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The dynamics of natural regeneration of *Tetraclinis articulata* (Vahl) Masters in the Moroccan Central Plateau

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Abstract

This work aims to determine the parameters affecting the natural regeneration of *Tetraclinis articulata* (Vahl) Masters, a species endemic to the north of Africa and is of major economic importance in Morocco. This enables to aid decision-making for forest management planning, notably in the Moroccan Central Plateau. The research work carried out was based on the stratified sampling method with rational allocation of plots. One hundred fifty plots were observed and selected on the basis of physiognomic features, height and cover of different *Tetraclinis* stands. Results show that natural regeneration of *T. articulata* is frequent in scarce pasture lands as well as in the environments which are characterized by high-altitudes, fresh expositions and relatively deep soils. These results are of high value for forest managers in order to reconcile between land use and human environmental disturbances, particularly with regard to climate change.

Key words: natural regeneration, *Tetraclinis articulata*, Moroccan Central Plateau.

Introduction

Tetraclinis articulata (Vahl) Masters is the only species of the *Tetraclinis* genera existing in the western Mediterranean region and is native to northwestern Africa. Morocco is home to the large pure populations of this coniferous stands, covering an area of 566,000 ha (HCEFLCD, 2015) representing some 11 per cent of the total forest area in the country.

As it stands, *Tetraclinis* stand is a major concern for the scientists and forest managers. The plant structures imbalance of *Tetraclinis* ecosystems, the overgrazing, the illegal logging and forest fires are the root cause of forest loss and *Tetraclinis* stand recovery. This regression can be most clearly seen through forest clearings (Fennane, 1988).

Similarly, the lack of natural *Tetraclinis* regeneration intensifies significantly the ecosystems regression. This situation is mainly due to the imbalance that has affected the ecosystems structures (Hadjadj *et al.*, 2009).

In Morocco, little research had been focused on natural regeneration of forest plant species, indicating that natural regeneration process remains limited due to the combined effects of increasing human management and adverse conditions of site (Boudy, 1950).

To assess the potential for natural regeneration of *T. articulata* in Morocco and identify the parameters in-

volving regeneration and ensure its sustainability, we have chosen a designated site named "Kharouba" and localized in the Moroccan Central Plateau. This site includes the fine *Tetraclinis* stands nationally.

Materials and methods

Study area

The study was conducted in "Kharouba", a designated site with a biological and ecological significance, located in the Moroccan Central Plateau (Latitudes: 33°30' 39.567" N and 33°36' 19.969" N) and (Longitudes: 5°48' 19.314" E and 5°55' 39.317" E). This priority site (AFM, 1996) covers 6,300 ha and is characterized by a skeletal soil, extreme landscapes and abundance of slate, sandstone and quartzite. Annual precipitation in the studied site ranges from 450 to 600 mm/year. Average yearly temperature varies from 1 to 34° C. The climate type tends to be subhumid and semi-arid including temperate and cool variations (MCEF, 2002).

As far as vegetation concerned, *T. articulata* seems to be the main plant formations occupying more than 90 per cent of the total area (MCEF, 2002).

Sampling procedure

According to Gordon (1976), the study of a large and diversified ecological site requires an appropriated

method. In “Kharouba” site, characterized by its forest stands and diverse ecological factors, a stratification is clearly necessary. We therefore supported a stratified systematic sampling. Thus, a total of 120 plots (400 m² surface area) were distributed over the different strata in the forest stand map. This division was carried out based firstly, on the physiognomic features, height and cover of the different *Tetraclinis* stands, and secondly, the altitude, exposition, soil, slope and substrate parameters. The association of these features aims to ensure floristic and ecological homogeneity.

In each plot, the following descriptors were observed (Tab. 1):

- natural seedlings number of *Tetraclinis articulata* at different age classes (Fig. 1);
 - *T. articulata* fructification: absent or abundant;
 - the grazing intensity: absent or intense;
 - the topographic variables represented by the altitude, exposition and slope;
 - edaphic descriptors: the edaphic descriptors adopted in this analysis are based on the soil depth and the nature of the bedrock identified using the geological and soil maps;
 - the vegetation structure that reflects the soil cover by tree, shrub and herbaceous strata;
 - the plant communities: vegetation analysis by the digital method showed five plant communities.
- *Lonicero implexae-Tetraclinium articulatae* Fennane 1982;
- *Phillyreo latifoliae-Oleetum sylvestris* Barbéro, Quézel & Rivas-Martínez 1981;

Tab. 1 - Descriptors used to evaluate the dynamic of natural regeneration of *T. articulata*.

descriptor	Modality	Signification
The number of natural seedlings of <i>Tetraclinis articulata</i>	REG1	natural regeneration is low or even absent
	REG2	natural regeneration is frequently abundant (>100 seedlings per hectare)
<i>Tetraclinis articulata</i> fructification	FRU1	Fructification is absent
	FRU2	Fructification is abundant
The grazing intensity	PRA	grazing is low to absent
	PRI	high grazing intensity
Altitude (m)	ALT1	altitude ≤ 700
	ALT2	altitude > 700
Slope (%)	Slop1	Slope ≤ 25
	Slop2	Slope > 25
Exposition	EXP1	North and West exposition
	EXP2	East and South exposition
Soil cover by tree, shrub and herbaceous strata	RVA1	The cover of tree stratum is low (≤50%)
	RVA2	The cover of tree stratum is high (>50%)
	RVH1	The cover of shrub and herbaceous strata is high (>50%)
	RVH2	The cover of shrub and herbaceous strata is low (≤50%)
Depth of soil	Sol1	shallow soil
	Sol2	skeletal soil
Nature of bedrock	RM1	Shale
	RM2	Shale and limestone
	RM3	Shale and sandstone



Fig. 1 - Natural seedlings of *Tetraclinis articulata*.

- *Coronillo viminalis-Tetraclinium articulatae* Barbéro, Quézel & Rivas-Martínez 1981;
- *Rhoë pentaphyllae-Pistacietum lentisci* Dallahi, El aboudi & Aafi 2016;
- *Clematido cirrhosae-Ceratonietum siliquae* Barbéro, Quézel & Rivas-Martínez 1981.

Globally, factors causing this diversity are the exposition, the altitude and in some cases land degradation (Barbéro *et al.*, 1981; Fennane, 1988, 2003; Chkhi-chekh *et al.*, 2015, Dallahi *et al.*, 2016a).

The basic data consist of a double entry matrix where plots are arranged in columns and variables in lines.

Results

The Eigenvalues

The eigenvalues analysis (Tab. 2) shows a high value for the first axis (0.66) which exceeds the minimum threshold required for a marked individualization of the groups (Benzecri, 1973). This first eigenvalue is distinct from those of the other axes of lower rank; it slightly exceeds the double of the second axis. This result accentuates the amount of information extracted from the first axis.

The factorial plan 1-2 helps to interpret 55.25% of the total inertia. It is therefore useful to retain it as a main plan.

Axis Interpretation

In order to facilitate the interpretation of the axes, we selected the modalities that show higher absolute contributions compared to the average ones (M'hirit, 1982; Ezzahiri, 1989).

The table 2 examination of the different contribution

Tab. 2 - Inertia explained and eigenvalues of the first three FAC axes.

	F1	F2	F3
Eigenvalues	0.66	0.29	0.21
Inertia rate (%)	38.50	16.75	12.32
Cumulative Inertia (%)	38.50	55.25	67.57

variables related to the first axis revealed two groups. The first one is located on the negative pole; it includes plots sampled at environments with high grazing intensity that are characterized by low altitudes, warm expositions and high slopes where the number of different aged seedlings is medium to low. On the positive side of the axis, we grouped plots that spread in the regions where the grazing is low to absent. These areas exhibit high altitudes, fresh expositions and relatively low slopes where the natural regeneration is very important. The first axis can be considered as the topographic variables indicator.

In the second axis, modalities with strong absolute contributions are those related to vegetation structure and grazing intensity. This axis explains the relationship between the cover of the different plant formations and the natural regeneration.

Characterization of the different regeneration backgrounds

Two groups representing the different regeneration backgrounds were highlighted (Fig. 2).

1st group

This environment, covering 674 hectare, or 10% of the total area (Fig. 3), includes the plots inventoried in places where the numbers of seedlings, of one year and over, exceed 100 plants per hectare.

These results were obtained in areas characterized by shallow soil where the roots of young seedlings are able to colonize the moist deep horizons and take advantage from soil water-use reserves.

Ecologically, this set is in the North and West exposition at an altitude between 700 to 1100 meters.

The fructification, as a major factor, is usually abundant in high altitude. This environment is characterized by an important tree stratum cover. However, the cover of shrub and herbaceous stratum is low. In these environments, the grazing is extremely rare or absent, promoting the young seedling establishment.

In this site characterized by the association of *Lonicero implexae-Tetraclinum articulatae* Fennane 1982, the main plant encountered are: *Tetraclinis articulata*, *Quercus rotundifolia* and *Arbutus unedo* (Dallahi *et al.*, 2017).

2nd group

This environment, covering 5,694 hectare (Fig. 3), corresponds to the plots observed in areas where regeneration is low or even absent in most cases. The regeneration difficulties are mainly related to the grazing intensity, the poor cover of the different plant formations, the expositions (East and South), the unfavorable soil conditions (compact limestone substrate) and the lack of fructification.

Plant species of this site belong to the associations: *Phillyreo latifoliae-Oleetum sylvestris* Barbéro, Quézel & Rivas-Martínez 1981; *Coronillo viminalis-Tetraclinum articulatae* Barbéro, Quézel & Rivas-Martínez 1981; *Rhoo pentaphyllae-Pistacietum lentisci* Dallahi, El aboudi & Aafi 2016 and *Clematido cirrhosae-Ceratonietum siliquae* Barbéro, Quézel & Rivas-Martínez 1981 (Dallahi *et al.*, 2017).

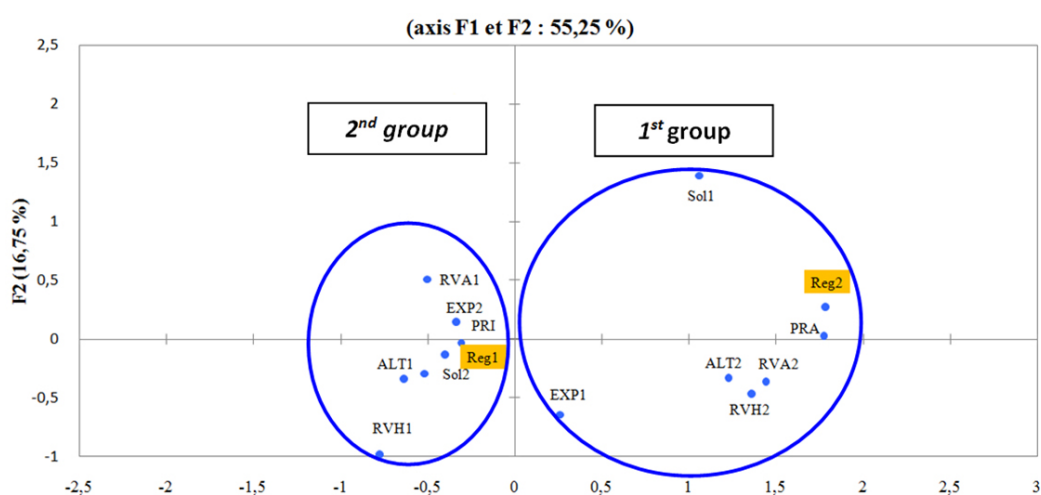


Fig. 2 - Factorial plan graph. (Legend: ALT1: altitude ≤700 m; ALT2: altitude >700m; RVA1: the cover of tree stratum is low (≤50%); RVA2: the cover of tree stratum is high (>50%); EXP1: North and West exposition; EXP2: East and South exposition; PRA: grazing is low to absent; PRI: high grazing intensity; REG1: natural regeneration is low or even absent; REG2: natural regeneration is frequently abundant; Sol1: shallow soil; Sol2: skeletal soil; RVH1: the cover of shrub and herbaceous strata is high (>50%); RVH2: the cover of shrub and herbaceous strata is low (≤50%).

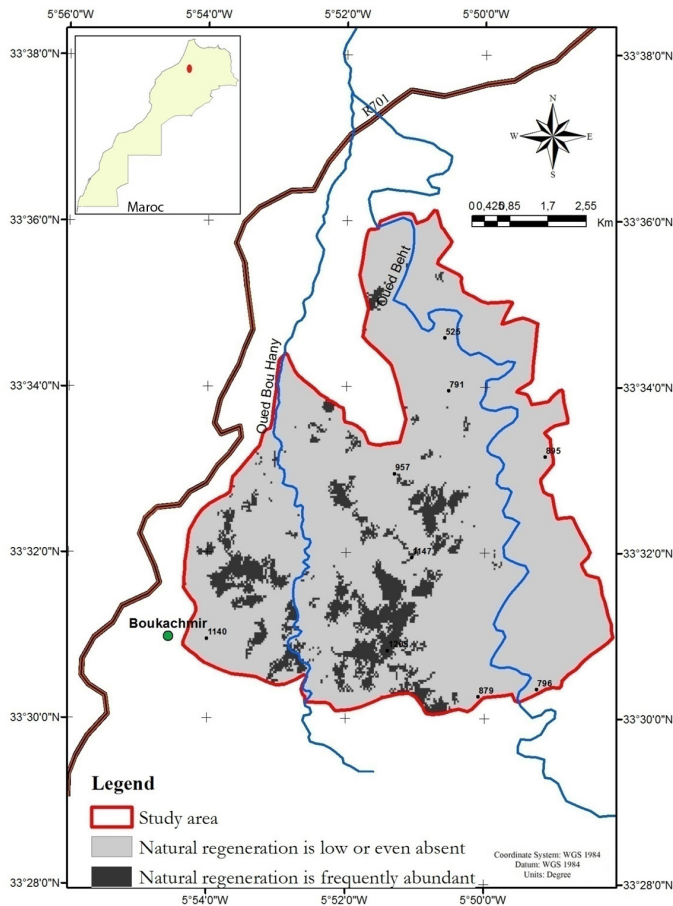


Fig. 3 - Distribution map of *T. articulata* natural regeneration in the studied site.

Discussion

Our results show that the natural regeneration of *Tetraclinis articulata* presents a high potential in the sites characterized by their fresh expositions, high altitudes and deep soils. Indeed, these environments provide a suitable condition for both establishment and growth of the plant seedlings. Similar observations have been reported by Haddouche *et al.* (2011) for *Tetraclinis articulata* in Algeria.

Likewise, this regeneration seems to be very dynamic especially when the tree stratum cover is high (>50%), therefore, providing the young plants with a shelter to prevent a drought risk. This is consistent with the research works carried out by Hadjadj *et al.* (2009) on *Tetraclinis articulata* in Algeria or *Pinus halepensis* Mill. in the southeastern French region by Loisel (1967) or *Pinus pinea* L. in Italy by Masetti & Mencuccini (1991).

Our data also exhibit that grazing is the main factor that affect negatively the natural regeneration of *Tetraclinis articulata*. This factor appears to act in two different ways. It is involved in soil compaction. On the other, livestock grazes the young plants and feeds

on the bud seedlings, thereby affecting their height growth (Hadjadj *et al.*, 2009).

The results show that *Tetraclinis articulata* is renewed through natural regeneration, which can easily occur if ecological conditions are right. However, when the degradation of the *Tetraclinis* ecosystem is very accentuated due to multiple human pressures (particularly overgrazing), structure formations become increasingly degraded, leading to the disappearance of the shrub stratum and the proliferation of annual species, hence the loss of favorable regeneration conditions. Similar observations were made by Benabid (2000) regarding *Quercus suber* in Morocco; by Hadjadj *et al.* (2009) about *Tetraclinis articulata* in Algeria or by Ezzahiri (1989) for *Cedrus atlantica* in Morocco.

Due to the lack of the natural regeneration, the remaining *Tetraclinis* forest becomes increasingly threatened, since the regeneration ensuring its sustainability will never occur in this excessive anthropized environment. If no intervention is undertaken, the forest structure will be reduced to a simple stand comprising degraded trees.

The forest structures degradation and the lack of the natural regeneration would lead in the near future to a disappearance of this forest ecosystem including its biodiversity. Statistically speaking, among 143 species inventoried in this designated biological and ecological site, 85 per cent of taxa are rare to very rare and are at risk of extinction (Dallahi *et al.*, 2016b).

The absence of natural regeneration and the *Tetraclinis* ecosystem degradation lead us to rethink and propose an alternative solution that could be involved in preserving sustainably this important ecosystem. Therefore, we propose:

- the restoration of *Tetraclinis* stands, through artificial regeneration and/or natural regeneration, should be undertaken by adopting suitable techniques in keeping with specific environmental conditions;
- the forest stands structure improvement through silviculture adapted to *Tetraclinis* ecosystem and the strengthening of the surveillance to avoid human pressure on this diversified site of Kharouba;
- the forest fencing in over grazed areas;
- the fodder production enhancement and the animal load adjustment according to the ecosystem productivity and capacity.

Conclusion

The natural regeneration of *Tetraclinis articulata* studied by multidimensional analysis allowed us to identify two regeneration backgrounds. This highlighted the dependence of such phenomena to human factors (grazing) and other parameters related to the station and forest stand such as exposition, altitude, soil depth and vegetation structure.

This study shows that natural regeneration of *T. articulata* is very abundant in the sites where the grazing is very rare, as well as in environments characterized by high altitudes, fresh expositions and relatively deep soils.

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