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REVIEW ARTICLE

Can a golf course support biodiversity and ecosystem services? The landscape context matter

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Abstract
Context In the last 30 years, the number of golf courses has increased dramatically worldwide. Since no other sport occupies and manages such large areas of green space, landscape context is crucial for determining their impacts or benefits.
Objectives (1) Examine how they affect the main landscape socio-environmental landscape components; (2) analyze the knowledge network structure characterizing the research focused on golf courses; (3) discuss the most common best management practices to mitigate their environmental impacts; and (4) suggest new research perspectives.
Methods This paper has reviewed 239 papers from academic library databases through a literature review and co-word network analysis.
Results Golf courses have impacted negatively on water and soil components, while positively on biodiversity, ecosystem services, and tourism, mainly in urban contexts. The best management practices have focused on soil, biodiversity and ecosystem services, water quality and quantity, and have given specific indications for amphibians, birds, turtles, and bee species. Few articles have considered the landscape perspective, despite the potential impact on natural or semi-natural landscapes.
Conclusions New clusters of research and management issues, in order to link biodiversity conservation with landscape perspective, have emerged: the need to increase (1) studies focused on the effects of golf courses on the ecological processes behind the functioning of the landscape, taking into account its composition and spatial configuration; (2) the proportion of native vegetation in the landscape composition, and density and complexity of vegetation in the landscape configuration.

Keywords Ecosystem services · Biodiversity conservation · Golf courses · Co-word network analysis

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Introduction

At the end of 2016, 33,161 golf facilities were present in 208 countries, with most of them (74%) located in the top ten golfing countries (including Australia, Canada, England, Japan, and the United States) (R&A 2017). In the last 30 years, the number of golf courses has increased dramatically worldwide, not only in countries environmentally suitable for their establishment and maintenance (England, Germany, France, Scotland, and Sweden), but also in Spain, Italy, and Greece, where the climate and environmental conditions are not favorable for their maintenance. Moreover, the inclusion of golf in the Rio Olympics Games in 2016 suggests that the number of golf courses will continue to increase.

The research efforts about the possible environmental implications of golf courses are still open (Briassoulis 2007; Colding and Folke 2009; Jarrett and Shackleton 2017), as no other sport occupies and manages such large areas of green space in the landscape. The majority of golf course research has historically shown intense debates worldwide between who is focused on their significant adverse environmental, economic and sociocultural consequences (Warnken et al. 2001; Davis and Morais 2004; Palmer 2004), and who considers them as a favorable measure for supporting biodiversity in urban context, providing suitable approaches to conservation and urban and peri-urban management (Colding and Folke 2009; Larson and Perrings 2013; Andersson et al. 2014; Jim and Chen 2016; Ortuño et al. 2016). Golf courses are often known as "green infrastructures" in an urban context and can play an important role in enhancing landscape connectivity for biodiversity (LaPoint et al. 2015; Deslauriers et al. 2018). Despite the crucial role of golf courses in providing landscape services, like connectivity among natural and naturalized patches, a concept that links landscape pattern, ecosystem services, aesthetics, values, and decision- making through a "structure function-value chain" (Wu 2013), there is a gap of knowledge in scientific literature that does not apply landscape approach to golf courses.

In order to better underline the strength and weakness of golfing research in the landscape context, the present literature review aims to: (1) examine how they impact or benefit the main landscape socio-environmental components; (2) analyze the knowledge network structure characterizing the international research that is focused on golf courses; (3) list and discuss the most common best management practices that can mitigate their environmental impacts; and (4) suggest new research perspectives.

Materials and methods

We conducted a comprehensive literature survey by screening all articles retrieved from academic libraries databases (Scopus, ScienceDirect, and Google Scholar), at the title, abstract, and keywords level by searching for the terms "golf course", "golf courses", and combining them with "impacts", "benefits", and "management". Only papers published in English scientific peer-reviewed journals were included.

The application of established guidelines for systematic review (Pullin and Stewart 2006) has determined the relevance of papers, with the exclusion of articles only listing golf courses under possible applications or with subject areas not related to the scope of the review (e.g. the effects of golf on human health). To measure the accuracy and reliability of the screening process, another reviewer analysed the first filter of titles and abstracts on a random subsample of 10% of references (Pullin and Stewart 2006). A Cohen's kappa analysis (Cohen 1960) was used to measure the level of agreement between the reviewers, given that Cohen's kappa is a statistical coefficient that represents the degree of accuracy and reliability in the statistical classification made by the two reviewers.

From each article, the basic variables and the socio-ecological components potentially affected by the presence of golf courses in terms of impact and benefit have been collected (Table 1).

To find an overview and possible research gaps for better locating, designing, and managing golf courses, while mitigating their impacts and improving their benefits, a co-word network analysis (CNA) was carried out on the keywords listed in each paper included in the literature review. The main purpose of this was to derive a network structure of knowledge among the concepts most investigated by the scientific literature related to golf course in order to describe in detail where the research activities in this field are focused as well as emerging research interests that must be developed.

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Table 1 The list and description of the variables acquired from each article included in the review

Variable	Description
Author	Name of author(s)
Year	Year of publication
Journal	Name of the peer-reviewed journal
Type of publication	Research article; review
Study Area	Name of the study area
Country	Name of the country of the study area
Golf Course Siting	Urban/peri-urban; agricultural; natural
Socio-environmental components affected by golf courses[a]	Water; soil; land use; landscape; biodiversity/ecosystem services; tourism; people
Type of effect	Positive (benefit); negative (impact)
Management/design suggestions	Management practices and design measures suggested by authors
Key-words	List of key-words

[a]The final list of socio-ecological components affected by golf courses has been elaborated after the analysis of all papers

In general, the co-word analysis (Callon et al. 1983) counts and analyses the co-occurrences of keywords in publications on a given research topic. It is based on the nature of words, which are important carriers of scientific concepts, ideas, and knowledge. Thus, when two or more keywords representing a special research topic appear in the same article, they have an intrinsic conceptual relationship (Ding et al. 2001). The greater the co-occurrence between two keywords, the closer their relationship. According to this "distance", the keywords can be further classified to summarize research focus using various statistical techniques such as factor analysis, cluster analysis, Multi-Dimensional Scaling (MDS) or other multivariate analysis methods (Yang et al. 2012).

CNA was focused on the occurrence frequency and the co-occurrence relationships among key-words listed by the authors in the articles of the review. It has been based on the following steps: (1) extraction of high frequency keywords; (2) data processing by building a high frequency keywords matrix; (3) data analysis by using multivariate analysis methods to find the composition, similarity, and relationship of knowledge; (4) visualization of results by using Social Network Analysis (SNA) to explore the concept network and developmental tendency of scientific research. According to the high-low word frequency boundary formula (Donohue 1973), high-frequency keywords with a cut-off point equal to 7 have been included in the similarity matrix and analysed through the Cosine similarity index.

Specifically, in the Co-Word Network map of this study, the vertices represented high-frequency key-words, and their sizes were proportional to the occurrence frequency. The line width of the linkages represented the strength of the connection between two different key-words. The wider the line, the stronger the linkage between the key-words.

Results of the review and discussion

General results of the review

The review has collected and organized 239 articles representing a large sample of the most relevant literature on this topic. There has been a substantial level of screening consistency (kappa = 0.739, $p < 0.001$) between the reviewers according to Landis and Koch (1977). Results have highlighted that the environmental research interest in golf courses increased significantly between 2000 and 2005 when it peaked. Interest has decreased steadily since then (Fig. 1).

With the exception of 5% of articles where the study area has not been specified, the study areas have been mainly in North America (67%), and Europe (20%). When the golf course name has been defined (35% of papers), the analysis of the landscape context

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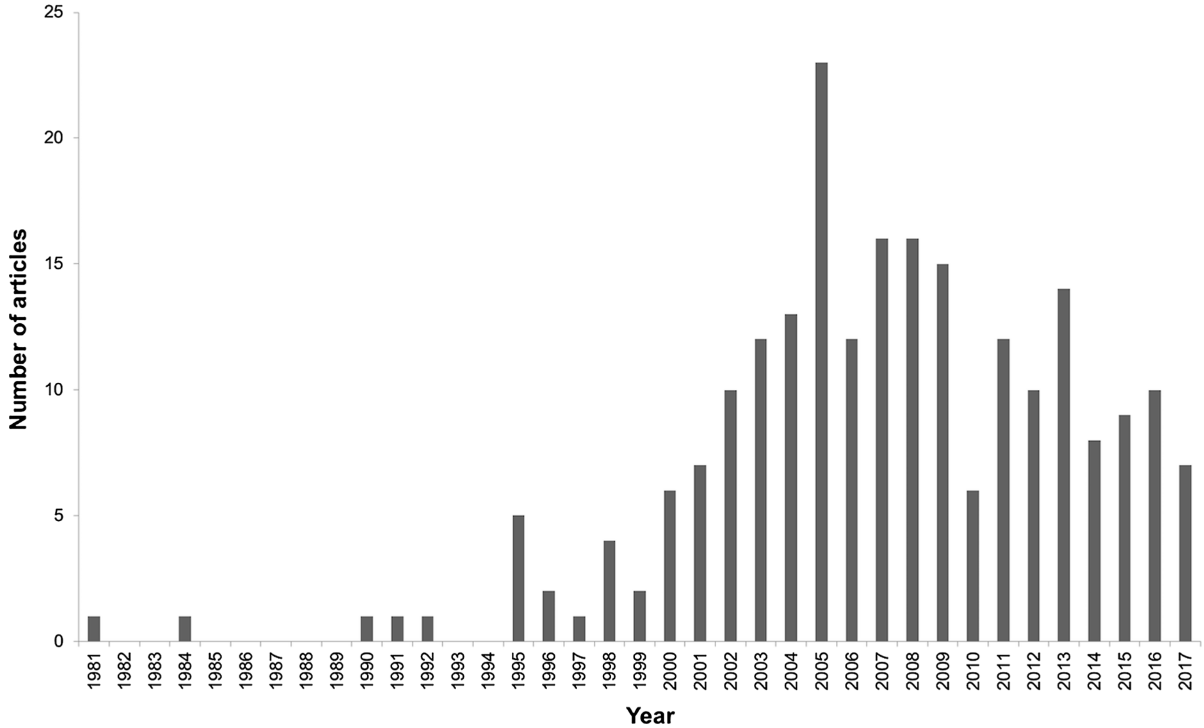

Fig. 1 Number of articles dealing with the topic "golf courses" from 1981 to 2017

has been carried out. In particular, three main landscape contexts have been identified: agricultural/semi-natural landscape context (Fig. 2a), natural landscape context (Fig. 2b), characterized by predominantly native species and natural ecosystems, which have not, are no longer, or have only been slightly influenced by human actions, and urban/peri-urban landscape context (Fig. 2c). The results revealed that golf courses have been mainly located in urban and peri-urban areas (77%) (Fig. 2d).

Finally, the analysis highlighted that golf courses have affected water, soil, land-use, landscape composition and spatial configuration, biodiversity/ecosystem services (ESs), tourism, and people. Water and soil have been the most negatively impacted components (33% and 19.5% of articles respectively), while biodiversity/ESs has been the component that has benefited most from the presence of a golf course (32.6% of articles) (Table 2). Few articles have dealt with the "landscape" component, showing a balance between impacts and benefits associated with the presence of golf courses (Table 2). Tourism has apparently been the only component not to be negatively impacted (10% of articles—Table 2). Finally, the component "people" featured in 14% of the articles reviewed (this component relates to the benefits and impacts people can derive individually by the presence of a golf course).

Golf courses and water

There has been a recognized strong relation between water use and golf courses, which can assume a positive or negative connotation depending on the landscape context (see Online Appendix I—Table a). The Worldwatch Institute has recognized the huge amount of water used for the irrigation of golf courses, estimating about 9,500,000 m^3/year to irrigate the world's golf courses (Chen et al. 2013; Dai et al. 2016; Larson and Perrings 2013; Ortuño et al. 2015; Salgot et al. 2012; Shao-Hua et al. 2012). In semi-arid and Mediterranean areas golf courses can potentially consume up to 10,000 m^3/ha/year of water, the equivalent of the average annual water consumption of approximately 12,000 people (Briassoulis 2007). In addition, golf courses can contaminate surface and groundwater due to the chemical inputs employed to maintain the "green" coverage (Yang et al. 2013).

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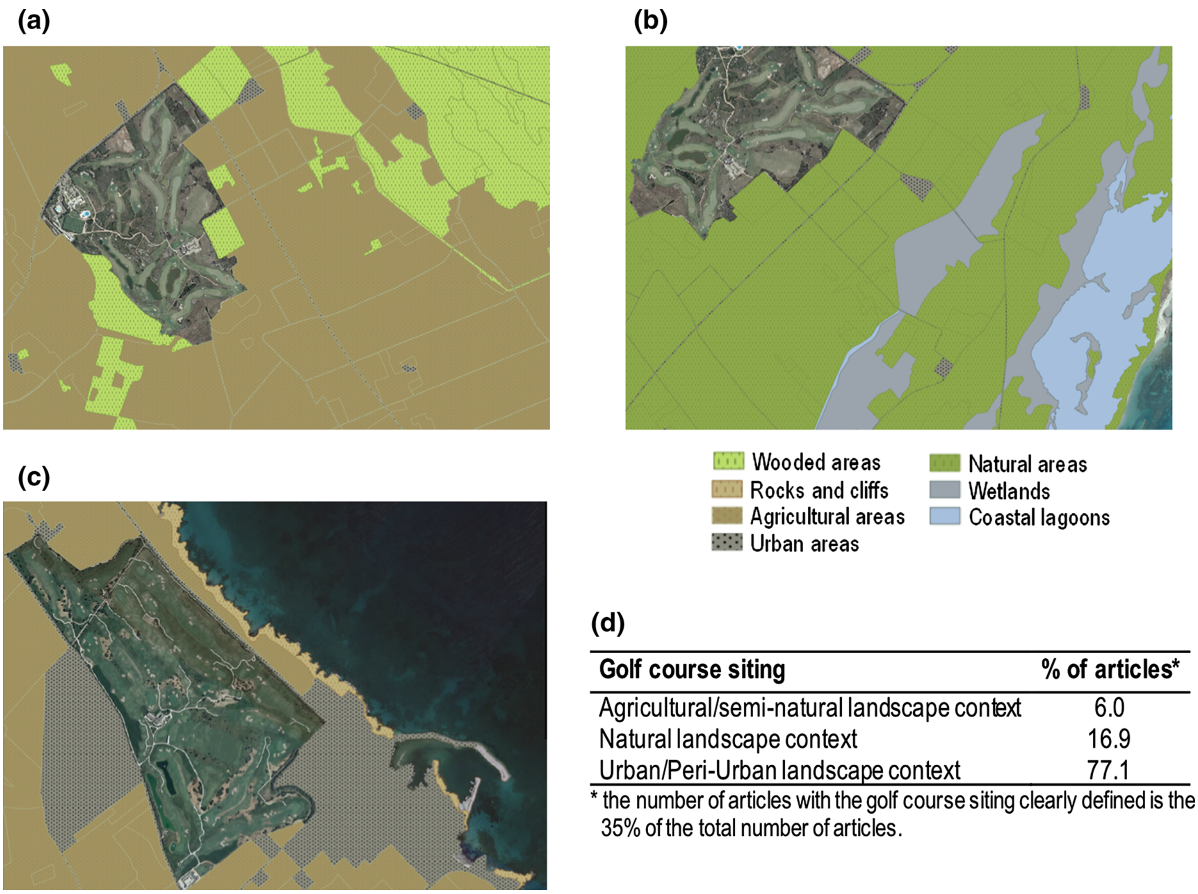

Fig. 2 Examples of landscape context: **a** agricultural/semi-natural, **b** natural and **c** urban/peri-urban. **d** Golf course siting classified according to the three examples of landscape context

Table 2 The % of articles dealing with the socio-environmental benefits and impacts related to the presence of a golf course on the components: water, soil, land-use, landscape, biodiversity/ecosystem services, tourism, and people

Socio-environmental component[a]	Benefits (%)	Impacts (%)	Total (%)
Water	10.0	33.0	43.0
Soil	3.2	19.5	22.7
Land-use	2.3	8.6	10.9
Landscape	3.6	3.6	7.2
Biodiversity/ecosystem services	32.6	14.0	46.6
Tourism	10.0	0.0	10.0
People	7.7	6.3	14.0

[a]The final list of socio-ecological components affected by golf courses has been elaborated after the analysis of all articles

However, Rodriguez Diaz et al. (2007) have suggested that water consumption for golf course irrigation is less important when compared to irrigated agriculture, mainly because in countries like Spain, Portugal, and Australia a significant component of golf course irrigation water derives from wastewater reuse and desalination sources, rather than via direct groundwater depletion (Matos et al. 2014), which is

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beneficial during the severe drought periods (Chen et al. 2013).

Kohler et al. (2004) have underlined that artificial wetlands present in golf courses have the potential to accept, store and filter runoff within the course and from neighboring areas. In particular, a golf course wetland, when well-sized, can exert a positive effect on water quality compared to water entering the golf course or water in the larger watershed.

Golf courses and soil

Soil quality has been the focus of several studies because of the recognized effects of golf courses on its abiotic and biotic components (see Online Appendix I—Table b). From the abiotic viewpoint, the review has highlighted possible changes in the soil structure that can affect its transmitting, exchange and agronomic functions, depending on compaction type. These changes in the soil structure could be due to the movement of heavy-tracked machines during their construction, as well as the use of scrape dozers with direct effects on the compaction of subsoil (Alaoui and Diserens 2011). The parameters used to evaluate the effect of soil compaction were bulk density, BD (Boone 1988; da Silva et al. 1994), penetration resistance, PR (Pagliai 1998) and pore size distribution, PSD (Dirksen 1999). Alaoui and Diserens (2011) showed that, during the construction of a golf course in an area without a strong tendency to aridity or wetness, BD was significantly higher in the wet soil plot compared to the control soil plot (BD = 1.59 g/m^3 at 0.30–0.40 m depth). PR was significantly higher both in the wet and the moderately dry soils compared to the control plots, reaching respectively a value of 1.4 Mpa (at 0.10 and 0.30 m depth) and of 1.2 Mpa (at 0.10 and 0.20 m depth). Finally, the pore size distribution decreased significantly only in the wet soil compared to the control plot, with a significant reduction in mesopores volume equal to 2.6% (from 43.8 to 41.2%) at 0.30–0.40 m depth. However, the most studied impact on soil has been chemical contamination (e.g. Obear et al. 2014; Udeigwe et al. 2015). According to the United States Golf Association (USGA), German and British specifications for golf greens, the green soil profile of a golf course (turfgrass) has a horizon of about 5 to 10 cm over 30 cm sand root zone over gravel, to increase the resistance to compaction and improved drainage (Panina 2010). The irrigation and fertilization of these man-made soils are responsible for the Fe presence (from 0.41 to 16.21 g kg^{-1}) in the formation of cemented layers. These Fe-cemented layers are formed at the interface of the green soil horizon and the sand root zone, or the interface of the sand root zone and the gravel layer at rates as high as 1.5 mm per year and become cemented in 10 years (Obear et al. 2014).

Udeigwe et al. (2015) demonstrated that there are no significant differences in concentration and chemistry of elements between managed (irrigated) and non-managed (non-irrigated) portions of golf greens, but there are strong positive relationships among elements (e.g., Fe on the one hand and Cr, Mn, Ni, and As on the other; Cu and Zn; As and Cr) and between these elements and soil constituents or properties such as clay, calcium carbonate, organic matter, and pH. In their research, these relationships were stronger in the non-managed area, an indication of the alteration of the chemistry of these elements by anthropogenic influences.

The biotic impact, on the other hand, is focused mainly on earthworm and microbial communities (Tu et al. 2011), landscape services and biodiversity conservation. This is because large turfgrass areas with effective management practices seem to be capable of absorbing and fixing carbon and retaining more soil than bare land (Selhorst and Lal 2011; Dai et al. 2016). In particular, Selhorst and Lal (2011) have hypothesized that the conversion of cropland soils to golf courses could enhance the SOC (soil organic carbon) pool. The magnitude of SOC sequestration was high in soils under fairways and rough areas, although, soils under fairways had higher total C accumulation in the top 2.5 cm (most likely due to more intensive management). Fossil fuel intensive maintenance emissions also proved to be a significant factor limiting net turfgrass sequestration potential. Substantial application of fertilizers, irrigation, and the use of both diesel and unleaded gasoline for maintenance activities, could reduce the net SOC sequestration potential. The authors have estimated that a newly constructed course could take 114 years to attain the equilibrium level of the SOC pool. Therefore, to maximize the SOC sequestration potential of golf turfgrass soils, management practices with low C-intensity should be utilized, by enhancing the

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use efficiency of all inputs such as irrigation, fertilizer, and fungicides.

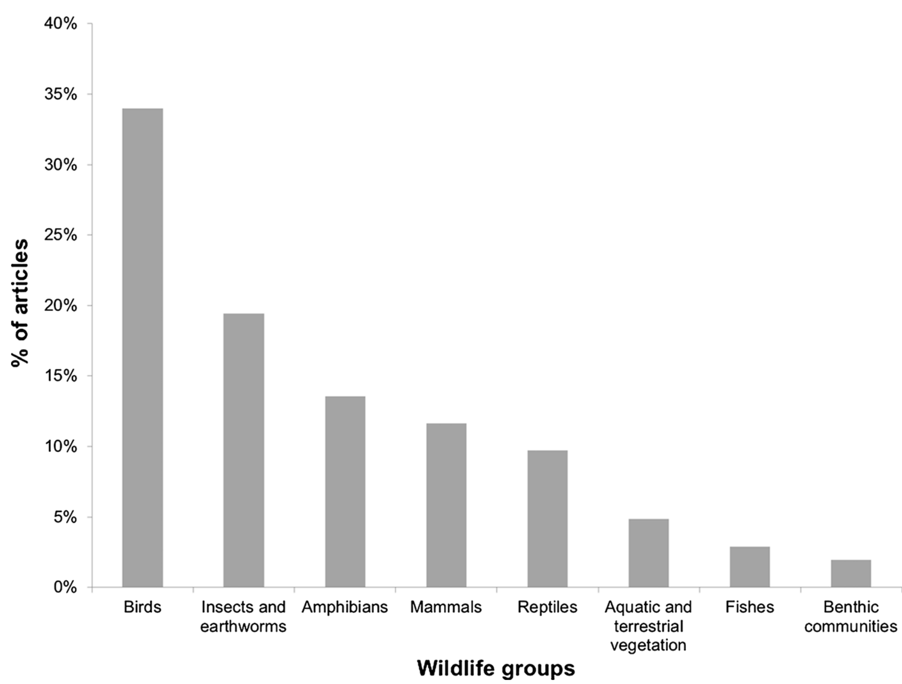
Landscape context of golf courses and their potential role towards biodiversity/ecosystem services' conservation

A focus of the literature review on the most studied interactions between golf courses and wildlife target groups has highlighted that birds are the most studied group (34%), followed by insects and earthworms (19.4%), amphibians (13.6%), mammals (11.7%), reptiles (9.7%), aquatic and terrestrial vegetation (4.9%), fishes (2.9%), and benthic macro-invertebrate communities (1.9%) (Fig. 3, Online Appendix I—Table f).

The results of the review revealed three crucial aspects to be considered when the potential role of golf courses in biodiversity/ecosystem services' conservation is investigated. First of all, the landscape context matters: if a golf course is built in urban or peri-urban areas some environmental benefits can accrue (Colding and Folke 2009; Andersson et al. 2014; Jim and Chen 2016), since new "green" habitats take the place of urban landscapes, with potential positive effects on biodiversity conservation and ecosystem services' provision (i.e., seed dispersal, pest regulation, and pollination) by enhancing the functional connectivity between different habitats, as well as the quality of life of people living nearby (i.e., daily nature encounters, noise reduction, absorption of pollutants in water and air) (Andersson et al. 2014; Saarikivi et al. 2015; Ortuño et al. 2016) (Tables c and e in Online Appendix I). In this perspective, Colding and Folke (2009), by analyzing a total of 101 comparative cases, focused their attention on the ecological role played by golf courses, which was directly proportional to the degree of anthropogenic impacts. Specifically, the ecological value increased progressively when moving from parkland (44%) to agricultural (69%), residential (84%) to highly urban land uses (94%).

The second and the third aspects referred to the earliest habitat replaced by the course and the age of a golf course, as both could contribute to its wildlife value (Dair and Schofield 1990; Gange and Lindsay 2002). As regards to the habitat they replace, in peri-urban and urban landscapes, where land-use intensification has led to the loss of landscape diversity and habitats, green space can represent the last trace of the cultural landscape, characterized in the past by biodiversity-rich habitats (Colding and Folke 2009; Andersson et al. 2014). Furthermore, few studies have focused on the possible benefits of golf courses in natural contexts, probably due to the difficulty in

Fig. 3 The % of articles dealing with the different wildlife target groups in the analyzed literature (details in Online Appendix I—Table f)



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defining a golf course as “natural” in a real natural context. If the presence of a “green” land-use, irrespective of the kind of green, could bring social-ecological advantages in an urban context, in a natural context the “kind of green” really matters. The debate has been ongoing for the past decade (Saarikivi et al. 2015), however the landscape typical of a golf course, often constituted by non-native species (see Online Appendix I—Table d), when viewed through the eyes of an ecologist, could appear as a “green” desert in natural areas, since its presence has reduced the overall biodiversity (species, habitats, and ecological functions) and the relevant provision of ecosystem services.

The age of a golf course can play an important role in enhancing biodiversity because, over time, a greater variety of habitats can characterize it. In this perspective, Tanner and Gange (2005) carried out a study to determine whether the abundance and species richness of certain animal taxa differed between old and young golf courses and whether they harboured different levels of biodiversity than the habitats they replaced (farmland). The authors sampled vegetation because the dominance and diversity in plant communities determine the composition and diversity of animal species, birds, ground beetles, and bumblebees. The results showed that the age of the golf course had no effect on diversity for any of the taxa studied, probably due to the mobility of the studied groups. However, for taxa that are less mobile or slow to disperse, course age could well affect their occurrence (Tanner and Gange 2005). On the other hand, golf courses can contain levels of biodiversity equal to or above that of the habitats they replace, probably because the variety of habitats that a golf course provides is potentially greater than that of farmland (Tanner and Gange 2005). As part of urban green systems, a golf course with a non-playable extension percentage of 40–50% could contribute to the support of biodiversity and the promotion of critical ecosystem services provided by urban landscapes (e.g. Colding and Folke 2009; Andersson et al. 2014; Fung and Jim 2017; Threlfall et al. 2017). In this sense, golf courses could contribute to City Biodiversity Index (Chan et al. 2014), and improve the quality of life of citizens as part of urban green infrastructures according to the recent EU Biodiversity Strategy to 2020, aiming to enhance biodiversity and ecosystem services.

More recently, Dobbs and Potter (2016) have highlighted that naturalized roughs can have conservation value by helping to preserve relict landscape types and associated plants, as habitat for urban wildlife (Tanner and Gange 2005; Colding and Folke 2009), and by supporting urban pollinators (Dobbs and Potter 2015), while serving as stepping stones between larger natural areas (Gange et al. 2003; Colding and Folke 2009).

Although golf courses are not considered natural land-use, they can contain unmanaged patches of natural vegetation that can be a way to preserve biodiversity in an urban context. Hodgkison et al. (2007) investigated the extent to which regionally threatened birds, reptiles, mammals and amphibians utilized habitats on suburban eucalypt-based golf courses in Australia. The results indicated that some of these golf courses could provide a refuge for a range of threatened wildlife and therefore had conservation potential. However they mostly only supported common urban-adapted species and therefore failed to realize that potential. In particular, it transpired that golf courses were a better refuge for threatened birds and mammals than for threatened reptiles and amphibians, probably because animals are known to respond to different landscape elements, depending on their morphology, home range and behaviour (Wiens 1989; Kotliar and Wiens 1990). The limited mobility of many amphibians and reptiles (Ficetola and DeBernardi 2004), as well as their susceptibility to the isolating effects of habitat fragmentation (Marsh and Pearman 1997), could inhibit their capacity to persist in isolated suburban golf courses. On the other hand, large, ground-based mammals could have a greater capacity for short-term persistence, given their relative longevity.

In Japan, a study to assess the value of golf courses for conserving forest biota in urban landscapes suggested that out of bounds forest and green belts between holes contained a greater variety of biota, suggesting that they provide habitat which is more similar to biota than turf grass areas (Yasuda and Koike 2006). In particular, the mixture of forest and turf communities in golf courses appeared to enrich the overall biota of the whole golf course, representing a refuge for flora and fauna. On the basis of these results, the authors underlined that further studies on the most suitable proportion of habitat for diverse biota were needed. In this context, the best

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combination of habitat suitable for grassland and woodland bird species was provided by a combination of 20% shrub cover and 60% grass cover (Mankin 2000).

In general, the management strategies, the presence of local threats, as well as landscape connectivity could affect the potential conservation value of a golf course (Hodgkison et al. 2007). Several articles have dealt with the potential negative effects of golf courses on wildlife species due to pesticide exposure (Knopper et al. 2005) or when they were compared with or proposed in the place of natural areas (e.g., LeClerc and Cristol 2005; Fox and Hockey 2007; Saarikivi et al. 2015). In this perspective, Hammond and Hudson (2007) have surveyed golf course managers to investigate their attitudes towards biodiversity conservation. Their study highlighted evident conflicts between management for wildlife and management for golf course maintenance, even if it demonstrated that the majority of course managers recognize the value of golf courses as a wildlife resource support. Chen et al. (2011) suggested in their study that a new golf course should be built in marginal lands (buffer zones of industrial parks, airports, polluted lands after remediation, abandoned lands, and so on). The use of marginal lands can produce some ecological benefits since, notably, such areas initially lack real plant cover. In Taiwan, for instance, developers of golf courses in marginal lands had to construct facilities using only 5% or less of the total available land area, leaving 95% of the land area covered by grass, trees, or ponds (Chen et al. 2011), enhancing the ecological role played by the marginal lands in question.

Golf courses, people, and tourism

"People" and "Tourism" represented the last analyzed socio-ecological components, being the focus of 14% of the articles in this review (Table 2) (excluding those dealing with the health benefits/impacts usually associated with the sport of golf).

The potential impacts of golf courses on people have been (see Online Appendix I—Table g): environmental contamination due to the presence of a golf course (O'Neill et al. 2014), the lifestyle impact, predominantly when golf courses are situated in socially sensitive areas, and when golf courses affect environmental components to which people attribute a value (Salgot et al. 2012).

On the other hand, the potential benefits provided by the presence of golf courses can be attributed to the environmental improvements they can generate in urban contexts, with positive effects on quality of life (Larson and Perrings 2013; Andersson et al. 2014), and property prices (Ortuño et al. 2016; Domínguez-Gómez and González-Gómez 2017).

Co-word network analysis

The co-word network map (Fig. 4) has shown the conceptual linkages among the key-words in the studied period (1981–2017). Broadly, three conceptual clusters could be identified as representing the main research issues related to golf courses (Fig. 4): (a) chemical contamination, (b) bird conservation supported by golf courses, and (c) biodiversity/ecosystem services conservation.

Golf courses represent intensively managed ecosystems with high levels of fertilization, pesticide application, and irrigation (Schlossberg and Schmidt 2007), where the main concern is surface and ground-water pollution via N leaching (Liu et al. 2011). The problem of water and soil chemical contamination, which represented the key-word mainly related to golf courses, depends on turfgrass management, in terms of the use of fertilizers and pesticides, and it can be increased by excessive irrigation choices. Unlike crop water requirements, irrigation on recreational sites or sporting areas is necessary to provide the desired function and aesthetics, because, as pointed by Carrow et al. (2010), yield is not the goal in turfgrass management, rather the goals are uniform density, color, and high quality green coverage. In addition, the presence of golf course wetlands has the potential to support rare species of amphibians (Fig. 4a) that have lost natural wetland habitat elsewhere (Boone et al. 2008; Colding et al. 2009). However, when species are attracted to areas that are not suitable for the maintenance of populations, the wetlands can act as population sinks (Howard et al. 2002). Accordingly, the co-word network map has highlighted that amphibians are the wildlife group most affected by chemical contamination (Fig. 4a). Their dependence on water leaves them vulnerable to both soil and water contamination (Berrill et al. 1993), because the application of pesticides is most intense during spring and summer, when the crucial stages of larval development occurr (Materna et al. 1995). However,

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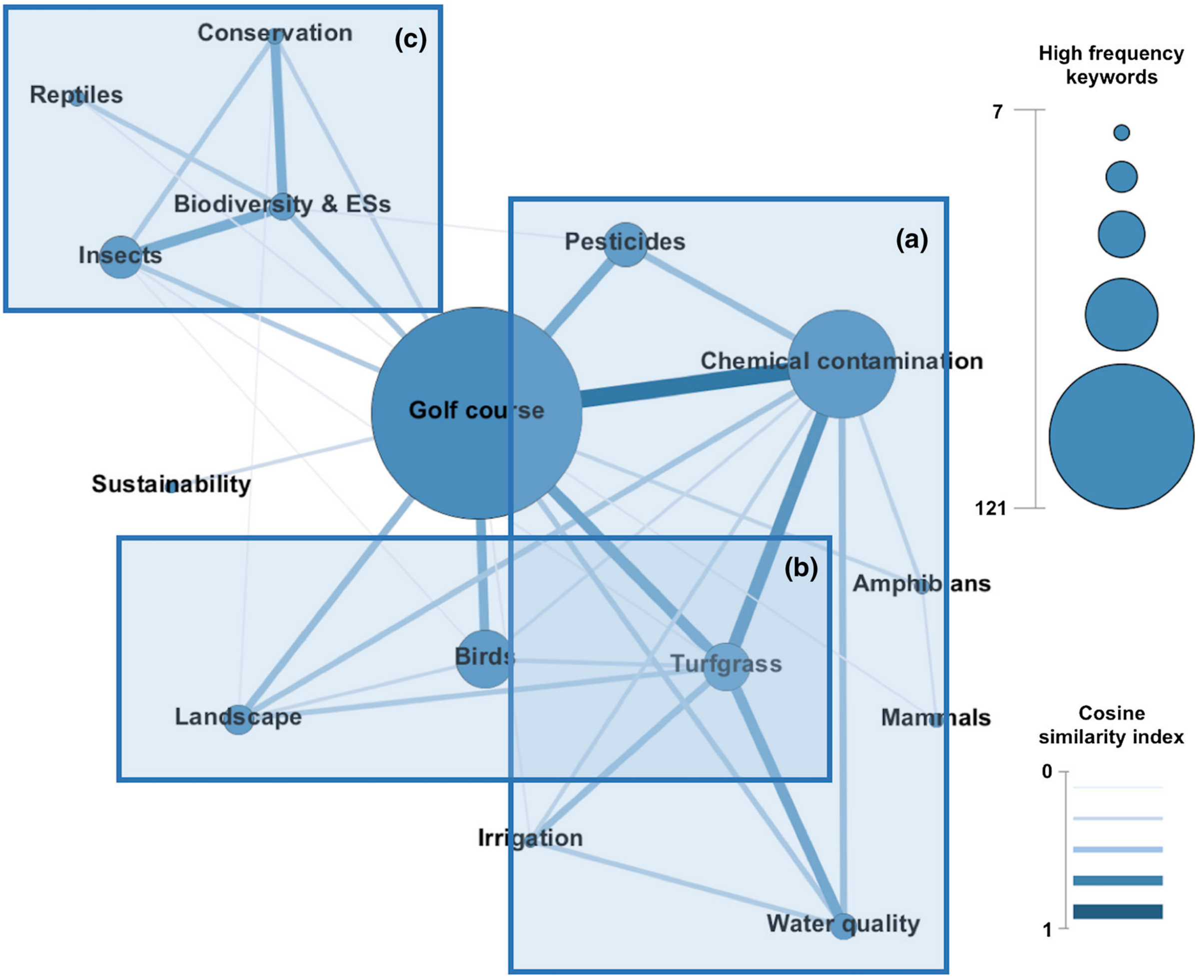

Fig. 4 Co-word Network map with cluster for **a** chemical contamination, **b** bird conservation supported by golf courses, and **c** biodiversity/ecosystem services conservation

best management practices, such as controls on the rate and the timing of fertilization and irrigation, can reduce leaching to minimal levels (Rice et al. 2017).

The same consideration has been possible for birds, another relevant wildlife target group, which has been linked both to landscape conservation (in terms of land-use and land-cover diversity) and sustainable turfgrass management (Fig. 4b). Increased degrees of landscape alteration can affect bird communities, since they use the landscape by taking into account habitat patch configuration elements such as area, shape, edge, and diversity (Jones et al. 2005). However, when an area becomes more urbanized some species are favored while others are not (Marzluff et al. 2001). In research carried out by Jones et al. (2005) in the state of South Carolina, 24 golf-course landscape units (GCLU) were analyzed in terms of landscape alteration to investigate its effect on avian species richness, distribution of breeding habitat groups, and relationships between landscape structure metrics and the breeding bird communities. The authors demonstrated that species richness was higher in less altered landscapes. The majority of birds associated with less-developed landscapes were woodland-breeding species, while urban-breeding species were found primarily in the more-altered landscapes. These results have been confirmed also by research carried out in Montreal where urban-breeding species were more common on golf courses than green spaces (Hudson and Bird 2009). Finally, a positive relationship between species richness and forestation has been highlighted (Jones et al. 2005) and

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demonstrated also by other research projects (Whited et al. 2000; Brotons and Herrando 2001; Hudson and Bird 2009).

In order to support a broader range of biodiversity, turfgrass should be managed as an urban green space that guarantees the maintenance of a greater diversity of habitat elements (Threlfall et al. 2016). In this context, the co-word network map has underlined an emerging cluster of research and management issues regarding the role of golf courses in biodiversity and ecosystem services conservation, where insects and reptiles were the most analyzed wildlife target groups (Fig. 4c). Golf courses, when part of a network of urban green spaces, can have a beneficial role in restoring and enhancing local biodiversity (Terman 2000; Colding and Folke 2009; Mackey et al. 2014), because they provide refuge for other species (Colding and Folke 2009), and support biodiversity connectivity by providing ecological corridors (Jim and Chen 2016). More specifically, they can supply critical resources for wild bees (Threlfall et al. 2015) and for semi-aquatic and wetland-dependent species (Harden et al. 2009). However, it is possible for golf courses to contribute to biodiversity conservation even in cases of agricultural intensification, where wildlife survival could be under increasing threat (Green and Marshall 1987).

In general, the co-word network map is in accordance with the results of the literature review; however, it has provided additional information as it represents a picture of the knowledge network structure characterizing the international research on golf courses, focusing only on key-words listed by the authors. However, the choice to include only key-words in the present analysis reduced the number of topics and did not allow for investigation into the type of connections (positive or negative) that existed among the key-words (Harden et al. 2009; Tu et al. 2011; Guzy et al. 2013). The two analyses can be considered complementary, since the results of the review support the comprehension of the co-word network map and the co-word network analysis has provided graphical results which are capable of aggregating and highlighting conceptual research issues and gaps useful to identify future research perspectives.

Selecting the location of golf courses

Choosing a location for a golf course is one of the most important decisions that can be made in landscape design and planning (Terman 1997). Given the problem of climate change and the scarcity of natural resources like water in drylands, there are several grounds on which golf course development can be opposed. Such opposition first developed in the United States in the late 1970s due to growing awareness of the adverse environmental and health impacts of golf course development (Briassoulis 2007, 2010).

The present review has underlined how some locations, like drylands and natural areas, are unsuitable for the settlement of golf courses, despite the fact that they can represent a tourist development opportunity. In particular, urban golf courses usually contribute to the quality of life of citizens (Maas et al. 2009), by providing great socio-economic development potential. For example, they can benefit local communities by improving the supply of recreational services, increasing regional property values, adding or expanding a specific economic activity (e.g., healthy tourism) and increasing high-income job opportunities (Peter 2007). Research carried out by Dai et al. (2016) revealed that, of the most important ecosystem services of golf courses, the recreational service accounted for more than 95% of the total economic benefit deriving from them. Further, if golf facilities are appropriately naturalized, the economic benefits can be combined with habitat preservation and nature conservation (Terman 1997).

The construction of golf courses in urban and peri-urban contexts is preferable for two reasons: (1) they, as large urban green spaces, can represent green infrastructures, and (2) they, when strategically planned and connected in a network of natural and semi-natural areas, can support a wide range of ecosystem services. However, the ecological role played by urban green areas in providing "rural" ES, like pollination and food production (Hall et al. 2016) has not been properly taken into account by urban planners (Gren and Andersson 2018). The identification of the most suitable location for the construction of a golf course should take into account all the socio-economic-ecological benefits and impacts (costs). This should guarantee a more realistic picture of the site in terms of socio-economic-ecological landscape functions and processes. Hence, incorporating ES into

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urban green planning could potentially contribute to mitigating the negative effects of urban expansion and possibly provide opportunities for strengthening the production capacity of the urban agricultural landscape.

Best management practices and recommendations

The analysis of the literature has allowed the collection of the best management practices for some of the component that interact most with golf courses (Table 3). In this table, the list of the best management practices is associated to the list of the most recent references, which are focused on impact mitigation and benefit enhancement in relation to the main socio-ecological components.

Of the many ecological initiatives focused on golf course management, it is possible to list the most commonly suggested:

– the application of an effective environmental management system according to the international standard ISO 14001 or the European Directive 2009/1221 EMAS (Salgot et al. 2012);
– the construction and management of "organic" golf courses;
– the development of competitions based on the application of best practices in environmental management by clubs;
– the inclusion of golf courses in the cultural landscape (Ole et al. 2015).

Table 3 The list of best management practices (BMP) focused on the mitigation of some impacts or the support of some benefits

Impact/benefit on	Best management practices	The most recent reference
Soil compaction	(a) To use a lighter machine	Alaoui and Diserens (2011)
	(b) To use the machine under dry soil conditions	
Soil contamination	(a) To adhere to soil test recommendations	Gan and Wickings (2017)
	(b) To use slow release formulations	
	(c) To program nutrient applications with turf needs	
	(d) To avoid fertilize application if rainfall is expected within 48 h	
	(e) To program irrigation practices with nutrient losses	
	(f) To adopt the use of organic formulations	
Support of biodiversity/ ecosystem services	(a) To integrate golf courses in ecological networks	Colding and Folke (2009)
	(b) To design habitat patches as large as possible	Terman (1997)
	(c) To ensure the suitability of golf course landscape for many species through design and management	Burgin and Wotherspoon (2009)
	(d) To ensure the suitability of golf course landscape for pre-development habitat through design and management	Terman (1997)
	(e) To manage artificial water bodies with surrounding natural water bodies as a mosaic of habitat	Chester and Robson (2013)
	(f) Specific BMPs for amphibians	Mackey et al. (2014)
	(g) Specific BMPs for bee species	Threlfall et al. (2015)
	(h) Specific BMPs for turtles	Winchell and Gibbs (2016)
	(i) Specific BMPs for birds	Threlfall et al. (2016)
Maintenance of water quality and quantity	(a) To reuse wastewater for irrigation	Dai et al. (2016)
	(b) To avoid spring fertilizing, the application of fertilizer to impervious surfaces and when heavy rain is expected	Bachman et al. (2016)
	(c) To educate golfers to lower aesthetic standards	Metcalfe et al. (2008)

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Conclusions and future research perspectives

Among the socio-economic components analyzed in this review, the landscape represents the focal point, because it determines the positive and negative effects on the other components. The landscape impact of golf courses is a widely-debated topic (Sláma et al. 2018). Among others, the most quoted negative impact is the utilisation of agricultural land, given that it is a largely non-renewable and very complex natural resource. Land devoted to food production is increasingly damaged by certain human activities like the intensive management required by golf courses.

From the often-neglected influence of the landscape context on local processes in landscape planning, some conclusions arise based on the results. In terms of future research perspectives:

(1) there is a strong need to increase the number of studies focused on the effects of golf courses on the ecological processes behind the functioning of the landscape, taking into account its composition (the diversity of land-covers) and spatial configuration (spatial pattern of land-covers);
(2) given the recognition that water use represents a critical aspect, it is important to identify possible herbaceous species that can be used as turfgrass in areas characterized by low water availability;
(3) the development of organic golf courses could be a design solution, but more information about non-traditional pest management is crucial;
(4) the assessment of the potential benefits of urban green space for supporting ecosystem services and biodiversity for citizens' well-being should be quantified;
(5) some landscape design and management strategies (Jones et al. 2013), such as increasing both the proportion of native vegetation in the landscape composition, and the density and complexity of vegetation in the landscape configuration, could be applied to golf course design in order to link biodiversity conservation with landscape perspective.

The landscape context matters because it represents the place where everyday local activities are carried out. Therefore, the perception of the local citizenry should be taken into account in landscape management. It is desirable to design sustainable golf courses that form part of the surrounding landscape, making them part of the ecological landscape network.

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