 10 repeats wherein n = 4 and p = 4 variables or characteristics.

## 2.3. Methods Statistical analysis

### 2.3.1. Analysis of variance

The analysis of variance with a criterion or factor classification test is to compare more than two means of multiple populations from simple data and independent random samples (Dagnelie, 1999). Performing the test is done either by comparing the value of  $F_{obs}$  with a theoretical value  $F_{1-\alpha}$  extracted from the table F of FISHER for a significance level  $\alpha = 0.05$ ; Or 0.001 to 0.01 and K1 and K2 degrees of freedom, or by comparing the value of the probability  $p$  always with different values of  $\alpha = 5\%$ , 1% or 0.1%. According to this hypothesis of equal means is rejected at  $\alpha = 0.05$ ; 0.01 or 0.001, is conventionally said that the observed difference is significant, highly significant or very highly significant. These differences of one, two or three asterisks (stars) are generally brand. This test was used to compare between the stations, the average of each of the four characteristics obtained of Atlas cedar.

### 2.3.2. Principal components analysis (PCA)

Technically, a principal component can be defined as a linear combination of optimally-weighted observed variables. In order to understand the meaning of this definition, it is necessary to first describe how subject scores on a principal component are computed Principal component analysis is quantitatively rigorous method for achieving this

simplification. The method generates a new set of variables, called principal components. Each principal component is a linear combination of the original variables. All the principal components are orthogonal to each other, so there is no redundant information. The principal components as a whole form an orthogonal basis for the space of the data.

### **2.3.3. Hierarchical ascendant classification**

Research for homogeneous groups can also be done by the hierarchical ascendant classification (HAC); this method allows to determine the level of similarity or divergence between individuals or sites and provides a breakdown of individuals or homogeneous class and is a hierarchical agglomerative method using the procedure from simple links and distance squared Pearson (Pearson correlation coefficient: it measures how two variables are correlated seeking linear correlations) to classify sites.

### **3. Results and discussion**

The inventory of topics Atlas cedar of Biological Reserve (3 stations: S1, S2 and S3) and Kef Lekhel (S4) is presented in Table 2. The results indicate that in the three stations of Biological Reserve, cedar is older (108 years) compared to that of Kef Lekhel. The total decline affected 6 trees and 22 others are affected by a partial decline at the Biological Reserve. This decline indicates that the species begins to suffer in the forest of Djebel EL Ouahch where conditions may become unfavorable (human perturbation by overgrazing, lack of silviculture, soil erosion, drought...)

**Table 2.** Current Status of Atlas cedar in the different stations.

| Station | Healthy trees | Partial decline | Decline | Defects | Cups | Number of trees | Total |
|---------|---------------|-----------------|---------|---------|------|-----------------|-------|
| S1      | 56            | 9               | 2       | 3       | 39   | 70              | 474   |
| S2      | 86            | 5               | 1       | 4       | 31   | 96              |       |
| S3      | 295           | 8               | 3       | 2       | 32   | 308             |       |
| S4      | 582           | -               | -       | 18      | -    | 600             | 600   |

The main factor in question on which there is consensus that climate change tends to accentuate the sharp decline in rainfall between other regions affected by the dryness of cedar and disruption of distribution, as well as increase temperatures and dry winds from the Sahara (Sirocco). Over the past two decades are characterized by more frequent and excessive atmospheric and soil drought. This has resulted in a severe decrease in soil water resources, estimated at low altitude (1600-1800 m) in the Ouled Yagub stations and Chelia, less than 40% of the AWR. According with Zine El Abidine (2003), edaphic drought may last 4-7 months (between April and July and October and November depending on the station). These droughts are all the more serious that coincide with the most active period of the Atlas cedar (Finkelstein, 1981; Aussenac and Guehl, 1990; Bentouati, 2008), and destabilize the functioning of several parameters of the tree and its environment. These repeated and sustained stresses reduce the physiological functioning of the tree (stomatal closure, decrease photosynthesis) over several months and successive years, leading gradually irreversible weakening of the tree. This situation is all the more likely to coincide with the results of Ducrey (1994) which shows that drought stress by edaphic or atmospheric affects primarily the mesophyll photosynthesis. He said that the Atlas cedar not very effectively controls loss of water and its adaptation to the drought lies in its good radial growth and its ability to quickly explore the deep soil. Toth (1990, 2005) observed that the growth of cedar is strongly and positively related to rainfall from May to July and especially from March to August. This result is the same with Ducrey (1994), who noted that the growth in height and diameter of the Atlas cedar is positively correlated with autumn rainfall and those of the early and late summer. Besides drought considered the main trigger factor, several other factors more or less binding, called predisposing or aggravating are challenged. The human activity (overgrazing undergrowth and soil compaction favoring water erosion responsible for the loosening of trees, fires, toppings, delimbing and illegal logging) introduces some factors which contributing to the weakening of the trees and make them more vulnerable to drought (Boisvenue and Running, 2006). In all stations, the values of parameters dendrometric coefficient of variation observed are significantly lower (0.09-0.31) except for the basal surface where they are high (0.32-0.66), this reflects an insignificant dispersion measures around their average inside the station (Table 3).

**Table 3.** Mean standard deviation and coefficient of variance of dendrometric parameters.

| Station | H (m)     |          |      | D (m)     |          |      | C (m)     |          |      | B.S (m <sup>2</sup> /ha) |          |      |
|---------|-----------|----------|------|-----------|----------|------|-----------|----------|------|--------------------------|----------|------|
|         | $\bar{x}$ | $\delta$ | cv   | $\bar{x}$ | $\delta$ | cv   | $\bar{x}$ | $\delta$ | cv   | $\bar{x}$                | $\delta$ | cv   |
| S1      | 23.48     | 3.15     | 0.13 | 0.65      | 0.11     | 0.16 | 2.06      | 0.33     | 0.16 | 0.34                     | 0.11     | 0.32 |
| S2      | 28.09     | 2.69     | 0.09 | 1.82      | 0.4      | 0.21 | 0.57      | 0.13     | 0.22 | 2.72                     | 1.26     | 0.46 |
| S3      | 16.19     | 2.00     | 0.12 | 0.32      | 0.07     | 0.21 | 1.04      | 0.23     | 0.22 | 0.09                     | 0.04     | 0.44 |
| S4      | 6.82      | 1.62     | 0.23 | 0.19      | 0.06     | 0.31 | 0.60      | 0.19     | 0.31 | 0.03                     | 0.02     | 0.66 |

summarizes the results of the description with only average minimum (min) and maximum (max); these two extreme values give an idea of the extent of the response variable on average by 40 individuals of Atlas cedar belonging to the four sites.

**Table 4.** The minimum and maximum averages of each variable.

| Extreme averages | Variables     | S1   | S2   | S3   | S4   |
|------------------|---------------|------|------|------|------|
| $\bar{x}$ min    | Height        | 18.3 | 25   | 13.2 | 4.2  |
|                  | Diameter      | 0.45 | 1.26 | 0.2  | 0.08 |
|                  | Circumference | 1.42 | 0.39 | 0.62 | 0.25 |
|                  | Basal area    | 0.16 | 1.25 | 0.03 | 0.01 |
| $\bar{x}$ max    | Height        | 30   | 32   | 18.8 | 32   |
|                  | Diameter      | 0.8  | 2.7  | 0.44 | 0.29 |
|                  | Circumference | 2.5  | 0.83 | 1.37 | 0.9  |
|                  | Basal area    | 0.5  | 5.72 | 0.15 | 0.07 |

The analysis of variance technique was performed to test the hypothesis of equal heights, diameters, circumferences and basal area at significance level  $\alpha = 0.05$ . The comparison between all 10 individuals of Atlas cedar in each station, the average values of each of the features discussed was performed using analysis of variance test (ANOVA) to test a model classification fixed, the results of statistical tests are summarized in table 5.

**Table 5.** Comparison of averages of each parameter studied.

| Variable      | DDL | SCE      | CM      | F <sub>obs</sub> | P        |
|---------------|-----|----------|---------|------------------|----------|
| Height        | 3   | 2584.429 | 861.476 | 145.131          | 0.000*** |
| Diameter      | 3   | 16.565   | 5.522   | 121.423          | 0.000*** |
| Circumference | 3   | 14.393   | 4.798   | 88.516           | 0.000*** |
| Basal area    | 3   | 50.076   | 16.692  | 41.831           | 0.000*** |

\*\*\*: very highly significant

The results from Tukey's simultaneous tests in Table 6 indicate that the mean level for height is significantly higher than that of the other parameters (the corresponding p-values being less than 0.05) and gives homogeneous classes for each parameter. Station 2 marks the highest averages.

**Table 6.** Homogeneous classes of each parameter.

| Station | Height | Diameter | Circumference | Basal area |
|---------|--------|----------|---------------|------------|
| S1      | 23.48b | 0.65b    | 2.06b         | 0.34b      |
| S2      | 28.09a | 1.82a    | 5.72a         | 2.72a      |
| S3      | 16.19c | 0.32c    | 1.04c         | 0.09c      |
| S4      | 6.82d  | 0.19c    | 0.60c         | 0.03c      |

Correlations between dendrometric parameters of the species (*Cedrus atlantica*) are significant for height/diameter, height/circumference, height/basal area. High correlations between these parameters are obtained from station 4 (Kef Lekhel) (Table 7). For such high correlation coefficients, this can be explained by a considerable stabilization of the morphology for each tree in the sampling station (Table 7).

**Table 7.** Results of correlations between dendrometric parameters of Atlas cedar.

| Station1                  |                     |                |                             |
|---------------------------|---------------------|----------------|-----------------------------|
| measures                  | Regression Equation | R <sup>2</sup> | Correlation coefficient "r" |
| Height/diameter           | Y=0.0105X+0.4026    | 8.87%          | 0.29                        |
| Height/<br>circumference  | Y=0.0428X+1.051     | 16.73%         | 0.40                        |
| Height / basal<br>area    | Y=0.0115X+0.0688    | 10.93%         | 0.33                        |
| Station 2                 |                     |                |                             |
| measures                  | Regression Equation | R <sup>2</sup> | Correlation coefficient "r" |
| Height / diameter         | Y=0.0832X-0.5127    | 31.17%         | 0.55                        |
| Height /<br>circumference | Y=0.0285X-0.2266    | 34.31%         | 0.59                        |
| Height / basal<br>area    | Y=0.2725X-4.9323    | 33.87%         | 0.58                        |
| Station 3                 |                     |                |                             |
| measures                  | Regression Equation | R <sup>2</sup> | Correlation coefficient "r" |
| Height / diameter         | Y=0.021X-0.0169     | 31.54%         | 0.32                        |
| Height /<br>circumference | Y=0.0567X+0.1192    | 23.61%         | 0.48                        |
| Height / basal<br>area    | Y=0.0106X-0.0856    | 29.93%         | 0.54                        |
| Station 4                 |                     |                |                             |
| measures                  | Regression Equation | R <sup>2</sup> | Correlation coefficient "r" |
| Height / diameter         | Y=0.0329X-0.0332    | 70.86%         | 0.84                        |
| Height /<br>circumference | Y=0.1013X-0.0889    | 72.92%         | 0.85                        |
| Height / basal<br>area    | Y=0.0092X-0.0313    | 67.13%         | 0.82                        |

The principal component analysis (PCA) was applied to the correlation matrix obtained from the four variables reduced centered on four stations by pairs. Calculations performed with Excel Stat (2010) give the characteristics of the 3 main axes. We can see that the first axis alone explains 68.5%. The coordinates of the initial variables on axis 1 are the correlations of these variables with axis 1, and the coordinates on axis 2 are the correlations of these variables

with axis 2 (Figure 1). The variables S1 and S4 have two long vectors that are characterized by strong correlations. Research homogeneous groups of Atlas cedar for 4 stations using simple link, the square distance of Pearson and a level of similarity of 80% was possible to observe three groups of stations. These groups were determined from the average of data from four stations observed on 4 dendrological characteristics. The different groups obtained are given in Figure 2.

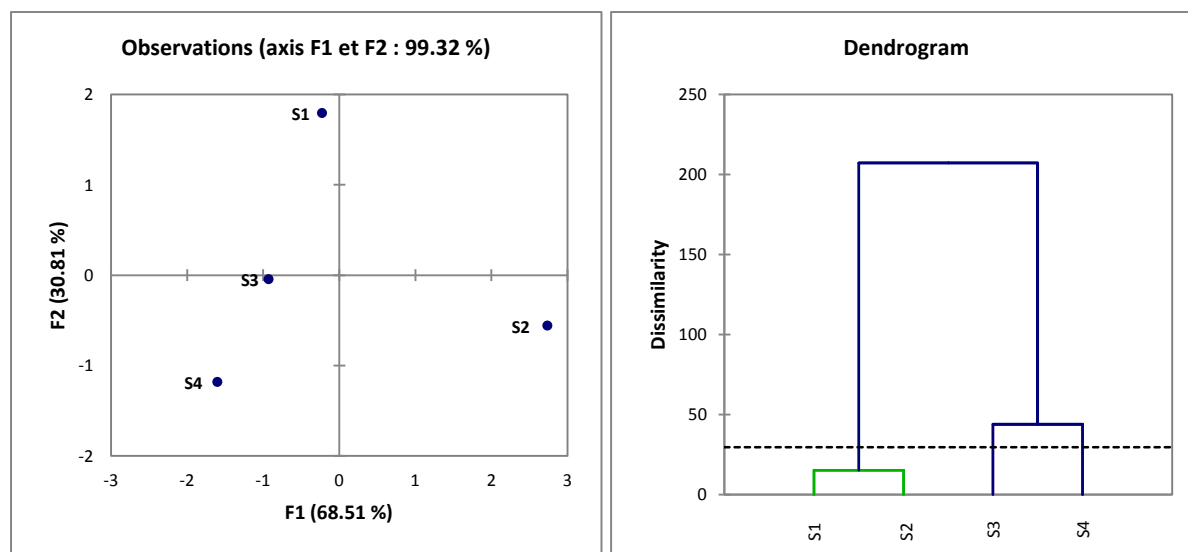


**Figure 1.** Principal component analysis.

**Figure 2.** Hierarchical ascendant classification.

## Conclusion

The aim of this work is to make a diagnosis of the current state of Atlas cedar plots of Djebel El Ouahch's forest. The importance of environmental conditions (climate and altitude) is considered. The methodology adopted is based on tree measurements (height of the tree, the circumference, diameter and basal area). Climate data show that the station of Kef Lekhel is in the area natural cedar atlas, while the biological reserve has a climate that differs from that of the natural range of the species. The observations made in the biological reserve helped to give an idea about the outbreak of the phenomenon of dieback of Atlas cedar in the station, to clarify the causes of dieback of biological reserves, it is worth further study on the factors of decline cedar (biotic and abiotic).

## References

- Allen C.D., Macalady A.K., Chenchouni H., Bachelet D., McDowell N., Venetier M., Kitzberger T., Rigling A., Breshears D.D., Hogg E.H. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *For. Ecol. Manag.*, 259, 660-684.
- Aussenac G., Guehl J. (1990). Ecophysiologie du cèdre. Conséquence pour la station de sylviculture et de production, *INRA, Nancy*, 191- 139.
- Barbero M., Bonin G., Loisel R., Quezel P. (1990). Changes and disturbances of forest ecosystems caused by human activities in the western part of the mediterranean basin. *Vegetatio*, 87, 151-173.
- Bentouati, A. (2008). La situation du cèdre de l'Atlas en Algérie. *Forêt méditerran.*, 29, 203-208.
- Boisvenue C., Running S.W. (2006). Impacts of climate change on natural forest productivity-evidence since the middle of the 20th century. *Glob. Change Biol.*, 12, 1-12.
- Brunetti M., De Capua E.L., Macchioni N.; Monachello S. (2001). Natural durability, physical and mechanical properties of Atlas cedar (*Cedrus atlantica* Manetti) wood from Southern Italy. *Ann. For. Sci.* 58, 607-613.
- Camperio Ciani A., Martinoli C., Capiluppi C., Arahou M., Mouna M. (2001). Effects of water availability and habitat quality on bark-stripping behavior in *Barbary macaques*. *Conserv. Biol.*, 15, 259-265.
- Cheddadi R., Fady B., François L., Hajar L., Suc J.P., Huang K., Demateau M., Vendramin G., Ortu E. (2009). Putative glacial refugia of *Cedrus atlantica* deduced from quaternary pollen records and modern genetic diversity. *J. Biogeogr.*, 36, 1361-1371.
- Chenchouni H., Abdelkrim S.B., Athman B. (2008). The deterioration of the Atlas cedar (*Cedrus atlantica*) in Algeria. Presented at the conference Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health. *A Review of Science, Policies, and Practices*, Umeå, Sweden, 25-28

- Condit R. (1998). Ecological implications of changes in drought patterns: Shifts in forest composition in Panama. *Clim. Change*, 39, 413-427.
- Dagnelie P. (1999). *Statistique théorique et appliquée*. Tome 02. Inférence statistique à une et à deux dimensions. Bruxelles. Université D&L, 659p.
- Ducrey M. (1994). Adaptation du cèdre de l'Atlas (*Cedrus atlantica* Manetti) au climat méditerranéen. Aspect écophysologique de sa réaction à la sécheresse. *Ann. Rech. For. Maroc*. T27 (spécial), 139-153.
- Et-tobi M., Mhirit O., Benzyane M. (2009). Changements climatiques, dégradations et dépérissements: Arguments et nouveaux outils pour une réforme de la sylviculture des cédraies au Maroc. *Ann. Rech. For. Maroc*, 41, 27-47.
- Ferris-Kaan R., Peace A.J., Humphrey J.W. (1998). Assessing structural diversity in managed forests. In *Assessment of Biodiversity for Improved Forest Planning*; Bachmann, P., Kohl, M., Paivinen, R., Eds.; Kluwer Academic Publishers: Dordrecht, the Netherlands, 331-342.
- Finkelstein D. (1981). Contribution à la caractérisation écophysologique du cèdre, étude de la croissance et des échanges gazeux. *Thèse. 3eme cycle, Université de Nancy*, 159p.
- Galiano L., Martinez-Vilalta J., Lloret, F. (2010). Drought-induced multifactor decline of Scots pine in the Pyrenees and potential vegetation change by the expansion of co-occurring oak species. *Ecosystems*, 13, 978-991.
- Huart O., Lejeune P., Lemoine N., Rondeux J. (2004). Proposition d'une méthode d'inventaire « sylvicole » pour le diagnostic post-perturbation des hêtraies wallonnes touchées par la « maladie du hêtre ». *Note technique forestière de Gembloux n° 12*, 26p.
- Kelly A.E., Goulden M.L. (2008). Rapid shifts in plant distribution with recent climate change. *Proc. Natl. Acad. Sci. USA*, 105, 11823-11826.
- Linares J.C., Taïqui L., and Camarero J.J. (2011). Increasing Drought Sensitivity and Decline of Atlas Cedar (*Cedrus atlantica*) in the Moroccan Middle Atlas Forests. *Forests*, 2, 777-796.
- M'hirit O. (1994). Le cèdre de l'Atlas (*Cedrus atlantica* Manetti). Présentation générale et État des connaissances à travers le réseau Silva Mediterranea "Le Cèdre". In : Le cèdre l'Atlas. Actes du séminaire international sur le cèdre de l'Atlas. Ifrane (Maroc), 7-11 Juin 1993.
- Mokrim, A. (2009). Dépérissement du cèdre de l'Atlas: Ambiance climatique et bilan de la croissance radiale. *Ann. Rech. For. Maroc*, 41, 48-68.
- Oliver C.D., Larson B.C. (1990). *Forest Stand Dynamics*; McGraw-Hill: New York, NY, USA, 467p.
- Slik J.W.F. (2004). El Niño droughts and their effects on tree species composition and diversity in tropical rain forests. *Oecologia*, 141, 114-120.
- Steinmetz G. (1986). Le Choix des Provenances et le Classment des Peuplements Porte-Graines. *Rev. For. Fra.*, XXXVIII: 69-73.
- Stewart P.H., Roustide R. (1974). Cours de sylviculture. *Institut National Agronomique, El Harrach, Alger*, 101p.
- Suarez M.L., Kitzberger T. (2008). Recruitment patterns following a severe drought: Long-term compositional shifts in Patagonian forests. *Can. J. For. Res.*, 38, 3002-3010.
- Toth J. (1980). Le cèdre III. La graine des plants en pépinière, reboisement, régénération naturelle. Forêt privée. *Rev. For; Europe*. N° 132, 41-47.
- Toth J. (1990). Le cèdre : Utilisation et qualité technologique. *La forêt prévue n° 194*, 57 -60.
- Toth J. (2005). Le cèdre de France. Etude approfondie de l'espèce. Paris, Le Harmattan. *Biologie, Ecologie, Agronomie*. 207p.
- Veblen T.T. (1992). Regeneration dynamics. In *Plant Succession: Theory and Prediction*; Glenn-Lewin, D.C., Peet, R.K., Veblen, T.T., Eds.; Chapman and Hall: London, UK, pp. 152-187.
- Zine El abidine A. (2003). Le dépérissement des forêts au Maroc : analyse des causes et stratégie de lutte. *Sécheresse* 14 (4), 209-218.