EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(1), 288–299
https://doi.org/10.12912/27197050/175651
ISSN 2719-7050, License CC-BY 4.0

Received: 2023.11.15
Accepted: 2023.11.29
Published: 2023.12.14

Cork Oak in the Maamora Forest (Morocco) – Updating its Distribution and Optimizing Cork Productivity for Sustainable Development

Souad Ghazi[1*], Rabea Ziri[1], Najiba Brhadda[1], Abdelazziz Chemchaoui[1], Hassana Ismaili Alaoui[1], Hassan Boukita[1], Bouchra El Asri[2], Lahbib Jdi[2]

[1] Ibn Tofail University of Kenitra, Av. de L'Université, Kénitra, Morocco
[2] Department of Water and Forests, Ibn Tofail University of Kenitra, Morocco
* Corresponding author's e-mail: souad.gkazi@uit.ac.ma

ABSTRACT

In order to optimize cork productivity in the Maamora forest, specifically in the northern part of the A, B, C, D, and E cantons, the study focused on the analysis and updating of the distribution of productive cork oak (*Quercus suber* L.) stands as well as the evaluation of cork production over the past two decades. For this purpose, the available maps were corrected and updated using GPS data and field surveys between 2019 and 2022. Similarly, a thorough examination of the archives related to cork harvesting from the water and forestry administration was conducted and enriched by data collection during the survey. The obtained results indicate that the productive area is approximately 39% of the total area in the study zone. Simultaneously, statistical data has highlighted significant fluctuations in the annual gross cork production, coupled with a concerning decrease of 21.29% during the second rotation. Indeed, during the second rotation, 30% of the productive area was not harvested, compared to approximately 14% during the first rotation. Similarly, only 59% of the productive area underwent two harvest cycles. Despite these fluctuations, the recorded productivity during the second rotation, at 0.68 stere/hectare/year, remains above the national average. The differences between cantons are also noteworthy, emphasizing the impact of local factors on cork harvesting. In this context, ensuring sustained cork productivity while ensuring the sustainability of vegetal capital against climate change requires the implementation of an adaptive management approach.

Keywords. Maamora forest; *Quercus suber L*; cartography; cork; production; productivity; climate change.

INTRODUCTION

The cork oak (*Quercus suber L.*) is an endemic species of the western Mediterranean basin, found along the Atlantic coast. Its natural distribution spans approximately 2.289.000 hectares (IPROCOR, 1991 cited in IPROCOR, 1999), predominating at 59.2% in Europe and 40.8% in the Maghreb (Quézel and Médail, 2003; Pausas et al., 2009). Despite its limited distribution, cork oak woodlands are experiencing a gradual decline due to various factors. Concurrently, cork production is decreasing, while demand continues to grow. The versatile applications of cork make it an essential resource in modern life.

In Morocco, cork oak woodlands are state-owned, primarily spanning the northwestern portion of the country, from the coastal plains to the regions of Western Rif and Northern Middle Atlas. Covering an area of approximately 350 000 hectares (Hammoudi, 2002; El Mansouri 2013), they represent 15.3% of the global cork oak area (Benabid 1989, Pereira et al. 2008 In Benazza-Bouregba, 2017). Among these cork oak woodlands, only 222 300 hectares are productive (El Antry and Piazzetta, 2014). However, despite their notable presence, the cork production in Morocco accounts for only 4% of the global production, indicating an underutilization of cork resources within Moroccan cork oak woodlands (El Abid and Famiri, 2011). The average productivity of Moroccan cork oak woodlands stands at 0.5 stere/ha/year, significantly lower than that of Portugal, the global leading producer, where it exceeds 2.5 stere/ha/year (Messat and Oukassou, 1993).

In this study, the primary objective was, first and foremost, to update the cork oak stand maps in order to gain a better understanding of the distribution of this natural resource and its evolution over time, which are essential for the sustainable management of the Maamora Forest, particularly in the northern part of Cantons A, B, C, D, and E. Secondly, it analyzed cork production over a two-decade period, examining fluctuations, differences among the cantons, and the factors influencing the harvest.

MATERIALS AND METHODS

Ecological and historical study of cork oak in the Maamora forest

Ecology of the cork oak

Cork oak thrives primarily in the oceanic Mediterranean region, characterized by mild winters, hot summers, and relatively mild drought, compensated by high atmospheric humidity. Winter temperatures play a significant role in its distribution, limiting its presence in continental regions (Boudy, 1950). Currently, cork oak is found in the warmest areas of the western Mediterranean basin, both in humid and subhumid regions (Bugalho et al., 2011).

In Morocco, cork oak occupies plains and mid-mountain areas, encompassing two bioclimatic zones, the thermo-Mediterranean and the meso-Mediterranean, from sea level up to 1600 meters in the Rif, the Middle Atlas, and 2000 meters in the High Atlas (Emberger, 1939; Sauvage, 1961; Benabid, 1982; Benabid, 1989). It prefers mild temperatures ranging from 13 to 18°C, although it can tolerate temperatures reaching 45°C (Boudy, 1950). An annual rainfall of approximately 500 mm and summer humidity exceeding 60% are the factors favoring the vitality of cork oak woodlands (Boudy, 1950). From an edaphic perspective, cork oak shows a preference for sandy and slightly structured soils, while it is averse to limestone and highly clayey soils. The natural distribution range of cork oak is characterized by sandy and compact substrates (Boudy, 1950).

Cork oak (*Quercus suber*) is an iconic tree species, and its ecological requirements as well as historical evolution in the Maamora forest in Morocco have piqued the interest of numerous researchers, such as Emberger (1939), Marion (1953, 1956), and Lepoutre (1965). They have emphasized the environmental factors influencing the distribution and growth of cork oak.

Historical background and prior management

The Maamora Forest, one of the largest plain cork oak woodlands in the world (Natividade, 1956), underwent economic developments from the early 20th century. These developments aimed to maximize the production of wood and male cork by adopting the coppicing of the cork oak woodland, which initially covered an area of 133.000 hectares. Between 1926 and 1938, clear-cutting operations were carried out on approximately 60.000 hectares (Figure 1). Additionally, between 1930 and 1935, a geometric plot plan was established to structure forest management. This plot plan, consisting of 5 cantons divided into 33 groups and then into 460 plots, was adopted by the various developments experienced by the Maamora Forest (HCEFLCD, 2014).

In the 1950s, the establishment of the paper pulp unit in Sidi Yahia du Gharb coincided with the Vidal development, leading to the conversion of cork oak into eucalyptus in the areas where its density was less than 100 trees per hectare. From 1973, during the Danish development (1973-1992), cork oak clearing operations were carried out, also affecting the areas with a limited terrier perimeter (less than 80 linear meters per hectare in cantons A and B, and less than 40 linear meters per hectare in cantons C, D, and E) (HCEFLCD, 2014). According to the conducted surveys, the program for converting to exotic species was suspended in 1982, marked by an awareness of the economic, social, and environmental importance of native species (Table 1).

In 1992, the surface area of the cork oak forest in Maamora was approximately 60.000 hectares. Currently, some previous conversions to exotic species were reversed after 2012, following the closure of the paper pulp unit in Sidi Yahia du Gharb. In 2008, this forest was registered, with an area of 131.758 hectares according to land title

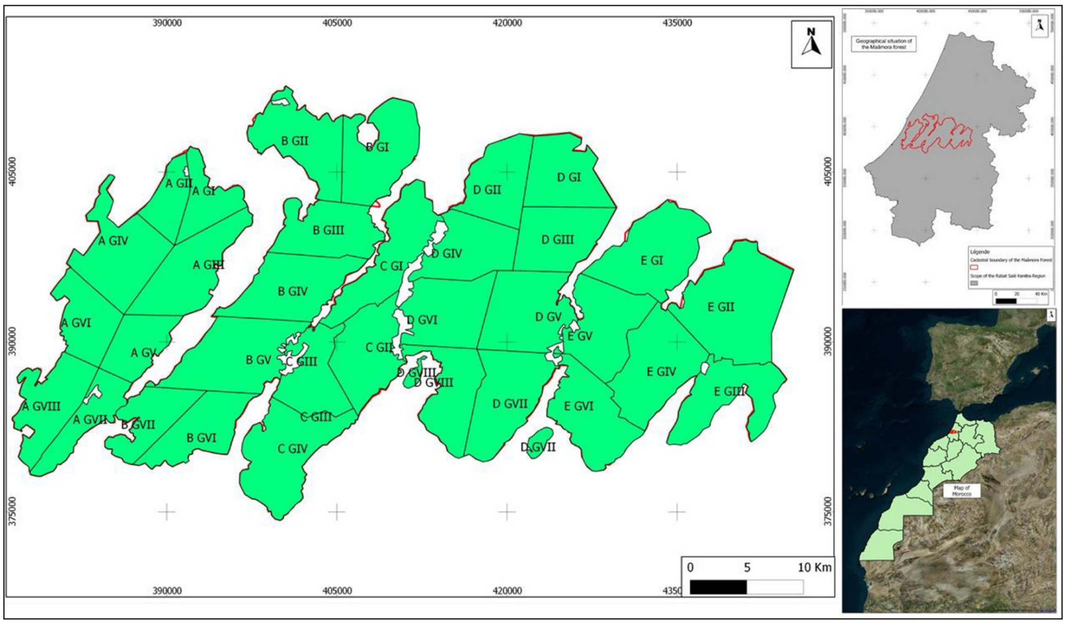

Figure 1. Maamora cork oak woodland in the early 20th century by blocks (Map created based on historical records in the archives and the boundaries of the blocks within the forest as per development plans)

Table 1. Evolution of the cork oak woodland area in the Maamora Forest from the early 20th century to 1992 (HCEFLCD, 2014)

Year	Area occupied by species (in hectares)		
	Cork oak	Reforestation (other species)	Unoccupied areas and temporary water bodies (day)
Early 20th century	133 000	0	853
1951	102 279	31 125	449
1972	86 862	45 655	1 336
1992	60 550	62 479	10 824

No. 69394/12 dated 24/04/2008, being an integral part of the state forest domain and subject to an exploitation regulation aimed at maximizing the production of cork reproduction. The main management is based on regular high forest, with a ten-year rotation for harvesting and a debarking coefficient of 2, while coppice stands are transformed into high forest after silvicultural work. Overall, the Maamora forest reflects a significant evolution, with recent efforts to restore cork oak populations while preserving its economic and environmental role in the region.

Study area

The study area encompasses the northern part of the Maamora forest, covering 48.25% of its total area, and has undergone significant changes with the introduction of reforested stands such as acacias, eucalyptus, and pines. Consequently, the cork oak population is characterized by its dislocation. In 1992, according to the 1992-2011 management plan, the productive cork oak area was approximately 24.996 hectares. Subsequent regeneration efforts favored cork oak over reforested species. This zone is administratively divided between the provinces of Kenitra and Sidi Slimane in the Rabat-Sale-Kénitra region, excluding other provinces in the region. It extends about 70 km from the Atlantic Ocean to the east, presenting significant variations in climate and topography.

The soil in the area is mainly sandy, characterized by a sandy layer on the surface, with a thickness ranging from 30 cm to 6 meters, resting on an emerging red clay subsoil in some places (Lepoutre, 1965). The terrain is gently undulating, with altitudes reaching around 7 meters along the Atlantic coast and up to about 300 meters to the east. Several wadis, such as Fouarat, Smento, Tiflet, and Touirsa, traverse the region from south

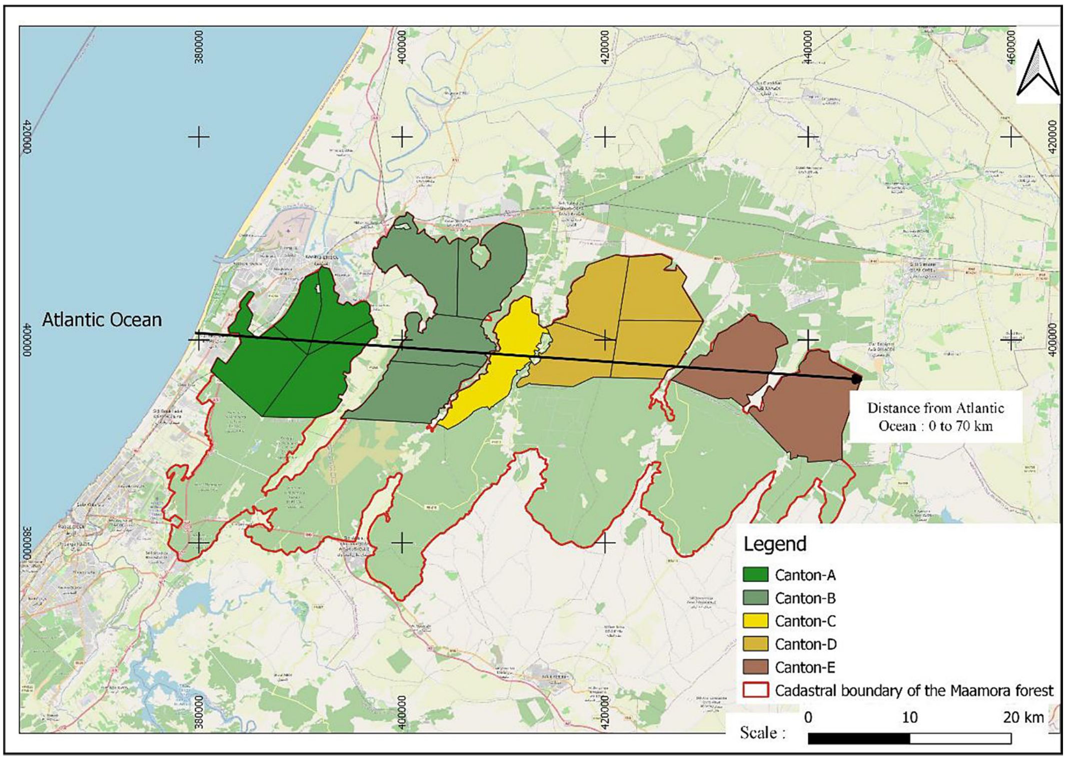

Figure 2. Geographic location of the study area

to north, with temporary depressions transforming into dayas (temporary water bodies) during rainy periods. These dayas typically dry up in the summer (Belghazi et al., 2011). From a bioclimatic perspective, blocks A and B have a warm subhumid climate, while blocks C, D, and E are characterized by a semi-arid climate with variations from warm to temperate, according to Emberger's classification (1955).

The bioclimatic conditions of the area benefit from ecological compensations, such as a relatively high and constant atmospheric humidity, which decreases from West to East (Benabid, 1982; Mokhtari et al., 2014; Laaribya et al., 2021). Nevertheless, the current bioclimatic conditions of the study area have undergone a transition to a semi-arid climate with cold winters, characterized by the lengthening of the dry period to approximately six months (Challi et al., 2021). This marks the lower arid limit of the bioclimatic conditions conducive to the development of cork oak (Laaribya et al, 2021).

Methodology

Accurate mapping of the distribution of productive cork oak stands is a crucial element of this study. Stand type maps, developed during the revision of the Maamora Forest management in 2014 by the Department of Water and Forests, serve as the foundation for this research. To ensure the accuracy of these cartographic documents, verification and adjustment were carried out using the plans associated with the old cork harvest contracts. However, this step was hindered by the fact that only cork harvest contracts from 2015 onward were accompanied by topographic plans. For the areas lacking these maps, GPS surveys and field surveys were conducted between 2019 and 2022. The areas located on the outskirts of douars (villages) and reforested areas were subject to intensive field surveys. Young stands that had not yet been exploited for cork were excluded from this mapping. The resulting map, following this procedure, is the corrected map of the distribution of productive cork oak stands for cork reproduction, serving as a reference for further research. Data analysis was performed using a Geographic Information System (GIS). As for the assessment of cork productivity in the forest, a comprehensive review of the archives held by all management units under the auspices of the Department of Water and Forests was conducted to cover the entire study area. The data from the last two rotations were collected. Moreover, during the period 2019-2022, which constituted the field survey phase, measurements of actual cork yield were collected in collaboration with local managers.

RESULTS AND DISCUSSIONS

Extent of the cork oak forest productive in reproductive cork

After an intensive collection of archives and GPS surveys conducted in the field during the period from 2019 to 2021, the map of the extent of the cork oak stand producing reproduction cork (secondary cork), covering the study area, was developed. An in-depth analysis of this map revealed that the area of productive cork oak stands amounted to approximately 24 879 hectares, which corresponds to 39% of the total study area, estimated at around 63 575 hectares. This detailed cartography provides a precise view of the distribution of mature cork oak resources, offering essential information for the management and development of this forest resource in the study region. It also contributes to a better understanding of the dynamics and importance of this natural resource in the local forest ecosystem. The breakdown of this area distributed among the cantons is illustrated in the Table 2.

Cork production effectively produced in the forest

Considering the 10-year harvest rotation set by the management regulations, the annual

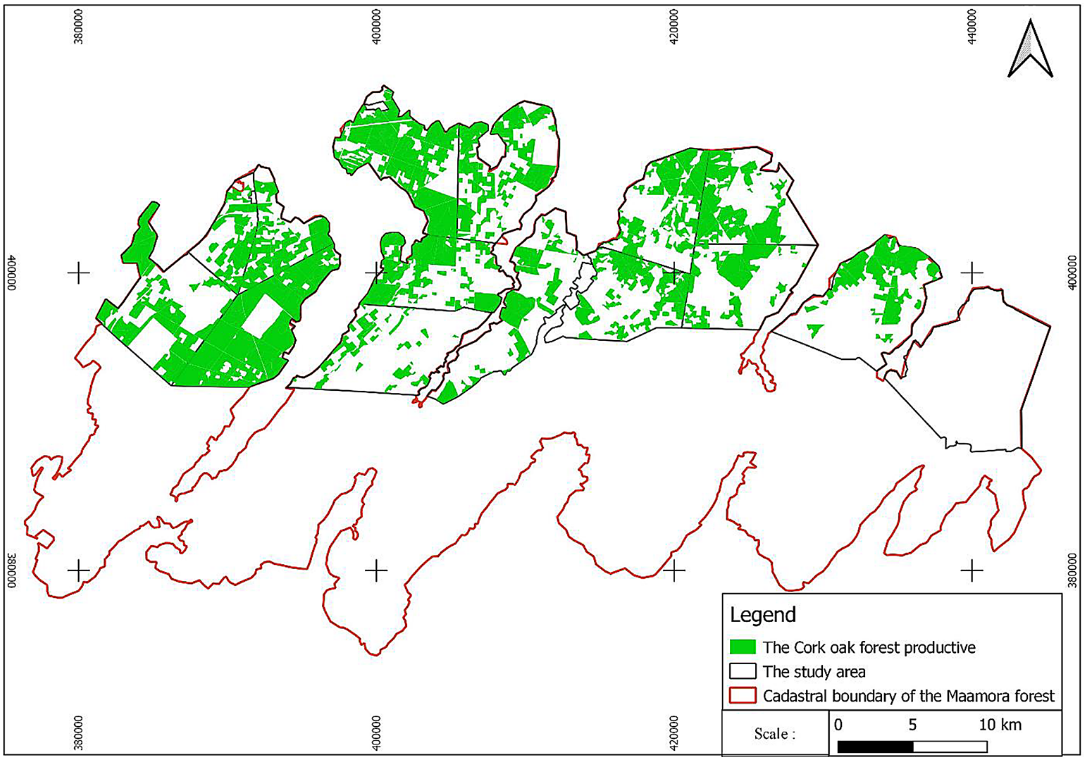

Figure 3. Extent of the cork oak forest producing reproduction cork

Table 2. Cork oak forest producing reproduction cork in the northern part of the Maamora forest

Canton	Total area of the canton (ha)	Area of cork oak forest (ha)	Coverage rate of the territory (%)
A	13 575	8 145	60%
B	17 500	7 738	44%
C	4 515	1 336	30%
D	15 290	6 002	39%
E	12 695	1 658	13%
Total	63 575	24 879	39%

harvest rate concerns an average area of approximately 2488 hectares.

Evaluation of the gross production realized during the period 2002–2021

Over the period from 2002 to 2021, encompassing the previous two rotations, the cork oak forest in the study area produced an average of around 19330 steres (st) of cork per year, of which 95% were reproduction cork (secondary cork) and 5% were male cork (virgin cork) (Figure 4).

It is worth noting that the volumes of raw cork products between 2002 and 2021 exhibit significant fluctuations. These variations in production are primarily attributed to the non-compliance with the programs outlined in the cork exploitation regulations. For instance, in the year 2011, the harvesting program was not executed, mainly due to the economic difficulties that affected the cork industry. However, the managers assert that this program was fully carried out in 2012. The highest recorded cork volume in 2013 actually corresponds to the production planned for that year, as well as the one initially intended for 2012 but realized in 2013. It should be noted that the production of reproduction cork is significantly higher than that of male cork. This observation is primarily explained by the orientation of the studied cork oak forest towards the production of reproduction cork, which is the most sought-after product in the international market. This orientation is achieved by applying the even-aged stand management method. Male cork production is typically the result of an increase in harvesting height. This increase is done progressively to expand the production area of the cork oak tree, and it is generally, around 20 cm, according to field observations.

Inter-rotation variability of raw cork production

Following an in-depth rectification process, the realized volume in the entire study area in accordance with the program for the 2002/2011 rotation amounted to a total of 216.413 steres, representing an average annual production of about 21.641 steres. In contrast, the average annual production for the 2012/2021 rotation was approximately 17.034 steres. Thus, a decrease of about 21.29% between the last two harvest cycles was observed. This downward trend in cork production over the past two rotations underscores a potential challenge for this natural resource, necessitating a thorough analysis of the underlying factors contributing to this decline.

From the perspective of the cantons, a significant decrease in production was observed in "Canton C," with a decline of approximately 96%. "Canton E" ranked second with a production decrease of about 37%. In contrast, the production in "Canton D" was less affected by this fluctuation, with only about a 4% decrease recorded. These disparities highlight the differentiated impact of local factors on cork harvest. In-depth investigations are necessary to identify the specific parameters

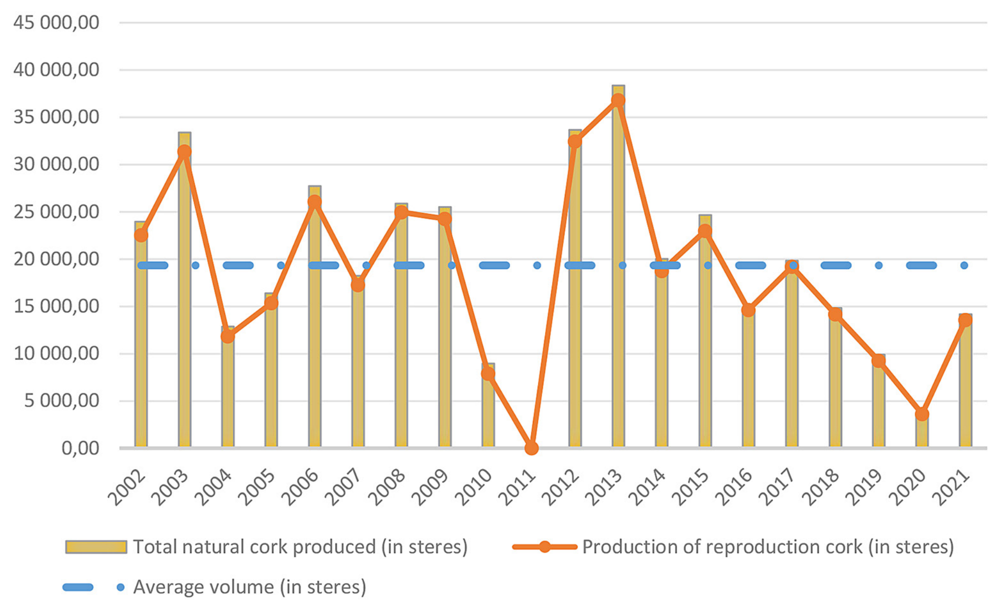

Figure 4. Evolution of gross cork production over the last two rotations

Table 3. Inter-Rotation fluctuation of average annual cork production during the period from 2002 to 2021 by Cantons

Canton	Annual average production (st/year) first rotation 2002/2011			Annual production (st/year) second rotation 2012/2021			Production fluctuation (%)		
	Reproduction cork	Male cork	Total cork	Reproduction cork	Male cork	Total cork	Reproduction cork	Male cork	Total cork
A	10033	481	10514	7385	257	7642	-26.39	-46.60	-27.32
B	5193	349	5542	4701	307	5007	-09.49	-12.06	-09.65
C	587	121	707	29	2	31	-95.11	-98.43	-95.67
D	3659	224	3883	3551	172	3724	-02.95	-22.95	-04.10
E	955	41	996	612	19	631	-35.90	- 53.58	-36.63
Total	20427	1215	21641	16278	756	17034	-20.31	-37.72	-21.29

behind these variations to develop tailored management strategies. Understanding the underlying causes is crucial to mitigate the negative effects of fluctuations and promote sustainable exploitation of this valuable resource. These measures could help cantons better preserve and manage their cork resources in the future.

Annual cork productivity in the study area by cantons

In order to ensure better spatial and temporal planning of the harvesting operation, the study of annual cork productivity is more relevant compared to the study of annual raw cork production. Prior knowledge of this productivity allows the planner to ensure, to the extent possible, a sustained yield for territorial communities and an improvement in income for a more or less constant population of users through job creation during the harvesting period. This planning requirement is stipulated by the legal framework governing the state forests of Morocco, namely the decree of "10/10/1917 on the conservation and exploitation of forests" and the decree of "20/09/1976 on law no. 1-76-350 regarding the organization of population participation in the development of the forest economy". Annual productivity is calculated based on the realized raw cork production relative to the area of the productive cork oak forest and the rotation period, which is typically set at ten years. According to the achievements in terms of raw cork harvesting for the period 2002–2021, the average productivity of the cork oak forest in the study area is 0.78 steres/ha/year (Figure 5).

The results indicate that the average cork productivity in the entire study area is higher than that recorded in the cork oak forests of Morocco, reaching approximately 0.5 steres/hectare/year. However, this productivity is significantly lower than that of the global cork oak forests, particularly in Portugal, reported to be 2.5 steres/hectare/year, according to Messat and Oukassou (1993). Regarding the cantons, it is observed that the productivity of "Canton A" is the highest, averaging 1.11 steres/hectare/year. This productivity gradually decreases in the other districts based on their distance from the coast, reaching less than half in "Canton E". However, "Canton C" records the lowest productivity. This variation can be

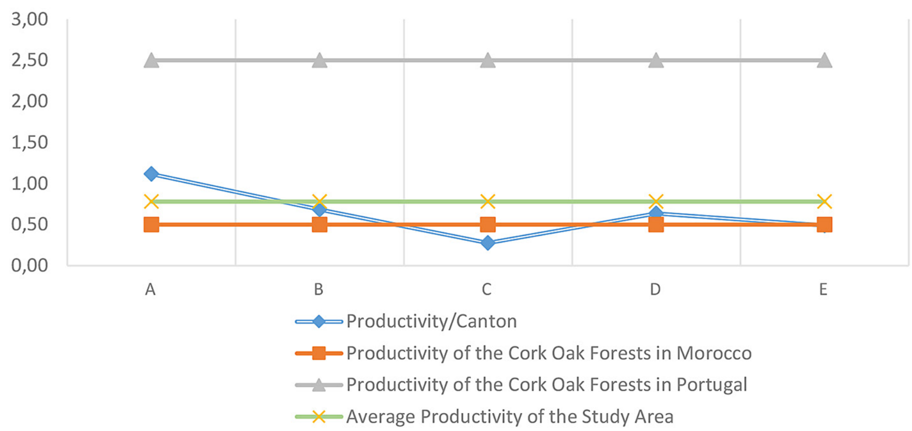

Figure 5. Average cork productivity during the last two rotations in steres/hectare/year

explained by the continental gradient combined with other factors such as sand depth, population density, and the age of the cork oak forest.

It is noteworthy that despite the decrease in cork production in the cork oak forest of the study area during the last rotation, namely 2012–2021, the recorded productivity at the study area level, which is 0.68 steres/hectare/year, remains higher than the average productivity of the entire cork oak forest in Morocco. This productivity is much higher at the "Canton A" level, reaching 0.94 steres/hectare/year, the one closest to the sea. However, it is lower at the "Canton E" level, the most continental, with 0.38 steres/hectare/year.

DISCUSSION AND ANALYSIS OF THE DATA

Regarding the evolution of the cork oak forest area over time, the analysis revealed significant variations by district (Figure 6). Indeed, the clearing of cork oak in favor of reforestation species, undertaken during the previous developments before 1982, is more extensive in "Canton E", characterized by a more continental climate. Currently, its productive cork oak forest covers only 13% of its territory. In contrast, "Canton A", with more favorable climatic conditions, has a coverage of about 60%. This distribution is strongly correlated with the criterion of continentality, except for "Canton C", which likely presents more restrictive conditions. Additionally, "Canton D" shows a slight improvement, linked to more favorable soil conditions.

The cork oak forest area in the study zone has experienced a slight decline since 1992. Indeed, it was approximately 24.996 hectares in 1992 and reached around 24.879 hectares in 2021. This modest change of 117 hectares can be largely attributed to the land mobilization for investment projects in Kénitra. Regarding cork production, the obtained statistical data have shown that cork production is not consistent over time and space, contrary to the objectives of forest management. There has been significant interannual variability in the volumes harvested for both reproductive and male cork during the studied period from 2002 to 2021 (Table 5). However, this observed interannual irregularity, along with the decrease

Table 4. Average annual cork productivity in the study area during the period from 2002 to 2021 by cantons

Canton	Average productivity (st/ha/year) first rotation 2002/2011			Average productivity (st/ha/year) second rotation 2012/2021			Average productivity (st/ha/year) third rotation 2002/2021		
	LR	LM	LT	LR	LM	LT	LR	LM	LT
A	1.23	0.06	1.29	0.91	0.03	0.94	1.07	0.05	1.11
B	0.67	0.05	0.72	0.61	0.04	0.65	0.64	0.04	0.68
C	0.44	0.09	0.53	0.02	0.00	0.02	0.23	0.05	0.28
D	0.61	0.04	0.65	0.59	0.03	0.62	0.60	0.03	0.63
E	0.58	0.02	0.60	0.37	0.01	0.38	0.47	0.02	0.49
Total	0.82	0.05	0.87	0.65	0.03	0.68	0.74	0.04	0.78

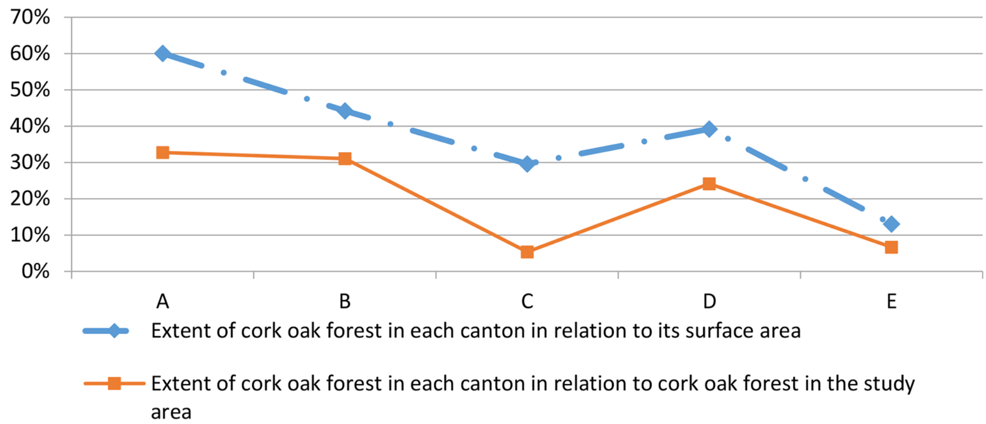

Figure 6. Current rate of coverage of cantons with cork oak forest

Table 5. Average annual production of cork categories and statistical indicators during the period from 2002 to 2021

Parameter	Reproduction cork	Male cork	Raw cork (total)
Average annual production (st/year)	18352.19	985.51	19337.70
Standard deviation (st/year)	9573.82	551.73	10011.08
Coefficient of variation (in %)	52%	56%	52%
Proportion	95%	5%	100%

of approximately 21.29% in cork raw production between the last two harvest cycles, results from the combination of several factors. Climate change, reported by the studies conducted in the region and confirmed by the World Meteorological Organization (2022), which declared that temperatures in the last eight years were the highest, combined with the physiological condition of the trees, constitutes the primary constraints for harvesting. Additionally, favorable signs for harvesting are indicated by the appearance of a reddish-pink color in the bark crevices (Haddioui, 1993). Taking this last observation into consideration, the harvested volume is directly impacted by the actual area involved in cork harvesting work. Thus, field investigations have allowed the creation of a map showing the spatial distribution of the harvested cork oak forest over the last two rotations (Figure 7).

The analysis of the data from this map revealed that the average annual area of harvested cork oak forest was 2146 hectares per year during the first rotation (2002–2011), while it averaged only 1752.8 hectares per year during the second rotation (2012–2021). This means that over 30% of the cork oak forest area was not harvested during the second rotation, compared to approximately 14% during the first rotation. “Canton C” was the least affected by harvesting activities during the last rotation, with about 92% of its cork oak forest remaining unharvested.

The cork production has been impacted by the fact that, despite the existence of the harvesting regulation specifying a ten-year harvesting rotation for reproduction cork, only 59% of the total cork oak forest area underwent two harvest cycles during the period 2002–2021. Meanwhile, 38.27% of the area was affected by only one harvest cycle (Table 7). Similarly, it should be noted that cork harvesting was abandoned during the period 2002–2021 on an area of approximately 624 hectares, representing 2.51% of the total cork oak forest area in the study area. “Canton B” was the most affected, with 445 hectares.

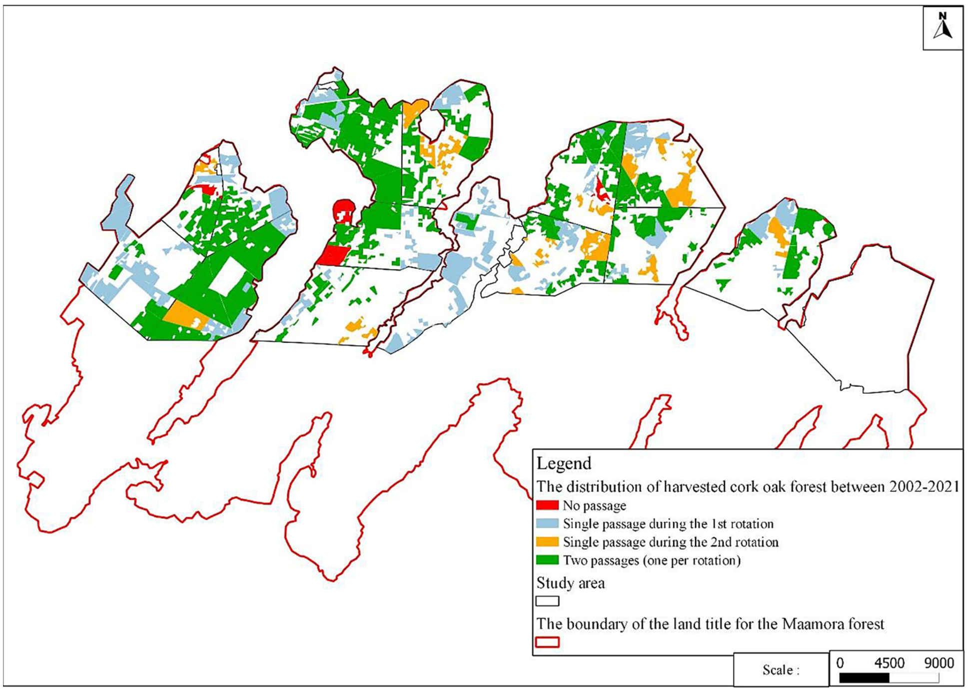

Figure 7. The spatial distribution of the harvested cork oak forest over the last two rotations

Table 6. The average annual area of harvested cork oak forest over the two rotations during the period 2002-2021

Canton	Average annual harvestable area according to the regulation (ha/year)	First rotation (2002-2011)		Second rotation (2012-2021)	
		Average annual realized area (ha/year)	%	Average annual realized area (ha/year)	%
A	814.5	755.6	92.77%	547.5	67.22%
B	773.8	661.0	85.42%	603.9	78.04%
C	133.6	133.6	100.00%	11.5	8.61%
D	600.2	451.4	75.21%	471.1	78.49%
E	165.8	144.4	87.09%	118.8	71.65%
Total	2487.9	2146.0	86.26%	1752.8	70.00%

Table 7. Extent of harvested cork oak forest and harvesting regulation (period 2002–2021)

Canton	Area of cork oak forest (ha)	Area harvested in 2 cycles		Area not harvested	
		ha	%	ha	%
A	8145	4984.0	61.19%	98.0	1.20%
B	7738	5356.0	69.22%	445.0	5.75%
C	1336	115.0	8.61%	0.0	0.00%
D	6002	3304.0	55.05%	81.0	1.35%
E	1658	974.0	58.75%	0.0	0.00%
Total	24879	14733.0	59.22%	624.0	2.51%

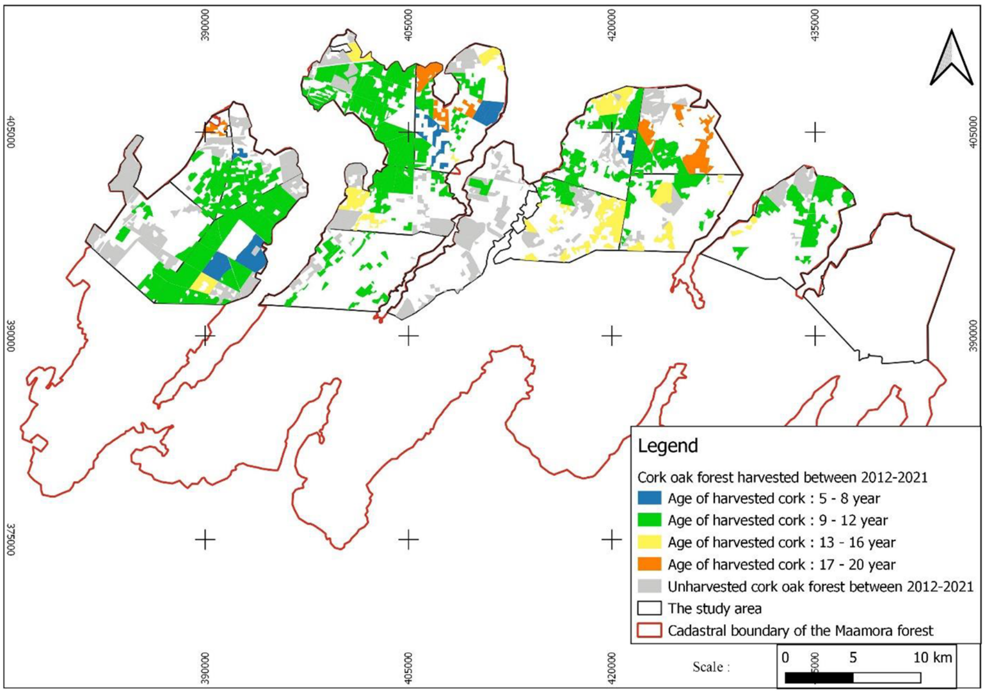

Figure 8. The cork oak forest area harvested during the rotation from 2012 to 2021 based on the cork's age at the time of harvest

"Canton A" and "Canton D" were also not fully harvested during this period, with unharvested areas of 98 hectares and 81 hectares, respectively. Furthermore, it is important to emphasize that the exploitable duration, set at 10 years in accordance with exploitation regulations, has not been adhered to in certain cork oak forest areas subjected to harvesting. This non-compliance has resulted in premature harvesting practices, with cork being extracted even at the halfway point of the designated 10-year period. Concurrently, other areas have experienced significant delays in harvest cycles, spanning almost two complete rotations (Figure 8).

The deviation from the recommended exploitation period raises concerns about the sustainable management of forest resources. Early harvests and excessive delays in the cork oak forest can compromise cork quality and overall productivity. It is crucial to scrutinize forest management practices carefully, ensuring their compliance with the established standards to ensure the long-term preservation of these precious ecosystems. Furthermore, even in specifically harvested areas, diseased or weakened trees are not harvested, in accordance with the findings of on-site investigations, information from local managers, and protocols established by the Department of Water and Forests.

CONCLUSIONS

This study provided a precise overview of the distribution of cork oak forests in the region between 2019 and 2021, along with their historical evolution. This information is crucial for sustainable management of cork oak and contributes to a better understanding of the dynamics of this forest ecosystem. It is imperative to continue monitoring and assessing the evolution of cork oak forests in the region, taking into account climatic factors and the pressures exerted by human activities. It is crucial to recognize that neglecting the cork harvesting age or abandoning this activity will have detrimental consequences for the harvest planning. This will compromise the effectiveness of cork harvesting regulations, even within the framework of forest management. Cork volumes will also be impacted by this irregularity and may gradually decline over time and space, if appropriate forest management measures are not implemented.

The decrease in production primarily stems from certain plots not being selected for harvest due to health issues or because the cork thickness does not meet commercial standards. Inadequate harvesting practices and tree damage directly affect cork volumes, jeopardizing the forest management projections. The delays in harvesting plots with cork thickness below the standards set by managers have a significant impact on planning and harvested volumes. Furthermore, the use of inappropriate volume measurement rates can also disrupt harvest planning. Cork production may also be confronted with structural factors, such as the decline of cork oak trees and the reduction in cork oak forest density.

Ultimately, the irregularities in cork harvesting inevitably compromise cork quality and have a direct impact on the socio-economic role of cork, both in terms of income for local communities and the foreign exchange generated by the cork processing industry in Morocco. The jobs in the sector, especially those of cork harvesters and factory workers, are also affected.

REFERENCES

1. Aafi A. 2007. Étude de la diversité floristique de l'écosystème de chêne liège de la forêt de la Maamora, Thèse de Doctorat d'Etat. Es-Scien. Agronomique, IAV Hassan II, Rabat, Maroc, 190.
2. Belghazi B., Badouzi M., Belghazi T. et Moujainni S. 2011.Semis et plantations de la forêt de chêne-liège de la Maamora (Maroc). Forêt Méditerranéenne, 2011, 32(3), 301-314.
3. Benabid A. 1982. Etudes phytoécologique, biogéographique et dynamique des associations et séries sylvatique du Rif Occidental (Maroc). Thèse Doct. ès-Sc. Fac. Sci. et Techn. St Jérôme, Aix Marseille III, pp. 199.
4. Benabid A. 1989. Ecologie, conservation et restauration des subéraies; session de formation continue, ENFI, salé, Maroc, 67.
5. Benabid A. 2000. Flore et Ecosystème du Maroc. Evaluation et préservation de la biodiversité, Edition Ibis Press, Paris, Librairie et éd. Kalila Wa Dimna. Rabat, 358.
6. Benazza-Bouregba M. 2017. Inventaire et identification des Basidiomycètes de la forêt de M'sila (Oran). Thèse de doctorat en Biotechnologie, Université Ahmad Ben Bêla d'Oran, 12-166.
7. Boudy P. 1950. Economie Forestière Nord Africaine. Tome II, Fasc. 1, monographie et traitement des essences forestières. Edition Larose, 29-43.
8. Bugalho MN., Caldeira MC., Pereira JS., Aronson J. and Pausas JG. 2011. Mediterranean cork oak savannas require human use to sustain biodiversity and ecosystem services. Frontiers in Ecology and the Environment, 9(5), 278-286. doi.10.1890/100084
9. Challi D., Dahmani J., Jdi E. Belahbib N. 2021. Evolution of climatic conditions between 1982 And 2016 in the Sidi Boughaba Biological Reserve (Kénitra, Morocco), Journal of Basic and Applied Research International, 27(5), 18-28.
10. El Abid A. and Famiri A. 2011. le liège au Maroc, le multi-usage. Travaux de Centre de Recherche Forestière, Collection Maroc Nature, Rabat, 75.

11. El Antry S., Piazzetta R., 2014. Les techniques de régénération du chêne-liège au Maroc. Forêt Méditerranéenne, 35(2), 161-170.
12. Elmansouri A. 2013. Analyse basée télédétection pour la mise en place d'un système d'information géographique pour le suivi de l'état sanitaire et l'exploitation du liège en Maamora. Mémoire de troisième cycle, Ecole Nationale Forestière d'Ingénieur, Salé, Maroc, 145.
13. Emberger L. 1939. Aperçu général sur la végétation du Maroc. Veroft. Geobot. Inst. Rubel, Zurich, 118.
14. Haddioui A. 1993. Production et industrie des lièges au Maroc, réalités et perspectives, Mémoire de 3ème cycle de l'INAU Rabat, 127.
15. Hammoudi A. 2002. Subéraie et biodiversité du paysage. Colloque Vivexpo. Inst. Médit. du liège. France, 3.
16. HCEFLCD, 2014. Etudes de base et gestions antérieures – les Procès-verbaux d'aménagement de la forêt de la Maamora. Aménagement Vidal (1951-1972); Aménagement Danois (1973-1992); Aménagement en vigueur (1992-2011) et Aménagement actuel (2014-2033), Rabat, Maroc.
17. Intituto del Corcho, la Madera y el Carbon (IPROCOR) 1999. Manuel didactique du leveur et de l'ouvrier spécialisé dans les travaux d'exploitation du chêne liège, version française.
18. Laaribya S., Alaoui A., Ayan S., Benabou A., Labbaci A., Ouhaddou H., & Bijou M., 2021. Prediction by maximum entropy of potential habitat of the cork oak (*Quercus suber* L.) in Maamora Forest, Morocco. Forestist, DOI: 10.5152/ forestist.2021.20059
19. Lepoutre B. 1965. Régénération artificielle du chêne liège et équilibre climacique de la subéraie en forêt de la Maamora. Ann. Rech. For. Maroc, 9(1), 1-188.
20. Marion J. 1953. Les repeuplements artificiels en chêne liège dans la forêt de la Maamora (Maroc). Ann. Rech. For. Maroc, 39-158.
21. Marion J. 1956. contribution à l'étude la régénération du chêne liège par rejets de souches. Ann. Rech. For. Maroc, 4(1), 25-63.
22. Marion J. 1951. La régénération naturelle du chêne liège en Maamora. Ann. Rech. For. Maroc, 25-27.
23. Messat S. and Oukassou D. 1993. Objectifs et technique d'aménagement des subéraies. Le liège au Maroc. Actes des sessions de formation continue, 62-65.
24. Natividade J.V., 1956. Subericulture. Ecole Nationale du Génie Rural et des Eaux et Forêts, Nancy, 303.
25. Pausas J.G, Pereira J.S., Aronson J. 2009. The tree in Aronson J., Pereira J.S., Pausas J.G., eds. Cork oak woodlands on the edge Ecology, Adaptive Management, and Restoration; Society for Ecological Restoration International. USA, 11-21.
26. Quezel P. and Medail F. 2002. Ecologie et biogéographie des forêts du Bassin méditerranéen, coll Environnement, Ouvrage, 576.
27. Sauvage Ch. 1961. Recherche géobotanique sur les subéraies marocaines. Travaux de l'institut scientifique chérifien, série botanique n°21, Rabat, 462.