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Mediterranean Riparian Areas–Climate change implications and recommendations

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Abstract

Riparian areas are unique ecosystems and ecotones that provide many ecosystem services. Their importance is even larger in dryland areas because of the water scarcity conditions. This is especially true in the Mediterranean region where their value has been recognized and utilized for thousands of years. This utilization has led to severe their degradation, and in many cases, elimination. The Mediterranean Basin is also considered one of the most sensitive regions to climate change impacts. In this review, review, firstly the characteristics of the riparian areas of the region were identified, based on its climatic and geographic conditions but also anthropogenic impacts. Secondly, the potential impacts of climate change on riparian areas were assessed by understanding the associated effects on the hydrologic regimes of rivers. Flow patterns are expected to become flashier with greater periods of drought and peak flows with higher magnitudes.

This should impact the ecological processes of riparian areas and their vegetation assemblages and exacerbate the existing pressures they already face due to the numerous and diverse anthropogenic activities in the region. Based on the current and future conditions, it is imperative that measures should be taken to protect and re-establish riparian corridors in the Mediterranean. Although many areas are protected by initiatives such as the Natura 2000 Network or the the Ramsar Convention, additional and innovative practices need to be implemented. Specifically, the adoption of ecosystem-based approaches such as nature-based solutions and soil and water bioengineering are recommended because they take into consideration the ecosystem services of riparian areas. Even when practices are implemented at a local scale, they need to adopt a watershed scale approach to understand the drivers of riparian areas and the impacts from anthropogenic activities. The key for the successful restoration of riparian areas is restoring the natural hydrologic and geomorphologic regimes. Finally, the methods utilized need to have a transdisciplinary approach that involves academics, policy makers, local experts and stakeholders.

Key words: Ecotones, Ecosystem services, Hydrologic regime, Mediterranean region, Riparian areas

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Introduction

Riparian areas are semi-aquatic ecosystems, ecotones or transition zones; the area where the two adjacent ecosystems, the terrestrial and the aquatic, meet and integrate (Naiman *et al.,* 2005). Spatially, they commence from the top of the canopy all the way down to the groundwater, from the edge of the aquatic ecosystem to the beginning of the terrestrial and along the length of the water body as one moves from the upstream mountainous areas to the downstream lowland areas and eventually, to the delta (Ilhardt *et al.,* 2000). Typically, riparian areas, are linear in shape which extend adjacent to streams and rivers with complex assemblages of plants and other organisms that change through time and space (Lowrance *et al.,* 1985). The riparian area widths are narrower along a small stream than adjacent to a large river. This has to do with the "zone of influence," the zone of the terrestrial area that is influenced by the adjacent aquatic ecosystem (National Research Council, 2002). Finally, these ecosystems are azonal because they can be found in all biomes and along the entire altitudinal gradients from high mountains to seacoasts (Baker *et al.,* 2003).

The definition utilized for riparian areas in this review is based on the National Research Council (2002) that states they are transitional zones between aquatic and terrestrial ecosystems; have biophysical, ecological and biota gradients; connect through surface and subsurface hydrology the uplands to the adjacent waterbodies; influence exchanges of energy and matter between terrestrial and aquatic ecosystems (zone of influence) and are adjacent to perennial, intermittent and ephemeral streams, lakes, and estuarine–marine shorelines. Riparian areas are distinguished from the adjacent terrestrial ecosystems due to the presence and influence of excess water from the aquatic ecosystem (Zaimes *et al.,* 2010; Arthun and Zaimes, 2020). These areas are also disturbance driven ecosystems, such as from floods and droughts (Lowrance *et al.,* 1985; Naiman *et al.,* 2005; National Research Council 2002). The unique hydrologic, soil and geomorphologic conditions lead to the distinctive and diverse riparian vegetation assemblages that can include trees, shrubs, grasses and forbs (Zaimes *et al.,* 2019c). The vegetation is hydrophilic because it prefers higher soil moisture conditions and can withstand periods of flooding. In riparian areas, one can see different vegetation gradients while moving from the aquatic ecosystem to the terrestrial one (Schismenos *et al.,* 2019; Stella *et al.,* 2013). Differences in vegetation can also be seen depending on the dominant geomorphic processes at a specific location (Emmanouloudis *et al.,* 2017). For example, on the outside bend of the meander were erosion occurs the vegetation will differ from the vegetation on the inside were deposition occurs (sand bar).

The uniqueness of riparian ecosystems is the reason for the many ecosystem services they offer (Zaimes *et al.,* 2019a). Some of the most important services they offer are (Mediterranean Wetland Outlook 2 2018; Schultz *et al.,* 2004; Srivastava and Singh, 2012; Zaimes *et al.,* 2011a, 2019e): provision of flood storage and reduction of flood magnitudes; reduction of surface and stream bank erosion; reduction of sediment loadings in water bodies; provision of groundwater recharge; production of natural crops; filtering, treating and preventing non point source pollutants; provision of habitat for birds, amphibians, reptiles, mammals and insects; provision of ecotourism opportunities; provision of habitat for rare, endangered and threatened species; carbon maintenance and sequestration; mitigation of climate change and of the urban heat island effects; provision of recreational opportunities and scenic beauty; provision of historical, archaeological, heritage and cultural opportunities, since many riparian areas have been inhabited for thousands of years; provision of educational and interpretive opportunities and provision of scientific research opportunities.

Wetlands, deltas and riparian areas are ecotones between aquatic and terrestrial ecosystems (National Research Council, 1995, 2002; Emmanouloudis *et al.,* 2017). These ecotones have similarities but are different ecosystems. Riparian areas include terrestrial areas that are saturated or inundated with water for short period of time. Most wetlands are under water year around and always have hydric soils. Riparian areas can have non-hydric soils. Finally, most riparian areas are highly connected with each other, linear in shape, high in energy because they are disturbance driven that support woody plants and emergent herbaceous plant cover. In contrast, wetlands support more frequently, deeper water submerged aquatic plants, are lightly connected with each other, oblong or circular in shape and with less intensive and frequent disturbances. Finally, deltas are confined at the mouth of streams or rivers as they enter a large water body (lake or sea), have multiple channels that shift through time and include both riparian areas and/or wetlands. Several ecosystem services of riparian areas have led to their conservation and sustainable management, especially in developed countries. In the Mediterranean region, despite their importance and significant degradation necessary research has not been conducted (Zaimes *et al.,* 2011a; Zogaris *et al.,* 2009). The aim of the study was to assess the major anthropogenic disturbances of riparian areas in the Mediterranean and review the impending climate change impacts of these ecosystems and recommended best practices for the region to better adapt to climate change impacts.

Mediterranean Riparian Areas

The Mediterranean includes 27 countries of Southern Europe, Northern Africa and the Middle East. It occupies about 2.3 million km^2 area and experiences Mediterranean climate more than 400 million inhabitants (Olson *et al.,* 2001). The climate is warm to hot and dry in the summer and mild to cool and wet in the winter. Temperature variation between summer and winter is relatively small because of their proximity to the Mediterranean Sea. The region also has a mosaic topography with flat areas along the seacoast and large and tall mountain ranges nearby, that influences hydrologic, vegetative and climatic regimes (Emmanouloudis *et al.,* 2011). The specific climatic characteristics depend on the latitude, altitude and distance from the sea. The climatic and topographic conditions along with the natural, frequent wildfires (Pausas and Lloret, 2007) and human impacts have led to this unique and highly biodiverse biome. Many consider it as the most heavily degraded because it has been inhabited by humans for thousands of years (Savopoulou *et al.,* 2017). Their negative impacts are evident with the many unsustainable agricultural lands and the few remaining natural ecosystems (Zaimes and Emmanouloudis, 2012).

Since the focus is on riparian areas, there is a need to understand the adjacent water bodies of the region. The rivers and streams have natural high flow variability with wet winters and floods to severe droughts during summers (Cid *et al.,* 2017; Zaimes *et al.,* 2010). Mediterranean streams, located in high altitudes have annual rainfall greater than 1000 mm, and low temperatures in winter with snow accumulation in many cases. They have perennial flow and the highest flow occurs after rain and snowmelt in spring (Lobera *et al.,* 2016). In contrast, streams located in semi-arid areas (lowland areas), have annual precipitation from 200 to 500 mm, with intermittent or ephemeral flow (Lobera *et al.,* 2016). This second type of streams are called "torrents" in the Southern Europe and "wadis" in the Middle East and North Africa (Emmanouloudis *et al.,* 2011). Torrents, compared to rivers, have more irregular flow that can change in hours from no flow to a flash flood event. These floods are characterized by large volume of water and high amount of sediments travelling at high speeds (Emmanouloudis *et al.,* 2011). Wadis in Arabic refer to a valley but can also refer to a dry river bed with ephemeral flow (Sen, 2019; Ouhamdouch *et al.,* 2020; Emam *et al.,* 2019). Wadis are located below alluvial fans that extend on gently sloping, nearly flat parts of the deserts. They have a braided pattern with no permanent channels. When water flows, it eventually infiltrates into the stream bed leading to extensive sediment deposits. The riparian areas of the region are typically adjacent to these types of streams that has led to their unique characteristics.

The vegetation assemblages of Mediterranean riparian areas are impacted by the climatic, hydrologic and geomorphologic characteristics. These characteristics lead to rich and dynamic riparian plant communities, with interannual fluctuations in richness and composition that differ and are more diverse that those of temperate riparian areas (Sabater *et al.,* 2008; Feio *et al.,* 2014; Kontsiotis *et al.,* 2019; Ferreira *et al.,* 2019). Their vegetation can vary for woody vegetation to herbaceous and mixtures. During dry season, groundwater is the only source of water for the stream/river reaches (Argyroudi *et al.,* 2009). Reduced groundwater inputs can lead to droughts that cause habitat loss, poor water quality and biotic interactions. The vegetation assemblages of the Mediterranean have shorter life spans, desiccation resistance or avoidance mechanisms, and high colonization rates (Bonada *et al.,* 2007; Santos, 2010). Finally, natural and human disturbances, shape riparian plant communities, making it difficult to find undisturbed plant communities. The Habitats Directive (92/42/CEE) has categorized six major Mediterranean riparian habitat types (Zogaris *et al.,* 2007; Zaimes *et al.,* 2010): i) Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Pandion, Alnion incanae, Salicion albae*); code: 91 E0. ii) Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia,* along major rivers (*Ulmenion minoris*); code: 91F0. iii) *Salix alba* and *Populus alba* galleries; code: 92A0. iv) *Platanus orientalis* and *Liquidambar orientalis* woods (*Plantanion orientalis*); code: 92C0. v) Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*); code: 92D0. vi) Riparian formations on intermittent Mediterranean water courses with *Rhododendron ponticum, Salix* and others; code: 92B0.

Major anthropogenic impacts on Mediterranean riparian areas: Humans have occupied the Mediterranean for thousands of years and utilized the ecosystem services of riparian areas, leading to their degradation (Table 1) (Zaimes and Emmanouloudis, 2012; Geijzendorffer *et al.,* 2019). The region has limited water resources and a strong population growth (United Nations, 2013). The agricultural areas and human activities of the region has expanded and increased from 2000 to 2015 (FAO and Plan Bleu, 2018). Agriculture is the number one user of freshwater in the region but there is a transition from non-irrigated to permanently irrigated crop lands (Malek *et al.,* 2018). Urban population continues to grow that should impact riparian areas, since many cities and towns are along streams, rivers or deltas (García-Nieto *et al.,* 2018). Furthermore, the increase in seasonal tourism in most Mediterranean countries, multiplies the population in coastal regions during summer (Gober, 2010; Collet *et al.,* 2014). Overall, human activities will further exacerbate pressure on water resources and riparian areas in the next decades (Ferreira *et al.,* 2019).

This land use intensification by agriculture and urban expansions has eliminated and/or simplified riparian ecosystems richness, structural diversity and quality (Corbacho *et al.,* 2003; Bruno *et al.,* 2014b). This intensification has led to their fragmentation in the lowlands of the Mediterranean, compared to the mountainous areas (substantially less agricultural activities) with negative effects on their ecosystem services (Zaimes *et al.,* 2011a). Mediterranean streams and rivers, due to strong seasonal and annual variability of the flow regimes, have been heavily regulated (Garófano-Gomez *et al.,* 2011; Grantham *et al.,* 2013). More than 3500 dams have been built during the 20th century (Lobera *et al.,* 2016). Dams and flood protection infrastructures lead to a more constant flow regime that alters the natural hydrologic regime, sediment transport capacity and dynamics, water chemistry, thermal regime and connectivity (Nilsson *et al.,* 2005; Bernal *et al.,* 2013; Bonada and Resh, 2013; Garófano-Gomez *et al.,* 2011) and disrupt the structure and composition of plant communities (Dufour *et al.,* 2007, Papastergiadou *et al.,* 2016; Bombino *et al.,* 2019; Zaimes *et al.,* 2019b). These changes cause ecological degradation, damaging the availability and quality of the habitat leading to a decrease in both species' richness and health of aquatic and riparian biota (Vericat and Batalla, 2006; Gendaszek *et al.,* 2012; Lobera *et al.,*

Table 1: The main pressures that riparian areas of the Mediterranean face, the knowledge gaps and recommended measures for their more sustainable management

Pressures	Knowledge Gaps	Recommendations
Long history of human disturbances	Shifts in riparian structure after human impacts	Protect and conserve natural riparian areas
Limited freshwater resources	Cause-effect of human activities on riparian communities	Preserve natural streamflow variability
Population increase	Effects of scale, land use heterogeneity, and high temporal hydrological variability on management	Enhance aquifer water recharge
Land cover and vegetation cover changes		Re-establish riparian ecosystems
Agriculture - Cultivation	Human impacts on the surface-groundwater	Restore hydrologic and geomorphologic regimes
Agriculture - Grazing	Riparian community resilience to climate change	Large-scale watershed approaches
Urbanization	Water body and riparian condition, links and functions	Collection of datasets at large spatial and temporal scales
Dam and flood protection infrastructures	Relationships between riparian areas and hydrogeomorphic drivers	Ecosystem-based approaches (nature-based solutions, soil & water bioengineering)
Alteration of hydrologic regimes	Why restoration initiatives have low success rates	Use of ecosystem level tools
Groundwater withdrawal	Information on ecosystems-based approaches	Establish wide, healthy and diverse riparian zones
Water Pollution	Interactions among native & introduced species	Knowledge transfer to stakeholders & decision makers
Invasive Species	Response capacity of riparian areas to multiple stressors	Stakeholder's involvements
Climate Change		Transdisciplinary approach
Tourism		Measure adaptation by stakeholders & decision makers

2016; Bruno *et al.,* 2014b). Groundwater withdrawal or major changes in land cover, primarily for agriculture, can result in reduced subsurface inflow to streams, changes in groundwater dynamics, and degradation of the riparian areas (Benejam *et al.,* 2008; Mencio and Mas-Pla, 2010). The need for water abstraction continues to rise, especially in the Mediterranean islands that are largely dependent on groundwater (Koutroulis *et al.,* 2013). Groundwater depletion leads to low or nil stream flows, especially during summers, but also decrease surface water quality, by decreased dilution of pollutants (Moustadraf *et al.,* 2008; Mencio and Mas-Pla, 2010). The decrease in water quality is also due to intensified agriculture, increased urbanization and loss of riparian areas (Zaimes *et al.,* 2019e). The increase of non-point source pollutants causes eutrophication of freshwater ecosystems (Navarro-Ortega *et al.,* 2015).

Alteration to the hydrologic regime, the increase in pollution and changes in the functionality of streams, rivers and riparian areas have led to the increase and expansion of invasive species (Jiménez-Ruiz and Santín-Montanyá, 2016). Invasive species further degrade riparian habitats (Van den Broeck *et al.,* 2015; Rouissi *et al.,* 2018; Fraixedas *et al.,* 2019). The new environmental conditions in the riparian ecosystems are more tolerable, in some cases, to invasive species. Alteration of the vegetative structure, competitive displacement of native riparian vegetation, reduction of arthropod and avian diversities, abundances and homogenization are some major impacts of invasive species (Bruno *et al.,* 2019; Herrera and Dudley, 2003). Examples of invasive species posing serious threats and problems in the Mediterranean riparian areas are *Robinia pseudoacacia*, *Ailanthus altissima* and *Arundo donax* (Bruno *et al.,* 2019; Nadal-Sala *et al.,* 2019; Constán-Nava, 2015). Overall, the riparian vegetation of the Mediterranean basin has decreased with increasing drought, flow regulation and agricultural activities (cultivation, grazing) (Bruno *et al.,* 2016; Aguiar *et al.,* 2018). This long history of human disturbances (Feio *et al.,* 2014) is the reason why Mediterranean river ecosystems have a highly endangered biodiversity, with 40% of the fish species being endangered (Mediterranean Wetlands Outlook 2, 2018).

Climate change, hydrologic regimes and riparian areas in the Mediterranean: The Mediterranean region is one of the most vulnerable to global change. Projections in the region forecast intensification of the hydrological cycle through increase in temperature, concentration of rainfall in shorter periods of the year, decline in precipitation up to 50% in summer, and increase in drought frequency and strength (Terrado *et al.,* 2014; Rault *et al.,* 2019). In addition, the decrease of the average river discharge and increase in water temperature and frequency of large floods in the region have been forecasted (Calbo, 2010). River discharges are estimated to decrease by 7 to 30 % by the end of 21st century (Lelieveld *et al.,* 2012). In the Mediterranean, negative trends in runoff have been observed in rivers located in Greece (Giakoumakis and Baloutsos, 1997), the Balkans (Genev, 2003; Rivas and Koleva-Lizama, 2005), Lebanon (Shaban, 2009), Turkey (Kahya and Kalayci, 2004) and Spain (Ceballos *et al.,* 2008). Most Mediterranean watersheds have snow-fed mountain springs. Hence, an increase in temperature will result in less snow accumulation and more rapid snow melt. These changes in the headwaters, and the increase in evapotranspiration should lead to higher winter and lower spring discharges and lower summer flows (Van den Broeck *et al.,* 2015). The hydrologic models based on different climate change scenarios predict intensification of low or no flow periods in many countries of the Mediterranean such as France (Lespinas *et al.,* 2014), Italy (Piras *et al.,* 2015), Spain (Majone *et al.,* 2012), Portugal (Mourato *et al.,* 2015), Morocco and Tunisia (Tramblay *et al.,* 2016; Marchane *et al.,* 2017), Israel, Syria and Lebanon (Smiatek *et al.,* 2014). A common scenario is, headwaters becoming intermittent or even ephemeral, while lowland aquifers are depleted and/or polluted (Choukr-Allah *et al.,* 2017). With climate change impacts on hydrology and increasing water demand due to growing population, the shift from perennial streams to intermittent and intermittent to ephemeral is likely to increase (Iglesias *et al.,* 2012). The increased pressure on shrinking water resources will compound the impacts on river and adjacent riparian ecosystems (Navarro-Ortega *et al.,* 2015). The variety of riparian plant communities found in natural floodplains is mainly controlled by the flow regime and fluvio-geomorphologic events (Belmar *et al.,* 2013; Leo *et al.,* 2019; Zaimes *et al.,* 2019b). This interaction between flow-biota is astounding in the Mediterranean rivers due to their increased biological diversity and highly variable flow regimes (Zaimes *et al.,* 2010; Garófano-Gomez *et al.,* 2013).

Many native riparian species have developed life cycles adapted to seasonal peak flows. The loss of seasonal flows may hinder the regeneration of these communities, reducing growth rates or favoring invasive species. Lateral connectivity of the riparian areas is also altered by reducing the frequency, magnitude and duration of floods (Charlton, 2008), causing loss of native riparian vegetation (Garófano-Gomez *et al.,* 2011; Zaimes *et al.,* 2019b). Severe droughts (longer, unpredictable, a seasonal or supra-seasonal droughts) due to climate change, will stress and deplete both native fauna and flora (Bond *et al.,* 2008; Mencio and Mas-Pla, 2010). Overall, more riparian areas, typically adjacent to intermittent and ephemeral streams, are expected to be prevalent with the significant reduction of riparian areas with characteristics of those adjacent to perennial streams.

Recommended measures for Mediterranean riparian areas: Maintaining or re-establishing riparian ecosystems is essential in the Mediterranean because most have experienced intensive land-use changes and other human disturbances for thousands of years (Table 1) (Corbacho *et al.,* 2003; Zaimes *et al.,* 2010). The growing human demands for water, are increasing the frequency and severity of water scarcity, leading to insufficient water supplies to support human and ecosystem needs (Bond *et al.,* 2019). Few studies have focused on shifts in the structure of riparian communities after human-induced hydrogeomorphic changes in the Mediterranean (Table 1) (Aguiar *et al.,* 2001; Salinas and Casas, 2007). The cause-effect of human activities on riparian communities needs to be determined while incorporating the effects of scale, land use heterogeneity, and high temporal hydrological variability on management and restoration practices (Cooper *et al.,* 2013). The preservation of natural streamflow variability should be a priority while human impacts on the surface water-groundwater relationship should also be better understood in the Mediterranean (Mencio and Mas-Pla, 2010; Cid *et al.,* 2017). Aquifer water storage and base flow generation alterations have significant effects on stream and riparian habitats. The importance of restoring riparian areas in the region is recognized, because numerous riparian areas have been designated as protected by the Habitat Directive (92/43/EEC) and the Ramsar Convention (Zaimes *et al.,* 2010; Ferreira *et al.,* 2019). The Water Framework Directive (WFD; 2000/60/EC), obligates European Union (EU) countries to assess the features of their riparian areas (Van den Broeck *et al.,* 2015; Magdaleno and Martinez, 2014). Despite these initiatives, many riparian areas continue to be threatened by human activities that reduce their area and deteriorate their quality. Most restoration initiatives have low success rates in re-establishing the same richness and stability found in natural riparian areas.

Successful management measures need to follow a large-scale hydrological approach to determine the origin of habitat variations and human pressures (Mencio and Mas-Pla, 2010). Conservation and restoration efforts carried out at local scale need to take into account land use, hydrologic and geomorphologic characteristics at the watershed scale (Bruno *et al.,* 2014a, b). In addition, the ecological restoration actions are hindered due to water scarcity in the Mediterranean (Cortina *et al.,* 2011; Vallejo *et al.,* 2012). More ecosystem-based approaches are being implemented in the region (Nunes *et al.,* 2016) such as nature-based solutions and soil and water bioengineering. Nature-based solutions can maintain riparian biodiversity and provide critical ecosystem services (Balzan *et al.,* 2019). To implement these approaches, information on the accumulated experiences of such efforts throughout the Mediterranean should be collected and analyzed (Zaimes *et al.,* 2019d).

Sustainable management plans need to incorporate the relationships between the structure of riparian woodlands and their hydrogeomorphic drivers (Cid *et al.,* 2017). Databases, at large spatial and temporal scales, are key to understand the variability of hydrology and ecology of riparian ecosystems (Hannah *et al.,* 2011). However, such databases are scarce in the Mediterranean, despite efforts to develop data networks. The extreme contrasts in climate, topography, geology, population distribution and water use, especially in river regulated water bodies, in the Mediterranean lead to diverse physical and human characteristics at the watershed scale (Collet *et al.,* 2014). Long-term data sets are also important to understand the interactions among native species and introduced species, especially for extreme events such as drought and floods (Magalhães *et al.,* 2007). Such studies, particularly in regulated systems, help guide flow recommendations to benefit native species (Kiernan *et al.,* 2012; Resh *et al.,* 2013). Measures should be taken to recover the hydrogeomorphic regimes to achieve self-sustainability of riparian ecosystems (González *et al.,* 2010). The water body and riparian condition, links and functions need to be further investigated, taking into consideration the impacts of water and riparian management for ecosystem services (Acreman *et al.,* 2014). Tools at the ecosystem level, connecting ecosystem condition to services, are required especially in climate change scenarios. In most cases, a wide, healthy and diverse riparian zone acts as a buffer for water bodies, minimizing intensive agriculture and other anthropogenic activities effects (Zaimes *et al.,* 2011b; Iakovoglou *et al.,* 2013). Finally, the success of restoring policies depend on riparian ecosystem and climate change information transferred and adopted by the stakeholders and decision makers (Betzold, 2015; La Jeunesse *et al.,* 2015).

The projected water scarcity and riparian areas degradation in the region highlight the importance to implement innovative water and habitat practices (Hejazi *et al.,* 2014) and strategic resources planning from global to regional and local scales (Koutroulis *et al.,* 2013). Stakeholders, the beneficiaries of ecosystem services, play a key role in interpreting climate change impacts on riparian areas. A methodology based on a transdisciplinary approach with the involvement of academics, policy makers, and local experts is suggested. Many physical models on climate change impacts on water scarcity exist, however, transdisciplinary approaches with local stakeholders' involvement are limited (Rault *et al.,* 2019). Improving the understanding of capacity of ecosystem responses to multiple stressors and defining measures to improve the ecological status of riparian areas are needed (Mencio and Mas-Pla 2010). This transdisciplinary approach will lead to greater acceptance of suggested policies and practices by the stakeholders and a higher rate of successfully restoring the riparian ecosystems and adjacent water bodies.

The pressure on riparian areas of the Mediterranean region in the future, will only continue to grow. It is imperative that actions and measures should be taken to ensure their ecosystem services for future generations. Riparian areas are resilient and with proper measures can be maintained and restored. Implementation of watershed, ecosystem-based and transdisciplinary approaches are few measures that should be promoted for the enhanced conservation and protection of these ecosystems. Finally, the key is the involvement of stakeholders and decision makers for the faster and more wide acceptance and implementation of these approaches.

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