RESEARCH PAPER

MAPPING ECOSYSTEM SERVICES OF FOREST STANDS: CASE STUDY OF MAAMORA, MOROCCO

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Received: April 26th, 2021 / Accepted: February 15th, 2022 / Published: March 31st, 2022
https://DOI-10.24057/2071-9388-2021-047

ABSTRACT. The concept of ecosystem services (ES) is increasingly used to analyze the relationships and interactions between humans and nature. Understanding the ecosystem services' flow and the ecosystems' capacity to generate these services is an essential element in considering the sustainability of ecosystem uses and the development of ecosystem accounts. For such purpose, we conduct spatially explicit analyses of nine ecosystem services in the Maamora forest, Morocco. The ecosystem services included are timber and industry wood harvest, firewood harvest, cork gathering, forage production, acorn gathering, forest carbon storage, and recreational hiking. Results make it possible to distinguish between the forest capacity to provide ecosystem services from their current use (demand) and assess them quantitatively. It came out that both capacity and flow differ in spatial extent as well as in quantity. Distinguishing capacity and flow of ES also provided an estimate of over-or under-utilization of services, and offer the possibility to map the ecosystem service provision hotspots (SPA) and degraded SPHs. The respective assessment of capacity and flux in a space-explicit manner can therefore support the monitoring of the forest ecosystem use sustainability.

KEYWORDS: assessment, ecosystem accounting, monitoring, spatial analyses, sustainability

CITATION: Benabou A., Moukrim S., Laaribya S., Aafi A., Chkhichekh A., El Maadidi A., EL Aboudi A. (2022). Mapping Ecosystem Services of Forest Stands: Case Study of Maamora, Morocco. Vol.15, № 1. Geography, Environment, Sustainability, p 141-149
https://DOI-10.24057/2071-9388-2021-047

Conflict of interests: The authors reported no potential conflict of interest.

INTRODUCTION

Ecosystem services (ES) are increasingly used as a concept for analyzing the relationships and interactions between humans and nature. It can also be referred to as a framework to support decision-making for sustainable natural resources' management, emerging from the scientific field to be serving the policy and operational domains in recent years (Plieninger and Bieling 2013). They are defined as the contributions that ecosystems make to human well-being, and result from the interaction of biotic and abiotic processes (MEA 2005). This concept emergence resulted in the development of ecosystem accounting The latter is considered as a new approach in ecology for the environmental assessment through measuring ecosystems and ecosystem service flows under human activities.

In Morocco, the national accounting sytem, which is based on branches, does not consider the multiple contributions of the forestry sector to the economy, particularly non-timber products and services. This contribution is rather incorporated into the 'Agriculture, Forestry and Fishing' branch. This explains why the economic role of forest ecosystems is still insufficiently highlighted (El Mokaddem 2016).

Spatial mapping of both ecosystem provision of ES and their current use by societies is a key feature of ecosystem services (Schröter et al. 2014). Mapping multiple ecosystem services has become an important scientific endeavor (Bryan et al. 2011, Turner et al. 2016). However, the number of ecosystem services considered in studies remains low and the validation of results is rarely performed (Seppelt et al. 2011).

Taking into consideration recent experiences of ES mapping in North Africa, this study aims at mapping the provisioning capacity and the multiple ecosystem services' use flow of the Maamora forest. It is also intended to assess this approach's relevance in designing and implementing innovative forest ecosystem management plans that best conciliate between the user populations' pressing needs and the natural resource sustainability requirements (Laaribya et al. 2021).

Area of study

The Maamora forest is located in Northwestern Morocco close to the Atlantic Ocean (Fig. 1). It is subdivided into five cantons, three of which (A, B, and C) will be concerned by this study. The topography is flat. The geological formations are primarily Pliocene to Pleistocene marine deposits (Aafi et al. 2005a), with sandy soils overlying a clay substrate. They are classified as aerosols according to the WRB nomenclature (FAO/IUSS 2006).

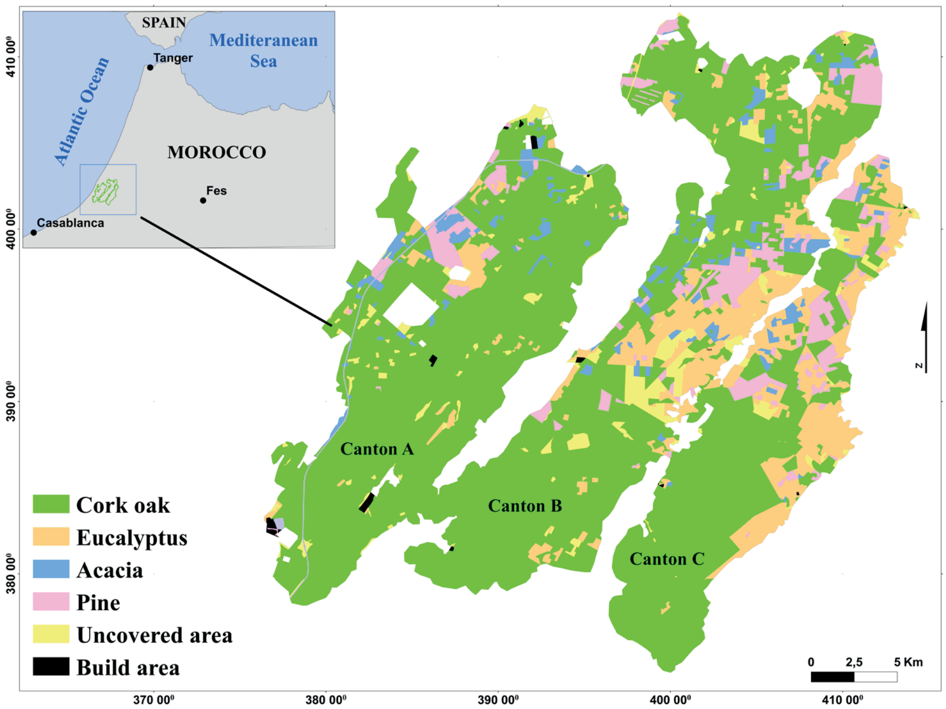

Fig. 1. Forest stand type map

The study area is dominatd by a Mediterranean climate with a dry season generally begining in late April or early May and extending through October (Aafi et al. 2005a). The spatial distribution of forest cover is illustrated by the stand type map (Fig. 1). It shows that more than 75 % of the study area is made out of natural stands of cork oak (*Quercus suber* L.), endemic species of the Mediterranean-Atlantic. The other stands are based on exotic species such as: *Eucalyptus camaldulensis* D., *Eucalyptus cladocalyx* F., *Eucalyptus gomphocéphalla* DC., *Eucalyptus gradnis* W., *Acacia molicima* D., *Acacia cyclops* A., *Pinus canariensis* C., *Pinus pinea* L., *Pinus radiata* D., *Pinus pinaster* Aiton., and *Pinus halipensis* Mill.

MATERIALS AND METHODS

This study is intended to develop spatial maps of some ecosystem services in the study area by distinguishing the capacity of their production by forest ecosystems as well as their flow. It is also sought to produce maps of spatial balance between capacity and flow for two ecosystem services taken as examples. Furthermore, it will provide tables of both capacity and flow accounting by ecosystem and at the level of each territorial unit. Such tables will serve as as a first draft of the ecosystem accounting drawing up.

Ecosystem Services' choice

This assessment emcompasses ecosystem services coming out of interviews lead with the Department of Water and Forestry officials and representatives of the few rural communes and NGOs. Similarly, the choice was oriented to step the guidelines of the International Common Classification of Ecosystem Services, covering a range of ecosystem services representing categories of provisioning and regulation, as well as cultural ones (Chan et al. 2012, Fagerholm et al. 2012).

The list of selected ecosystem services and assessment indicators in the study area are showens in Table 1.

The indicators used (Table 1) for the spatial assessment of ecosystem service capacity and flow provide relevant, reliable, and accurate measures (Burkhard et al. 2012). These measures generally correspond to annual averages per hectare. The reference year is that of 2016 as it corresponds to the new Maamora forest management plan launching (DEF 2015).

Spatial units

The spatial units taken as the basic unit for determining the average values of ecosystem services were defined taking into consideration the recommendations of the SEEA (System of Environmental-Economic Accounting). Such system, undeniably allows for the human and institutional dimensions in the establishment of ecosystem spatial accounting. Thus, two spatial units are to be distinguished:

- The administrative units are defined according to the division of the territorial communes. It benefit from the revenues generated by the forest products' valorization.

- The traditional grazing units for livestock and Firewood harvesting rights are quite granted to the user tribes.

Spatial models of ecosystem service capacities and flow patterns

Considering the collected data sets, the spatial mapping was based on distinct spatial models according to the selected indicators (Schröter et al. 2014) as indicated in Table 1. The used data are from the stand types' map

Table 1. List of selected ecosystem services and assessment indicators

Section	Supply					Control	Cultural Activity
Ecosystem services	Forage (grazing)	Lumber and industrial wood	Firewood	Cork	Acorns	Carbon storage	Recreational hiking density
Indicators	SLU·ha^{-1}	m^3·ha^{-1}	stere·ha^{-1}	stere·ha^{-1}	t·year^{-1}	mg·ha^{-1}	km·km^{-2}

Note: SLU is Standard Livestock Unit.

established as part of the Maamora Forest management study (DEF 2015). It is carried out, after determining the useful area, based on preliminary interpretations; stratification criteria; choice of symbols; delineations of strata; verification of strata in the field; final interpretation; drafting of the map and cutting into parcels.
The area of forest stands scheduled for harvesting is showed in Table 2.

The data sources used in this study are as follows:

- The cutting program was established in the framework of the Maamora Forest management study (DEF 2015). This plan defines the annual program.

- The average annual area of the programmed forest area was calculated by species and/or type of silvicultural operation, as well as by administrative unit (Tab.2).

- The average yields of forestry cuts. Knowing that they vary significantly depending on the species, its age, as well as the considered type of silvicultural and harvesting operation, their yields were estimated based on the analysis of data from auctions conducted between 2004 and 2014.

- The results of the research conducted on (i) carbon storage in forest stands in the Maamora, (ii) Firewood removals, (iii) grazing, (iv) recreation and leisure.

- Socio-economic data from the general population census.

- Forest tracks were assimilated to hiking trails. Their plots were used for both the capacity maps' development and the recreation trails' ecosystem service.

Spatial Balances of Ecosystem Services

The balances were created for two services: Firewood and livestock grazing. These services are the major constraints faced by forest managers in relation with the realization and success of forest ecosystem restoration, recovery, and enhancement projects.

This type of spatial map makes it possible to delimit as precisely as possible the strong pressure prone areas regarding a given service, or those with unused production potential by measuring the involved quantities using appropriate indicators.

RESULTS

Harvesting of lumber and industrial wood

The analysis of the capacity (Fig. 2a) and flow (Fig. 3a) maps of the ecosystem service of the lumber and industrial wood harvest show high spatial variability. The high spots of this service are almost localized in the eastern parts of the two cantons B and C of the Maamora Forest. The scattered patches' form is rather observed in canton A.

This situation is explained by the spatial distribution of artificial stands, particularly Eucalyptus plantations, which contribute up to 96 % of this ecosystem service's production capacity, estimated at 302,607m^3 (Table 3). These plantations were mostly located in the eastern parts of the Maamora subject to human pressure, climate severity, and capricious edaphic conditions (Dahmani 2006, Laaribya et al. 2013).

This spatial variability also characterizes the levels of its supply capacity; it thus rises, according to the zones, from 0.1–1.5 m^3·ha^{-1}·yr^{-1} to more than 43 m^3·ha^{-1}·yr^{-1}. This difference is directly related to the planted stands' type and the planned cuts' nature during the management period under consideration (Table 2). It is also influenced by the effects of the new management objectives' implementation set to convert artificial woodlands in areas of regeneration and recovery of the cork oak's natural stands.

The flow map (Fig. 3a) remains largely comparable to that of capacity (Fig. 2a), given the implementation rates of previous management plans. It vary significantly depending on the stands'types as well as on the failure to take into account the illegal cutting phenomenon of Eucalyptus wood poles that is obvious in certain forest areas. Such situation results in a flow of this service set at 224,515 m^3·yr^{-1} on the scale of this study.

Thus, the achievements' analysis of the cited above management plans reveals that the intervention program concerning pine stands is the most well respected with a success rate of nearly 85 %, followed by that of Eucalyptus with 75 %, and lastly Acacia-based plantations with barely 42 %.

Firewood harvesting

The capacity map for the ecosystem service of harvesting Firewood shows a clear distinction between the southern and northern parts of the study area (Fig. 2b). The former area has a capacity of little more than 0.5 stere·ha^{-1}·yr^{-1}, while the latter has higher levels with up to 41 steres·ha^{-1}·yr^{-1}, in some places. This high spatial variability in this service capacity is the result of the cover heterogeneity of the artificial forest stands as previously mentioned.

The supply capacity levels of this service are also impacted by the recommended conducting rules for these series of cork oak. The realization of regeneration operations was done only by whole plot under cover of trees, considering the total absence of regeneration either by stump sprouting or by natural seedlings. The silvicultural maintenance operations (Table 2) in the form of depressing, pruning, formation pruning, and thinning are also defined for young stands of the cork oak.

The flow map of these services (Fig. 3b) was also established by applying the same implementation rates of the previous management plans except for the cork oak series. It is noted a solemn commitment on the part of the forestry administration officials to meet the challenge of the reconstitution and restoration of the Maamora original ecosystem, through a strict application of the dedicated silvicultural conducting rules by capitalizing on past failure experiences. This will raise the contributing share of these natural stands in this service flow to nearly 58 %, followed by plantations of Eucalyptus with 28 %.

Firewood harvesting by local populations was also taken into consideration when mapping this service flow. Considered as the primary beneficiaries, they have the right, as enshrined in the current forestry law, to collect dead wood lying around to satisfy their domestic needs for heating and cooking. However, these uses have evolved and have been, over the years, transformed into almost

Table 2. Area of forest stands scheduled for harvesting

Types of forest cutting	Silvicultural cuts			Regeneration and maintenance of cork oak stands				Cork harvest
	Pine	Acacia	Eucalyptus	A	B	C	Total	
Area, ha	6867	2624	10,965	8286	2021	3126	13,433	89,343

Note: A – area to be regenerated on 1st pass; B – area to be maintained on 1st pass; C– area to be regenerated on 2nd pass.

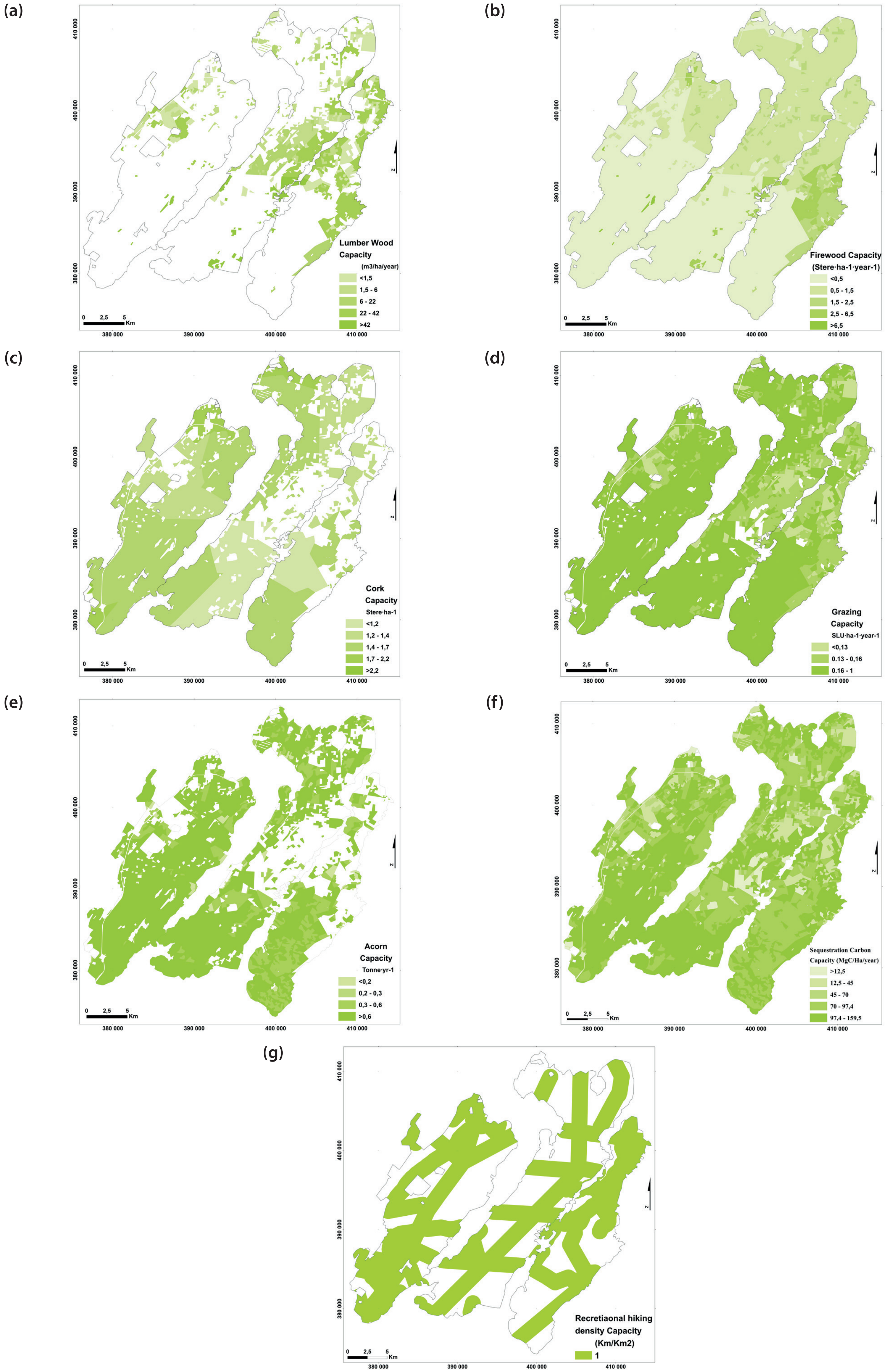

Fig. 2. Maps of the ecosystem services capacity: 2.a) Lumber and industrial wood harvest, 2.b) Firewood harvest, 2.c) Cork harvest, 2.d) Forage production, 2.e) Acorn gathering, 2.f) Carbon storage, 2.g) Recreational hikin

generalized criminal practices, in search of new financial resources to improve their standard of living through direct sale to the nearest urban centers, whether it be raw firewood or transformed into charcoal wood.

This uses' mutation is mainly due to the vertiginous bordering urban zones' sprawl and the subsequent needs' increase in terms of woody fuels used in the functioning of the bread ovens, the brick factories, the Moorish baths, the pressings and others (Bendaanoun 1996, Hemmich 2003). Thus, the firewood flow varies very significantly spatially without a particular noticeable trend. It is estimated at less than 1.4 stere^{-1}ha^{-1}·yr^{-1} particularly in the southeastern part of the study area and can reach the threshold of 160 stere^{-1}ha^{-1}·yr^{-1} in its eastern part, where a large population is concentrated within rural settlements which are considered as black spots in terms of wood cutting offenses (Aafi 2007).

That explain the hight level of flow wich represent more than three times of the supply capacity estimated at 49,816 steres·yr^{-1}, wich is an average of overharvesting rate equal to 1.66 steres·ha-1·yr^{-1} (Table 3). Moreover, referring to the results of the spatial balance map (Fig. 4a), this deficit rate varies significantly between communes, ranging from 1 to more than 4 steres·ha^{-1}·yr^{-1}.

Cork harvesting

The spatially explicit maps of cork harvesting capacity and service flow (Fig. 2c and 3c) accurately reflect the condition and structure of cork oak stands, the history of past harvests, which are set at 5 with a 9-year rotation, and the regeneration efforts of this natural species undertaken in recent years by the forestry administration.

The western parts containing the most preserved stands show the highest capacity levels, reaching up to 6.4 steres·ha^{-1}·yr^{-1} in their northern and southern extremities. However, the eastern portions show low capacities of only 1.1 stere·ha^{-1}·yr^{-1}, particularly in its highly disaggregated northern areas. The latter are classified in high proportion in the regeneration management group.

This spatial heterogeneity in this service provision, estimated on average at more than 77,261 steres·yr^{-1}, could have been more pronounced if the stands' density factor was taken into consideration, instead of being assessed solely based on average production yields of reproductive cork and male cork estimated respectively at 8.36 and 0.28 steres·ha^{-1} throughout the study area (Hammoudi 2002, DEF 2015).

The yields' diversity remains very much influenced by the still young age of the regeneration perimeters carried out under the conversion programs of the old artificial plantations. These plots, covering nearly 15 % of the surface area of cork oak stands, will only be partially affected by the cork harvesting program during the current management period. (Hammoudi 2002, DEF 2015).

The flow map of these ecosystem service (Fig.3c) was established on the basis of the implementation rate of previous cork harvest programs. This rate is estimated at 96%, which shows the importance given to this sector.
Although this ecosystem service flow is subject to better control and regulated organization through two stages with a separation between the operation of exploitation and sale, Moroccan cork production remains poorly valorized. It is mainly destined for export, with varying degrees of transformation (raw, semi-worked and worked cork) (Hammoudi 2002).

Forage

The forage production capacity map (Fig. 2d) accurately expresses the equilibrium pastoral load that determines the small livestock units' number that a grazing area can support without compromising its sustainability. It illustrates the potential for forage production, which is highly differentiated between the natural and artificial stands in the study area.

This potential is estimated at 300 Forage Unit (FU)·ha^{-1}·yr^{-1} for cork oak stands (FU: Forage Unit), 50 FU·ha^{-1}·yr^{-1} for hardwood reforestation, and 40 FU·ha^{-1}·yr^{-1} for softwood plantations (Laaribya et al. 2013, 2021; DEF 2015). Knowing that these average yields vary significantly from one year to another depending on the recorded rainfall volume. They are also highly sensitive to the nature of soils, density, and structure of stands (M'hirit et al. 1995, Benabid 2000, Aafi et al. 2005a).

Based solely on the stand types' map, the capacity map produced in this way broadly follows a northwest-southeast gradient, with a near-dominance of the capacity threshold of 1 Standard Livestock Unit (SLU)·ha^{-1}·yr^{-1}, delivered by the cork oak-based areas of different density classes. These forests' stands provide more than 95 % of the average annual capacity of this service, estimated at 54,941 SLU.

The flow map (Fig. 3d) provides information on the real pastoral load, defined as the load imposed on the grazing, evaluated annually at 178,303 SLU (Table 3). Since this is an ecosystem service whose flow is defined as a right of use recognized by the riparian populations, organized into traditional tribes delimiting 5 spatially distinct pastoral parks, this map shows a variation in flow levels that is very perceptible at the territorial level.

Thus, the map of spatial balance (Fig. 4.b) shows a positive balance of 0.4 SLU·ha^{-1}·yr^{-1}, recorded at the level of

Table 3. Accounting tables for ecosystem services

Peuplement	Firewood harvesting (Stere/year)		Harvesting of timber and industrial wood (m^3/year)		Forage (SLU/year)		Cork Harvesting (Stere/year)		Carbon storage (MgC)	Acorn gathering (Tonne/year)
	Capacity	Flow	Capacity	Flow	Capacity	Flow	Capacity	Flow	Capacity	Capacity
Acacia	4 526	12 234	4 464	1 857	402	546			168 872	
Eucalyptus	13 744	46 627	292 729	218 083	1 543	4 325			1 430 545	
Pin	3 369	9 453	5 415	4 576	600	1 421			202 331	
Chêne-liège	28 177	99 463			52 396	172 011	77 261	74 170	6 869 864	34 487
Vide									33 078	
Total	49 816	167 777	302 607	224 515	54 941	178 303	77 261	74 170	8 704 689	34 487

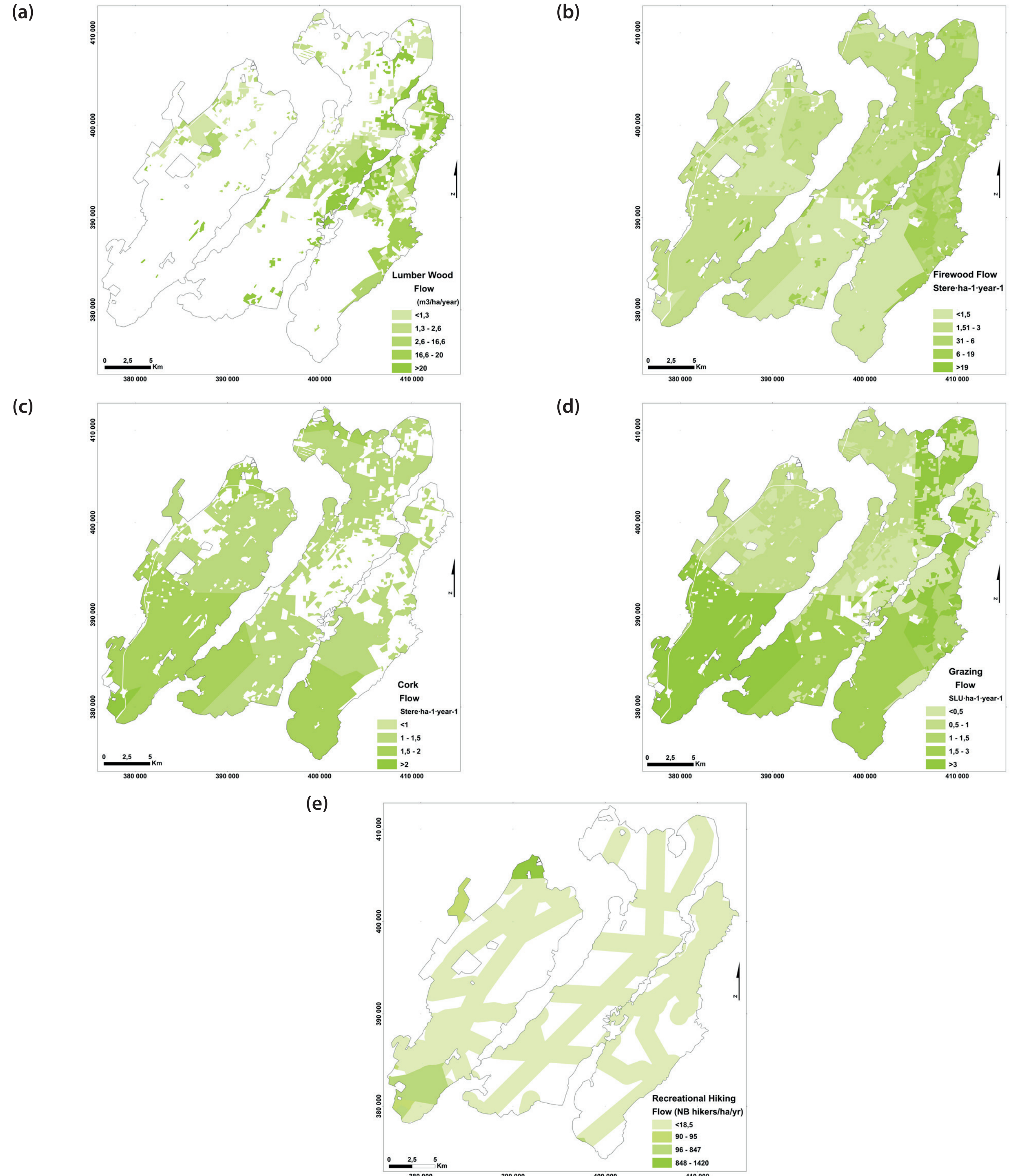

Fig. 3. Maps of the ecosystem services flow: 3.a) Lumber and industrial wood harvest, 3.b) Firewood harvest, 3.c) Cork harvest, 3.d) Forage production, 3.e) Recreational hiking

the pastoral park of Ameur-Haouzia, while it is negative in the other four parks with overgrazing rates ranging from 0.6 to over 3 SLU·ha^{-1}·yr^{-1}.

This observed variability between the different pastoral parks is also the expression of the related differences in terms of the number and composition of the herd, the extent of irrigated and rural agricultural areas, as well as the mode of herd management, supplementation in fodder units used by households as well as their standard of living (DEF 2015). It is known that supplements only contribute up to 25 % of the herd's needs in fodder units, and nearly 8 % for useful agricultural areas (UAA) dominated by high value-added crops such as arboriculture to the detriment of high-balance cereal crops forage.

Thus, the flow levels vary from less than 0.4 SLU·ha^{-1}·yr^{-1} in a few terroirs in the northeast, to nearly 6 SLU·ha^{-1}·yr^{-1}, mainly in the terroir located southwest of the study area.

Acorn gathering

The acorn production capacity map of the cork oak (Fig. 2e) highlights a clear territorial variability, with a distinction between the eastern and western parts. It shows capacity levels ranging from less than 0.1 t·ha^{-1}·yr^{-1} to more than 0.7 t·ha^{-1}·yr^{-1}. Which reprsents an average annual capacity of 34,487 tons.

This substantial territorial heterogeneity is the result of considering the density criterion in the evaluation. Thus, if an average production yield of a cork oak tree was

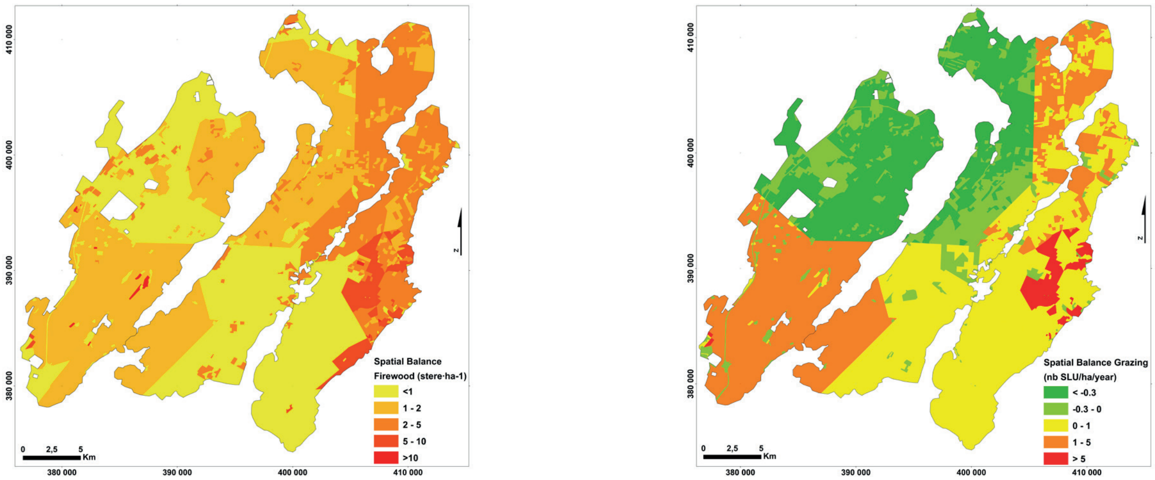

Fig. 4. Ecosystem services spatial balances: 4.a) Firewood harvesting, 4.b) Forage production

estimated at 6 kg·tree^{-1}·yr^{-1}, the number of trees retained by density classes is estimated at 250 tree·ha^{-1} for the dense class, 150 tree·ha^{-1} for the medium dense class, 75 tree·ha^{-1} for the light class and 25 tree·ha^{-1} for the sparse class (Aafi 2005b, DEF 2015).

The flow map of this ecosystem product has been considered identical to the capacity map since all the acorns produced are assumed to be consumed in full. Thus, its flow is mainly ensured by the local populations who are almost systematically involved in the acorn collection activity, either for self-consumption or for marketing.

In recent years, it is observed that acorn harvesting is used to harvest as many acorns as possible at an early stage, not only in times of shortage to feed livestock, but rather to maximize the profits generated from sales in urban centers.

Carbon storage

The map of the carbon storage capacity (Fig. 2f) shows a very marked spatial variability, from less than 12.5 MgC·ha^{-1}·yr^{-1} in some isolated and very bare areas, to more than 100 MgC/ha/yr in the parts covered by dense stands of the cork oak, contributing to 79 % of the annual average capacity estimated at 8.7 Tons of Carbon (Table 3). This variability reflects the heterogeneous distribution of forest cover, especially since the assessment was based on both the types and densities of stands.

Capacity varies significantly, depending on the density classes, from 65 to 237 MgC·ha^{-1}, with a mean value of 121 MgC·ha^{-1}, concentrated mainly at the level of the soil and tree biomass with nearly 51 % and 47 % of the total carbon stock respectively (Oubrahim et al. 2015). For the Eucalyptus stands, an average yield was fixed at 154.55 MgC·ha^{-1}, considering the dense class dominance for more than 93 % of the covered area and whose carbon stocks fluctuate according to the compartments, depending on the number of their rotations (Boulmane et al. 2017). This average value was also retained for Acacia stands and reduced by 50 % for resinous forests' stands.

The flow map was considered similar to the capacity map, knowing that the carbon flows released by the rural user populations remain very low as compared to the stored quantities by the forest ecosystems. Nevertheless, given that the Maamora forest is located between three large cities in Morocco with a very high urban density and a declared ambition to develop the industrial sector, a more thorough study, taking into consideration the final users of this ecosystem service, would be useful to better measure the major environmental role of this ecosystem in carbon storage at a regional or even national and global spatial scale.

Recreational hiking

The ecosystem service capacity map for recreational hiking (Fig. 2g) simply reflects the trail network, which is made up of both hiking trails and main trails. These trails are taken as territorial boundaries between municipalities or as boundaries between the main management groups that divide the Maamora forest stands.

It is only at the level of the five (5) dedicated recreational sites where it is noted a high density of trail network created as part of recreational development projects to accommodate the public (CRF 2011, El Mokaddem 2016). Outside of these natural areas, there is a strong capacity for recreational hiking; the capacity to provide this service remains almost equal, over an area exceeding 43,000 ha, or nearly 60 % of the area of the study area.

This ecosystem service's flow (Fig. 3e) shows that it is delivered to village hikers along spatial corridors as delineated and defined by the grid network of forest roads. However, it is also delivered within the five recreational sites created within the study area to accommodate a high proportion of urban visitors. Thus, flow levels are highly variable. They range from less than 5 hikers·ha-1 to nearly 500 hikers·ha-1 on weekend days in the spring and summer seasons. This high frequentation is recorded mainly at the recreational sites located in the northern and southern extremities of the western part of the study area. These high ratios greatly reflect the pressure of visitors coming from the main metropolises: Rabat, Salé and Kenitra, frequenting those sites being accessible through the main national roads (CRF 2011, Laaribya et al. 2013, El Mokaddem 2016).

DISCUSSIONS

The application of the ecosystem services mapping approach as a tool for sustainable management of forest ecosystems was based based upon seven ecosystem. The latter are intimately linked to the management objectives assigned to the Mamora Forest by its management plan, as well as to the commitments made by the country in the framework of the Convention on Biological Diversity and the Aichi targets (DEF 2015, CBD 1992). This choice also takes into consideration the multiple, sometimes contradictory, expectations of the different actors involved in defining the future of this natural area (DEF, 2015, Laaribya & al., 2021), known for its particular characteristics in terms of structure, health and physiology, as well as the fragility of its physical environment (García-Nieto & al. 2015).

In this regard, it is important to specify that the management study of the Mamora forest was carried out according to approaches based on the participation and adhesion of the riparian user populations, as well as of all the local actors involved in its management so as to guarantee a better valorization of the forest resources and to improve their contribution in the local economic development efforts (DEF 2015). The main management objectives assigned to the forest of Mamora aim its suberaie rehabilitation to ensure its sustainability, while improving its functions of reproduction cork and fodder units' production, and of neighboring towns' protection against wind erosion.

The sustainable management of forest areas inevitably implies taking into account their production capacities in terms of goods and services, often competitive, with regard to the various users and actors concerned. This requires compromises to be made on the temporal and spatial levels by the different users, including in particular (i) users with rights to harvest dead wood and to graze their livestock within well-defined territories, (ii) the territorial communes benefiting from revenues resulting in particular from the forest products' sale such as cork, timber and industrial wood, as well as firewood, (iii) the companies in charge of forestry work (iv) manufacturers involved in the activities of the forest products' valorization to various degrees, (v) hikers interested in leisure and recreation activities, (vi) neighboring urban populations in search of a clean environment, as well as the international community urging more conservation of nature and biodiversity for better adaptation and mitigation of the climate change phenomenon (DEF 2015, Maes & al. 2018).

Based on the above, the mapping of ecosystem services by distinguishing the capacity of their production and the flow of their provision, constitutes a better tool for assessing both the bio-physiological characteristics of forest ecosystems, as well as the impacts induced on the different user groups concerned by each or a group of forest ecosystems. Spatial identification of service provision hotspots (SPHs) and degraded areas can better inform decision-makers on how to implement rational, sustainable, and equitable forest resource management. Understanding the flow of ecosystem services and the capacity of ecosystems to generate these services is an essential element for understanding the sustainability of ecosystem use as well as developing ecosystem accounts (Palomo et al. 2012, Schröter 2014).

In this sense, the spatial balances created between the capacity and flow of ecosystem services are of particular interest in this regard. They allow a fine and precise analysis of the ecosystem services' use sustainability , as in the case of firewood production or cattle grazing taken as an example in our study. This corroborates the results obtained in several studies conducted in this area (Schröter et al., 2014, Burkhard et al, 2012; Nedkov et al. 2012). Similarly, the ecosystem services' accounting table for both capacity and flow (Table 3) can be a first step towards establishing environmental or ecosystem accounting (SEEA-EAA 2012, Schröter et al., 2014). It displays information that is as relevant as it is reliable for establishing sustainable management of forest ecosystem. In fact, this type of table can be constructed according to different possible spatial units (territorial communes, pastoral park, tribal terroir, etc.). This makes it possible to show the differences observed between the intrinsic potential of forest ecosystems to provide ecosystem services and the current levels of their use.

The use of these tools that support the implementation of an ecosystem accounting system as well as of the ecosystem service mapping approach, by distinguishing between capacities and flows, are fully in line with the guidelines advocated by both the SEEA and the TEEB (SEEA-EAA 2012, TEEB 2010).

This work's ES mapping results can support sustainable management of natural resources and spatial planning. They can also be applied to the development of nature-based solutions for social and economic challenges as well as in environmental education to share information about the importance of ecosystems for ES delivery and to promote choices supporting the sustainable use of those precious ecosystems. It's based on a better understinging of the interactions between land management, ecological processes and ecosystem service provision. Indicators can help to better understand these interactions and provide information for policy-makers to prioritize land management interventions (Geneletti & al. 2020, van Oudenhoven et al. 2012).

CONCLUSIONS

Spatial mapping of ecosystem services is a new approach to forest ecosystem assessment and analysis. It provides a better understanding of the complexity of attributes, uses, and direct and ultimate beneficiaries of multiple and diverse ecosystem services.

Based primarily on the stand type map and management plan for the Maamora Forest (DEF 2015), the produced spatially explicit ES maps are of great value in presenting the assessment results of the capacities and flows of each ecosystem service. This way of quantification and specialization is a new technique for guiding natural area management decisions towards more spatial and territorial equity and trade-offs in pursuit of forest resource conservation and enhancement goals.

Spatial balance maps and ecosystem accounting tables at different reference spatial units contribute greatly to this perspective. The determination of hotspots and cold ones, as well as the easy comparison between territories, by type of ecosystem service, can only offer managers and stakeholders the necessary information to make decisions in a clear and documented way. Such decisions should be defined based on a compromise between the range of ecosystem services of forest ecosystems, and between their different direct and final beneficiaries.

REFERENCES

Aafi A. (2007). Etude de la diversité floristique de l'écosystème de Chêne-liège de la forêt de la Maamora. Thèse de Doctorat D'Etat Es-Sc., Institut Agronomique et Vétérinaire Hassan II, Rabat, Maroc, 190 p. [in French].

Aafi A., Achhal El Kadmiri A., Benabid A., Rouchdi M. (2005a). Richesse et diversité floristique de la subéraie de la Mamora (Maroc). Acta Botanica Malacitana 30: 127–138. Available at: http://www.bioveg.uma.es/abm/volumenes/vol30/08.mamora.pdf.

Aafi A., Achhal El Kadmiri A., Benabid A., Rouchdi M. (2005b). Utilisation des images satellitaires SPOT pour la cartographie des types de peuplements de la forêt de la Mamora (Maroc). Revue Française de Photogrammétrie et Télédétection 178 (2): 30–35.

Benabid A. (2000). Flore et écosystèmes du Maroc: Evaluation et préservation de la biodiversité. Ibis Press, Paris, France. 359 p.

Bendaanoun M. (1996). La Maâmora un patrimoine national vital pour l'avenir de Salé et de la région. Journée d'étude 'Sauvons la Maâmora', Ecole National Forestière d'Ingénieurs, Salé. 30 p.

Boulmane M., Oubrahim H., Halim M., Bakker M.R., Augusto L. (2017). The potential of Eucalyptus plantations to restore degraded soils in semi-arid Morocco (NW Africa). Annals of Forest Science 74, 57, DOI: 10.1007/s13595-017-0652-z

Bryan B.A., Raymond C.M., Crossman N.D., King D. (2011). Comparing spatially explicit ecological and social values for natural areas to identify effective conservation strategies. Conservation Biology 25(1): 172–181.

Burkhard B., Kroll F., Nedkov S., Muller F. (2012). Mapping ecosystem service supply, demand and budgets. Ecological Indicators 21: 17–29.

CBD, 1992.Convention on Biological Diversity. United Nations.

Chan K.M.A., Satterfield T., Goldstein J. (2012). Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics 74: 8–18.

CRF (Centre de Recherche Forestière) (2011). Etude relative aux attentes sociales vis à vis de la forêt marocaine, Forestry Research Center, Ministerial Department of Water and Forests, Rabat, Morocco: 10–29.

Dahmani J. (2006). Etude de la régénération naturelle et artificielle du Chêne-liège (Quercus suber L.) dans les forêts de la Mamora et de Témara. Thèse de Doctorat d'Etat, Faculté des Sciences, Université Ibn Tofaïl, Kénitra, Maroc, 138 p.

DEF (Département ministériel des Eaux et Forêts) (2015). Management plan of the Maamora forest, Morocco. Ministerial Department of Water and Forests, Kenitra, Morocco. 206 p.

El Mokaddem A. (2016). Estimation of the economic and social value of the services provided by Mediterranean forest ecosystems: Mamora forest, Morocco. Plan Bleu, Valbonne. 85 p. Available at: https://planbleu.org/sites/default/files/publications/rapport_foret_maroc_c2_6oct2016.pdf

Fagerholm N., Käyhkö N., Ndumbaro F., Khamis M. (2012). Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services. Ecological Indicators 18: 421–433.

FAO/IUSS (2006). IUSS Working Group WRB World Reference Base for Soil Resources 2006: a Framework for International Classification, Correlation and Communication. 2nd edition. World Soil Resources Reports no. 103. Food and Agriculture Organization of the United Nations, Rome. Italy. 128 p.

García-Nieto A., Quintas-Soriano C., García-Llorente M., Palomo I., Montes C., & Martín-López B. (2015) Collaborative mapping of ecosystem services: The role of stakeholders´ profiles. Ecosystem Services 13: 141152, DOI: 10.1016/j.ecoser.2014.11.006

Geneletti D., Esmail B. A., Cortinovis C., Arany I., Balzan M., van Beukering P. J., & Burkhard B. (2020). Ecosystem services mapping and assessment for policy-and decision-making: Lessons learned from a comparative analysis of European case studies. One Ecosystem 5: e53111, DOI: 10.3897/oneeco.5.e53111

Hammoudi A. (2002). Suberaie and landscape biodiversity. Vivexpo conference, Institut Méditerannène de Liège, France, 5 p. Available at: http://www.vivexpo.org/foire/images/Abdelaziz%20Hammoudi.pdf

Hemmich H. (2003). Evaluation des activités anthropozoogènes exercées dans la Maâmora occidentale et processus de gestion durable. Mémoire de 3ème cycle ENFI, Salé. 89 p.

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. 7 p., DOI: 10.5152/forestist.2021.20059

Laaribya S., Alaoui A., Gmira N., Gmira N. (2014). Contribution to the assessment of pastoral pressure in the Maâmora forest. Forest routes and overgrazing. Nature et Technologie C- Sciences de l'Environnement 10: 39–50.

M'hirit O., Benzyane M., Naggar M. (1995). L'Aménagement sylvopastoral. Actes de l'atelier sur le sylvo-pastoralisme- ENFI (Maroc), 25–28 Octobre 1995. Annales de la Recherche Forestière au Maroc. Rabat: 20–35.

Maes J, Teller A, Erhard M, Grizzetti B, Barredo JI, Paracchini ML, Condé S, Somma F, Orgiazzi A, Jones A, Zulian A, Petersen JE, Marquardt D, Kovacevic V, Abdul Malak D, Marin AI, Czúcz B, Mauri A, Loffler P, Bastrup-Birk A, Biala K, Christiansen T, Werner B. 2018. Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg.

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DC. 64 p.

Oubrahim H., Boulmane M., Bakker M.R., Augusto L., Halim M. 2015. Carbon storage in degraded cork oak (Quercus suber) forests on flat lowlands in Morocco. iForest 9: 125–137, DOI: 10.3832 / ifor1364-008

van Oudenhoven A.P.E., Petz K., Alkemade R., Heina L., de Groot R. S. (2012). Framework for systematic indicator selection to assess effects of land management on ecosystem services. Ecological Indicators 21 (2012) 110–122. doi:10.1016/j.ecolind.2012.01.012

Palomo I., Martıin- Lopez B., Potschin M., Haines-Young R., Montes C. 2012. National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Ecosystem Services, 13 p., DOI: 10.1016/j.ecoser.2012.09.001

Plieninger T., Bieling C. (2013). Resilience and the Cultural Landscape: Understanding and Managing Change in Human-Shaped Environments. Cambridge University Press, Cambridge. Landscape Ecol 28: 1841–1843, DOI:10.1007/s10980-013-9922-9

Schröter M., Bartonb D.N., Remmea R.P., Heina L. (2014). Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. Ecological Indicators. Volume 36, Pages 539-551, DOI: 10.1016/j.ecolind. 2013.09.018.

SEEA-EEA, 2012. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf

Seppelt R., Dormann C.F., Eppink F.V., Lautenbach S., Schmidt S. (2011). A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of Applied Ecology 48: 630–636, DOI: 10.1111/j.1365-2664.2010.01952.x

TEEB, (2010). The Economics of Ecosystems and Biodiversity: Ecological and economic foundation. Earthscan, Cambridge.

Turner K.G., Andersonc S., Gonzales-Chang M., Costanza R., Courvillef S., Dalgaarda T., Dominati E., Kubiszewski I, Ogilvye S., Porfirio L., Ratna N., Sandhui H., Suttonc P.C., Svenning J.C., Turner G.M., Varennes Y.D., Voinov Y., Wratten S. 2016. A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. Ecological Modeling 319: 190–207.