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Abandoned Quarries in the Akreuch Area (Western Morocco): Inventory of Flora for a Rehabilitation Strategy

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Abstract

Quarrying is an activity contributing to the vitality of the Moroccan economy. However, most of these quarries were abandoned at the end of extraction and became dump and later a place of uncontrolled landfills. The number of restored or rehabilitated quarries is limited and this threatens several aspects of the environment, especially, the quality of surface and ground water, landscape, forests, etc. This also gives rise to increased erosion risk. The study identifies plant species covering 10 abandoned quarries in the region of Rabat, especially the Bouregreg River and its affluent Akreuch in order to define a strategy for their restoration or rehabilitation. Field surveys were led to locate and map 10 abandoned quarries and to sample plant species. Herbaria were established and species were identified and classified. The results of the study distinguished 46 different plant species spread over 45 genera and 27 botanical families. The most dominant family in the quarries visited is *Asteraceae*. These results will allow us to study the vegetation dynamics in these abandoned lands and serve as a basis, in the selection of appropriate species in eventual restoration or rehabilitation projects.

Keywords

Akreuch, Bouregreg, Flora, Quarries, Rehabilitation, Restoration

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1. Introduction

In the Mediterranean countries, extractive activities increase pressure on soil and water resources already limited, which accelerates the process of erosion and subsequent destruction of existing arable lands [1]. The Rabat-Sale-Zemmour-Zaer Region is rich of quarries; according to the national inventory of quarries published by the Ministry of Transport in October 2012 [2], this region counts 117 quarries among the 1885 quarries spread over Morocco. 41% are abandoned including two quarries declared rehabilitated, 49% active and 10% suspended.

Quarry exploitation is defined as a temporary land occupation; rehabilitation must allow the impacted land to regain its former position, or to be intended for a new use. In terms of restoration planning, analysis of the natural regeneration process is a good starting point for the selection of appropriate species to use [3]. Native plants are adapted to the soil, temperature, and the regime of their environment. They are genetically adapted to the local ecology [4]. This study identifies the flora of 10 limestone and marl abandoned quarries in the region of Akreuch and falls within the definition of a strategy for their redevelopment.

2. Material and Methods

2.1. Study Area

The abandoned quarries explored (**Table 1**) are located on the Atlantic coast in the Rabat-Sale-Zemmour-Zaer Region and belong to the private domain. They are between the mouth of Akreuch, the dam of Sidi Mohammed Ben Abdellah and the Bouregreg River (**Figure 1**). The normal average temperatures in the region vary from 7˚C in winter to 26.4˚C in summer [5]. The annual rainfall has a normal rate of 560 mm. The study area is characterized by Paleozoic terrains ranging from the Ordovician to Carboniferous with shale, sandstone, quartzite and compact limestone facies; the Cenozoic overlies on the Paleozoic by a major unconformity. Cenozoic materials are represented by Neogene sandstone and marl facies. The sedimentary series underlies Quaternary limestone [6]; (**Figure 2**).

2.2. Flora Balance Sheet

The study of the flora of the 10 abandoned sites is based on field surveys conducted in 2014 (spring/summer). Floristic inventories have been developed in a systematic way in order to be as exhaustive as possible.

The choice of targeted sites is based on their concentration in a sensitive environment because of their proximity to urban areas, the Bouregreg River and its affluent Akreuch. These Quarries are prone to uncontrolled waste sites, which may affect the surrounding areas as they represent a breeding ground for pollution and a risk to the sanitation and the health of neighboring residents and local wildlife.

Field campaigns carried out in the region of Akreuch between the end of May and the end of June 2014 have led to the establishment of a floristic inventory of plant species in 10 abandoned quarries. These quarries were geolocalized and accompanied by a mapping using GIS and satellite images (Landsat 8) dating back to April 2013 and rechecked using a Magellan GPS. The latter has allowed the delimitation of the land concerned and the

Table 1. Characteristics of the study sites.

Quarry	Exploiting	Commissioning	Closing Date	Rock Nature	Area (m²)	Municipality
C1	Med Boudkhil	-	-	Marl	11,510	Souissi
C2	Abassour	-	-	Marl	7800	Souissi
C3	Fadil-Dar Dmana	1978	2003	Limestone	23,000	Souissi
C4	SDT-SOCAROA (Ste Doukkala)	1973	2007	Limestone	157,500	Oum Azza
C5	SOGECAR	1969	2008	Limestone	103,200	Hssaine
C6	Ste Rougani	1945	2008	Limestone	45,800	Oum Azza
C7	Belahcen	1959	2008	Limestone	13,500	Oum Azza
C8	El Mohami	1970	1992	Limestone	57,000	Oum Azza
C9	SDT-SOCAROA (Ste Doukkala)	1975	2007	Limestone	57,300	Oum Azza
C10	SDT-SOCAROA (Ste Doukkala)	1973	2007	Limestone	14,500	Hssaine

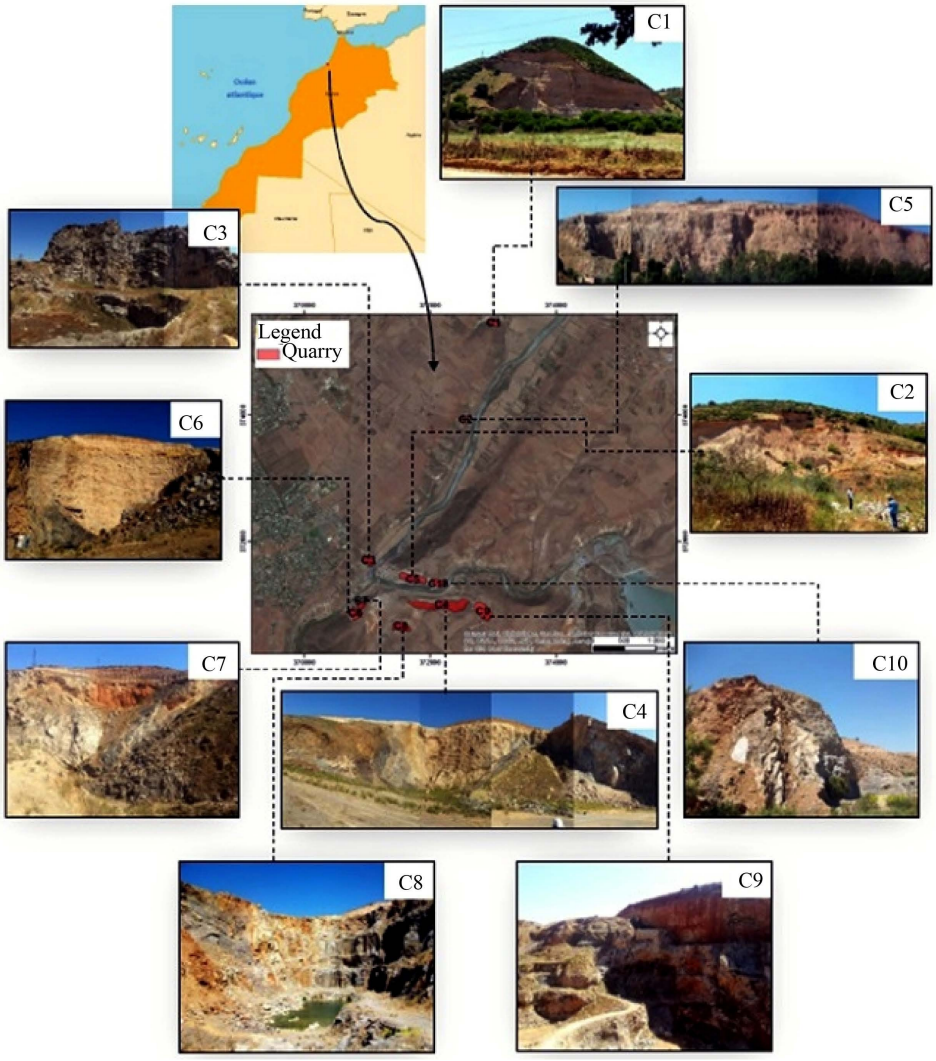


Figure 1. Geographical situation of the studied quarries.

specification of their area that is estimated to 491,100 m^2 (**Table 1**) and also the organization of the different layers of information that formed the basis for the collection of vegetation data.

Quarries surfaces were covered and photos were taken for each collected plant species. The collection was done in a systematic way, herbaria were established and the sampled species growing on the floors and walls of quarries were determined in the Department of Natural Resources and Environment-IAV Hassan II, Rabat (Morocco) and have been classified by quarry, life form, family, genera and class, endemic species and very rare species have been specified according to taxonomic keys and previous studies [7]-[11].

3. Results and Discussion

In order to better know the flora colonizing the abandoned quarries, tables of identified species were developed for each quarry including their characteristics (**Tables 2-11**). The number of species sampled and identified is 130 species.

C1 quarry, located on the right bank of the Bouregreg River, is a former marl quarry, with a height of 43 meters, mostly dominated by the family *Asteraceae*. Dicotyledons occupy 86% of the overall total including two endemic species to Morocco; they are listed as very rare and belong to the geographical division Maamoura-Zemmour-Zaer [9] [10]; it comes to the species *Phagnalon saxatile* and *Centaurium umbellatum* (**Figure 3**). Therophytes are best represented in this quarry (**Table 2**).

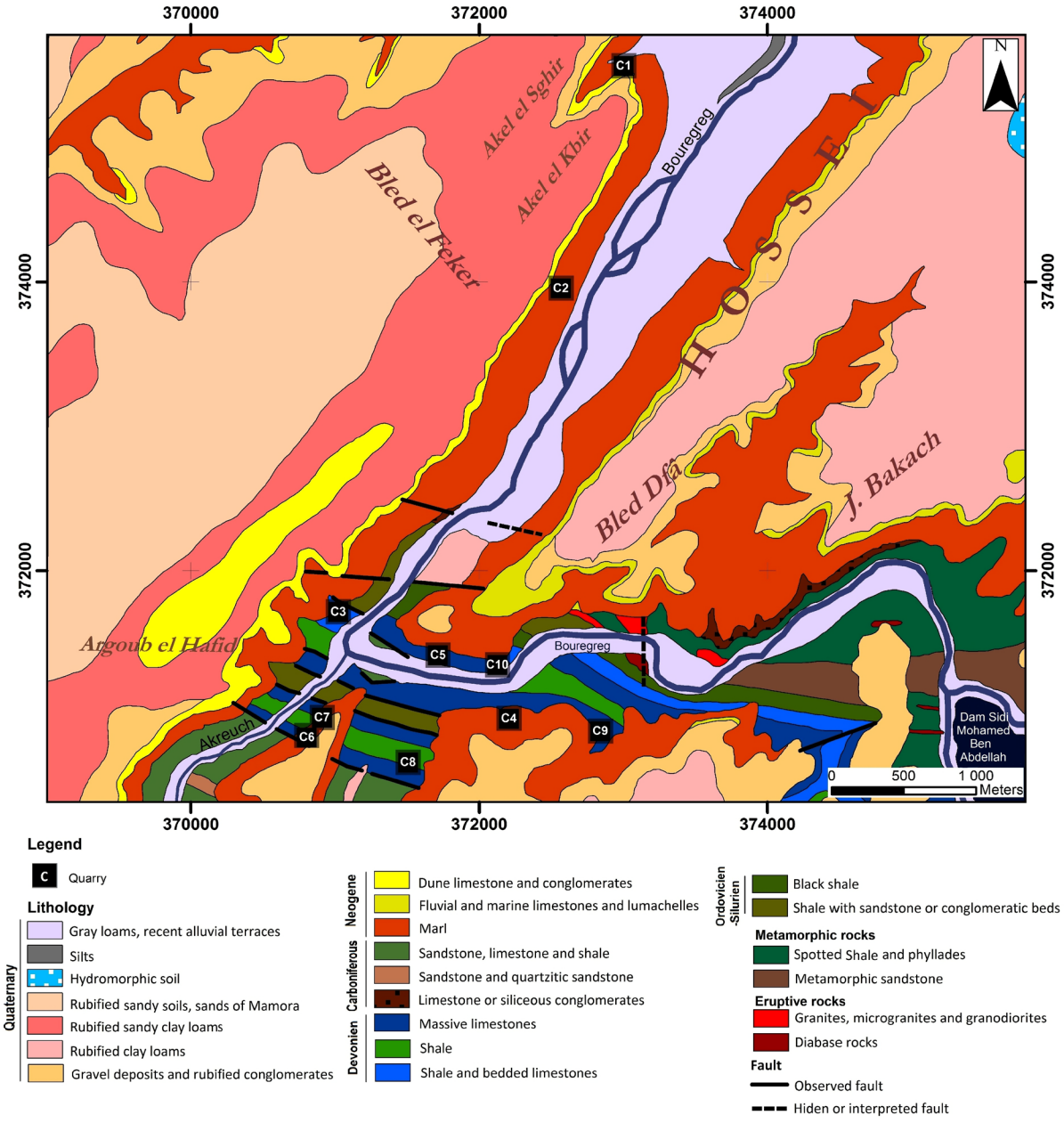


Figure 2. Geology of the study area (According to the geotechnical map of Milliès-Lacroix [6]).

C2 quarry is a former exploitation of marl with a height of about 52 meters, located on the right bank of the Bouregreg River. Surveys carried out in this quarry have revealed 11 different species in which the *Asteraceae* family ranks first. Dicotyledons are strongly represented and include an endemic species to Morocco classified very rare; the species *Phagnalon saxatile*. The most common life form in this abandoned land is Therophyte (**Table 3**).

C3 quarry is an old clay pit, located 40 meters from the Bouregreg River with a height of 70 meters. 23 species were identified, including the species *Phagnalon saxatile* and the species *Centaurium umbellatum*; classified very rare and endemic to Morocco, they are specifically associated to the North Atlantic Moroccan geographic division. This division has 200 very rare taxa [9] [10]. The quarry is characterized by the presence of 18 different families of which 83% belong to Dicotyledons. The most dominant life forms are respectively Hemicryptophyte (8 species) and Phanerophyte (6 species) (**Table 4**).

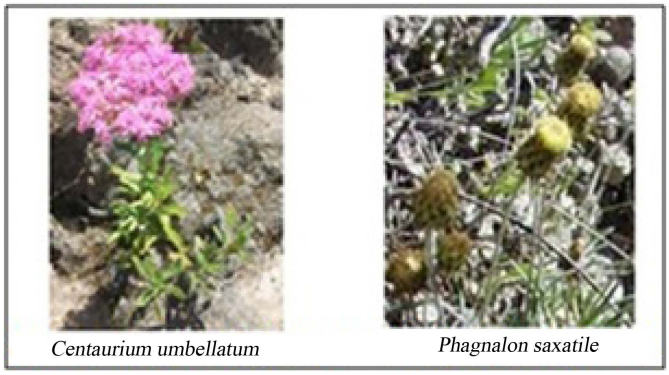


Figure 3. Photos of some rare species of the study area.

Table 2. List of species identified in the quarry C1.

Quarry	Family	Species	Genera	Life Form	Class
C1	*Apiaceae*	*Ammi majus* L.	*Ammi*	*Therophyte*	Dicotyledons
	Asteraceae	*Aster squamatus* Spreng.	*Aster*	*Hemicryptophyte*	Dicotyledons
	Asteraceae	*Chrysanthemum coronarium* L.	*Chrysanthemum*	*Therophyte*	Dicotyledons
	Asteraceae	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Chenopodiaceae	*Beta macrocarpa* Guss.	*Beta*	*Hemicryptophyte*	Dicotyledons
	Euphorbiaceae	*Euphorbia terracina* L.	*Euphorbia*	*Therophyte*	Dicotyledons
	Fabaceae	*Trifolium angustifolium* L.	*Trifolium*	*Therophyte*	Dicotyledons
	Gentianaceae	*Centaurium umbellatum* Gilib.	*Centaurium*	*Therophyte*	Dicotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Polypogon monspeliensis* (L.) Desf.	*Polypogon*	*Therophyte*	Monocotyledons
	Resedaceae	*Reseda lutea* L.	*Reseda*	*Therophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 3. List of species identified in the quarry C2.

Quarry	Family	Species	Genera	Life form	Class
C2	*Asteraceae*	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Fabaceae	*Trifolium angustifolium* L.	*Trifolium*	*Therophyte*	Dicotyledons
	Lamiaceae	*Marrubium vulgare* L.	*Marrubium*	*Chamaephyte*	Dicotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Poaceae	*Polypogon monspeliensis* (L.) Desf.	*Polypogon*	*Therophyte*	Monocotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Polygonaceae	*Rumex pulcher* L.	*Rumex*	*Hemicryptophyte*	Dicotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 4. List of species identified in the quarry C3.

Quarry	Family	Species	Genera	Life Form	Class
C3	*Apiaceae*	*Elaeoselinum asclepium* (L.) Bertol.	*Elaeoselinum*	*Hemicryptophyte*	Dicotyledons
	Apiaceae	*Torilis arvensis* (Huds.) Link	*Torilis*	*Therophyte*	Dicotyledons
	Asclepiadaceae	*Asclepias curassavica* L.	*Asclepias*	*Hemicryptophyte*	Dicotyledons
	Asteraceae	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Caprifoliaceae	*Scabiosa atropurpurea* L.	*Scabiosa*	*Hemicryptophyte*	Dicotyledons
	Casuarinaceae	*Casuarina* L.	*Casuarina*	*Phanerophyte*	Dicotyledons
	Euphorbiaceae	*Ricinus communis* L.	*Ricinus*	*Phanerophyte*	Dicotyledons
	Fabaceae	*Trifolium angustifolium* L.	*Trifolium*	*Therophyte*	Dicotyledons
	Gentianaceae	*Centaurium umbellatum* Gilib.	*Centaurium*	*Therophyte*	Dicotyledons
	Lamiaceae	*Lavandula multifida* L.	*Lavandula*	*Chamaephyte*	Dicotyledons
	Liliaceae	*Asparagus albus* L.	*Asparagus*	*Geophyte*	Monocotyledons
	Moraceae	*Ficus carica* L.	*Ficus*	*Phanerophyte*	Dicotyledons
	Plumbaginaceae	*Limonium sinuatum* (L.) Mill.	*Limonium*	*Hemicryptophyte*	Dicotyledons
	Plumbaginaceae	*Plumbago* L.	*Plumbago*	*Hemicryptophyte*	Dicotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Phragmites australis* Trin. Ex Steud.	*Phragmites*	*Geophyte*	Monocotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons
	Solanaceae	*Solanum sodomaeum* L.	*Solanum*	*Chamaephyte*	Dicotyledons
	Typhaceae	*Typha latifolia* L.	*Typha*	*Geophyte*	Monocotyledons
	Urticaceae	*Parietaria mauritanica* Durieu	*Parietaria*	*Hemicryptophyte*	Dicotyledons
	Verbenaceae	*Vitex agnus-castus* L.	*Vitex*	*Phanerophyte*	Dicotyledons

Table 5. List of species identified in the quarry C4.

Quarry	Family	Species	Genera	Life Form	Class
C4	*Asteraceae*	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Brassicaceae	*Diplotaxis catholica* (L.) DC.	*Diplotaxis*	*Therophyte*	Dicotyledons
	Fabaceae	*Trifolium angustifolium* L.	*Trifolium*	*Therophyte*	Dicotyledons
	Poaceae	*Avena alba* Vahl	*Avena*	*Therophyte*	Monocotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Ranunculaceae	*Delphinium peregrinum* L.	*Delphinium*	*Therophyte*	Dicotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 6. List of species identified in the quarry C5.

Quarry	Family	Species	Genera	Life Form	Class
C5	*Amaranthaceae*	*Chenopodium murale* L.	*Chenopodium*	*Therophyte*	Dicotyledons
	Asteraceae	*Chrysanthemum coronarium* L.	*Chrysanthemum*	*Therophyte*	Dicotyledons
	Asteraceae	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Myrtaceae	*Eucalyptus* L'Hér.	*Eucalyptus*	*Phanerophyte*	Dicotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Papaveraceae	*Papaver rhoeas* L.	*Papaver*	*Therophyte*	Dicotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Poaceae	*Polypogon monspeliensis* (L.) Desf.	*Polypogon*	*Therophyte*	Monocotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 7. List of species identified in the quarry C6.

Quarry	Family	Species	Genera	Life Form	Class
C6	*Asteraceae*	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Juncaceae	*Juncus maritimus* Lam.	*Juncus*	*Geophyte*	Monocotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Poaceae	*Avena alba* Vahl	*Avena*	*Therophyte*	Monocotyledons
	Poaceae	*Cynodon dactylon* (L.) Pers.	*Cynodon*	*Geophyte*	Monocotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Phragmites australis* Trin. Ex Steud.	*Phragmites*	*Geophyte*	Monocotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 8. List of species identified in the quarry C7.

Quarry	Family	Species	Genera	Life Form	Class
C7	*Asteraceae*	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Gentianaceae	*Centaurium erythraea* Rafn	*Centaurium*	*Therophyte*	Dicotyledons
	Juncaceae	*Juncus maritimus* Lam.	*Juncus*	*Geophyte*	Monocotyledons
	Lamiaceae	*Marrubium vulgare* L.	*Marrubium*	*Chamaephyte*	Dicotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Polygonaceae	*Rumex pulcher* L.	*Rumex*	*Hemicryptophyte*	Dicotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 9. List of species identified in the quarry C8.

Quarry	Family	Species	Genera	Life Form	Class
C8	*Asteraceae*	*Centaurea calcitrapa* L.	*Centaurea*	*Hemicryptophyte*	Dicotyledons
	Asteraceae	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Juncaceae	*Juncus maritimus* Lam.	*Juncus*	*Geophyte*	Monocotyledons
	Poaceae	*Avena alba* Vahl	*Avena*	*Therophyte*	Monocotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Poaceae	*Cynodon dactylon* (L.) Pers.	*Cynodon*	*Geophyte*	Monocotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Phragmites australis* Trin. Ex Steud.	*Phragmites*	*Geophyte*	Monocotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 10. List of species identified in the quarry C9.

Quarry	Family	Species	Genera	Life Form	Class
C9	*Asteraceae*	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Asteraceae	*Silybum marianum* (L.) Gaertn	*Silybum*	*Therophyte*	Dicotyledons
	Fabaceae	*Trifolium angustifolium* L.	*Trifolium*	*Therophyte*	Dicotyledons
	Myrtaceae	*Eucalyptus* L'Hér.	*Eucalyptus*	*Phanerophyte*	Dicotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Cynodon dactylon* (L.) Pers.	*Cynodon*	*Geophyte*	Monocotyledons
	Poaceae	*Avena alba* Vahl	*Avena*	*Therophyte*	Monocotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledons
	Solanaceae	*Nicotiana glauca* Graham	*Nicotiana*	*Phanerophyte*	Dicotyledons

Table 11. List of species identified in the quarry C10.

Quarry	Family	Species	Genera	Life Form	Class
C10	*Amaranthaceae*	*Chenopodium murale* L.	*Chenopodium*	*Therophyte*	Dicotyledons
	Asteraceae	*Chrysanthemum coronarium* L.	*Chrysanthemum*	*Therophyte*	Dicotyledons
	Asteraceae	*Dittrichia viscosa* (L.) Greuter	*Dittrichia*	*Chamaephyte*	Dicotyledons
	Asteraceae	*Phagnalon saxatile* (L.) Cass.	*Phagnalon*	*Phanerophyte*	Dicotyledons
	Asteraceae	*Scolymus hispanicus* L.	*Scolymus*	*Therophyte*	Dicotyledons
	Myrtaceae	*Eucalyptus* L'Hér.	*Eucalyptus*	*Phanerophyte*	Dicotyledons
	Papaveraceae	*Glaucium flavum* Crantz	*Glaucium*	*Hemicryptophyte*	Dicotyledons
	Papaveraceae	*Papaver rhoeas* L.	*Papaver*	*Therophyte*	Dicotyledons
	Poaceae	*Avena alba* Vahl	*Avena*	*Therophyte*	Monocotyledons
	Poaceae	*Cynodon dactylon* (L.) Pers.	*Cynodon*	*Geophyte*	Monocotyledons
	Poaceae	*Hyparrhenia hirta* (L.) Stapf	*Hyparrhenia*	*Hemicryptophyte*	Monocotyledons
	Poaceae	*Phragmites australis* Trin. Ex Steud.	*Phragmites*	*Geophyte*	Monocotyledons
	Poaceae	*Polypogon monspeliensis* (L.) Desf.	*Polypogon*	*Therophyte*	Monocotyledons
	Poaceae	*Vulpia fasciculata* (Forssk.) Fritsch	*Vulpia*	*Therophyte*	Monocotyledons
	Scrophulariaceae	*Verbascum sinuatum* L.	*Verbascum*	*Hemicryptophyte*	Dicotyledon

C4 quarry is the largest one in the study area, called Doukkala, after the name of the company that was exploiting the Devonian limestone. With a height of 70 meters and a length of over 900 meters, C4 has 7 different families including the very rare species *Phagnalon saxatile*, and the species *Diplotaxis catholica* endemic to Morocco and the Iberian Peninsula. The latter is classified as extinct or with a dubious presence (**Figure 4**) and belongs to the *Brassicaceae* family.

The class of Monocotyledons is not widespread: only two species of the *Poaceae* family: *Avena alba* and *Vulpia fasciculata* belonging to the Therophyte life form (**Table 5**).

C5 quarry is an abandoned limestone farm situated on the left bank of the Bouregreg River in the Hssaine municipality. With a height of 65 meters, this quarry is occupied by 7 different families with 83% belonging to the Dicotyledons class and is mostly dominated by the Therophyte life form. *Phagnalon saxatile* species has been recorded in this quarry (**Table 6**).

C6 is a former limestone quarry with a height of 70 meters, mostly occupied by the *Poaceae* family followed by the *Asteraceae* family. Dicotyledons class is the most present with a rate of 55%. It is noted in this quarry that the life form Hemicryptophyte and Geophyte are the most important with the same attendance rate. The quarry also recorded the species *Phagnalon saxatile* (**Table 7**).

C7 is a former limestone quarry, with a height of 60 meters. Its exploitation affected the water table which favored the appearance of some species typical of wetlands [12] (**Figure 5**); *Juncus maritimus* of the *Juncaceae* family, *Marrubium vulgare* of the *Lamiaceae* family and *Rumex pulcher* of the *Polygonaceae* family.

Figure 4. Photo of *Dipolataxis catholica*.

Figure 5. Photos of some species typical of wetlands.

The quarry counts 9 different families in which *Asteraceae* is the most dominant, two species classified very rare and endemic to Morocco, namely the species *Phagnalon saxatile* of the *Asteraceae* family and *Centurium erythraea* of the *Gentianaceae* family. Therophytes and Hemicryptophytes are best represented in this quarry (**Table 8**).

The former limestone quarry C8 reaches 50 meters in height. The extraction exposed the water table and spawned the emergence of a source in the quarry, which has promoted the development of some hygrophilous species *Juncus maritimus*, *Phragmites australis* and *Centaurea calcitrapa* [13]. Families showing the largest number of species are *Poaceae* followed by *Asteraceae*. Monocotyledons are best represented in this quarry with a rate of 60% of the overall total (**Table 9**).

C9 quarry is a former limestone exploitation of a height of 70 meters, dominated by *Asteraceae* and *Poaceae*. The life form Therophyte is the most common (5 species from a total of 13 species). Dicotyledons are strongly represented including the very rare species *Phagnalon saxatile* (**Table 10**).

C10 is an abandoned limestone quarry about 30 meters high. *Asteraceae* and *Poaceae* represent two-thirds of the overall total that includes the species typical of wetlands: *Cynodon dactylon*, *Phragmites australis* and *Polypogon monspeliensis* of Monocotyledons class. In more or less dry areas of the quarry, species *Polypogon monspeliensis* is gaining ground; this plant is pollinated by wind and water and is transported by wool and skin of animals [14]; (**Table 11**).

3.1. Results and Discussion

Statistical analysis conducted on the resulting tables shows that the *Asteraceae* is the most dominant with 34 species and 34 genera of the flora of the 10 quarries (26% of the overall total), followed by *Poaceae* with 30 species and 30 genera (23% of the overall total). The latter is leading in the ranking of the flora of Moroccan wetlands [15]. The family that occupies the 3rd rank is *Solanaceae* with 10 species and 10 genera (8% of the overall total); (**Figure 6**). The first three families of Moroccan vascular flora are always identical and in the same order: *Asteraceae*, *Fabaceae* and *Poaceae*. They totalize 1329 species, which is over a third of the national specific inventory [10]. In the elaborated inventory, the order is different; the family *Fabaceae* occupies the 5th rank with 5 species and 5 genera (4% of the overall total) after the families *Papaveraceae* and *Scrophulariaceae* with 8 species and 8 genera (6% of the overall total) each.

Dicotyledons, the best ranked class, include 95 species belonging to 36 different genera and 23 different families while Monocotyledons class is present with 9 species belonging to 9 different genera and 4 different families.

The species recorded in all quarries is *Dittrichia viscosa*. This plant, mainly distributed in the western Mediterranean countries, [16] is present in degraded sites [4]. Species *Nicotiana glauca*, *Scolymus hispanicus* and *Phagnalon saxatile* are recorded in 9 quarries, while other species are recorded in less than 9 quarries.

3.2. Systematic Aspect

Quarries that recorded the highest number of different species are C3 (23 species, 23 genera and 18 families all

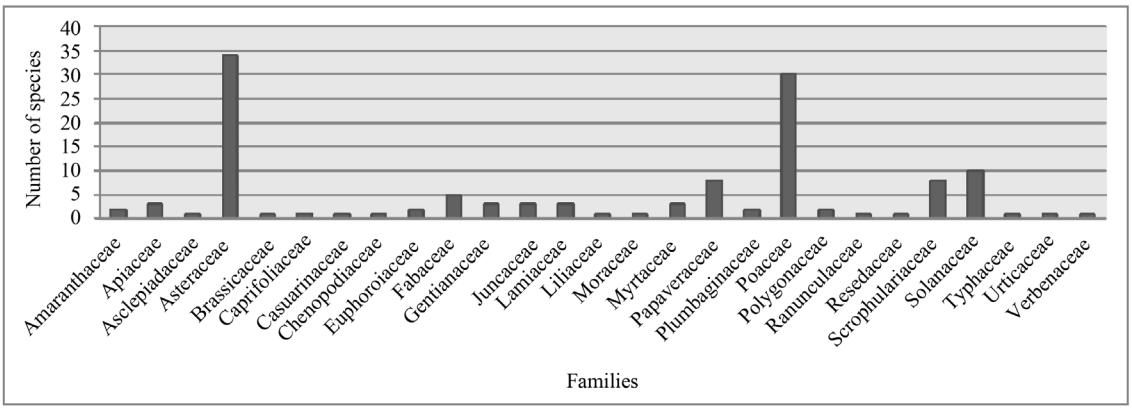


Figure 6. Ranking of families by number of species in the 10 abandoned quarries.

different), followed by C10 (15 species, 15 genera and 6 families all different). Other quarries have less than 15 different species (**Figure 7** and **Figure 8**).

The class of Dicotyledons dominates in all the quarries except C8 quarry where the class of Monocotyledons dominates with 60% of the overall total (**Figure 9**).

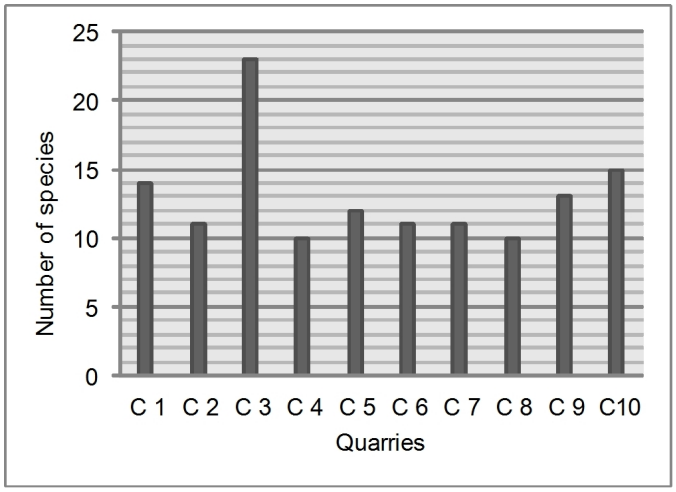


Figure 7. Number of different species by quarry.

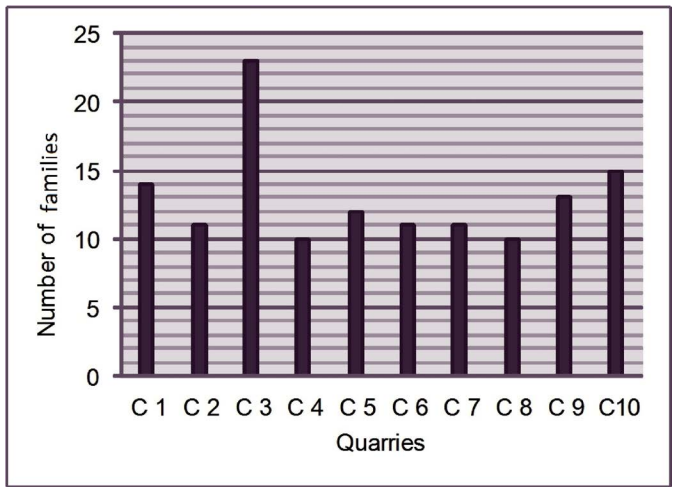
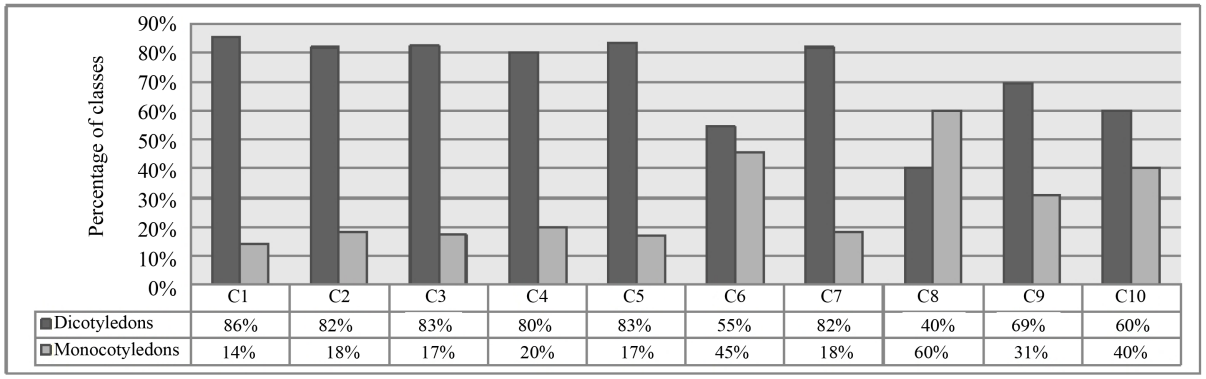


Figure 8. Number of different families by quarry.



	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Dicotyledons	86%	82%	83%	80%	83%	55%	82%	40%	69%	60%
Monocotyledons	14%	18%	17%	20%	17%	45%	18%	60%	31%	40%

Figure 9. Percentage of classes in the 10 quarries.

The life forms of identified species were classified according to the Raunkiaer system [17]. The latter classifies plants according to the position of their perennating buds in relation to the soil surface and also to their adaptation to unfavorable seasons. According to the spectrum of life forms (**Figure 10**), it is evident that the type Therophyte is the predominant and is represented by 36% of the total flora. The type Hemicryptophyte represents 24% of all species; these two types characterize the flora of Moroccan wetlands [15]. The Phanerophytes represent 19%, the Chamaephytes11% and the Geophytes 10% of total flora.

Quarries that sheltered the largest number of species of Therophyte are C1 (8 species), C10 (7 species), C4 (6 species) and C5 (6 species). The Hemicryptophyte life form is more dominant in the C3 quarry (8 species) followed by Phanerophyte (6 species) whereas it doesn't exceed 3 species in other quarries. No Geophyte species were found in C1, C2, C4 and C5 (**Figure 11**).

3.3. Environmental and Ecological Aspects

From the results, the most dominant species is *Dittrichia viscosa* of the *Asteraceae* family, many studies have shown that this plant grows in limestone or silica sol [18], it often locates in abandoned lands, on rocky coasts or screes of mountains, and it is characterized by a pioneering character when there is no competition among plants [16], followed by *Nicotiana glauca* known for its productivity of large amounts of seeds easily dispersible by the wind and for its resilience to a broad range of environmental conditions [19], *Phagnalon saxatile* the very rare species endemic to Morocco having a preference for calcareous soils [20], and *Scolymus hispanicus* which is common in poor soils waste places and abandoned agricultural lands [21].

The proximity of the Bouregreg River and its affluent Akreuch as well as the accumulation of rainwater and the attainment of the water table have favored the emergence of a few native wetland plants: *Marrubium vulgare*, *Scabiosa atropurpurea*, *Phragmites australis*, *Typha latifolia*, *Vitex agnus castus*, *Juncus maritimus* and *Cynodon dactylon*.

Therophytes have registered a large presence in the entire inventoried flora; this life form has an invader character and represents an indicator of hyperdegradation [22] [23].

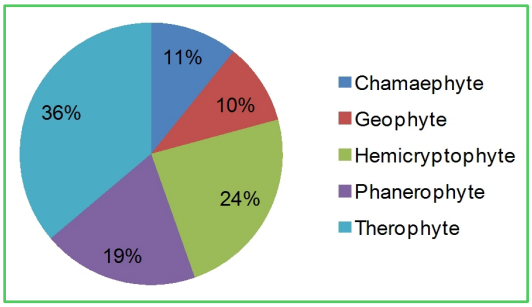


Figure 10. Spectrum of life forms in the 10 quarries.

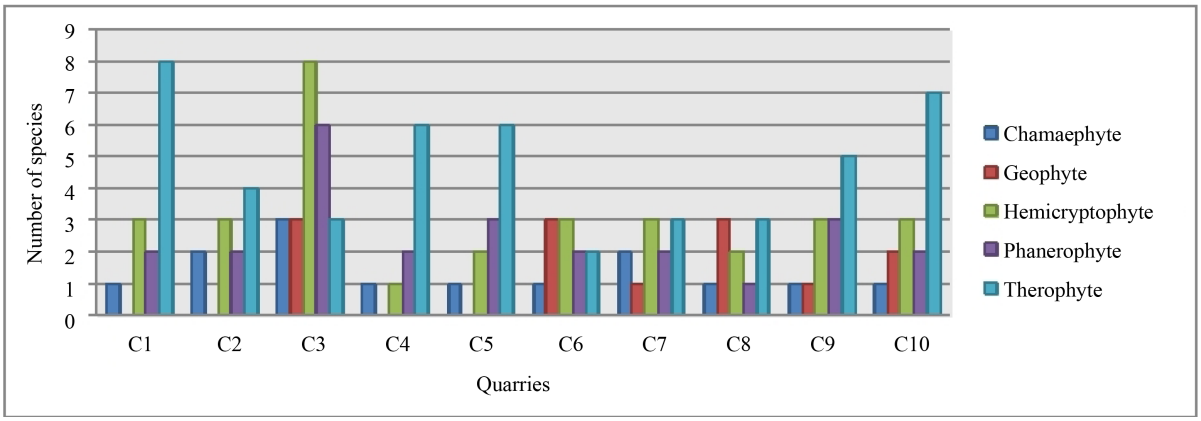


Figure 11. Distribution of life forms by quarry.

4. Conclusion

From botanic studies conducted, it can be concluded that:

1) Quarries shelter several plants with characteristics of Mediterranean species.
2) The majority belongs to the families *Asteraceae* and *Poaceae* that occupy 49% of the flora of all quarries, followed by *Solanaceae*, *Scrophulariaceae*, *Papaveraceae* and *Fabaceae*.
3) The frequency of the dominance of some species is explained by the ease of dispersion of their seeds by wind or animals.
4) The existence of the Bouregreg River and its affluent Akreuch contribute to biodiversity in this region.
5) The floristic analysis has revealed that 73% of the species inventoried are part of the Dicotyledons class and the life forms Therophyte (36%) and Hemicryptophyte (24%). Dicotyledons are largely dominant with 95 species including very rare, extinct or with a dubious presence species.

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