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The efforts for cork oak forest management and their effects on soil conservation

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Abstract

The Shoul oak grove is a forested ecosystem inherited from a Holocene phase of ecological optimum; its evolution, through the double geologic and human temporality, and in relation with several processes of degradation, led to the progressive loss of its environmental equilibrium and further to the reduction of its economic contributions. The fragility of these forests is the consequence of the convergence of two main factors, i) the intrinsic fragility of the forested environment based on an unstable balance between the tree, the leached soils and their moisture content ; ii) the anthropological action on the forest environment and its degradation with the change of its floristic composition.

During the colonization the new context was at the origin of the new social and economic relation between the forest and the surrounding populations. The current use of this oak grove is in a classic scheme of the reports society / forest in Morocco. The population is especially of pastoral main activity in the bordering communes.

But the oak groves of Mamora-Shoul are integrated into the area of influence of several cities, what exposes the forest to the risks of uncontrolled urbanization. These oak groves are thus in the centre of interest of several stakeholders with opposite behaviour and a new paradigm of relation rural/urban.

Through a double approach, environmental and socio-economic, this paper will try to bring elements of answer by analyzing the interactions between a forest which reached an alarming threshold of degradation and a society affected by important changes in its modes of intervention and exploitation.

Key words: Morocco, Atlantic Meseta, Shoul plateau, Forest management, water and soil conservation, assisted regeneration of cork oak.

Resumen

Los esfuerzos para dirección de bosque de alcornoque y sus efectos sobre conservación de suelo, la meseta Shoul, región de Rabat, Marruecos

La arboleda de roble Shoul es un ecosistema arbolado heredado de una fase de Holocene de grado óptimo ecológico; su evolución, por la doble temporalidad geológica y humana, y en relación con varios procesos de degradación, conducida a la pérdida progresiva de su equilibrio ambiental y con relación a la reducción de sus contribuciones económicas. La fragilidad de estos bosques es la consecuencia de la convergencia de dos factores principales, i) la fragilidad intrínseca del ambiente arbolado basado en un equilibrio(saldo) inestable entre el árbol, los suelos leached y su contenido de humedad; ii) la acción antropológica sobre el ambiente forestal y su degradación con el cambio de su composición floristic.

Durante la colonización el nuevo contexto estaba en el origen de la nueva relación social y económica entre el bosque y las poblaciones circundantes. El empleo corriente de esta arboleda de roble está en un esquema clásico de la sociedad de informes/el bosque en Marruecos. La población es sobre todo de actividad pastoral principal en las comunas de lindar.

Pero las arboledas de roble de Mamora-Shoul son integradas en el área de influencia de varias ciudades, que expone el bosque a los riesgos de urbanización incontrolada. Estas arboledas de roble son así en el centro de interés de varios tenedores de apuestas con el comportamiento de enfrente y un nuevo paradigma de relación rural/urbana.

Por un doble acercamiento, ambiental y socioeconómico, este papel(periódico) tratará de traer los elementos de respuesta por analizando las interacciones entre un bosque que alcanzó un umbral alarmante de degradación y una sociedad afectada por cambios importantes de sus modos de intervención y explotación.

Palabras clave: Marruecos, Atlántico Meseta, Shoul meseta, dirección Forestal, agua y suelo conservación, regeneración ayudada de *Quercus suber*.

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Introduction

Around the Mediterranean sea, forests cover a large part of the surface. *Quercus suber* represents an original specie and a very rich ecosystem, with a high relation between soil, the plant and water (De Sousa *et al.,* 2008). The current dynamics is very different on the two sides of the Mediterranean, with a tendency for over-cutting and overgrazing on the southern side, while fire represents the most important threat in southern Europe.

In the Maghreb (Conacher and Sala, eds, 1998), the tendency is for the replacement of traditional forests, by exotic species or by more intensive land uses such as dry farming or overgrazing, despite the poor quality of soils and their potentially high erodibility (Coelho *et al.,* 2002). The reduction of organic matter and vegetation cover, results in soil compaction and higher overland flow generation, in the overgrazed areas, whilst in the ploughed areas, erosion yields become higher. The traditional land management systems, involving a combination of agriculture, animal husbandry and forestry, produce the least amounts of overland flow and the lowest soil erosion rates. The *Quercus suber* forests seem to be the more conservative land use, compared to pastures and cultivated areas; it generates smaller overland flow amounts, inferior to 10% of rainfall in average. An increase of grazing pressure within *Quercus suber* forests leads to significantly higher overland flow amounts (Coelho *et al.,* 2000, 2002). The total disappearing of trees enhances overland flow generation to the double, compared to the overgrazed areas, within forest stands. It's why, the assessment of techniques of forest management and of soil-water conservation represent an urgent question for environmental research in this region.

In Morocco, in spite of the important recession of the cork oak forests, it still covers around 350,000 hectares: 15% of the world forests of cork oak and 7% of all the Moroccan forests; Due to its position in the Atlantic Meseta, the Shoul forest is one of the most southern forests of cork oak and the most exposed to the hydro stress. The cork oak remains for Morocco a noble tree, as it performs multiple functions, namely, the production of cork and fire or charcoal wood, of fodder and of fruits, in addition to its ecological role. The conservation of the cork oak forests meets many constraints and showed a low number of success stories. It's why it was important to lead measurements in the field on many samples of forests, natural ones and managed ones, in order to try to determine the promising techniques of conservation.

In the Atlantic Meseta, the human pressure on the forests, made them loose their original extension (important retreat on the borders and de-densification) and natural characteristics (modification of their floristic composition). The evolution of the cork oak forest, in relation with several processes of degradation, led to the progressive loss of its environmental equilibrium and further to the reduction of its economic contributions. The fragility of this forest is the consequence of the convergence of two main factors: the weak environment based on an unstable balance between the tree, the leached soil and its moisture content; the anthropological action on the forest environment and its degradation (Machouri, 2005).

The traditional use concerns both agriculture by sedentary populations (cereal production) and grazing by mobile tribes inside and around the forests. Both agriculture and grazing have an important responsibility in the forests degradation and retreat (Eaux et Forêts, 1998; Nafaa, 2002; Roose, 1994). The modern forest management itself participated in this trend of retreat through some choices of management not well conducted. Nowadays, the position close to important cities explains certain forms of degradation and the apparition of new activities, with the need for space for their implementation.

Our study has for main objective to estimate the techniques of forest management, namely the assisted regeneration of the cork oak and the plantation of eucalyptus or pine and their effects in term of conservation of the soils and water; and this, through the realization of measures in the field (measures of the vegetation, of the states of the soil surface, of the water dynamics) and measures in the laboratory of the fertility and organic matter).

Material and methods

The Sehoul Plateau, located between the Mamora forest in the north, and the Grou valley in the south West, is a part of the Palaeozoic Atlantic Meseta. Despite its location in the more favourable parts of Morocco in terms of climatic conditions, it consists of marginal land with a high poverty and important indicators of degradation. On the surface of the plateaus, the Pliocene and Pleistocene calcarenites have been deeply weathered and furnished a thick fersiallitic soil (CPCS,

1967) in which processes of leaching have occurred and produced a thick sandy horizon which represents a fragile soil, stabilised by the organic matter, but threatened by runoff and wind erosion, in case of vegetation cutting. This region, which was originally covered by cork oak and used before the 20th century, for grazing or forestry, is now cultivated and records important changes in the soil use and the cropping techniques. Current trends include replacement of evergreen oak forest by fast growing trees such as *Eucalyptus* species, and an increase in agriculture and grazing activities.

The team of research functioned in the field for the evaluation of the state of degradation and of the water and soils conservation techniques. The forest technicians strongly contributed in this research and the WOCAT tools —questionnaire technology and questionnaire approach— were used, to evaluate the practices. The WOCAT method, used for this assessment, is characterized by the rigor of the process used for the identification of the forms of degradation, their causes and for the selection of the most promising technology to protect and rehabilitate natural resources subjected to the degradation.

The evaluation of these WSC techniques and their effects in terms of soil protection and conservation was realized through field measurements of vegetation and of soil surface, in the laboratory on soil fertility and organic matter.

— Vegetation measurements:
a) Cover density.
b) Biomass measurement.
c) Floristic diversity.
— Soil surface measurements:
a) Soil moisture.
b) Soil cohesion.
c) Resistance to penetration.
d) Stoniness and crusting.
— Soil structure and soil fertility:
a) Organic carbon.
b) Organic matter.
c) Total nitrogen.

The planting and regeneration techniques were assessed at various sites and compared to natural types of cork oak covers:

— Natural cork oak, with 4 degrees of density, dense, normal, clear and sparse cork oak.

— Assisted regeneration of cork oak, with comparison between a fenced plot, 4 years old in 2008, and a plot recently opened to grazing, 10 years old in 2008.

— Artificial reforestation, both with Eucalyptus and Pine.

The methods of assessment vary in function of the nature of cover:

— For the herbaceous stratum, the method chosen consists in making readings on 100 points situated along a ribbon of 20 m of length stretched out, above the herbaceous plants. The reading is made every 20 cm. All the sorts which contact a vertical needle are listed in every observed point.

— For the shrub stratum, the method chosen by linear interception consists in measuring on a direct line of 20 m, the width of the horizontal projection of the plants. The relationship of the length occupied by the individuals of the same sort expresses its covering.

— The trees stratum: the covering is made by means of a hand made densimeter. The method consists in making readings on 100 points situated along a line materialized by a ribbon-metre (of 20 m of length) stretched out below trees. The reading is made vertically from down to top every 20 cm.

The biomass or total weight of plants by unit of surface is expressed in kg of vegetable substance or dry material after passage in the steam room. The measures are reported to the unit of surface. For herbaceous stratum, the used method is direct cutting and weighing of the herbaceous inside a quadrate of 1 m^2. For shrubs, the measure of the biomass is approached in an indirect way through representative «branches-units».

We realized in each site, 10 measures of humidity on a 10 cm depth by using a TDR. The measure of the cohesion of the soil is made with a Torvane. For every site, we realized 10 measures. The measure of the resistance to the penetration is made by means of a penetrometer. For the pebbles covering and the encrusted surfaces, the used method is the one of quadrats points. The measures of the stability of the structure of the soil and the fertility were realized at the Laboratory of the Research Center of Forests.

For the floral variety, the method was listing the present sorts within a plot of land of 1 m^2.

With the aim of estimating the change of the surface of the Shoul forest between 1987 and 2007, a mapping method combining remote sensing and GIS was used. Two images ASTER of a resolution of 15 m were treated and classified by the software ERDAS imagine 9.1, then treated by the program PC Raster.

Radioisotope ^{137}Cs, used as a sediment tracer, is an innovative technique in soil erosion investigations and possesses many advantages compared to the traditional

methods (Zapata, 2002). It permits to establish patterns of soil behaviour (spatial redistribution) within the landscape and to determine quantitative assessments of medium-term (more than 40 years) (Walling and He, 1997). Several investigations in different regions of Morocco (Alhoceïma, Rif, Mohammedia, Azrou, Zaër, etc.), have confirmed the potential of this technique; however the majority has concerned agricultural plots (Benmansour, 2000; Bouhlassa *et al.,* 2000; Nouira *et al.,* 2003, 2004, 2008; Duchemin *et al.,* 2008). In this work we tried to use the ^{137}Cs measurements to estimate soil loss in a low density area of cork oak forest in Sehoul.

^{137}Cs is an artificial radionuclide, with half life of 30 years, produced from atmospheric nuclear-weapons occurred in the late 1950s and early 1960s. Once it reaches surface soil, as fallout in association with precipitation, ^{137}Cs is quickly and strongly adsorbed by fine soil particles. Physical processes are the dominant factor responsible of its redistribution. Any subsequent movement of ^{137}Cs will reflect soil redistribution pattern (Zapata, 2000).

The ^{137}Cs technique is based on measured ^{137}Cs inventories at individual sampling points of the studied site; therefore a sampling protocol is of great importance. In our case, samples were collected from circumference of two circles of radii 10 m and 20 m and one core from the circles center (Fig. 1). To ensure that all ^{137}Cs is retained, samples were extracted to a depth of 32 cm. Depth distribution of ^{137}Cs concentration is established by dividing soil core into 2 cm incremental samples (Fig. 2).

Figure 1. The two circles of radii 10 m and 20 m.

Figure 2. Sampling system.

The natural and social environment

The cork oak Mamora-Sehoul forest constitutes an ecosystem inherited from the Holocene optimum, during which was developed a dark layer, rich with organic matter, on top of the leached sandy horizon of the soil. This sandy layer corresponds to a former leached horizon, removed as a dune during a dry crisis in the Würm period; the leached horizon of the old fersiallitic soil (CPCS, 1967) conserved at its basis, a weathered red horizon rich of clay with forms of suffosion pockets on the Pliocene calcarenite (MADRPM, 2006).

The forest of Sehoul covers a surface of 8,395 ha, which corresponds to 21.5% of the territory of the Commune. The vegetation formations are diversified and sharply dominated by the cork oak (57% of the total surface of the forest). 46% of the cork oak covers are dense, 21% have an average density and 30% are in a clear or scattered state; only 3% are in mixture with secondary essences.

The forest offers many possibilities of use, in addition to the cork exploitation; it is a main pasture land, and an important resource of fire wood.

Regular exploitation and cutting operations are organised by the forestry administration and made by enterprises. The administration has also the duty of planning the forest management. The income of such exploitation feeds, from the reform of 1976, the communes' budget. But overgrazing and irregular cutting of fire wood threaten the forest ecosystem and leads to land degradation.

Due to the proximity of urban agglomerations, the forest is also visited for leisure. The orientation towards

a tourist function can lead to a complete transformation of the management rules.

The population was around 20,000 inhabitants in 1994, and declined to 19,706 in 2004. This population is distributed in 36 «douars» inside 7 tribes (Jiahna, Oulad Aziz, Jouaneb, Jbabra, Azzouzyine Ouled Mâala, Ouled Aïssa, Ouled Alouane). More than 40% is beyond the lowest rate of rural poverty in Morocco (Aderghal and Watfeh, 2006). The population of the commune is dominated by young people. But the illiteracy is high in spite of the nearness of Rabat: 63.9%, divided over 50% for men and 79.3% for women. Besides, the city's nearness facilitates the rural migration and limits the availability of manual labour for the agriculture. The majority of the farmers (77%) are over 50 years old and 30% are more than 65 years old. This can constitute a constraint for investment. The farmers of rather young age groups (less than 35 years), thus the most motivated for innovative projects, represent only 3%.

The forest is the property of the state, while the communities living in and around the forest are considered as legal users. It is surrounded by a farming community based on the forest resources, which represents a perpetual belt of poverty, with a free exploitation of the resources by the «legal users».

Basis of the pastoral system, the forest was also considered as source of foodstuffs for the populations. The main exploited products, as the mushrooms, the artichokes, the hearts of dwarf wild palm trees, pear and especially acorns, bark of cork and tannins, were partially auto-consumed. A commercial practice of these products existed and concerned especially the tannin and the cork for hives (traditional honey production).

During all the 20th century, the relationship of the populations with the forest recorded important variations catalyzed by the effects of a rigorous organized legislation during the first years of the Protectorate (Fadloullah and Belfquih, 1978). The approach for exploitation of the forest, privileged by the administration of the Protectorate, is based on the theme of an ecological crisis of the forest provoked by the mode of use (free opening of the forest) and by the drought which constitutes a handicap for the natural regeneration and which facilitates the proliferation of the destructive parasites.

The process engaged by the application of the new legislation engaged the forest in an irreversible evolution (Nadir, 2008); it explains the break of the links between the local rural population and their territory; the access to the exploitation of the forest resource passes by the filter of the technical administration and the municipality which grant the authorizations of exploitation and occupation. During this period occurred also the opening of the forest to the industrial undertaking for the benefit of some capitalist companies; this led to the sylvicultural management and the stake in defense of the forest which was a part of productive spaces of the local populations.

The transformation of the systems of production is materialized by the extension of new cultivated fields to the detriment of the forest. This extension, especially on the slope lands, can be not only considered, as an answer to the increase of the population and to the increase of needs, but also as an indication of the participation in the general agricultural dynamics in Morocco (Lesne, 1959; Le Coz, 1964; Laouina, 2007; Laouina *et al.,* 2004).

The reduction of the breeding in the use of the space is obvious. We can estimate it through the reduction of the number of animals during the period 1936-1952. For all the tribes Zemmour, the decrease of the livestock was estimated at 32%, while the population increased by 24.5%, what made the average number of heads of cattle per capita, 5.5 heads/inh.

Today, on a livestock consisted of 57,989 heads, 64.3% are ovine races, 18.9% of cattle and 16.8% of goats. The number of heads per capita is 2.9.

Under the influence of the concentration of the villages and cultivations, in spaces where the forests were cut, and because of the reforestation of some parts of the remnant space by pine and eucalyptus, lands reserved for the herds were reduced, pulling at the same time a concentration on more narrow pastures, with not enough possibility of movement.

The forest offers also a landscaped variety and a natural potential in an outer-urban space. It can constitute an excellent entertaining space for four towns, Rabat, Salé, Kénitra and Khémisset, of a population about 2 million inhabitants. In outer-urban situation, the forest offers a space of relaxation and rest for city visitors during weekend in spring or even winter.

Further to these circumstances, the forest became the object of degradation which result from the anthropological action, through overgrazing, the wooden taking, combined to the hydro stress caused by the recurring droughts. So, the natural non regeneration of the forest, questions its role on the ecological, economic and social plan.

Among the important indicators, we note that in 1,975. 27% of the farmers did not possess a cattle, while at present, little are the ones who do not practice

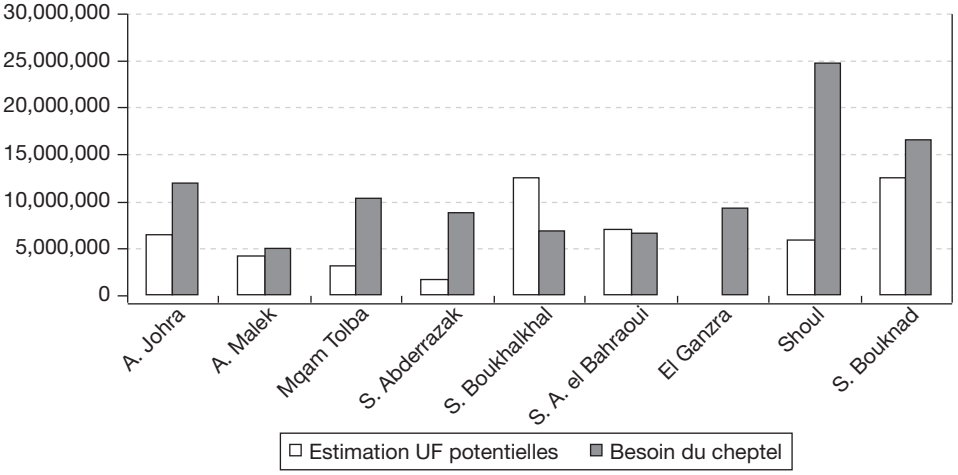

Figure 3. Fodder potential *versus* needs in the various communes of the Atlantic Meseta.

breeding. In fact, 12% of the farmers have at least a cattle, in association with city-dwellers. The load of the forest is at present about 2.8 small units/ha/year, while the direct measure of the biomass, reveals that the fodder average capacity of the forest, is only 248 fodder units/ha (Fig. 3). The forest is not the only fodder resource used by these farmers who practice, at the same time, the cultivation of cereals. So, the contribution in feed of farmlands should be taken into account.

As the cultivated surface, which is of 20,100 ha, among which 790 ha irrigated by 500 motor-pumps, and taking into account the size of the global livestock which is about 157,800 small units (equivalent to sheep and goats), and measures made on the scale of 30 plots of land in rainfed cultivation of cereals, we notice that these lands cannot supply more than 65 FU (equivalent to a kg of barley) for every animal. The fodder balance assessment remains negative (Fig. 3), because, almost 50% of the fodder needs on the scale of the commune must be brought from the market or by practices ending in an overgrazing of the forest and of the cultures residues (Van Dijck e*t al.,* 2006).

The overexploitation of the forest thus engenders an intense degradation of the soil and a progressive reduction of the pastoral plants consumed before having the time to fruit; later they disappear totally, leaving the place to the sorts not consumed, as the asphodel. The imbalance between the total number of the livestock frequenting the forest, and its fodder capacity explains that the natural regeneration is not possible any more (Laouina *et al.,* 2006).

The changes in the management principles can be summarized as follows:

— During the past centuries, the Atlantic Meseta was a grazing region inhabited by mobile tribes.

— In the early 1900s, after the French colonization, the forest delimitated areas became owned by the state and from 1976, the forest is considered as a source for communes' income.

— In spite of the transformation in the agricultural system, we observe the resistance of the grazing activity and an overgrazing situation in and out of the forests.

Assessment of the degradation and of the efforts of management

The forest which constitutes the main parameter of the socio-economic life and the main resource in rural areas is threatened by overexploitation (overgrazing, pressure on the fire wood).

The signs of the degradation of the forest are visible (Nafaa, 2002; Antari, 2007). We can notice the scale of the phenomenon on some trees, wounds and parasitic attacks. Also, the dominance of the *cistus* and of the asphodel, the decrease of abundance of the plant and animal species, the deterioration of the forest structure and the absence of the natural regeneration are demonstrations of the state of destruction of the vigor and the integrity of the forest which constitutes a central axis for any initiative of the development of the zone.

The measures showed that the traditional land management systems, involving an equilibrate combination of agriculture, animal husbandry and forestry, under a weak human pressure, produce moderate amounts of

overland flow and soil erosion (Coelho *et al.,* 2002, 2007). When the pressure increases, the vegetation cover is affected; in this case, overland flow and erosion are significantly enhanced.

The degradation concerns also the floristic composition of the forest and have both an ecological aspect (loss of biodiversity, weakness of the soil cover) and an economic impact (loss of fodder potential and of resource production). The border degradation of the cork oak forest is more important than the one recorded inside the forests; but, even in these degraded margins, the ecologic situation remains relatively stable, compared to what is recorded in the completely cut zones, where the bare soil acquires a real negative behavior in term of soil erosion and water loss.

To remediate the situation of degradation, the tendency was for the replacement of natural cork oak forest by exotic species (eucalyptus or pine). Recently, the efforts are oriented to the management of the degraded cork oak covers by plantation or seeding of this specie for regeneration of the forest; but this kind of management still concerns very small surfaces. The objectives of the operations are to assure the cork oak regeneration, to improve the cork yield and to reduce the land degradation, by the mitigation of overland flow and the increase of infiltration.

From an experimental plot to the other, the rate of success of cork oak plantations can vary in the extreme cases between 0 to 100%; it is in the plots where the stake of defence is respected, that the recorded rate of success is the highest. The natural conditions allow the regeneration of the forest, only if the human pressure is not too high. The evaluation of the experiment also proved an improvement of the biomass, of the biodiversity and the rate of organic matter in the soils. However, with the opening of these experimental plots to grazing, we note an immediate loss of some of the gained characteristics and the return to the initial state, of a scattered oak forest.

The foresters chose as promising technology, the assisted regeneration. The conditions of the implementation of this technology seem to be rigorous, relevance of the choice of the experimental plots of land, choice of plantations or seeds, good preparation of the soil, respect of the calendar of plantation, installation of the fence for the stake in defense, weeding, harrowing and watering during the first two years.

It seems that the assisted regeneration of cork oak is an endogenous technology which was revealed by the foresters and then developed. The declared objectives are the regeneration to insure the perpetuity and the development of the forest, the conservation of water and soil, the production of cork, the wooden production, the production of fodder, the covering of lands, the socioeconomic development of the populations and the production of services (landscapes, leisure activities) for the urban populations. But all these objectives are not always obtained.

Several methods of monitoring and measurements were used for the assessment and gave the following results.

Mapping

Forests are present in the North of the Mamora and in the central part of the Sehoul, south of the Bouregreg river (Fig. 4). The deforestation and the extension of the cultivated area date from the early years of the 20th century and the limits of most of the forests were fixed in the years 1920-1930. But inside the forests and in the remnant pastures, internal degradation by overgrazing and wood gathering still continues.

The forest represents nowadays a real mosaic surrounded by cultivated fields (Fig. 5). The speed of retreat can be very rapid in some cases. The results obtained showed a regression of the Shoul forest about 100 ha

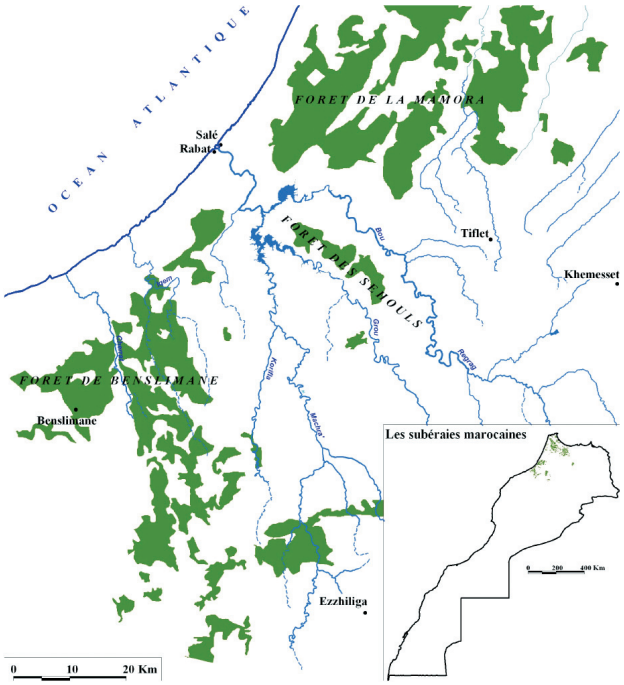

Figure 4. The reduction of the *Quercus suber* forest to only some elements of plateaus.

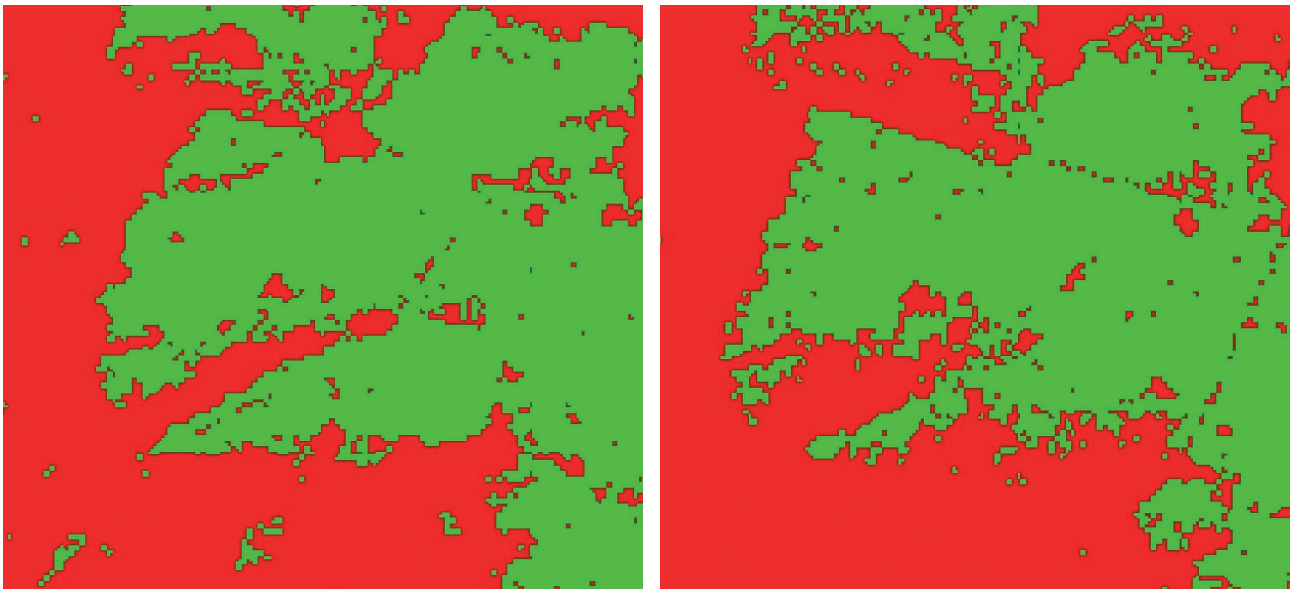

Figure 5. The borders of the Sidi Azzouz forest in 1987 and 2003. From: Aster images.

in the last 3 years, and a larger regression between 1987 and 2003 (Fig. 5) in the case of the Sidi Azzouz forest (South of the Shoul commune).

The use of radioisotopes (^{137}Cs)

Depth distribution profile of ^{137}Cs

The depth distribution shape shows a sharp decrease of ^{137}Cs activity concentration with increasing depth which can be fitted by an exponential function (Fig. 6). Most of ^{137}Cs is contained within the top 10 cm from surface, with retention of 86% of the ^{137}Cs and sharp drop in ^{137}Cs activity below that depth. Distribution is typical of non-agricultural sites. In agricultural fields, tillage contributes to homogenization of ^{137}Cs throughout plough layer.

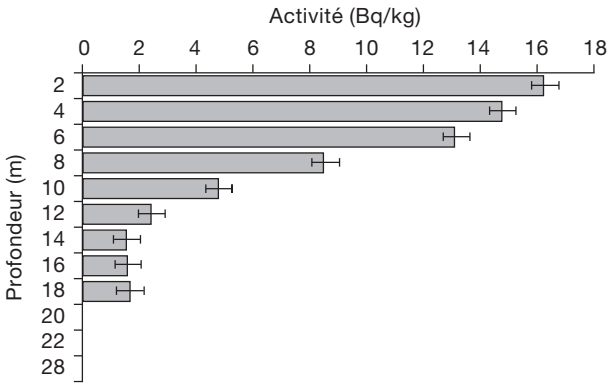

Figure 6. Depth distribution profile of ^{137}Cs in cork oak forest soil.

Quantitative assessments of soil loss by using the distribution profile model

Assessment of ^{137}Cs redistribution, and thereby soil redistribution, is commonly based upon comparison of measured inventories of ^{137}Cs in study sites with reference site. Reference site is considered as undisturbed, suffering from neither erosion nor deposition. Negative deviation from reference inventory is considered as soil erosion, while positive deviation represents deposition soil. In our study site reference value was found of about 1,530 Bqm^{-2} with a coefficient of variation of 22%.

To derive quantitative estimates of the rates of soil erosion and deposition from ^{137}Cs radioactivity measurements, several models are used (Zapata, 2002). In this proposed study we used distribution profile model; it takes account of ^{137}Cs depth distribution within the soil. Generally, ^{137}Cs distribution in non-agricultural fields has an exponential shape with a coefficient of distribution h0. From ^{137}Cs depth distribution profile in cork oak forest, h0 was determined of about 94 kg m^{-2} (Fig. 7).

Estimated rates of soil loss in sampling points, by applying distribution profile model, range from 1.2 to 12.4 tha^{-1} yr^{-1} with a mean loss of 6 tha^{-1} yr^{-1}. Depo-

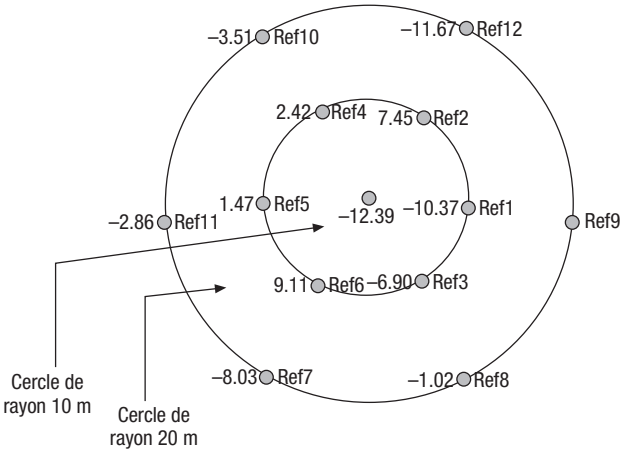

Figure 7. Erosion and deposition rates ($tha^{-1}\ yr^{-1}$) estimated by using distribution profile model for all sampling points; negative values are expressing erosion while positive are deposition.

sition assessments are between 1.47 and 9.11 $tha^{-1}\ yr^{-1}$ with a net deposition of about 4 $tha^{-1}\ yr^{-1}$. Figure 7 is an illustration of the spatial distribution of soil erosion and deposition.

An other study based on ^{137}Cs technique was conducted, in the same time, in three agricultural fields next to the cork oak forest, of about 200 m far. Two of the parcels are under cereal/legumes rotation and the third one is a monoculture of vine for more than 30 years. Rates assessed at the first plot by using mass balance 2 model leads to a negative sediment balance, more erosion than deposition. Mean erosion rate was obtained of about 12 $tha^{-1}\ yr^{-1}$. However, in the second plot, even it is under cereal/legume rotation too, soil loss was slightly less important, erosion rate was found of 8 $tha^{-1}\ yr^{-1}$. The field ploughed in vine monoculture presents a mean erosion of about 11 $tha^{-1}\ yr^{-1}$.

Although experimental sites (cork oak forest and plots) are under the same climatic conditions, rainfall of 400 mm and agricultural fields ploughed in opposite slope direction with rotation systems, cork oak forest presents less soil loss.

The vegetation and soil surface measurements

The obtained data are the result of analyses and direct measures made on 30 experimental plots inside the forest. Globally, the forest slopes are weak; 40% of the plots have a slope which does not exceed 2%. Only 13% of the studied cases have a slope which varies between 25 and 35%. The soils are often shallow, 10% only reach 100 cm; 30% of the cases, have depths which vary between 30 and 60 cm, and 16%, have a lower depth than 15cm.

45% of the surface is covered by rock fragments or by pebbles, with a rate of covering which varies between 40 and 80%; it's why the streaming does not get organized. But, this means that the sheet erosion is enough efficient to evacuate the fine elements and to concentrate the coarse particles and the pebbles at the surface.

50% of the forest lands have values of organic matter, varying between 2 and 6% and only 3% of the cases have a rate of organic matter superior to 6%. 47% of the forest lands are very poor in term of organic matter (less than 2%).

The texture remains relatively coarse, but the substratum is often impervious. So, given the weak depth of soils, the capacity of keeping water is relatively small. The water table is then often perched, reaching the surface during the excessively wet phases, and so provoking important streaming, establishing rills and gullies, even in the agricultural zones, in haloes around the forest.

Vegetation cover

Herbaceous

The plot of regeneration of cork oak put into defence, old of 4 years, records the most important covering of the herbaceous (average 70% of the surface) in 2008 and 82% in 2009 (more humid year). And we recorded in this regenerated plot the weakest rate of the bare ground.

The plot of regeneration of cork oak is also the richest in perennial plants others than the asphodel; these sorts represent 8% of the total herbaceous cover, while they represent only 4.4% in the plot of regeneration opened to grazing and do not exceed 2% in the plot of natural cork oak.

We record in the plot of regeneration of cork oak the weakest rate of asphodel cover (only 2% of the herbaceous plants in 2008). While in the plot opened to grazing, the rate of the asphodel, which is an intrusive sort, indicator of overexploitation, reaches 15% and it reaches 34% in the plot of clear natural cork oak.

In the plot of reforestation of Eucalyptus, the covering of the herbaceous is low, not exceeding 42.5% of the

surface and the rate of bare soil is important (28.5%). But these rates remain moderate, in comparison with the plot of land of scattered natural cork oak where we recorded the highest rate of bare ground reaching 33% of the total surface and the weakest contribution of the herbaceous (only 20% of the surface).

Litter

In the plot of reforestation of Pine, we record the highest covering of the litter, reaching 55% of the surface, while the rate of the herbaceous and the bare ground is respectively 40 and 5%. The abundance of the litter under the pine can be explained by the deposit on the surface of the pine needles and by the absence of specific microfauna, responsible of the decomposition of the litter.

Shrubs and young trees

The results of the average covering of shrubs, obtained by the method of linear interception show that the plot of regeneration of cork oak put into defence, records the most important rate (67% of the surface). This stratum is characterized by a net dominance of *Cistus monspeliensis* and *Cistus salviifolius*, who represent 87% of the total shrubs, the young trees of cork oak regenerated (not exceeding 2 m height), represent 13% of the total shrub cover. The rate of success of the plantations of cork oak reached 85% as the stake in defence was respected and the guarding well assured during the first two years. But the measures realized in 2009 after 5 years of stake in defence, show that 47% of the regenerated trees of cork oak, are still shrubs (not exceeding 2 m height).

In the plot opened to grazing, we record the weakest covering of shrubs (only 17% of the surface), constituted essentially by cistus and at the contrary the highest rate of herbaceous (70% of the surface); in the dense, normal and clear cork oak the covering of the shrubs is respectively 51%, 39% and 43%.

The shrubs in the Eucalyptus and Pine plots represent respectively 28.5% and 18% of the surface (*Cistus monspeliensis, Cistus salviifolius, Gnidium Daphne* and *Chamaerops humilis*).

The total biomass (herbaceous + shrubs)

Measured in the plot of regeneration in defence is 6,619 kg of green matter/ha. A high part of this biomass (68.5%) is produced by the herbaceous (Asphodel + other herbs). In the plot opened to grazing, we record 2,567 kg of green matter/ha. But this biomass remains very important, in comparison with the plot of scattered cork oak where we record only 466 kg/ha. In the plots of dense, normal and clear cork oak, the biomass is respectively estimated 1,375, 1,200, and 606 kg/ha (Fig. 8).

The asphodel which is a pastoral intrusive plant, indicator of overgrazing, represents only 6.7% of the total herbaceous production in the plot of regeneration. In the one opened to the pasture, the rate of the asphodel increases and reaches 46% of the total herbaceous production. This rate exceeds 61% in the plots of clear and scattered cork oak.

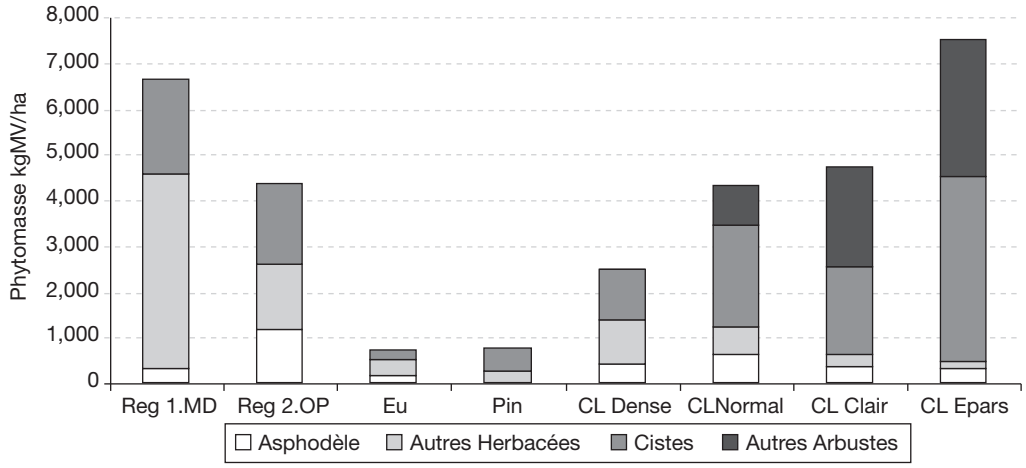

Figure 8. The biomass of various sites in the cork oak forest.

In the plot of Pine, we record the weakest biomass of herbaceous (250 kg of green matter/ha) which represents then the lowest potential in term of fodder for grazing. In the Eucalyptus the green matter of herbaceous reaches the value of 525 kg/ha. In the degraded cork oak covers, most of the biomass is represented by shrubs and asphodel. Its high amount (7,486 kg/ha) doesn't correspond to a high value in term of fodder production (the good herbaceous represent only 2% of the total biomass).

The biomass of the cork oak trees (measures made at the Benslimane forest) is 3.52 kg of green matter for each tree (Machouri, 2005). As the average density of the forest of Shoul, is 147 tree/ha (Eaux et Forêts, 2001), we can estimate that this forest produces an amount of accessible leaves biomass of about 518 kg/ha.

Floral diversity

The plot of regeneration still enclosed contains the highest number of species (25 sort/m^2 in 2009). The plot of dense cork oak contains 22 sort/m^2. The plot of regeneration opened to grazing contains 20 sort/m^2, what is important in comparison with the normal and scattered cork oak which contain respectively 18 and 16 sort/m^2. The plots of Eucalyptus and Pine record the weakest number of the floral sorts that is respectively 13 and 14 sort/m^2 in 2009 (very humid year) and only 8 and 9 sort/m^2 in 2008.

Production of cork

The results of inventory by plot of land (Eaux et Forêts 2001) reported to the total forest show that the production of reproduction cork is 327 kg/ha while the production in male cork is 258 kg/ha.

The production of energy wood in the forest of Shoul

The amount of wood consumed by the households of the users of the forest is estimated at 1,174 tons (or 1,752 steres/year). The forest offers 1,1 steres/ha/year, which means 9,234 steres on 8,395 ha. This quantity is widely superior to the amount consumed (Eaux et Forêts 2001). But, in addition to the allowed consumption, a high amount of energy wood is cut for the cities' needs, and create forms of very deep degradation.

Assessment of the surface soil parameters

The plot of regeneration put in defence records the highest rate of humidity during a dry period (7.15%), and at the contrary, the resistance to the penetration (2.04 kg/cm^2) and the value of cohesion of the soil (0.063 KPa) the weakest of all the forest. This is explained by the absence of grazing in this plot still enclosed for 5 years. In the plot of regeneration opened to grazing, the humidity is lower (4.34%), but this value is superior to the ones recorded in the natural plots of cork oak, namely in the degraded ones. In the pine plot, the humidity is 5.34%, due to the importance of litter and of the trees' canopies.

The high content of organic matter and nitrogen in the plot of regeneration facilitates the microbial activity and the pedogenesis and enriches the soil, what explains the important covering of the herbaceous even in presence of dense shrubs.

After the opening to grazing, we notice that this content become weaker but remain comparable to the one recorded in the scattered cork oak. In the Pine, the content in organic carbon is the lowest (1.33%) what indicates that the microbial activity is very weak. This can explain the abundance of the litter under this cover and the poverty of the soil in nitrogen, and the slowing down of the mineralization of the organic matter. This can explain the very weak production of the herbaceous sorts.

Rain simulation

Grazing in forest is a still long-lived tradition in the commune of Shoul and the pastoral breeding remains one of the bases of the economic and social organization of the population among which the precariousness of the resources and the low level of life stresses their dependence towards the resources of the forest. The cattle, the ovine races, but also the goats are often led in the forest during all the periods of the year. This system of traditional breeding is based essentially on an extensive but continuous exploitation of the herbaceous plants under forest of cork oak.

In the objective to estimate the impact of the pasture on the degradation of the forest of Shoul, experiments by rain simulation with measures of the states of surface and the infiltration were led on three samples of plots of land of cork oak (Nafaa, 2002; Antari, 2007). The first one represents a plot of land of assisted rege-

neration of cork oak for about 5 years and put into defence, the second also corresponds to a plot of land with assisted regeneration of 10 years but opened to grazing and the last one is a plot of natural cork oak.

The choice of the sites of measures is based on the distinction between the grazed plots and the ones in defence, to estimate the impact of the pasture on the hydrological behavior of the forest grounds. The studied plots of land constitute a homogeneous physical unit in term of pedology (fersiallitic soil) and topography (slopes < 5%). The conditions of humidity were also similar in the three sites with values of initial humidity varying between 2 and 6% and an antecedent rain of 7 mm which occurred 10 days before the tests of simulations.

Under the conditions of rain intensity (50 mm/hour), the streaming becomes almost the main rule in the plots of grazed forest. Indeed, in the plot opened to grazing, the streaming is premature and starts from the first 15 mn in spite of a weak initial humidity (2%) while the plot in defence did not stream even after 60 min. In the case of both grazed plots, the natural oak and the planted one, the release of the streaming took place before even the stabilization of the humidity which arose only at about the 50th minute of the beginning of the simulation.

The streaming is more important in the plot strongly grazed of oak regenerated (Fig. 9); the runoff coefficient is of 18% against only 2% in the natural oak. The plot of regeneration presents a strong compaction in April, 2008. This is the result of the concentration of the herds in this plot desired by the cattle of the bordering douars, because of the various plants developed during the 10 years of defense.

The results obtained by the method of the double ring (Fig. 10) show a net differentiation between the grazed forests and those put in defence. Indeed, in the forest in defence, the rate of initial infiltration is 5 times as raised that of the grazed forest. At the stage of saturation, the regime of infiltration which indicates the hydraulic conductivity to saturation (Ksat) translates so clearly this effect of the collapse on the hydrological processes of the ground. Ksat which is about 60 mm/hour in the forest in defence pass at 6 mm/hour only in the forest opened to grazing.

The soil loss calculated on the scale of the small plot of simulation (0.24 m^2), vary of 1 g/hour/m^2 in the forest of natural oak to 4 g/hour/m^2 in the plot of land grazed of 10 years. These differences can be bound to the fact that the excessive grazing at the level of the plot of land of 10 years increases the fragility of the soil because it destroys the superficial crust what gives place to a heterogeneous surface very favorable to the mobilization of particles by the streaming. However, in spite of the destruction of the crust by the animals' feet (which is supposed to improve the infiltration), it is the collapse of the in-depth ground, under the influence of the weight of the cattle, that takes it by reducing the porosity and consequently the hydraulic conductivity of the ground. So, the parts not disintegrated or still closed by the crust facilitate the streaming whereas the disintegrated zones are easily moved by the drainage.

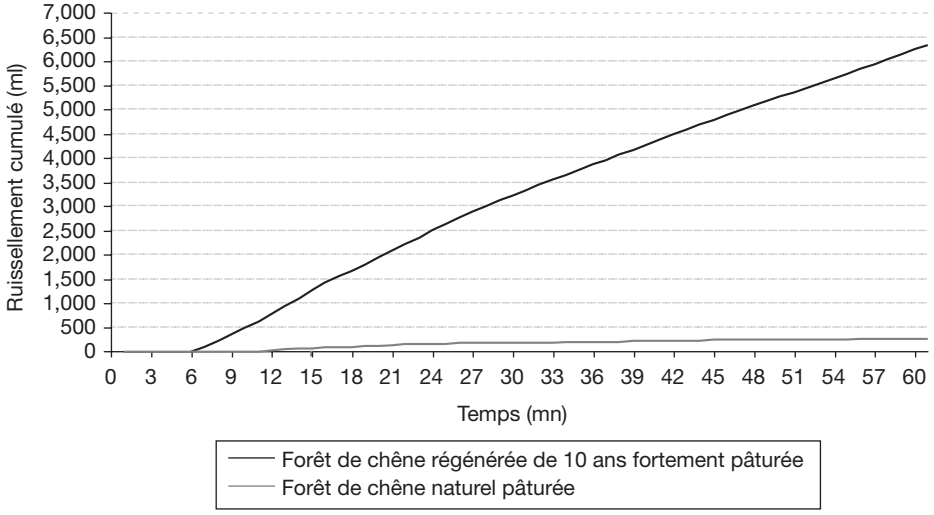

Figure 9. Evolution of runoff in two oak plots natural and regenerated under various degree of grazing.

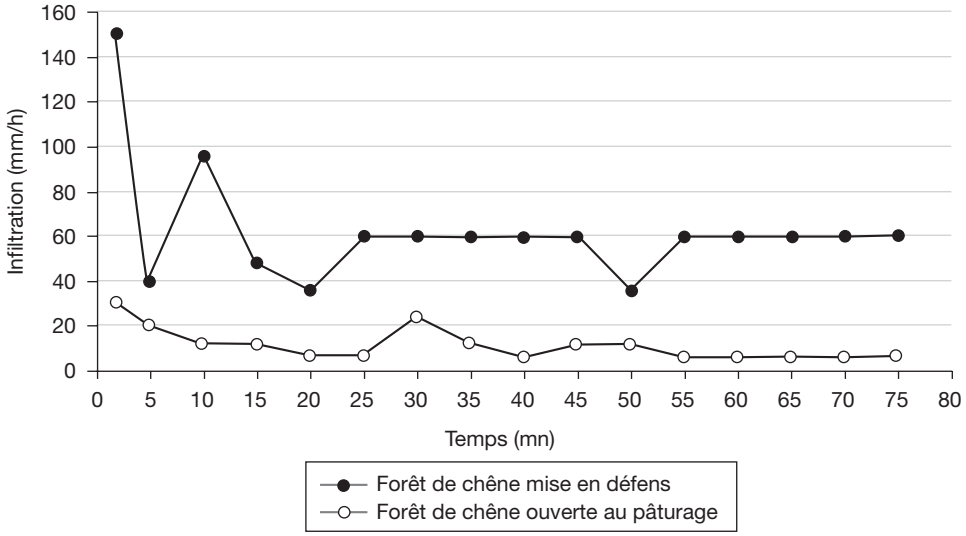

Figure 10. Evolution of the infiltration in two plots of land of enclosed and grazed forest.

Conclusion

The measures made in the Shoul region prove that the forest behaviour is much more in favour of the conservation of soil and water, compared to other uses (Nafaa, 2002; Aderghal *et al.,* 2007). They also show that the choice for forest management, by cork oak regeneration, with grazing regulations and protection, represents the more promising alternative to remediate the current situation of land degradation. But, this choice requires a high financial supply and a real appropriation by the local population.

The current situation of the Shoul forest, with natural non regeneration of the cork oak forest, questions its role on the ecological, economic and social plan; this explains the appeal to extent the assisted regeneration, as promising technique to perpetuate this heritage.

But, if the techniques of reforestation and of water and soil conservation seem to be advanced well and mastered by the forest agents, the obtained results remain insufficient and cannot guarantee the survival of the forest. To take up the challenge, it is imperative to consider the peri-forest zones which constitute haloes of poverty and explain the strong pressure on the forest; this shows the necessity of integrating them into the programs of forest management.

The herbaceous plants of the forest of Shoul are dominated by the annual sorts, the long-lasting sorts are little represented; this dominance reflects the importance of the degradation, engendered by a strong anthropological and grazing pressure. This explains why, during the dry season and in autumn, the soil is not protected and then easily eroded.

The long-lasting sorts are dominated by the asphodel, intrusive sort indicator of overexploitation, while in the plot of regeneration still enclosed, the asphodel is rare. The high rate of the asphodel in the grazed surfaces, even under the dense covers of oak, is a factor of poverty in term of fodder and economic income. The perennial sorts, the most interesting in term of fodder and of soil conservation are rare both in the degraded surfaces and in the reforested areas planted with Eucalyptus, and are only represented by the asphodel, while in the Pine they are absent.

The very important covering of shrubs in the regenerated plots, constituted essentially by cistus, influences negatively the growth of cork oak trees through the competition for water and fertilizers, what requires operations of clearing of cistus.

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