

Article

Floristic Composition, Diversity, Palatability, and Forage Availability of Forest Rangelands in the Southern Mediterranean Region of Northern Morocco

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Abstract: Forest rangelands are an important component of extensive goat production in the Mediterranean region. The aim of this study was to survey the floristic composition, lifespan, life forms, phytogeographic relationships, palatability degree, and forage availability of forest rangelands in Northern Morocco. To achieve this goal, a plant species inventory was carried out, and a digital herbarium was constructed. Forage availability was estimated using the quadrat method. According to the results, 358 taxa were recorded with 228 genera and 66 families. The flora is mainly dominated by Asteraceae, Fabaceae, Poaceae, and Lamiaceae families. Six principal life forms of plants were recognized with the predominance of therophytes (48.3%). The Mediterranean floristic category was the most dominant in the flora (73.7%) with 264 species. The palatability degree was studied for 95 taxa, known by herders. The palatable plant group was highly represented with 32 species. Of these identified taxa, 93% were evaluated as potential sources of forage for grazing animals. The forage availability depended considerably on the season and the existing plant species ($p < 0.01$). The spring recorded the higher value with 3143 kg DM/ha. In conclusion, forest rangelands have a high biodiversity, which they need for rigorous protection to preserve their floristic composition and diversity.

Keywords: botanical composition; biomass; flora diversity; silvopastoral area; grazing goat; Southern Mediterranean

Citation: Chebli, Y.; Chentouf, M.; Cabaraux, J.-F.; El Otmani, S. Floristic Composition, Diversity, Palatability, and Forage Availability of Forest Rangelands in the Southern Mediterranean Region of Northern Morocco. *Land* **2023**, *12*, 215. <https://doi.org/10.3390/land12010215>

Academic Editors: Fausto Sarmiento, Andreas Haller, Carla Marchant and Masahito Yoshida

Received: 8 December 2022

Revised: 6 January 2023

Accepted: 7 January 2023

Published: 9 January 2023



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1. Introduction

In Northern Morocco, forests cover an area of 544,291 ha, including 475,332 and 68,959 ha of natural and artificial forest formations, respectively. It is the most forested region of the country with 26% of the afforestation rates [1].

The forest lands ensure an appreciable and free forage production for grazing animals. Livestock production is related to grazing goats in the forest rangelands, which guarantees their free year-round feed. Shrub and tree species constitute their main feed resources. Compared to dairy goats, meat goat production is still largely dominant in the region, where forest rangelands are their unique feed source. In the study region, forest pastures contribute between 43 and 100% of the energy and 38 and 100% of the protein intakes of grazing goats [2,3]. Their number is about 627,000 heads concentrated in mountainous areas of the region [4]. Silvopastoral areas have also very important socio-economic roles for local populations [5]. In addition, goat farming contributes largely to the region's total agricultural income (from 68 to 100%) [6].

Rangelands are essential and cheap feed sources for grazing livestock [7]. Overall, pastoral activities are a common and traditional practice, but they come with a heavy price

because rangelands are suffering from a diminution of highly palatable species due primarily to overgrazing according to several studies [8–10]. The production systems based on pastures will inevitably experience a decline in productivity since palatable species are often replaced with less palatable or even toxic species [2,11].

In the Mediterranean region, forests cover about 7.5% of the entire region. They are known, in general, for their rich flora, with an estimated 25,000 vascular plant species [12]; however, they tend to be represented by low endemic species, between 5 and 10% in most cases [13]. Many researchers justify this diversity by the different conditions of each Mediterranean habitat [14]. Over the years, forests were a great source of income for many local populations by supplying wood and other goods in this region. However, this situation changed a bit lately between the Northern and Southern Mediterranean side. In the North, exploitation of forests dropped due to a decrease in profitability while in the South, the pressure on forests is as strong as ever [12]. In both sides, pastures share similarities from a floristic composition point of view, but they still have some uniqueness as each forest lands underwent a different process of change [7].

In North Africa, the flora is similar to the near regions of Europe and Africa, with widespread forests but suffers from great potential dangers [15]. These forests are characterized by the biodiversity that is essentially due to the coexistence of species from the Mediterranean, Saharian, and Macaronesian origins. Especially in Northern Morocco, forests host a plethora of typical Mediterranean botanical species [16]. They are known for their high biodiversity but, on the other hand, are experiencing serious threat levels, as they are under several degradation drivers [10,17,18]. They suffer from a loss in the biodiversity section, and they are degraded or even threatened with extinction following human activities without neglecting the effects of natural droughts, which are very frequent in the Mediterranean region. Thus, this situation requires conducting research on the floristic composition and diversity of forest rangelands. The floristic analyses of vegetation (diversity, production, palatability) could clarify the impact of many different factors in the evolution of woodlands [19]; there are so many variables affecting forest rangelands negatively or positively, depending on their intensity [10]. Compared to other rangelands, research carried out concerning the Southern Mediterranean forest is relatively less and remains scarce. In addition, a few studies focused on the ecology, palatability, and forage availability of plant species in the Mediterranean forest rangelands of Northern Morocco.

In this context, this study aims to investigate the floristic composition, lifespan, life forms, phytogeographic relationships, palatability degree, and forage availability of the North Moroccan forest rangelands in order to provide up-to-date information about the existing flora and diversity.

2. Materials and Methods

2.1. Study Area

The current botanical study was carried out in forest rangelands of Northern Morocco situated on the southern side of the Mediterranean area. The studied region is bordered by the Mediterranean Sea to the north, the Al-Hoceima region to the east, the Atlantic Ocean to the west, and the Gharb region to the south (Figure 1). It is under the Mediterranean climate, which is characterized by rainy and cold seasons during winter and mild during summer. Overall, the annual precipitation varied between 250 and 700 mm. In general, the mean temperature of 3 to 14 °C in winter and from 21 to 38 °C in summer (minimum and maximum, respectively) was characteristic for the studied region (Figure 2). It is a mountainous area mainly covered with shrub species and oak trees.

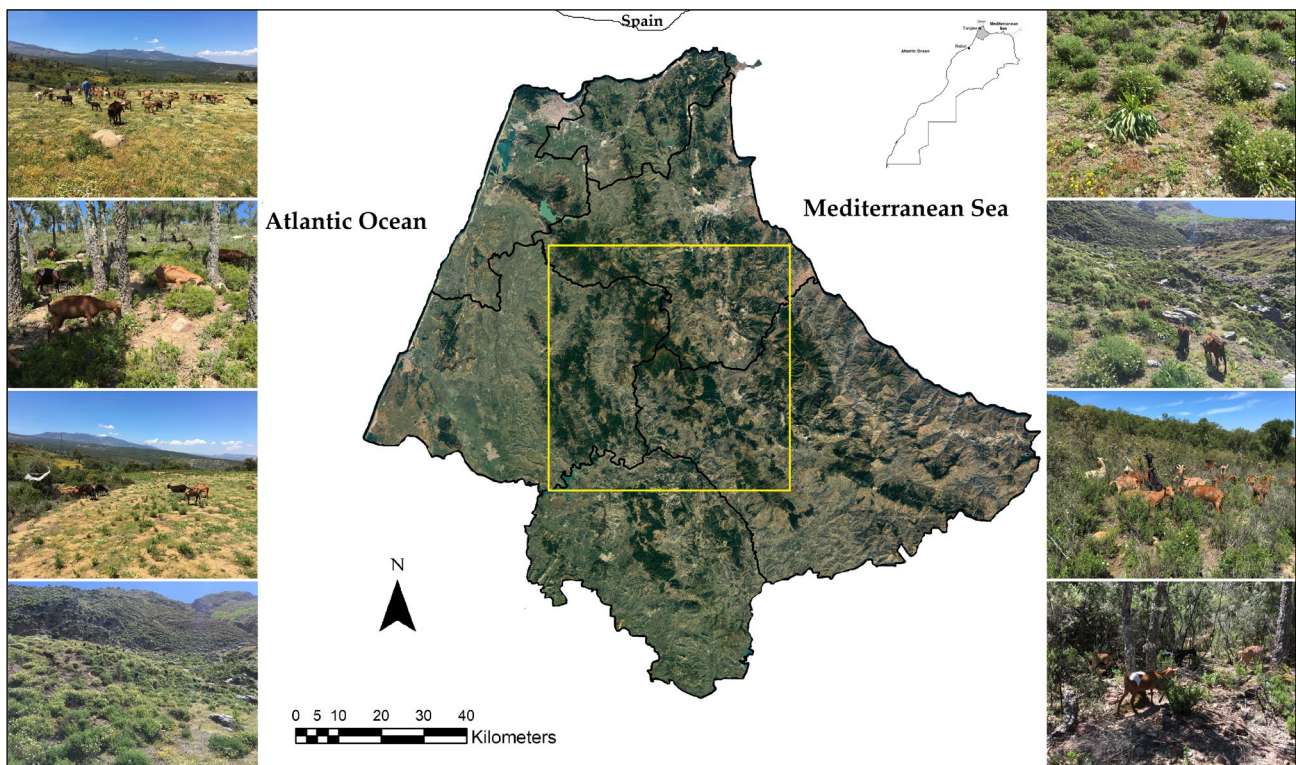


Figure 1. Map and photos of the studied forest rangelands in Northern Morocco. (Map was produced by Chebli in 2022 from the United States Geological Survey (USGS) archive).

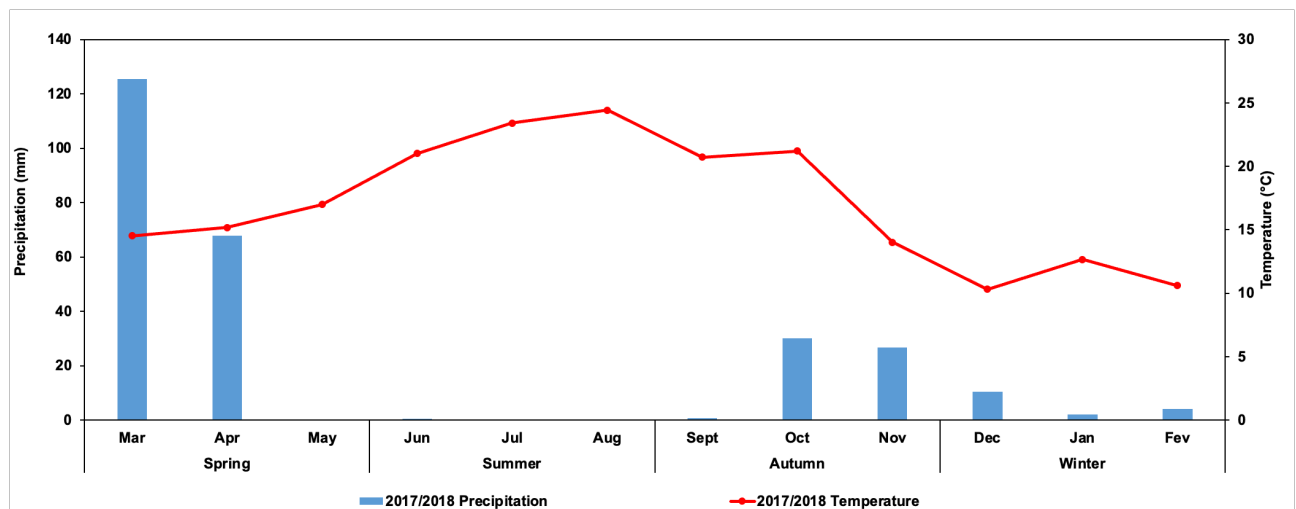


Figure 2. Monthly mean of temperature (°C) and precipitation (mm) in the study area (Northern Morocco) based on FiledClimate database (regional weather station).

The study area is a domanical forest covered with heterogeneous vegetation that goes from the low formations of the rockrose species (*Cistus* species), resulting from the degradation of the sylvatic series, up to the high oak groves. Vegetation includes oak species (*Quercus* species.) associated with shrublands dominated by the strawberry tree (*Arbutus unedo* L.) and the *Cistus* spp., inclusive of wrinkle-leaved (*C. crispus*), Montpellier (*C. monspeliensis*), and sage-leaved (*C. salviifolius*) rockroses. The average size of goat flocks grazing in the study area is less than 80 animals per farm. Grazing in the forest rangelands is practiced during spring, summer, and autumn under the supervision of the herders themselves or one of their family members. For the winter, the duration of grazing decreases to values as low as 1 to 3 h per day (browsing fallow land around the farm). During this

season, pasture access is very limited, and herders delimb tree branches as fodder and bring them to the goat shed. Livestock watering is guaranteed by water sources and streams inside the grazed forested rangeland.

2.2. Data Collection

2.2.1. Botanical Study

The botanical study was conducted from September 2017 to August 2018 to identify different plant species. The vegetation inventory was carried out during the blooming and fruiting period of vegetation to draw up a list of the plant species present in the study area. The quadrat method was used to measure the floristic composition. Several numbers and sizes of quadrats were tested to get the most representative quadrat to minimize the effect of rangeland heterogeneity. Three line transects (Lt) were installed in the studied forest rangelands. The line transects were selected based on visual difference and change in the vegetation composition. A total of twenty quadrats were installed between 250–550 m a.s.l along each transect line: Lt 1 (35° 08' N; 5° 18' W), Lt 2 (35° 15' N; 5° 23' W), and Lt 3 (35° 18' N; 5° 24' W). Quadrats were installed at every 50 m altitudinal drop along transect lines. All woody plant species, including trees and shrubs, were recorded in 20 m × 20 m quadrats while herbaceous species were recorded in twenty sub quadrats (5 m × 5 m) that systematically covered the entire main quadrat. All plants species of each transect were classified and identified in the field with the aid of flora catalogues, such as the catalogue of Moroccan plants [20], the flora of North Africa [21], the practical flora of Morocco [22], and flora and ecosystem of Morocco [23]. A photo collection of each plant species (leaf, stem, flower, and fruit) using a high-resolution digital camera was done to construct a digital herbarium. This herbarium was used as a base to compare and verify the accuracy of the collected plants identification. We carried out the taxonomic identification of the samples at the laboratory of Regional Center for Agricultural Research of Tangier (INRA-Morocco), considering the recent modifications.

The forest degradation was evaluated using the perturbation index. It was calculated using the following equation [24]:

$$\text{Perturbation index} = \frac{\text{Number of chamaephytes} + \text{Number of therophytes}}{\text{Total number of species}} \quad (1)$$

2.2.2. Palatability Index

Palatability is the corollary of the animal's appetite for the selected forage. It was determined by the direct observation of grazing goats [18] and has been complemented by interviews with several herders, who use the studied forest rangelands as a feed source for their livestock. The palatability of each plant species by grazing goats is calculated through the palatability index. It is widely used as an indicator of palatability degree based on indigenous knowledge of local herders. The palatability index has a possible range from 0 to 5: (0) complete avoidance and completely non-palatable species, (1) occasionally palatable or poorly palatable, (2) moderate preference and medium palatable, (3) palatable, (4) very palatable, and (5) complete preference and highly palatable [25–28].

2.2.3. Forage Availability Measurement

Forage availability (biomass production) of rangelands varies over the season and regarding the existing palatable species. Biomass measurement was estimated during each grazing season (spring, summer, and autumn). Therefore, 80 quadrats of 40 m² were selected from floristically and structurally homogeneous places according to the minimal area concept. They were implemented seasonally in the study rangelands to estimate the forage availability of woody species. In this study, only the accessible and selected part of each plant species by goats were considered. The selected plant species includes *Arbutus unedo*, *Erica Arborea*, *Cistus salvifolius*, *Cistus monspeliensis*, *Lavandula stoechas*, *Myrtus communis*, *Olea europaea* var. *sylvestris*, *Phillyrea latifolia*, *Pistacia lentiscus*, *Quercus* spp., and

Rubus ulmifolius. The goats tended to select the leaves, stem shoots, and fruits of all these species. For herbaceous, 80 quadrats of 1 m² were installed, each one embedded within one shrub quadrat. In the field, the biomass measurements were started in the last month of each studied grazing season (May, August, and November). The winter season was excluded from the measurements because it is not considered a grazing season by herders as the animals are kept in the shed and grazed only around the farm. After collection, plants samples were transported to the laboratory and dried in an oven at 55 °C until a constant weight to determine their dry matter (DM) [5]. For each species, mean plant biomass in Kg DM per hectare was calculated by season.

2.3. Statistical Analysis

Forage availability was analyzed using a general linear model (GLM) procedure of SAS. Data analyses were performed using SAS software v9.x (SAS Inst. Cary, NC, USA) to determine the seasonal variation of biomass production during spring, summer, and autumn. The significance level was declared at $p < 0.05$. In case of significant effect, the means were compared using the Tukey's test.

3. Results and Discussion

3.1. Brief Paleoecological Analysis

Thanks to its geographical position and climate, Northern Moroccan forests have always been characterized by high biodiversity (about fifteen forest species: cedar, cork oak, fir, pine, zeen oak, tauzin oak, cedar, etc., and many endemic species) [29,30]. These forests contain important Mediterranean species, such as *Cistus* and *Ericaceae*, due to the similarity of climate and the narrowness of the strait of Gibraltar that is produced during a not very remote period (Pliocene) [31]. In addition, there are strong flora from the Atlantic domain of the Euro-Siberian region (from Portugal, Spain, Atlantic France, and the British Isles) [31].

Studies providing historical information on ecosystem changes and species dynamics in the Rif mountains are scarce [32]. According to some paleo-ecological studies, cedar (*Cedrus atlantica*: Atlas cedar) has been present in North Africa since 8000 BP [33], formed true forest ecosystems, and dominated the Rif landscape between 8000 and 6000 BP [32]. After 6000 BP, cedar forests were progressively degraded due to the aridity and were replaced by deciduous oaks [32]. Currently, in the Rif region, cedar forests are found between 1500 and 2500 m altitude; at the supra-Mediterranean level, they are infiltrated by sclerophyllous or deciduous oaks; at the Mediterranean level, they are pure and dense; and at the Oro-Mediterranean, they are sparse and infiltrated with species of bare grasslands or junipers [29]. Even occupying small areas estimated at 15,200 ha [30], the cedar forests played a key role in the Moroccan economy because they are exploited in timber with of 1 m³/ha/year in Rif [29,34]. Cork oak forests are found at the meso-Mediterranean level, much less degraded but less extensive, and at the supra-Mediterranean level in relatively dry areas; however, deciduous oaks species (*Quercus canariensis* and *Quercus pyrenaica*) constitute degraded and much less extensive forests in the meso-Mediterranean level, whereas they are present in the wetlands of the supra-Mediterranean [29]. Tauzin oak appears in the central-western part of the Rif in the humid and perhumid meso-Mediterranean and supra-Mediterranean levels [29].

In the 80s and 90s and at low altitudes, the olive groves (*Olea europaea* var. *sylvestris*) were totally extinct, and coccifera meadows were no longer visible except in the form of matorrals [35]. The situation of Tetraclinis and natural pine forests was not very different, and cork and green oak forests previously constituted the bulk of the forest massifs of the central Rif, today occupy only a very small area because they have been heavily degraded [30,35]. At high altitudes, the fir forest risks disappearing, and the natural regeneration capacities of this endemic formation are greatly weakened by the drying out of seedlings [35], and most cork groves have disappeared, as have the oak groves (zeenaie, tauzaie)

[30]. The deciduous forests of *Quercus canariensis* which have been exploited in a regular and systematic way seem irrecoverable [35].

3.2. Floristic Composition of the Study Area

3.2.1. Taxonomic Diversity

Flora is a fundamental element of natural ecosystems that reflect the effect of the total environment. Climatic conditions cause significant changes in the floristic composition of natural rangelands. The precipitation is considered the dominant factor driving the floristic composition and diversity [36]. Overall, the southern side of the Mediterranean region, mainly Northern Morocco, is an area of winter rainfall. During the last decade, it observed of a variability on precipitation distribution and quantity. As shown in Figure 2, 72% of the annual precipitation is recorded during spring, compared to 6% during the winter season. As reported by several authors [37–42], this precipitation variability could have an impact on the diversity of plant families, phenology, and life cycles.

The diversity and habitat class of plant families examined in the current study are presented in Figure 3. Based on the obtained results, the floristic diversity of forest rangelands of Northern Morocco comprises 358 species, which are taxonomically distributed among 228 genera in 66 families (Supplementary Materials Table S1). Thus, taxonomic diversity in the study area is 1.57 species per genus. Herbaceous flora contributes to 86.1% of species while shrubs and trees contain 11.7 and 2.2%, respectively. The dominant herbaceous species were *Anthemis cotula* L., *Brachypodium distachyon* (L.) P.Beauv., *Bromus* spp. (inclusive of *B. hordeaceus* L., *B. mollis* L., *B. rubens* L., and *B. tectorum* L.), *Clinopodium nepeta* (L.) Kuntze, *Cynodon dactylon* (L.) Pers., *Medicago* spp. (inclusive of *M. ciliaris* (L.) Krock., *M. minima* L., *M. orbicularis* (L.) Bartal., *M. polymorpha* L., *M. sativa* L., and *M. truncatula* Gaertn.), *Ranunculus* spp. (inclusive of *R. bullatus* L., *R. ficaria* L., *R. macrophyllus* Desf., *R. muricatus* L., *R. paludosus* Poir., and *R. parviflorus* L.), *Rumex* spp. (inclusive of *R. bucephalophorus* L., *R. conglomeratus* Murr., *R. intermedius* DC., and *R. spinosus* L.), *Trifolium* spp. (inclusive of *T. arvense* L., *T. campestre* Schrb., *T. isthmocarpum* Brot., *T. scabrum* L., *T. stellatum* L., *T. subterraneum* L., and *T. tomentosum* L.), and *Vicia* spp. (inclusive of *V. faba* L., *V. hirsuta* (L.) Gray, *V. lathyroides* L., *V. lutea* L., *V. peregrina* L., and *V. sativa* L.). In the study area, *Arbutus unedo* L., *Calicotome villosa* (Poir.) Link, *Cistus* spp. (inclusive of *C. crispus* L., *C. monspeliensis* L., and *C. salvifolius* L.), *Erica arborea* L., *Lavandula stoechas* L., *Myrtus communis* L., *Phillyrea latifolia* L., and *Pistacia lentiscus* L. were the dominant shrub species. *Quercus* spp. (inclusive of *Q. coccifera* L., *Q. faginea* L., and *Q. suber* L.) and *Olea europaea* L. subsp. *europaea* var. *sylvestris* (L.) (Mill) Lehr were the dominant trees. Compared to the botanical composition of different Southern Mediterranean [16,43,44] and Middle Eastern regions [45–47], the studied forest rangelands of Northern Morocco recorded a higher number of taxa. In the oak woodlands of Greece, a Northern Mediterranean silvopastoral region, a total of 302 plant taxa were identified [48]. However, 364 taxa were recorded in cork oak forests of the Northwestern Iberian Peninsula [49], which is slightly similar to the current funding. In addition to the climatic conditions, the difference in taxonomic diversity could be due to other environmental conditions, such as topography and soil composition [43,47], human action [44,50,51], and animal grazing, which greatly affects the botanical composition of rangelands [10,52–54].

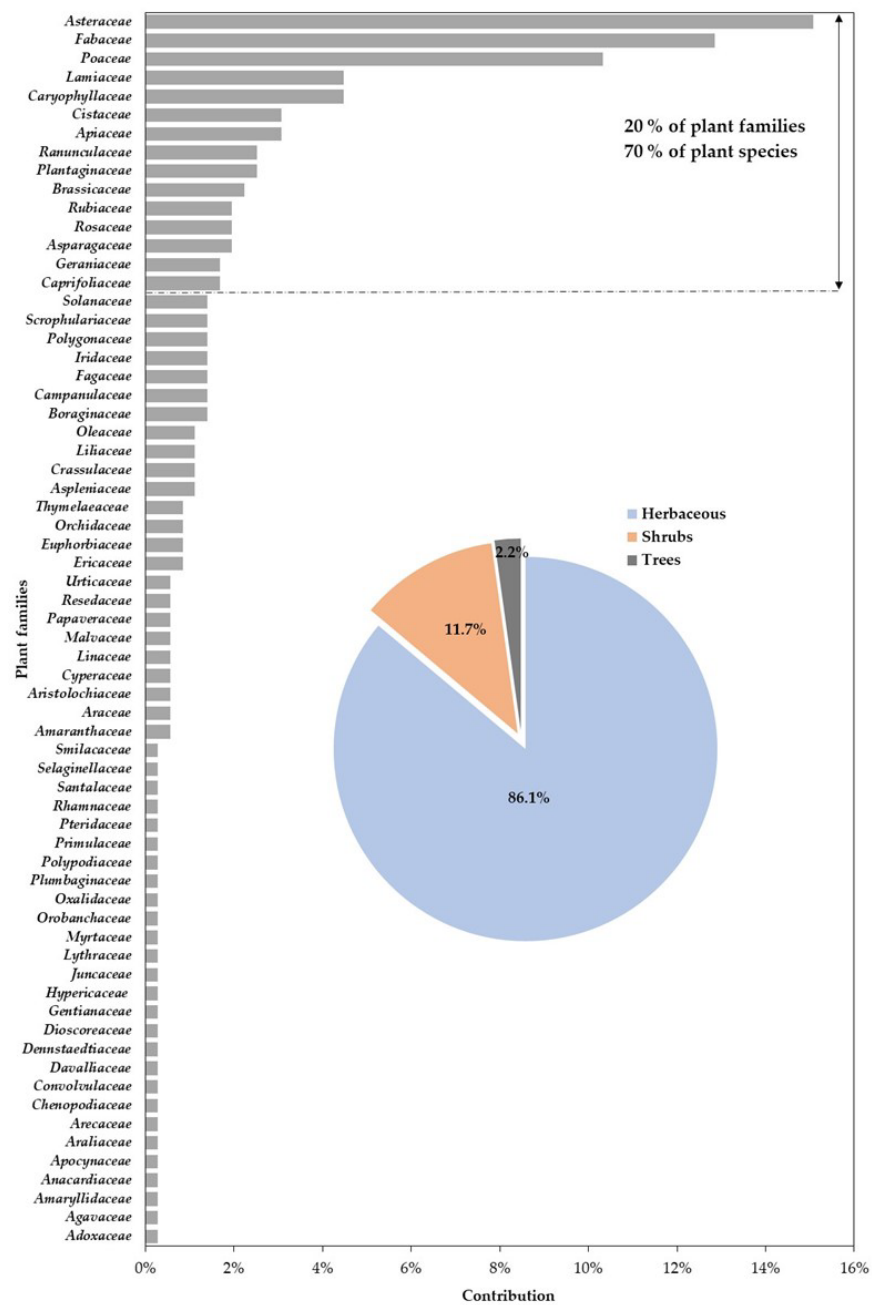


Figure 3. Diversity histogram and habitat class of plant families in the studied forest rangelands of Northern Morocco.

Based on plant longevity or life span, it was determined that most of the flora found in the studied forest rangelands were perennials with 235 species (66%) and exceeds the annuals (123 species, 34%). The predominance of perennials could be explained by the low rainfall recorded during the studied year, which is not enough for the development of the annuals. The perennial plants are more adapted to the climatic and soil conditions of the studied mountainous region and adapted to its extreme habitats. In addition, it was reported that the presence of annual species decreases with the increase of altitude [55,56]. The same tendency of changes in growth type along gradients have been observed in other studies [56–58].

Asteraceae was the leading family in number with 54 species (15.1%) followed by Fabaceae with 46 (12.8%); Poaceae with 37 (10.3%); Lamiaceae and Caryophyllaceae with 16 each (4.5%); Apiaceae and Cistaceae with 11 each (3.1%); and Caprifoliaceae,

Geraniaceae, Asparagaceae, Rosaceae, Rubiaceae, Brassicaceae, Plantaginaceae, and Ranunculaceae with 6 to 9 species each (1.7 to 2.5%). These fifteen families (20% of plant families) represent 70% of the total recorded taxa. Boraginaceae, Campanulaceae, Fagaceae, Iridaceae, Polygonaceae, Scrophulariaceae, and Solanaceae were represented by 5 species each (1.4%). Aspleniaceae, Crassulaceae, Liliaceae, and Oleaceae were represented by 4 species each (1.1%). Forty flora families were represented by three species and less. Similarly, Asteraceae, Poaceae, Fabaceae, and Lamiaceae have been reported as dominant families in Southern Mediterranean forest [43,53,59].

The richest genera in the studied forest rangelands are *Trifolium* (8 taxa); *Cistus* (7 taxa); *Medicago*, *Ranunculus*, *Veronica*, and *Vicia* (6 taxa each); *Quercus* (5 taxa); and *Asplenium*, *Campanula*, *Cynosurus*, *Galium*, *Plantago*, and *Rumex* (4 taxa each). These genera represent 19% of the flora. Most of the families in the area are polytypic with 205 species (57%) while 135 families are monotypic (43%), which means they are presented by a single genus and single species.

3.2.2. Biological Spectrum and Perturbation Index

The evaluation of the biological spectrum is based on the seasonal observations of life forms of each plant species. Figure 4 illustrates the life form spectrum of the flora recorded in the studied forest rangelands of Northern Morocco according to Raunkiaer [60]. Six principal life forms of plants were recognized. The Raunkiaer life form spectrum showed that therophytes were the dominant life form in the study area with 173 plant species (48.3%) followed by hemicryptophytes with 85 plant species (23.7%), phanerophytes with 50 plant species (14.0%), geophytes with 29 plant species (8.1%), chamaephytes with 20 plant species (5.6%), and parasites with one plant species (0.3%). According to the normal spectrum of Raunkiaer [60], the therophytes revealed the maximum deviation (+35.3%) and geophytes the minimum (+4.1%). On the contrary, a negative deviation of -32% has been observed for phanerophytes followed by chamaephytes (-3.4%) and hemicryptophytes (-2.3%). This trend of life form spectra is similar to other Southern Mediterranean cork oak forests [61–64]. As reported by several authors [65–69], most of the forests in the Mediterranean basin are under therophytisation phenomena (abundance of therophytes). This situation could be explained by the human disturbances, which lead to increasingly severe situations, ranging from therophytisation to encroachment of woody plants [70]. The degradation process was already observed in the Mediterranean forest rangelands of Northern Morocco [10]. In addition, the prevalence of therophytes could be due to the long dry period and cold winter in the study region [71]. The chamaephytes are weakly represented (5.6%), which may be due to the large development of the phanerophytes [16]. However, it was reported that hemicryptophytes are the most numerous in the cork oak woodlands in Kabylia, Algeria (36%), followed by therophytes (33.4%) [11].

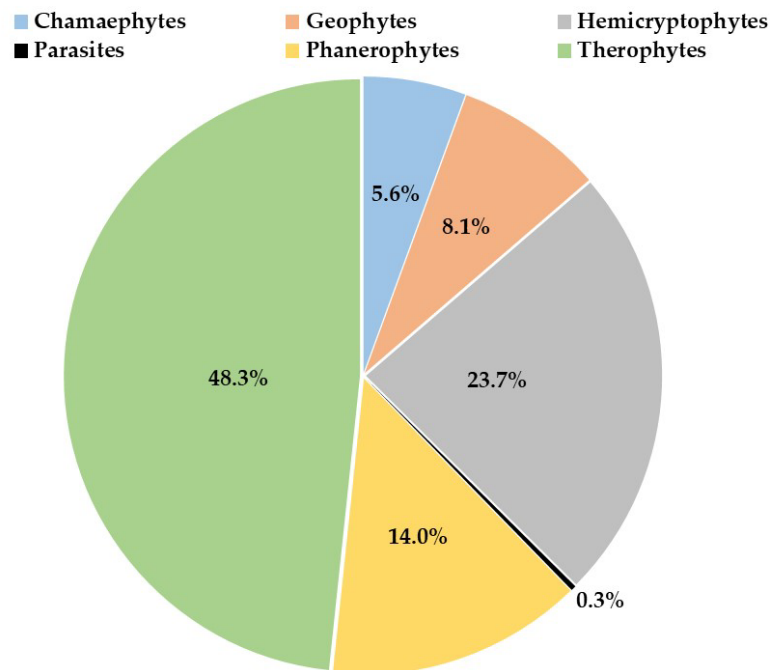


Figure 4. Life form spectrum of the flora recorded in the studied forest rangeland of Northern Morocco.

The perturbation Index of the studied forest rangelands was estimated at 54%. This index remains lower than that recorded in other Southern Mediterranean ecosystems, such as the Nador massif in Morocco (63.6%) [64] and in Tlemcen, Algeria (76%) [72]. However, a lower perturbation index was noted in the cedar forest of Djurdjura (31.7%) [73] and cork oak woodlands of Bissa forest (42%), Algeria [43], which are slightly less affected by overgrazing and degradation. The forest degradation is mainly related to human activities. According to two recent studies conducted in forest rangelands of Northern Morocco [10,74], this perturbation could be caused by fires (forests in Northern Morocco lose approximately 1185 ha/year due to fires, i.e., 43% of burned Moroccan forests); fuelwood extraction, which is 2.5 times higher than the potential of forest production; agricultural expansion (73,600 ha of forests were converted cultivated land during the last three decades); and shifting cultivation, which is responsible for the disappearance of 1000 ha of forest every year.

3.2.3. Phytogeographical and Chorological Analysis

The chorological analysis of the recorded plant species in the studied forest rangelands of Northern Morocco is displayed in Figure 5. According to the result, the collected material was classified into three major phytogeographical groups: monoregional, biregional, and pluriregional. The dominant group was biregional with 142 species (39.7%), followed by the monoregional with 120 species (33.5%), and pluriregional with 47 species (13.1%) groups. The least 49 (13.7%) plant species were distributed among other chorotypes: Circumboreal with 19 species (5.3%), Paleotemporal with 12 species (3.4%), Cosmopolitan with 9 species (2.5%), Subcosmopolitan with 5 species (1.4%), and finally the Paleosubtropical with 4 species (1.1%).

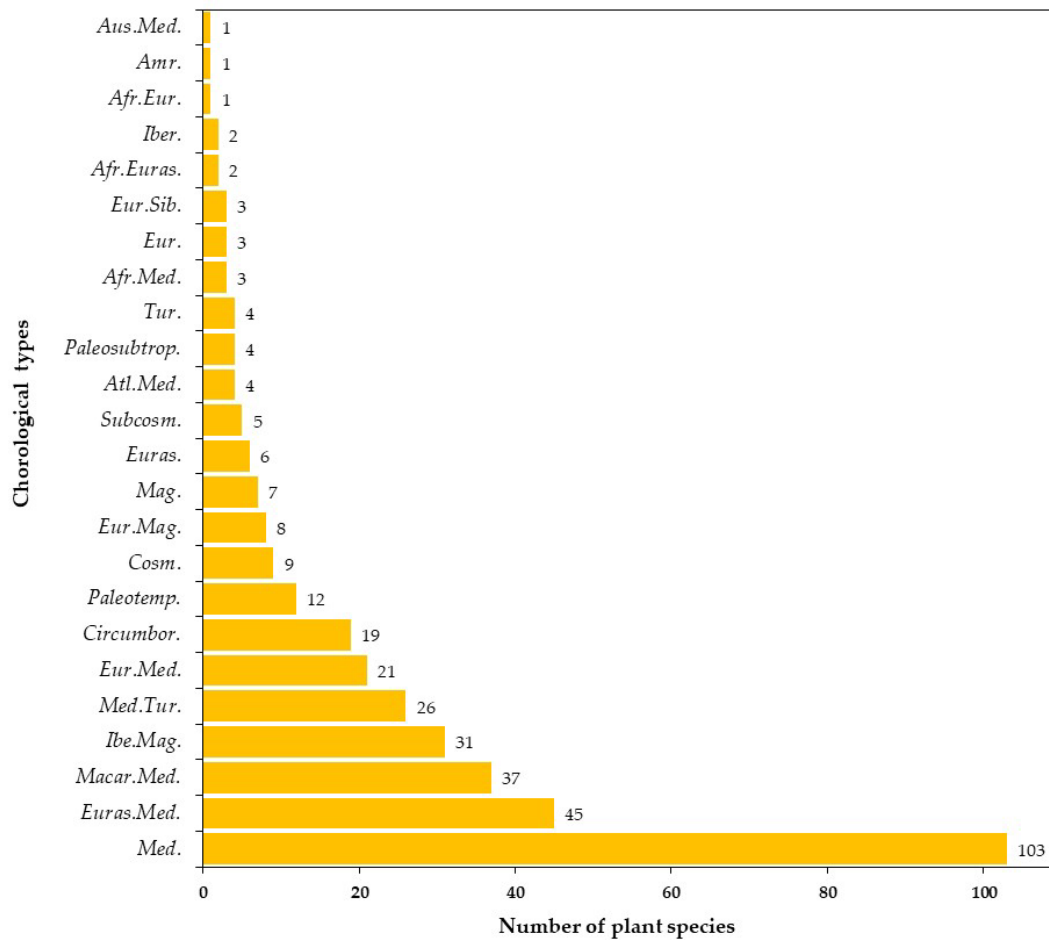


Figure 5. Chorotype spectrum of the recorded plant species in the studied forest rangelands of Northern Morocco. Afr: African, Amr: American, Asi: Asian, Atl: Atlantic, Aus: Australian, Cau: Caucasian, Circumbor: Circumboreal, Cosm: Cosmopolitan, Eur: European, Euras: Eurasian, Iber: Iberian, Ira: Iranian, Macar: Macaronesian Mag: Maghrebian, Med: Mediterranean, Paleosubtrop: Paleosubtropical, Paleotemp: Paleotemporal, Sib: Siberian, Subcosm: Subcosmopolitan, Tur: Turanian.

The monoregional taxa are dominated by Mediterranean chorotype distribution with 103 species (28.8%), followed by the Maghrebian taxa with 7 species (2%), Turanian taxa with 4 species (1.1%), European taxa with 3 species (*Agrimonia eupatoria* L., *Ornithogalum umbellatum* L., and *Veronica agrestis* L.), Iberian taxa with 2 species (*Campanula lusitanica* Loefl. and *Linum suffruticosum* L.), and finally the American taxa with 1 species (0.3%).

The biregional taxa are represented by 8 main chorotypes forming 97% of the total number of plant species surveyed in this group: the Mediterranean/Macaronesian (37 recorded species forming 10.3%), the Iberian/Maghrebian (31 recorded species forming 8.7%), the Mediterranean/Turanian (26 recorded species forming 7.3%), the European/Mediterranean (21 recorded species forming 5.9%), the European/Maghrebian (8 recorded species forming 2.2%), the Asian/European (6 recorded species forming 1.7%), the Atlantic/Mediterranean (4 recorded species forming 1.1%), and finally the African/Mediterranean and the European/Siberian taxa with 3 species each (0.8%). While the lowest plant species contribution was recorded for the African/European, the Australian/Mediterranean, and the European/Caucasian with less one species each (*Halimium umbellatum* (L.) Spach., *Solanum linnaeanum* Hepper & P.M.L. Jaeger, and *Crataegus monogyna* Jacq., respectively).

The pluriregional taxa represented mainly by two chorotypes: the African/Asian/European (45 recorded species forming 12.5%) and the Asian/European/Mediterranean with

2 recorded species forming 0.6% of the taxa (*Misopates orontium* (L.) Raf. and *Vicia hirsuta* (L.) Gray, respectively).

The Figure 6 displayed the chorological distribution of the of the surveyed plant species in the studied forest rangelands. The results showed a strong dominance of the Mediterranean floristic category in the flora of the study region (264 species forming 73.7% of recorded species), followed by taxa of European influence (33 species forming 9.2% of recorded species), wide distribution taxa (30 species forming 8.4% of recorded species), naturalised species with 20 species (5.6%), endemic taxa with 7 species (2%), and finally the allochthonous with 4 species (1.1%). The Mediterranean climate could explain the prevalence of its floristic category [75]. This finding agrees with several works conducted in the Southern Mediterranean woodlands, which appears a high prevalence of the Mediterranean category (50 to 72%) [16,43,63]. In Southern Mediterranean region of Northern Morocco, it was estimated a decrease by 25% of the forest during the last three decades due to the drought, fire, soil erosion, and human activity [10]. To this forest regression, it could be due to the menace of disappearing endemic plant species and the decrease of the floristic diversity of the Mediterranean woodlands [16,76].

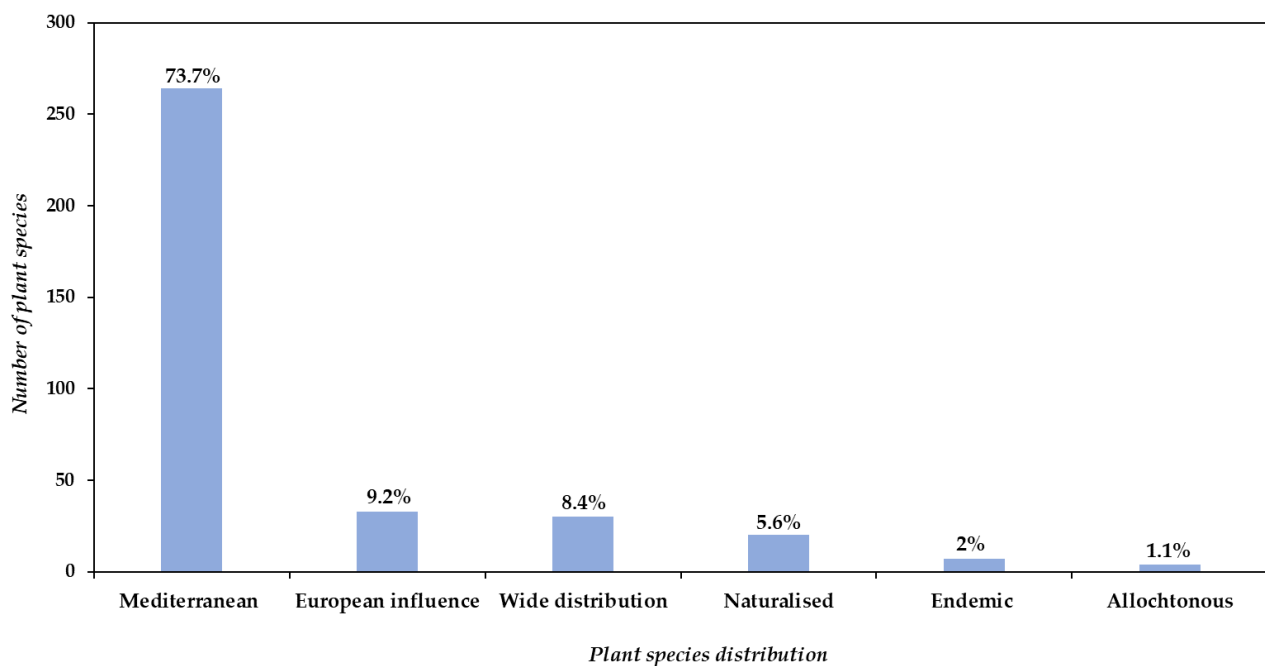


Figure 6. Chorological distribution of the flora recorded in the Southern Mediterranean Forest rangelands of Northern Morocco.

3.3. Palatability and Biomass Production

3.3.1. Plant Species Palatability

The selection of the plant species by small ruminants is a function on the available information regarding their palatability and their relative abundance. The relationship between grazing animals and selected forage varies across environmental gradients [77,78] and often depends on the palatability of each plant species [79].

Palatability is defined as plant characteristics or conditions that stimulate a selective response by the animals' preference for a specific plant, and this has a wide influence on the degree of acceptability or rejection of available forage. As is known, preference depends on the palatability, abundance, and availability of each plant species [80].

The botanical composition of the diet selected by goats is characterized by a wide spectrum of plants, grasses, and shrubs compared with cattle and sheep [81]. Goats are more tolerant of some noxious plant compounds compared to other ruminants. They are

better digesters of feed with low nutritional values due to their ruminal microbiota and the tanninase activity [82].

The palatability classification was based on the palatability index of goats ranging from (0) complete avoidance and completely non-palatable species to (5) complete preference and highly palatable [25–28]. The palatable species remain highly preferred throughout the year and the non-palatable (unpalatable) species are avoided or occasionally selected during drought seasons.

The palatability degree was studied for a total of 95 taxa, which represent 27% of the total taxa of the study forest rangelands. The reason for studying these taxa only is that they are the only ones identified by the local herders and are predominant in the study area. Figure 7 represents the palatability degree of the identified taxa in the study forest rangelands. The identified plant species were classified into 6 major groups according to their palatability degrees. A total of 15 species representing 16% of the total number of identified species were completely preferable and highly palatable, and 25 species forming 26% of identified species were very palatable. The palatable plant group was highly represented with 32 species (34%) among the identified taxa in the study area with different palatability degrees. The moderate preference and medium palatable group contain 11 species (12%) of the identified plant species while 5 species (5%) were occasionally palatable or poorly palatable. The complete avoidance and completely unpalatable species group was concerned with 7 species (7%) of the identified taxa by herders. Consequently, 93% of these identified taxa (88 species) was evaluated as potential sources of forage for grazing goats.

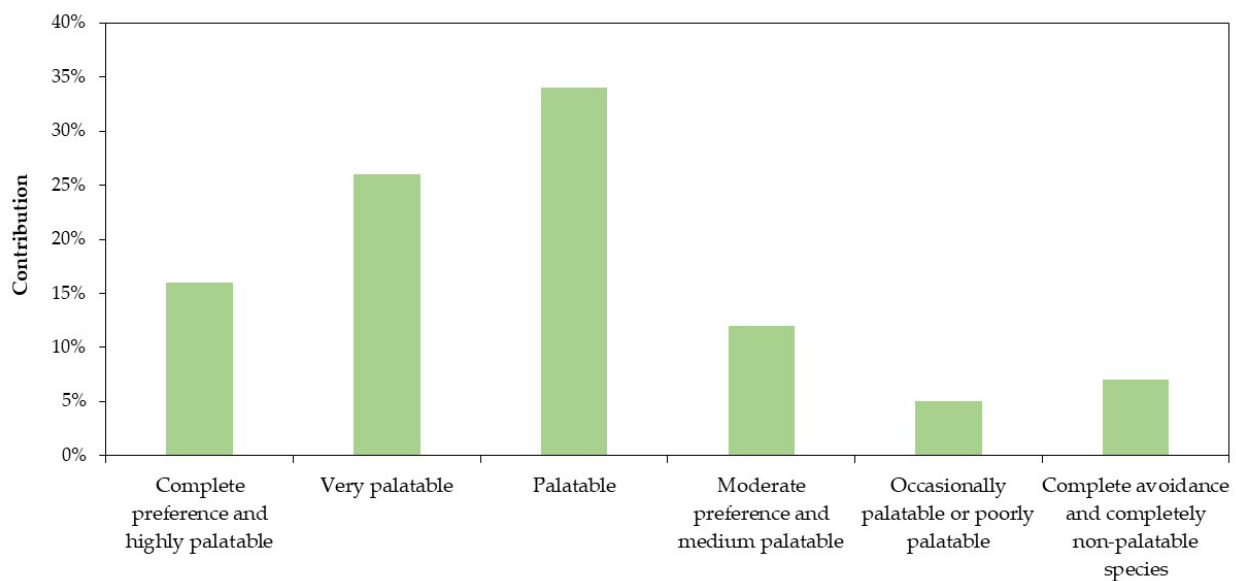


Figure 7. Palatability degree of the plant species ($n = 95$) by local herders in the studied forest rangelands of Northern Morocco.

In a Southern Mediterranean rangeland of Libya, authors recorded only 60% of palatable and 40% unpalatable plant species [53]. The obtained results depend on the number of recorded taxa, which is low in the Libyan rangeland (179 species) and type of grazing animals. Overgrazing could also induce retrogressive succession, as palatable plants are under continuous defoliation and are eventually replaced by other occasionally palatable or unpalatable species [10,83,84].

Liliaceae and Asparagaceae contain poorly palatable or avoided species and these represent 3% of all studied families. The following species, *Asteraceae*, *Cistaceae*, *Ericaceae*, *Fabaceae*, *Fagaceae*, *Lamiaceae*, and *Poaceae*, had very large numbers of very palatable and palatable species. Some examples of palatable and non-palatable flora identified in the

study area are illustrated in Figure 8. According to herders and our direct observations of grazing goats in the field, *Arbutus unedo* (Strawberry tree), *Calicotome villosa* (Spiny broom), *Cistus crispus* (Wrinkle-leaved), *Cistus monspeliensis* (Montpellier cistus), *Cistus salvifolius* (Sage-leaved rockroses), *Erica arborea* (Tree heath), *Lavandula stoechas* (Topped lavender), *Myrtus communis* (Common myrtle), *Phillyrea latifolia* L. (green olive tree or mock privet), *Pistacia lentiscus* (Lentisk), *Rubus ulmifolius* Schott. (Elm-leaf blackberry), *Quercus coccifera* (kermes oak), *Quercus faginea* (Portuguese oak), *Quercus suber* (Cork oak), and *Olea europaea* L.: *O. europaea* var. *sylvestris* (Wild olive) constitute the main palatable and selected plant species by goats. In addition to their pastoral use, many of the studied plant species have aromatic and medicinal properties, including *Arbutus unedo*, *Agave americana* (American aloe), *Clinopodium nepeta* (Lesser calamint), *Ceratonia siliqua* L. (Carob), *Cistus albidus* L. (Grey-leaved cistus), *Crataegus monogyna* Jacq. (Common hawthorn), *Dittrichia viscosa* L. (False yellowhead), *Lavandula stoechas*, *Melilotus sulcatus* L. (Furrowed melilot), *Mentha pulegium* L. (Pennyrile), *Mentha suaveolens* Ehrh. (Apple mint), *Myrtus communis*, *Origanum vulgare* L. (Oregano), *Papaver rhoeas* L. (Common poppy), *Pistacia lentiscus*, *Quercus rotundifolia* L. (Holm oak), and *Rubus ulmifolius*.

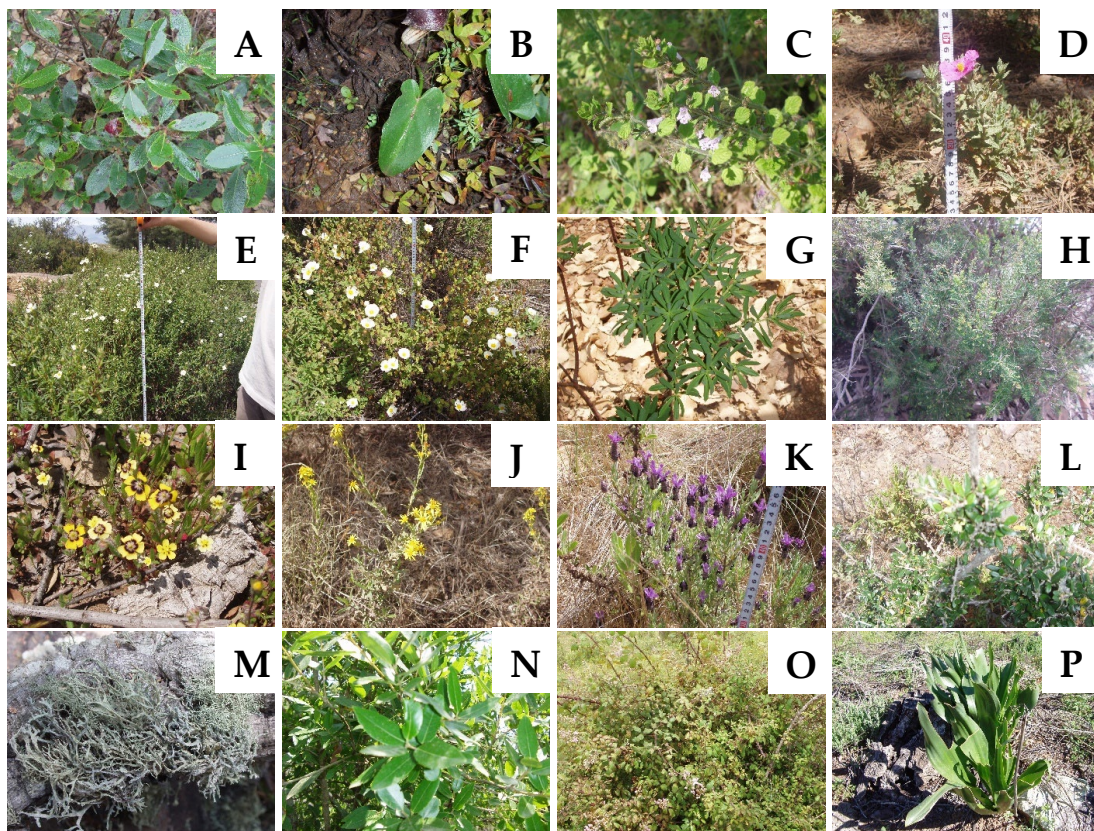


Figure 8. Palatability degree of some flora recorded in the Southern Mediterranean forest range-lands of Northern Morocco. (A) *Arbutus unedo* (palatable); (B) *Arisarum simorrhinum* Durieu (non-palatable); (C) *Clinopodium nepeta* (palatable); (D) *Cistus crispus* (highly palatable); (E) *Cistus monspeliensis* (highly palatable); (F) *Cistus salvifolius* (highly palatable); (G) *Daphne gnidium* L. (non-palatable); (H) *Erica arborea* (palatable); (I) *Tuberaria guttata* (L.) Fourr. (moderate preference); (J) *Inula viscosa* (L.) Greuter, (palatable); (K) *Lavandula stoechas* (palatable); (L) *Olea europaea* var. *sylvestris* (palatable); (M) *Parmelia physodes* (moderate preference, Lichen); (N) *Phillyrea latifolia* (highly palatable); (O) *Rubus ulmifolius* (palatable); (P) *Drimia maritima* (L.) Stearn (non-palatable) (Photos by Chebli).

3.3.2. Forage Availability

The browsed diet of goats was composed mainly of shrub species (*Arbutus unedo*, *Calicotome villosa*, *Cistus* spp., *Erica arborea*, *Lavandula stoechas*, *Myrtus communis*, *Phillyrea latifolia*, *Pistacia lentiscus*, and *Rubus ulmifolius*), trees (*Quercus* spp. And *Olea europaea*

subsp. *O. europaea* var. *sylvestris*), and herbaceous flora (*Anthemis cotula*, *Brachypodium distachyon*, *Bromus rigidus*, *Calamintha nepeta*, *Dactylis glomerata*, *Medicago* spp., *Trifolium* spp., and *Vicia* spp.). These results are in accordance with several investigations conducted in the forest rangelands of Northern Morocco about the feeding behavior of browsing goats [2,3,5].

The mean values of the biomass production of the study forest rangelands are displayed in Figure 9A. The forage availability along the goats' itineraries depended considerably to the season and the existing plant species ($p < 0.01$). The spring recorded the higher value with 3143 kg DM/ha; however, the lowest forage availability was observed in summer and autumn (2156 and 1623 kg DM/ha, respectively). This fact could be due to the vegetation cycle and to the weather conditions more favorable for plants during spring. The study year was dry, which is characterized by low rainfall and high temperatures that affected plant growth negatively and, consequently, the produced forage during summer and autumn [85,86]. During all studied seasons, *Erica Arborea* contributed highly to the forage availability (about 27%), followed by *Arbutus unedo* (18 to 22%), *Cistus salvifolius* (14 to 18.5%), and *Cistus monspeliensis* (9.5 to 14%). The contribution of *Lavandula stoechas* does not exceed 6%. Depending on the season, these species contributed between 81 and 92% to the total forage availability. The contribution of herbaceous species varies among seasons from 4.5 to 13.8%. The biomass of other woody species is composed of more than 90% of *Myrtus communis*, *Olea europaea* var. *sylvestris*, *Phillyrea latifolia*, *Pistacia lentiscus*, *Quercus* spp., and *Rubus ulmifolius*. These woody groups recorded a slightly high biomass contribution during summer (about 4.7%) compared to spring and autumn seasons, when their contribution was about 3.5% (Figure 9B). The half biomass of the other woody species is mainly composed of *Pistacia lentiscus*. In the Mediterranean forest of Southern Spain, it was also confirmed the seasonal forage availability of different plant species [87]. As reported by several authors, shrub and tree species were more selected by grazing goats independently to the season [87,88]. Goats select a wide range of mixed plant species to satisfy their foraging needs [89,90]. The studied floristic diversity revealed that the Southern Mediterranean forest rangelands of Northern Morocco constitute an important source of feed for grazing goats.

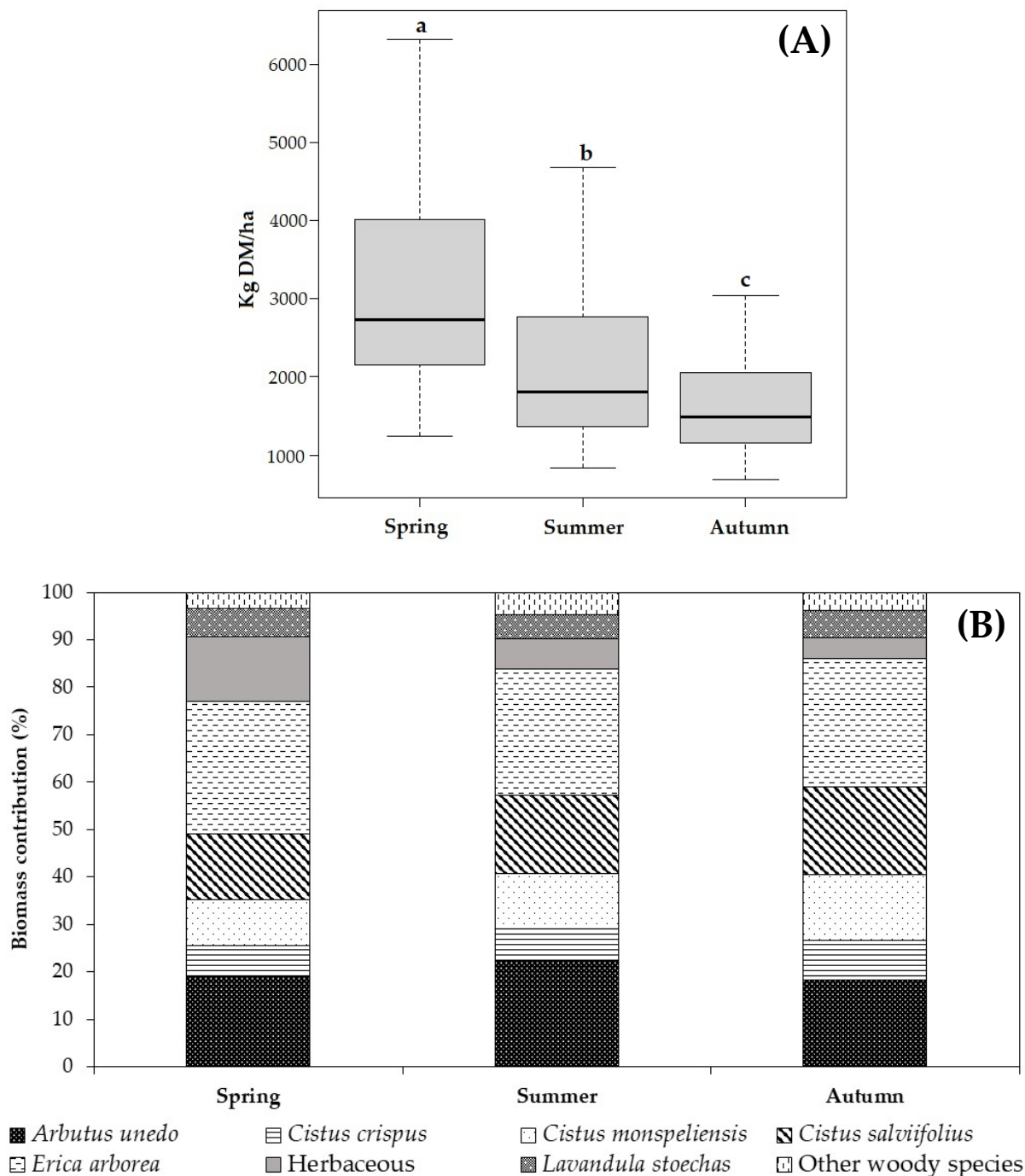


Figure 9. Forage availability (A, Kg DM/ha) and contribution (%) of each palatable plant species (B) in forest rangelands of Northern Morocco. Different letters (a–c) are significantly different ($p < 0.05$).

4. Conclusions

This study constitutes an important contribution to the research conducted in the Mediterranean region to describe the botanical composition and to determine the floristic diversity values of forest rangelands, especially in the Southern Mediterranean side. The results emphasized the high floristic diversity of the studied forest rangelands of Northern Morocco compared to many other regions in the Southern Mediterranean basin. A total of 358 taxa was recorded in the study area distributed taxonomically among 228 genera in 66 families. The flora is mainly dominated by Asteraceae, Fabaceae, Poaceae, and Lamiaceae. Analysis of biological spectrum revealed the predominance of therophytes (48.3%), hemicryptophytes (23.7%), and phanerophytes (14%). Prevalence of therophytes is

attributed to the drought, fire, soil erosion, and human activity. The perturbation index of the studied forest rangeland was estimated at 54%, which is confirmed by the high presence of annual species (36%) despite the low recorded rainfall. In addition to their pastoral use, many of the studied plant species have aromatic and medicinal properties.

The protection and conservation of forest rangelands are needed more than ever, particularly for the oak forest, which must benefit from rigorous protection to preserve its floristic composition and diversity. Fortunately, the very appreciable forest management efforts recently undertaken by the Waters and Forests Agency have made it possible to reactivate and rehabilitate parts of the forest in Northern Morocco.

To develop targeted decisions to preserve the forest rangelands, further studies are recommended on the impact of land use changes on biodiversity dynamics.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/land12010215/s1>, Table S1: List of plant species collected in forest rangelands of Northern Morocco with their life form, chorotype, and familial description.

Author Contributions: Conceptualization, Y.C.; methodology, Y.C.; investigation, Y.C, M.C., S.E.O.; resources, Y.C.; data curation, Y.C.; writing—original draft preparation, Y.C.; writing—review and editing, Y.C., M.C., J.-F.C., S.E.O.; project administration, Y.C., M.C., J.-F.C.; funding acquisition, Y.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The National Institute of Agricultural Research (INRA), Rabat, Morocco and the Academy for Research and Higher Education-Development Cooperation Committee (ARES-CCD), Brussels, Belgium. This study is realized in the framework of Programme de Recherche à Moyen Terme (PRMT: 2017–2020) and Research for Development Project (PRD: 2013–2018).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available upon request from the authors.

Acknowledgments: The authors wish to thank the goat herders for their patience and participation in this study.

Conflicts of Interest: The authors declare no conflict of interest.

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