Review

The changing land use and land cover in the Mediterranean Basin: implications on forest ecosystem services

Bright Danso Appiagyei[1]*, Latifa Belhoucine-Guezouli[1], Enoch Bessah[2], Boutkhil Morsli[3]

[1]University of Tlemcen, Department of Forest Resources – Tlemcen, 13000, Algeria
[2]Kwame Nkrumah University of Science and Technology, Kumasi, PMB, Ghana – Department of Agricultural and Biosystems Engineering
[3]National Institute of Forestry Research (INRF), Tlemcen, Algeria

Abstract

Appiagyei, B.D., Belhoucine-Guezouli, L., Bessah, E., Morsli, B., 2023. The changing land use and land cover in the Mediterranean Basin: implications on forest ecosystem services. *Folia Oecologica*, 50 (1): 60–71.

The Mediterranean Basin covers more than 2 million square kilometres and is surrounded by three continents: Africa, Asia, and Europe. It is home to more than 500 million people and is projected to reach 670 million by 2050. The basin is rich in species diversity, with a great wealth of endemism. The supply of ecosystem services is greatly challenged due to the trend of land use and land cover (LULC) change coupled with other global change drivers. The current study thoroughly reviewed the existing body of knowledge on the impacts of LULC change on forest ecosystem services. The LULC change is driven by synergetic factor combinations of urbanization, population increase, agricultural land abandonment and deforestation putting additional strain on forest ecosystem services. The review shows the potential impacts on biodiversity as well as ecosystem services such as wood and non-wood forest products, water resources, and carbon stock. Moreover, there is evidence showing the threats of LULC change to saproxylic beetle species, a key agent in the nutrient cycling process, posing a significant risk to a nutrient-deficient ecosystem. Therefore, there is a need to mitigate the challenges posed by LULC change and adapt forest management practices to impending changes to sustain the provision of ecosystem goods and services.

Keywords
biodiversity, forest cover, landscape, land-use practice

Introduction

Land use and land cover (LULC) change research has gained momentum in the last decades and still dominate global discussions among scientists and researchers because of its primary role in several pressing issues such as global climatic change, food security, soil degradation and biodiversity loss (Geist and Lambin, 2002; Overmars, 2006). The land-use change issues surfaced on the research platform several years ago, when the land surface impact on the climate was discovered (Lambin et al., 2003). According to Otterman (1974), Charney et al. (1975) and Sagan et al. (1979), it was detected in the mid-1970s that land cover change alters the surface

*Corresponding author:
e-mail: dansob64@gmail.com

albedo and thus surface-atmosphere energy exchanges with an impact on regional climate. Subsequently, the studies in the early 1980s found that the terrestrial ecosystems acted as sources and sinks of carbon, revealing the effects of LULC change on the global climate via the carbon cycle (Woodwell et al., 1983; Houghton et al., 1985). The terrestrial biosphere has provided valuable resources such as food, medicine, fibre, non-wood forest products and freshwater to humans for several years. However, Ramankutty and Foley (1999) argued that the earth's environment in the last three centuries has witnessed a huge transformation due to human activities. The recognition of environmental damage due to human activities is not a new concept. As far back as 1864, Marsh identified the severe impacts of human activities on the earth's landscape (Ramankutty and Foley, 1999). In a follow-up study in the mid-century, Thomas (1956) endorsed the findings of Marsh and reported that the noticeable global change over the years has been a result of direct human alteration and land cover transformation. In a recent study, Kareiva et al. (2007) found that about 50% of the earth's surface transformation or degradation was due to human actions.

The conversion and alteration of the natural ecosystem to agriculture production has been the primary means of land exploitation by humans (Ramankutty and Foley, 1999). Globally, in the last three centuries, about 12 million km^2 of forests and woodlands have been removed, grasslands and pastures have declined by roughly 5.6 million km^2 and agriculture has expanded by 12 million km^2 (Richards, 1990). According to Foley et al. (2005), land-use practices such as agricultural expansion may trade short-term benefits (increased food supply) for long-term losses in ecosystem services. Although land-use practices differ from one region to another, Foley et al. (2005) emphasized that the rationale of land tillage is inherently the same; the exploitation of land resources to meet human needs, usually at the cost of modification of the environmental conditions.

The Mediterranean Basin, which covers more than 2 million square kilometres, is home to a great variety of ecosystems and species. The basin is surrounded by 21 countries with a population of more than 500 million and is projected to reach 670 million by 2050 (Lieutier et al., 2016; Bleu, 2019). The Mediterranean forests provide a wide range of critically important ecosystem services such as food, medicines, wood forest products, hydrological hazard mitigation, climate regulation, ground water recharge and purification, pollination, recreational and leisure use and the provision of habitats for forest species (FAO, 2013; Noce and Santini, 2018). The provisioning of these services undoubtedly makes the forest vital in sustaining human life (Bengtsson et al., 2000; Foley et al., 2007). Over the last decades, the region has undergone intense LULC change due to the relocation of people to the coastal border, forest fires, the abandonment of farms and grazing land, the rapid expansion of tourism-related activities, urbanization, deforestation, and the intensification of agriculture (Falcucci et al., 2007; Serra et al., 2008; Geri et al., 2011; Besacier, 2013). The objective of this paper is to present an overview of the Mediterranean LULC change and its implications on forest ecosystem services based on a comprehensive review of the scientific literature relevant to this study. Specifically, the study sought to answer the following questions: (i) How has the Mediterranean forest evolved in the light of LULC change? (ii) How has LULC change impacted the Mediterranean forest ecosystem services? Following this introduction, we structured the review into five major sections. We first discussed observed LULC change trends of the Mediterranean basin. We briefly describe the Mediterranean forest ecosystems. We proceeded to discuss the impacts of climate change on biodiversity. We then summarized the scientific literature on the LULC change impacts on forest ecosystem services. Finally, we concluded with a summary and outlook of the impact of LULC change on forest ecosystem services in the Mediterranean basin and proposed some research directions to improve LULC studies.

The Mediterranean basin

The Mediterranean basin (Fig. 1) is a meeting point for three continents, Europe, Asia, and Africa. It has a great diversity of plants and animals and is considered one of the biodiversity hotspots (Myers et al., 2000) in the world because of its high species richness and endemism rate (Thompson, 2005). According to Scarascia-Mugnozza et al. (2000) about half of the Mediterranean flora is endemic, which has evolved over a long period under diverse climatic conditions. The total area showing a Mediterranean-type climate (MTC) is about 2.3 million square kilometres, with transitions toward temperate forest ecosystems (in the European mountains) and toward arid ecosystems (in North Africa and the Near East). The basin is essentially marked by seasonal and annual variability. For example, the mean annual temperatures vary between 5 and 8 °C, and the mean annual precipitation ranges from 300 mm to more than 2,500 mm (Quezel et al., 1977). It is one of the few places on earth with a long history of intense human activities (Thiébault et al., 2016). The basin, as a result of increased exposure to diverse conditions such as; political, climate, and socio-economic factors, serves as a perfect example of human-environment co-evolution (Thiébault et al., 2016).

Methodology

To assess the impact of land use and land cover change on forest ecosystem services in the Mediterranean basin, an extensive literature search was conducted in Scopus and Google Scholar databases in July 2020 for original peer-reviewed publications without restricting publication year using the following search terms: ("land-use" OR "land use land cover") AND (''impact'' OR ''effects'') AND

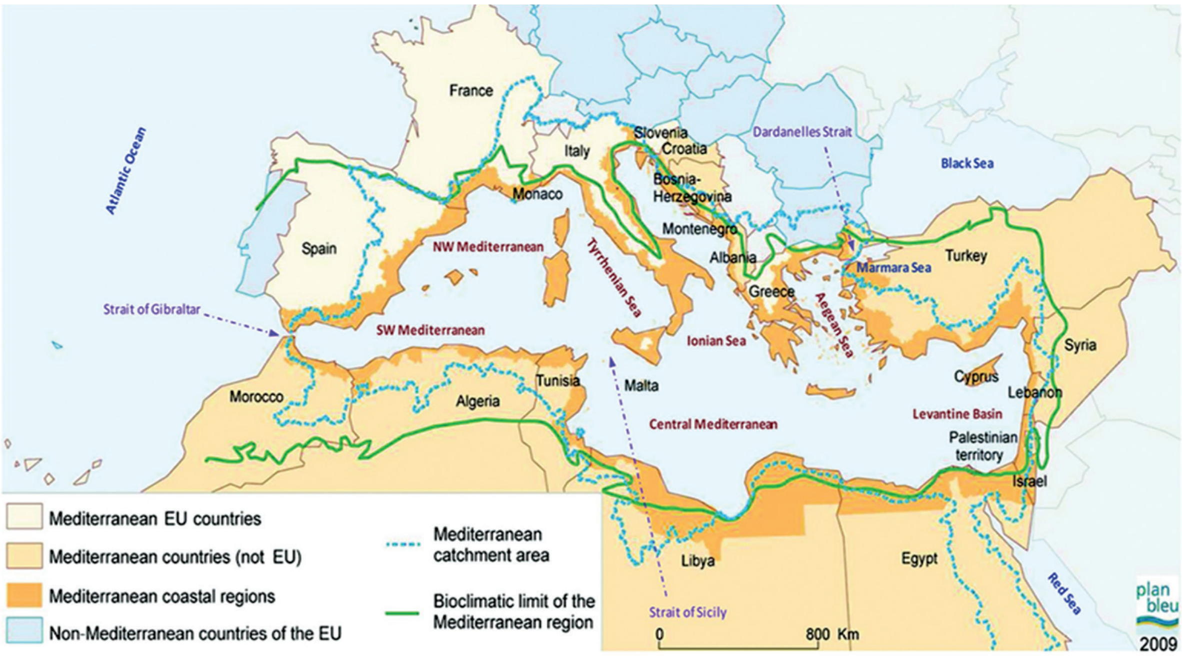

Fig.1. The Mediterranean basin. Adapted from Bleu (2009).

(''forest ecosystem services'' OR ''ecosystem services'') AND ("Mediterranean"). We reviewed the abstracts to remove the articles that did not address the scope of this review and only used the terms as buzzwords. These included articles focusing on the temperate biomes of some Mediterranean countries (e.g. Spain, France, Italy and Portugal); studies assessing the LULC change impacts of different ecosystems (shrubland, grassland, and marine) other than the forest; and LULC change articles that focused on geographic areas outside the Mediterranean Basin (unless otherwise used for comparison). Based on the aforementioned criteria, 78 articles were considered relevant for this study. In addition to the peer-reviewed papers, reports, conference proceedings papers, theses, and book chapters that effectively addressed the topic and were conducted in the Mediterranean basin were considered. After selecting the studies that fit the scope, a summary of the review notes was made for each paper. The features of the study were described together with notes on the issues investigated.

Mediterranean land use and land cover (LULC) change trend

The landscape of the Mediterranean basin is an integration of forests and other woodlands, which are strongly interconnected with urban and agricultural/rural areas (Besacier, 2013). The forest ecosystem has provided humans with multiple goods and services for a very long time. However, increasing human activities such as overgrazing, fire, deforestation, and unsustainable management have degraded the landscape (Brochier and Ramieri, 2001). The current landscape is a result of a long-term interaction between human populations and forest ecosystems (Besacier, 2013).

Human impacts may have increased when people lived as hunter-gatherers, they became significant with the advent of domestication, about 10,000 years ago in the Near East (Harris, 2004). According to Falcucci et al. (2007), 75% of the original postglacial area of the Mediterranean forest was lost at the end of the nineteenth century following the post-industrial revolution. In general, the increase of human activities in the past contributed to biodiversity loss, deforestation and soil erosion (Giordano and Marini, 2008). Although, the Mediterranean land cover has been changing since the end of the 1940s (Lavorel et al., 1998; Fox et al., 2012), the change has varied from one area to another across the region. For example, the forest area in southern France between 1965 and 1976 increased by 2,428 km^2 per year, whereas the forest area in Tunisia decreased by 130 km^2 per year over the same period (Shoshany, 2000).

In summary, a wealth of historical and contemporary literature shows that the Mediterranean landscape has witnessed a significant LULC change due to series of extensive and often interlinked phenomena: urbanization; crop expansion in the most fertile lands and agricultural abandonment in marginal areas; frequent and several intense summer forest fires; and the rapid expansion of tourist activities and infrastructures, along the coasts (Antrop, 2004). These changes have varied among different areas (the northern, southern and eastern) of the basin and been either positive or negative.

Mediterranean forest ecosystems

In the Mediterranean basin, forests cover more than 48.2 million ha of which the largest cover (35 million ha) is found in the northern area, followed by the eastern area (8.8 million ha) with the least coverage in the southern area of the basin (4.4 million ha) (Quezel and Medail, 2003; Fady and Médail, 2004). The Mediterranean forest has over 30,000 diverse plant species (Lieutier and Paine, 2016). It is considered one of the 34 biodiversity hot spots (Medail and Quezel, 1997; Benabid, 2000). The abundance and richness of the basin according to Noce and Santini (2018) is due to its harbouring role during the glacial age. The forest ecosystem is highly dominated by sclerophyllous plants. Trees are usually resistant to drought with a high number of ligneous structures and low water levels. The plants are also rich in volatile substances (Lieutier and Paine, 2016). Unlike temperate forest ecosystems, Mediterranean forests have a smaller leaf area index (Hickler et al., 2012), moderate biomass and primary productivity probably, due to summer droughts. Further, in contrast with both temperate and boreal forests, the Mediterranean forest landscape consists of several isolated and usually small-sized patches of stands. This is because of the blend of several factors, such as paleogeographic, climatic, and ecological processes, as well as ancient and current human activities (Quezel and Medail, 2003).

Impact of LULC change on biodiversity

Human-induced biodiversity loss has increased in the last century (Ceballos et al., 2015; Steffen et al., 2015). Land-use and associated pressures have been the main drivers of terrestrial biodiversity change (Vié et al., 2009). Among the major changes induced by anthropogenic actions, the loss of biodiversity stands out due to its irreversibility (Freitas, 2006). Land-use change is acknowledged as the main threat to biodiversity as it contributes to damage, fragmentation, and the loss of (semi-) natural habitats (Foley et al., 2005; Pereira et al., 2012). The loss of biodiversity has severe impacts on the ecosystem function and services with consequences on human livelihood (Cardinale et al., 2012). Moreover, García-Vega and Newbold (2020) found that the decline of biodiversity may lessen the carbon (IV) oxide sequestration capacity that could undermine climate change mitigation.

The Mediterranean forest ecosystem harbours several species of plants and animals (Bleu, 2019). However, for several years, much of this forest has been lost or transformed as a result of human settlement and habitat modification (Tucker and Evans, 1997). It is one of the four most altered hotspots on earth (Myers et al., 2000). The increasing anthropogenic pressures on the forest ecosystem have had an impact on the abundance and diversity of plants, vertebrates, fungi, and beneficial insects. A growing body of literature on biodiversity has reported the decline of species richness and endemism rate in the intense agricultural and urban locations in the basin (Matson et al., 1997; Preiss et al., 1997; Lavorel et al., 1998; Donald et al., 2001; Benton et al., 2003; Lavergne et al., 2005; Falcucci et al., 2007; Newbold et al., 2015; García-Vega and Newbold, 2020).

A detailed report by Bleu (2019) on the state of the Mediterranean forest shows that strong human pressure during the Neolithic caused the decline of mammal species. Fungi constitute one of the largest and most diverse kingdoms of eukaryotes and a significant biological component of forest ecosystems (Bleu, 2019). The Mediterranean forest ecosystems host a number of fungi species (Angelini et al., 2016). The progressive decline of these significant species in the basin has been linked to habitat dwindling due to clear-cutting and timber harvesting (Dahlberg et al., 2010). Huhndorf et al. (2004) emphasize that the removal of considerable quantities of timber from the understorey affects the growth of fungi, the establishment of mycorrhizal associations with plant seedlings, and the maintenance of mycorrhizal fungi associations in seasonally dry forests. Beside fungi species, the Mediterranean basin is home to saproxylic beetles. Saproxylic beetles are a group of insect species that depend on deadwood or wood-decaying fungi for some portion of their life cycle (Speight, 1989). A robust study by Stokland et al. (2012) shows that these insect species constitute a key component of the forest nutrient cycles because of their role in the decomposition process. Moreover, they add to the insect biomass in forests that is available for higher trophic levels, such as breeding birds (Bleu, 2019). Despite the role of these organisms in the forest ecosystem, the study of García et al. (2018) shows that logging and wood harvesting, forest fires, agricultural expansion, timber plantations, and grazing by livestock are contributing to the decline of beetle populations at the Mediterranean level. Further, the study indicates that urban development has led to an irreversible destruction of the habitat of saproxylic beetles. For instance, the construction of large tourism projects, a grave concern for coastal places in France, Spain, Italy and Turkey modifies tree population age structures and tree density of the host species that saproxylic beetles need to complete their life cycle.

It is evident from the above studies that land-use changes, have negative impacts on biodiversity. However, contrary to these reports, other emerging studies have pointed out that the studies on species loss due to land-use changes especially, species-area relationship studies (SAR) have consistently overestimated species loss (Pereira et al., 2012; De Camargo and Currie, 2015). For instance, the studies of Gerstner et al. (2017) and Pereira and Daily (2006) show that broad-scale assessments of biodiversity loss usually do not consider the capacity of species to disperse or adapt to changing environments and basically assume that natural habitats altered by land use cannot shelter local biodiversity. Similarly, the report of Bleu (2019) shows that while overgrazing, urbanization, and changes in fire regimes are identified as the most common threats to plants at risk of extinction in the Mediterranean basin, the most widespread vegetation type such as sclerophyllous shrublands, are maintained by grazing and sporadic fires. To mitigate this challenge, the report concludes that the balance between sustainable grazing levels and fire regimes is fundamental because many of the endemic and restricted-range plants depend on anthropogenic habitats maintained by grazing.

LULC change impacts on forest ecosystem services

Ecosystem services are the benefits humans derive from the ecosystem. They preserve human existence through their species and natural supporting systems, which constitute it (DAILY, 1997). A myriad of studies have highlighted that the current pace and magnitude of LULC change could alter the supply of ecosystem services (FOLEY et al., 2005; SCHRÖTER et al., 2005; TAYYEBI et al., 2015). In the Mediterranean basin, similar studies have reported the possible impacts of LULC change on the provision of ecosystem services (BELLOT et al., 2007; FALCUCCI et al., 2007; LÓPEZ-MORENO et al., 2011; GARCÍA-VEGA and NEWBOLD, 2020).

Wood and non-wood forest products

Timber is among the essential ecosystem services that forests provide. The Mediterranean forest ecosystem supplies a lot of wood and non-wood products required for the socio-economic building of rural places and also to meet the growing needs of the urban population (PALAHI et al., 2008). The main provisioning services of the Mediterranean forest ecosystem are wood products (roundwood, sawnwood, wood-based panels, wood pulp, paper and paperboard and fuelwood) (FAO, 2013). Economically, the supply of these products supersedes all other provisioning services (VIZZARRI et al., 2017) as they are easy to quantify.

In the Mediterranean basin, several LULC change studies have shown that the forest cover has declined over the last decades (WILLIAMS, 2000; DIMITRAKOPOULOS, 2001; PAPANASTASIS, 2008; MINETOS, 2009; LA MELA VECA et al., 2016). However, specific studies on LULC change impact on wood production are limited. Well-organized information on the direct assessment of the loss of wood due to the LULC change is not readily available. NOCE and SANTINI (2018) found that between 1990–2000, the Mediterranean basin recorded a 3% decrease in total wood. Similarly, the reports of WWF (2004) shows that the previously 3 million hectares of cork oak forests in the Maghreb (North Africa) countries has reduced to only a quarter (~750,000 hectares). In general, the possibility certainly exists that the increasing LULC change coupled with the novel climatic conditions in the basin will further aggravate the decline of wood production if effective and workable management plans are not put in place. The Mediterranean forest ecosystem is not only known for the supply of wood products but also for non-wood forest products (NWFPs) (Fig. 2). CROITORU (2007a) listed cork, fodder, mushrooms, honey, and others (berries, medicinal plants, pine nuts, chestnuts, etc.) as major non-wood forest products of the Mediterranean forest ecosystem. BERRAHMOUNI et al. (2007), reported that globally, cork oak remains the sixth-highest export, with an estimated annual export value of around US$ 329 million. Other NWFPs such as mushrooms, olives and carob also add to the local economies by providing raw materials to the

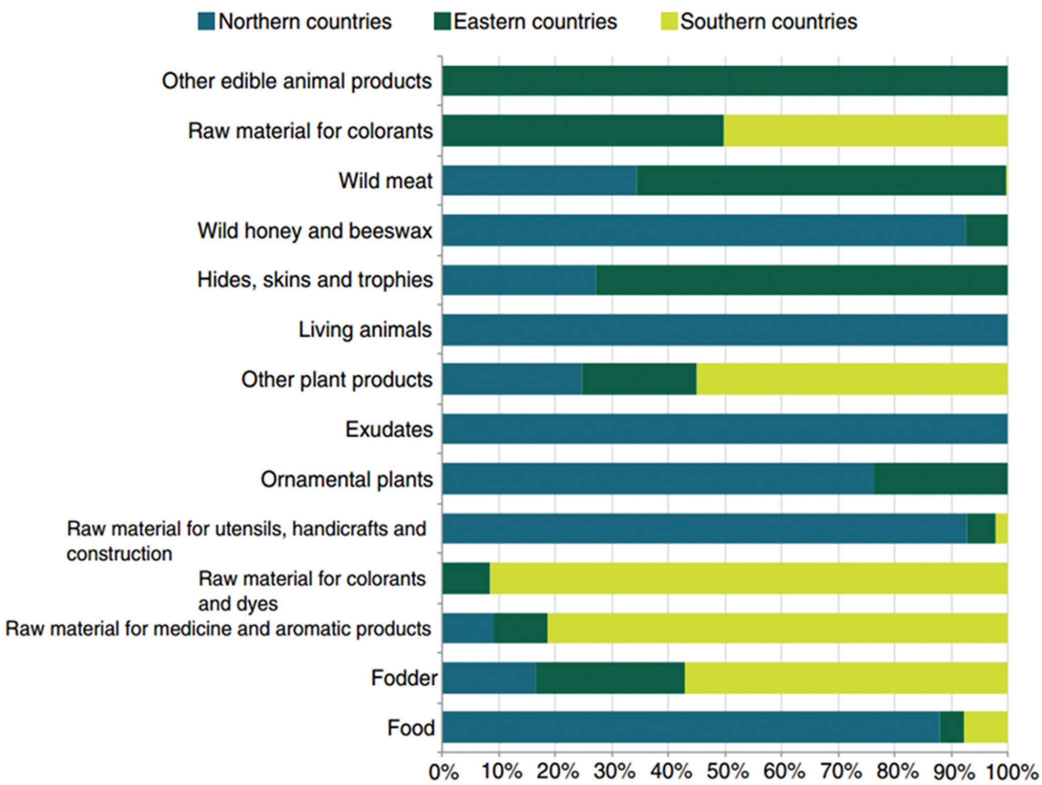

Fig. 2. Percent (%) of various categories of non-wood forest products (NWFPs) provided by northern, eastern and southern countries, 2005. Adapted from FAO, 2010.

industry, which in turn protects jobs in the sector (Bleu, 2019). LULC change impacts on non-wood forest products in the Mediterranean basin have been studied extensively. Croitoru (2007b) reported the decline of cork production and linked it to forest abandonment and the development of plastics as substitutes for cork.

An increasing number of studies have also reported the decline of the argan forest cover in the basin (Bouzemouri, 2007; le Polain de Waroux and Lambin, 2012; Maanan et al., 2019). The argan tree provides the argan fruit. The argan fruit pulp, leaves, and oilcake (by-product) serve as an important livestock feed (Elbaz, 2016). Further, the tree is of particular interest to Mediterranean communities because of its culinary, cosmetic, and medicinal benefits (Charrouf, 1998; M'hirit et al., 1998; Moukal, 2004; Faouzi and Martin, 2014). A comprehensive remote sensing analysis of argan stands distribution and its spatiotemporal dynamics in Morocco, by Mounir et al. (2015) showed that the argan stands decreased from 1,050,677 ha in 1987 to 999,079 ha in 2014, a loss of about 5%. In conclusion, there seems to be an agreement among scientific studies that LULC change is causing the decline of NWFPs in the Mediterranean basin. However, depicting LULC change as the principal cause may be a simplification of more complex processes, as other factors may be involved in their reduction.

Water resources

The forest protects the soil, regulates the water cycle, and accommodates most of the earth's biodiversity (Millennium Ecosystem Assessment, 2005). It is a key component of the hydrological cycle. LULC change such as deforestation, reforestation, and hillslope farming has been found to modify soil properties, throughfall, and infiltration rates, which eventually alter the hydrological cycle at the basin and hillslope scale (Hurni et al., 2005; Goudie, 2018).

Globally, the impact of LULC change on the hydrological cycle has been well documented. Ruprecht and Schofield (1991) in an attempt to study the impacts of deforestation on the groundwater system reported that groundwater increased from 0.11 m per year to 2.3 m per year after 10 years in a partially deforested catchment. The authors further stated that streamflow initially increased by 30 mm per year (4.0% rainfall) compared with a native forest average streamflow of 8 mm per year (1.0% rainfall). In a follow-up study, Sahin and Hall (1996) found that for a 10% reduction in forest cover, the water yield from conifer-type forests increased by 20–25 mm, eucalyptus-type forests increased by only 6 mm, whereas deciduous hardwood recorded 17–19 mm increase in water yield. In a recent study, Guzha et al. (2018), reported the increase of streamflow after a forest cover loss in East Africa.

Similar findings of LULC change impacts on the hydrological cycle have been reported in the Mediterranean environment around the world. The assembled evidence from the Basin shows that anthropogenic-induced land-use changes such as urbanization, agricultural expansion, and deforestation have contributed to the decrease in water discharge, net water deficit and prolonged flows in dry seasons (Bellot et al., 2007; López-Moreno et al., 2011; Braud et al., 2013; Cooper et al., 2013). Moreover, the impacts on various hydrological variables due to the forest cover increase in the northern area and the afforestation projects in the southern and eastern areas have also been reported. Beguería et al. (2003) in an earlier study found the decline in streamflow in central Spanish Pyrenee and linked the findings to forest and shrub cover increase in the previously cultivated area. Subsequently, Iroumé and Palacios (2013), in central Chile, a similar Mediterranean environment, detected annual water reductions in three river basins where the net increase in forested areas affected more than 16% of the total catchment area. These findings were further supported by the study of Eekhout et al. (2020). The authors found that reforestation in the Mediterranean headwater catchments contributed to plant water stress and a decline in reservoir storage. Furthermore, several modelling studies have also reported similar findings in consensus with theoretical, observational, and experimental findings (Table 1). In summary, available scientific evidence clearly shows that LULC change in the Mediterranean basin has a potential impact on the hydrological cycle. Thus, it is conceivable that the hydrological cycle will continue to witness further modifications as LULC change increases. Coupled with climate models projections (Giorgi & Lionello, 2008; Collins et al., 2013; Seager et al., 2014), which uniformly point towards dryness in the coming decades, it is more likely that tree growth in the basin will be affected. This will have an impact on the forest's productivity in an already water-limited ecosystem.

Carbon storage

The world's forests store over 650 billion tons of carbon in various components: 44% in biomass, 45% in soil, and 11% in deadwood and litter (FAO, 2010). Multiple studies have demonstrated that land-use changes such as agricultural expansion, cropland abandonment, and forest regrowth are the primary means of carbon transfer between the land and the atmosphere (Houghton et al., 1999; Caspersen et al., 2000; Pacala et al., 2001; Birdsey and Lewis, 2003; Tian et al., 2003). The IPCC (2006) report shows that LULC change is a prominent source of carbon flux. Likewise, Eggleston et al. (2006) and Watson et al. (2000) reported that land use activities such as crop production, urbanization and industrial growth have contributed to about 136 (±55) Gt carbon or 25% of the total anthropogenic emissions of carbon dioxide (CO_2) in the last 150 years.

The Mediterranean forest ecosystem contributes immensely to carbon sequestration, which helps regulate the climate both at the regional and global levels. It has been estimated to sequester carbon between 0.01 and 1.08 t C ha^{-1} (aboveground and belowground) annually (Croitoru and Merlo, 2005). In the Mediterranean basin, broad studies on the impacts of LULC change on

Table 1. Changes in the hydrological variables due to LULC change in the Mediterranean Basin

Region	Pre-LULC	Post-LULC	Model	Hydrological impact	References
Italy	Forest/Maquis	Deforestation	PBRR	Streamflow reduction (13%)	Niedda et al. (2014)
Turkey	Water	Irrigation	RCM	Decrease water yield	Yilmaz et al. (2019)
Italy	Farm land abandonment	Reforestation	AGWA	Reduce water yield	Nasta et al. (2017)
France	Agricultural land	Urbanization	GR4J	Decrease run off	Fox et al. (2012)Spain
Land abandonment		Afforestation recharge	_	Decrease annual aquifer	Bellot et al. (2001)
Tunisia	Watershed	Farming (terraces)	SWAT	Reduce surface runoff	Khelifa et al. (2017)
Spain	Watershed	Re-vegetation & SWAT	RHESSys	Decrease river flows	Morán-Tejeda et al. (2015)

PBRR, Physically based rainfall–runoff model; RCM, Regional Climate Model; AGWA, Automated Geospatial Watershed Assessment; RHESSys, Regional Hydro-ecological Simulation System; SWAT, Soil and Water Analysis Tool.

carbon stock have been carried out in the last few decades (Padill a et al., 2010; Parras-Alcántara et al., 2013; Muñoz-Rojas et al., 2015; Fonseca et al., 2019; Maanan et al., 2019). There is good evidence that LULC change contributes significantly to changes in carbon storage in the basin. Padilla et al. (2010), reported that the conversion of pastures to woodland in the Sierra Nevada, Spain, accounted for an increase in carbon sequestration above 30,000 t CO_2 per year. The authors found that holm oak (*Quercus ilex* Linnaeus.) and pine forests sequestered the highest carbon with cereal crops being the lowest.

Similarly, in Morocco, carbon stock increased from 4.81 Tg C in 1996 to 4.98 Tg C in 2017 due to the increase of forest and cultivated lands (Maanan et al., 2019). Studying the influence of the replacement of the *Quercus pyrenaica* species (QP), which represents the climax vegetation of Serra da Nogueira in Portugal, by *Pseudotsuga menziesii* (PM) and *Pinus nigra* (PN) plantations (fast-growing species), Fonseca et al. (2019) found that 30 years after the climax vegetation replacement, carbon gains were recorded in forest species biomass and forest floor (1.3 Mg C ha^{-1} per year in PN and 4.0 Mg C ha^{-1} per year in PM). In Majorca Island, Rodríguez Martín et al. (2019) found a significant increase in soil organic carbon stock (SOCS) in the agricultural zones on mountain slopes, associated with abandoned crops in terrace cultivation in the last 10 years. An earlier study concluded that the soil organic carbon tends to decline when converting grasslands, forest or other native ecosystems to croplands and tends to increase when restoring native vegetation on former croplands or by restoring organic soils to their native condition (Guo and Gifford, 2002).

In conclusion, while LULC change can have both positive and negative impact on the carbon stock depending on the type of the post-LULC, quantifying the direct impact of LULC change on carbon stock is difficult due to the large uncertainties attached to the possible interactions with other global change drivers.

Summary and outlook

On the global scale, LULC change has received much attention due to its patent impacts on earth processes such as forest ecosystems. Land-use issues have not only attracted the attention of researchers but also of urban planners and environmentalists advocating for sustainable land use. In this review, we have assessed the current trend of land use and land cover (LULC) change and its impacts on the Mediterranean forest ecosystem services. The Mediterranean LULC change is driven by synergetic factor combinations of urbanization, population increase, agricultural land abandonment, and deforestation, leading to increased pressure on forest ecosystem services.

A disparity between the northern, southern, and eastern rims of the Mediterranean is a result of different degrees of urbanization, industrialization, deforestation, and distinct population growth rates. In essence, the Mediterranean forest ecosystem is currently undergoing profound, sometimes irreversible changes due to LULC change. Several theoretical, experimental, modelling, and field studies have reported the potential impacts of LULC change on biodiversity as well as ecosystem services such as wood and non-wood products, water resources, and carbon sequestration. Moreover, there is empirical evidence that LULC change is having a detrimental effect on saproxylic beetle species which play an important role in the nutrient cycling process, posing a significant threat to a nutrient-limiting ecosystem.

To minimise the adverse impacts of human pressures and sustain ecosystem services, a multi-purpose land use, such as mixed agroforestry systems should be encouraged as an alternative to monoculture cropping (barley, beans, olives etc.) and crop pasture rotations (Schulz et al., 2010). In addition, challenges to ecosystem services due to land use and land cover change should be addressed through a transdisciplinary approach that embraces diversity of points of view and includes community participation (Nocentini et al., 2022).

In conclusion, although considerable effort has been made in LULC change research, the understanding of the interactions of LULC change with other global change drivers in the forest ecosystem system is still lacking. Further, the direct assessment of LULC change impacts on wood production in the basin is very rare. More research is needed in these areas, especially in the understudied ecosystems (southern and eastern Mediterranean region) threatened by desertification, an evidence of ecosystem depletion.

Acknowledgement

The authors thank the Intra-Africa ACADEMY project N0 2017-3052/001-001 of the European Union for support. We also thank the technicians of the research laboratory of soil, water and forest management of the University of Tlemcen for technical support.

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Received July 9, 2022
Accepted November 16, 2022