Narrative Review Article

Ecosystem Disruption and Environmental Injustices Caused by Modern Golf Courses

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ABSTRACT

This paper examines how modern golf courses cause ecosystem disruption and environmental injustice. Intensive maintenance renders these landscapes heavy contributors to ecological degradation. Empirically, golf developments trigger severe habitat fragmentation, exemplified by clearing 100 acres (about 40 hectares) of forest at Cobbs Creek. Chemical management poses eco-toxicological threats, with pesticide application averaging seven pounds per acre annually, causing groundwater pesticide concentrations up to 780% above the regulatory limit in a modeled worst-case scenario. Resource exploitation is most acute in arid climates like California's Coachella Valley and Los Cabos, Mexico, where the average U.S. golf course consumes up to 800,000 gallons of water daily and Coachella Valley courses alone account for about 18% of local water supplies. Crucially, a profound pattern of environmental injustice emerges: while affluent populations enjoy exclusive recreation, marginalized communities disproportionately bear the ecological burdens, facing restricted green space access and heightened health risks, including a 126% increase in the odds of developing Parkinson's disease for nearby residents. This narrative review aims to synthesize evidence on the ecological and environmental-justice impacts of modern golf courses and to evaluate policy and management solutions capable of reducing these harms. To mitigate these disparities, this paper evaluates progressive solutions, emphasizing stricter chemical regulations, transparency audits, and eco-centric remodeling such as the 50% water-reduction turf restoration executed at Pinehurst No. 2. Ultimately, it argues for transforming golf courses from resource-intensive symbols of exclusivity into models of sustainable, inclusive land use.

Keywords: Golf Courses; Ecosystem Disruption; Environmental Injustice; Water Overuse; Chemical Contamination

INTRODUCTION

Golf courses, often viewed as venues for leisure and relaxation, are commonly associated with scenic landscapes and social and economic status. However, these manufactured landscapes require constant irrigation particularly in arid regions such as California and Mexico. In Coachella Valley, California, over 120 golf courses collectively account for about 18% of the local water resources, with a single course alone consuming as much as 1 million gallons (about 3.8 million liters) of water per day (1). In Mexico, 13 golf courses along the Los Cabos coast consume 7.09 million cubic meters of water annually (2). This can cause significant issues for neighboring communities regarding water sources and

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its availability. Additionally, combined with the constant irrigation is widespread use of fertilizer and pesticides. Modern golf courses come at a heavy cost of cutting down forests and reshaping natural landscapes, and introducing toxic substances into the remaining nature, threatening wildlife and local water sources.

At the same time, most of these golf courses are also inaccessible to surrounding communities due to its high fees and privatized use of land, raising concerns of environmental injustice. While nearby communities often of lower economic class face limitations to water use and green space, golf courses remain lush with bright and healthy turf (3). This highlights the social disparities where environmental burdens are carried by many, and the benefits are only for the privileged few to experience. Accordingly, this narrative review aims to synthesize evidence across ecological, public health, and environmental-justice literature to characterize the extent of harm caused by modern golf courses and to evaluate the solutions proposed to address it, thereby contributing an integrated framework that connects ecosystem disruption directly to its disproportionate social and health burdens. This paper first investigates the extent to which modern golf courses damage the living environment and ecosystem, which further raise public health concerns and social inequalities. Then, it discusses policy and economic solutions to ecosystem disruption and injustice issues caused by golf courses worldwide.

ECOSYSTEM DISRUPTION BY GOLF COURSES

Golf courses around the world lead to significant ecosystem disruption through land alteration, chemical use, and intensification of climate vulnerability. One notable example is the redevelopment of Cobbs Creek Golf Course in Philadelphia (4). As part of the reinstallation of the golf course, more than 100 acres (about 40 hectares) of century-old forest, including several hundred mature trees, were cut down. These trees were homes to multiple species of native mammals, insects, and birds such as the American Robin and Red-Tailed Hawk. The removal of these trees displaced huge amounts of individual animals, and increased local temperatures by eliminating the natural shade. This also compromised the forest's ability to absorb stormwater, greatly increasing the risk of floods in nearby neighborhoods (5). In replacement of all this ecological value, developers installed monocultural turf grass, which offers minimal ecological value but instead requires heavy amounts of irrigation and chemical maintenance to maintain its pristine appearance. This further contributes to the damage to nearby environments and communities. In a synthesis by Colding and Folke that involved nearly 200 golf courses, golf courses showed higher ecological value than comparison land uses in 64% of cases, with that ecological benefit concentrated on land that had already been degraded by agricultural or urban use rather than on natural or already-protected habitat (6).

Urban expansion is a major driver of vegetation loss and habitat fragmentation. In a satellite-based study by Nguyen et al. (7) in Perth, Australia, as shown in Figure 1, the authors tracked vegetation cover and habitat connectivity across the same urbanizing region using satellite imagery spanning 30 years, and found that broader urban development drove substantial fragmentation of native vegetation overall. Beyond land-surface effects, the intense chemical maintenance of golf courses continues to disrupt ecosystems in more harmful ways. In Slovakia, a hydrogeological modeling study of a golf course near the Rusovce water source found that, under a worst-case combination of high precipitation, flooding, and inadequate bedrock sealing, pesticide concentrations in groundwater could reach 0.880 μg/L—nearly 780% above the European drinking water limit of 0.100 μg/L (8). This demonstrates that under unfavorable site conditions, these chemicals can persist in soil long after application and accumulate to concentrations far exceeding safe limits in groundwater, lakes, and other water bodies. Contamination of streams poses a significant health threat to not only aquatic life but also land animals, vegetation, and ultimately humans who source groundwater for hydration. In the United States, this issue is even worse. The United States uses pesticides up to 15 times the amount allowed by European regulations (9).

In a New York environmental audit, it found that across 52 golf courses in Long Island they used 192 different pesticide products that contain 50 different active ingredients totaling to more than 50,000 pounds (about 22,680 kg). This averages to 7 pounds of pesticides per acre annually (about 7.8 kg/ha), which is more than triple the mere 1.5 pounds of pesticides per acre (about 1.7 kg/ha) used for agricultural land (10). This poses a significant threat towards humans and the environment because many of the pesticides are designed to persist in the places applied to combat weeds and insects more effectively. In addition, as weather and natural systems occur, these pesticides discharge into groundwater,

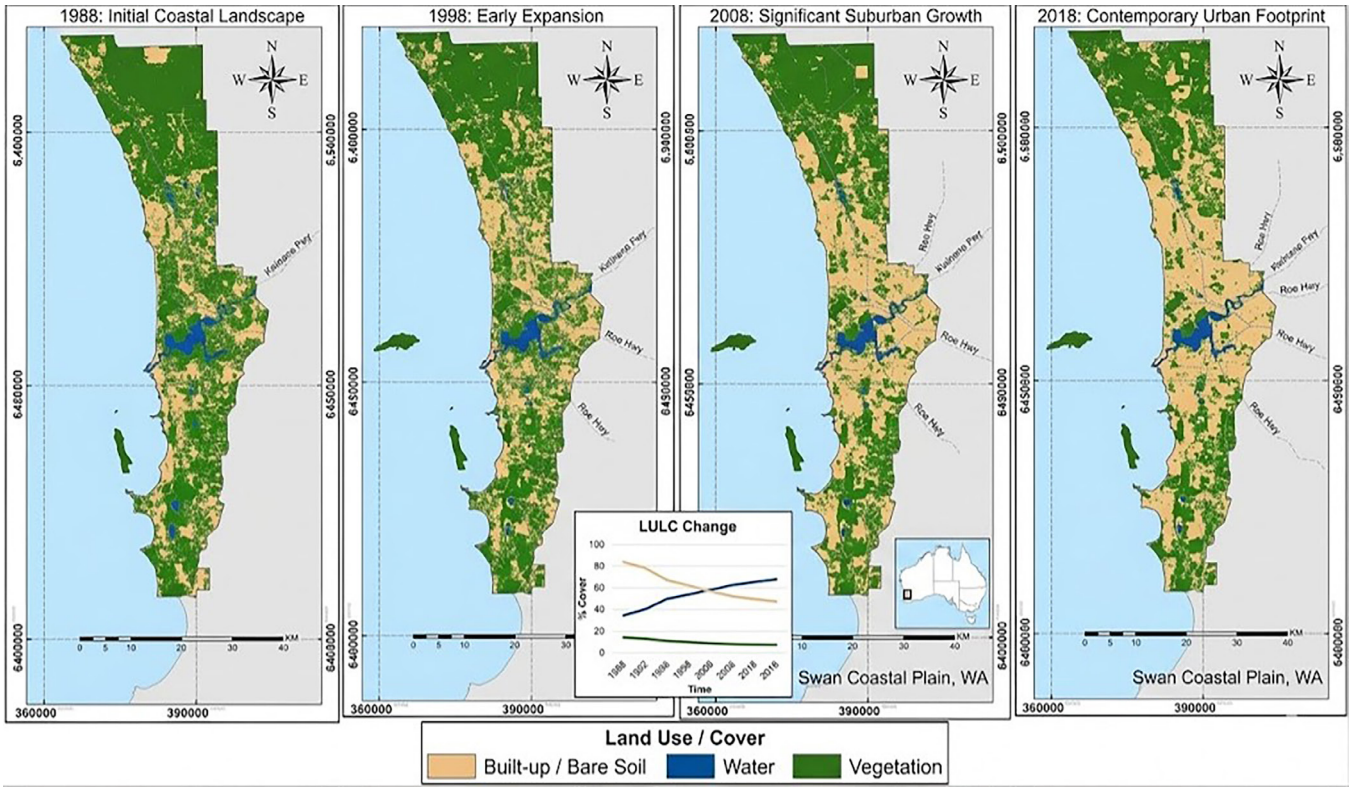

Figure 1. *Map of land cover classification for the Perth, Australia metropolitan region across four time steps between 1988 and 2018, illustrating native vegetation fragmentation driven by broader urbanization, within which golf courses helped maintain vegetation connectivity. Reproduced from Nguyen et al. (2020) (7), licensed under CC BY 4.0.*

nearby lakes, and accumulate in the soil, potentially affecting the surrounding ecosystems for years. This excessive chemical use can also lead to eutrophication when a water body becomes overly enriched with nutrients. In a study of 80 golf courses across the United States, phosphorous levels in water samples were found to exceed toxicity regulations by 86% (11); notably, this same study concluded that golf courses did not show widespread or repeated pesticide-related water-quality impacts overall, with phosphorus singled out as the principal exception, which suggests that nutrient runoff rather than pesticide contamination per se is the more consistent water-quality concern at golf courses. In Cape Cod, Massachusetts for example, researchers have found golf courses to be nitrogen hotspots, causing groundwater pollution, air acidification, and dead zones in lakes (Center for Watershed Protection). This can lead to algae blooms, causing oxygen depletion and fish die-offs, further disrupting the ecosystem.

Combined with chemical applications, constant grass cutting and pressing are part of the routine to maintain the fresh appearance of golf courses. On average, turfgrass maintenance in both Europe and the United States produces between 1.0 to 1.6 metric tonnes of CO_2 per hectare annually, with mowing and fertilizer production as the biggest contributors to greenhouse gas (GHG) emissions (12).

On average, a U.S. golf course requires up to 110,000 gallons of water each day to maintain while the average household requires only 400 gallons a day (13). This drastic difference illustrates the disproportionate share of local water resources that golf courses can consume relative to residential users, as shown in the image below (14).

ENVIRONMENTAL INJUSTICE CAUSED BY GOLF COURSES

Another misleading part of golf courses is their environmental injustice by disproportionately exposing nearby communities to harmful chemicals and unequal access to resources such as water and green space.

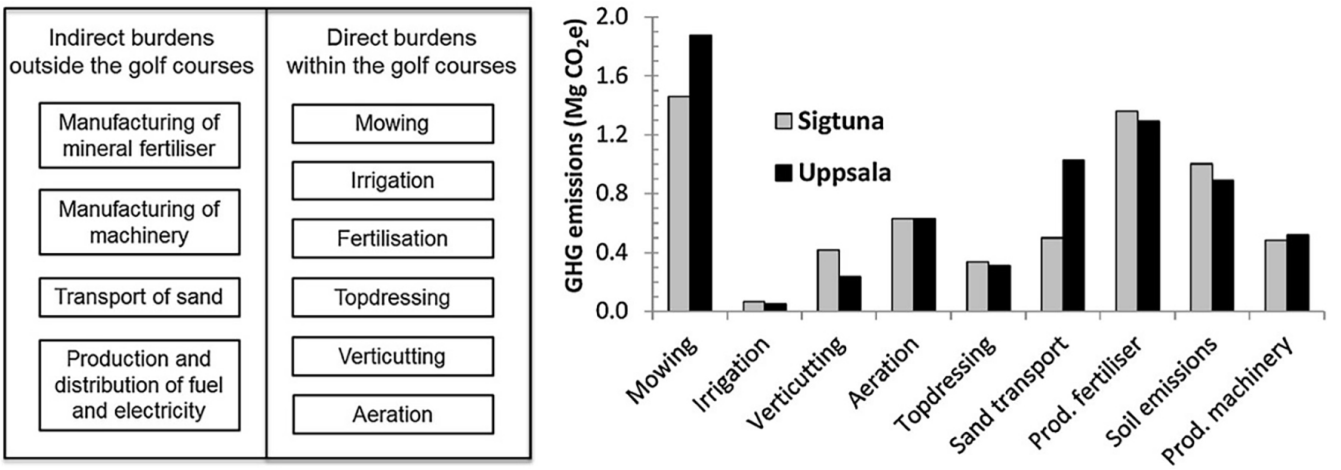

Figure 2. *Energy Use and Greenhouse Gas Emissions from Turf Management of Two Swedish Golf Courses. The left panel shows the indirect (off-course) and direct (on-course) sources contributing to golf course greenhouse gas (GHG) burdens; the right panel shows the resulting GHG emissions broken down by maintenance activity for the two surveyed courses, Sigtuna and Uppsala. Adapted from Tidåker et al. (2017) (12).*

Figure 3. *Comparison of Water Golf Courses, Ski Resorts, and Pools Usage in California. Adapted from Lurie (2015) (14).*

These chemicals have been found to cause cancer and neurological diseases such as Parkinson's disease. When living within 1 mile of a golf course, the odds of developing PD were increased by 126% compared to living 6 miles away from a golf course (15). In addition, people who live in water service areas that have golf courses in vulnerable groundwater regions have 82% higher chances of developing PD compared to water service areas that don't have golf courses in vulnerable groundwater regions (15).

Similarly, reports show that the chemicals also runoff and contaminate local groundwater and lakes, harming local ecosystems and increasing the risk of human cancer through exposure to the polluted water sources. Roundup, a herbicide brand that contains glyphosate as its active ingredient, was found to be used on almost every golf course. This led to two court cases in America involving course superintendents who got cancer from using Roundup (16). Additionally, a broader national study by the Center for Biological Diversity and partner

organizations on pesticide exposure and environmental injustice found that 12 out of 14 tracked pesticide biomarkers were present in the blood and urine of Black or Mexican Americans at levels up to five times higher than the average for white Americans (17). Injustices also extend beyond just health and contamination. During times of drought and water restriction in arid regions such as Georgia and other states, golf courses are often not held to the same rules and continue to irrigate their grounds while surrounding communities are forced to reduce basic water use such as washing cars and watering lawns (3).

Golf courses also strengthen social inequalities as well as restrict access to green spaces. While golf courses are often viewed as environmentally friendly and ecologically valuable, most golf courses are privatized and require expensive memberships to access, effectively restricting the space to only a handful of people. One study has found that 3.4% of the U.S urban population live within 1 kilometer of a golf course, but are more than 1 kilometer from public green space (18). This exclusion would disproportionately affect people who lack access to greenspace generally; notably, however, Ryan's own analysis found that the neighborhoods that would benefit most from improved golf-course access tend to be wealthier and predominantly White, while lower-income, ethno-racial minority communities most lacking in greenspace access are often located farther from golf courses altogether, the broader environmental-justice concern that these communities already face limitations on their access to recreational green space while also bearing the health consequences of chemical exposure from golf courses located nearby. In Los Cabos, Mexico, this can be seen through satellite imagery, where golf courses are the only areas of greenery in the region (2).

To make matters worse, these golf courses were built mainly for the purpose of tourist attraction, meaning that many of the locals don't have money to join these pricy golf courses and access the only green spaces in the region. Golf-community developments also further reinforce social inequality by not just limiting green space but economic burden as well when golf courses fail. Across the U.S, multiple golf courses have collapsed, and the home values within the community plunge by 25%, with extreme cases falling as low as 50% (19). These failed golf courses then often become overgrown and environmentally hazardous, affecting the community's health as well as posing an economic burden especially towards the middle-class families who sacrificed more to live the luxurious life in a golf community.

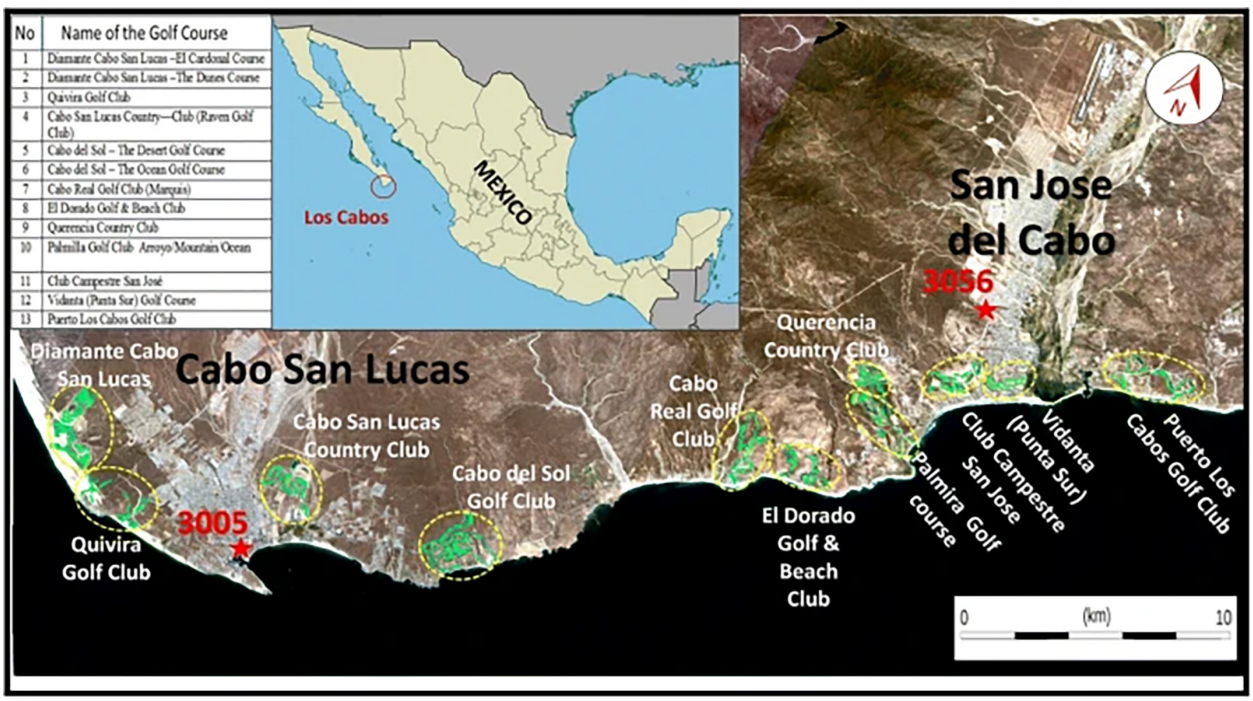

Figure 4. *The tourist corridor of Los Cabos, position of the weather stations 3005 and 3056 and digitized areas of 13 golf courses (Landsat image from Google Maps as base). Adapted from Wurl (2019) (2).*

SOLUTIONS TO ECOSYSTEM DISRUPTION & ENVIRONMENTAL INJUSTICE

The environmental challenges that golf courses bring, deforestation and different forms of maintenance, require more targeted and strict regulations. In the United States, policies should be made and enforced in ways similar to the European Union's pesticide regulations. Governmental regulations of pesticide use could dramatically reduce the volume and toxicity of chemicals released through golf course maintenance in the U.S. (9). Golf courses should also be required to publish public audits similar to the case of Lindeblad v Monsanto (16) in Washington State as a form of reflection and have local governments and officials better monitor resources and chemical appliances. Transparency is necessary and residents of surrounding neighborhoods have the right to understand the extent of the golf courses' ecosystem disruption and potential public health concerns if any exist. In addition, golf courses should also replant trees and restore how the land was originally, before the golf course was built. A good example of this would be The Pinehurst No. 2 (20). As shown in Figure 5, the golf course dug out 35 acres (about 14 hectares) of irrigated turf and replaced them with native wire grasses, pine straws, sand, and variants of local trees, effectively reducing their water use by almost 50%. (21).

Figure 5. *Better Golf Using Less Water: The Transformation of Pinehurst No. 2. Adapted from Merrick (2024) (20).*

A restoration of trees also cools down the temperature of golf courses and also serves their natural purpose of providing habitats and water irrigation, another topic requiring immediate attention. In drought-prone regions like Arizona and California, it should be required that they use recycled water and water from nearby lakes and streams rather than fresh groundwater that are important to local animals and vegetation. In Coachella Valley, California, Sunnylands Golf Course has replaced 60 acres (about 24 hectares) of turf with drought-tolerant tall grass to cut back on land needing water, and have let non-play zones grow brown (22). These actions should be more strictly enforced in golf courses of similar climate to lessen water consumption and preserve native species of plant. Leaving non-play zones, tall grass, and trees to grow on their own also significantly minimizes the area requiring chemical and machine maintenance, naturally leading to less chemicals being used and less CO_2 being emitted.

Environmental and social harms caused by modern golf courses also need to be recognized and addressed with solutions. As with the environmental regulations discussed above, golf courses should adopt practices similar to Europe's stricter standards, which promote biodiversity (23). This in turn would not only lessen the ecological risk of golf courses, but also reduce the risk of developing Parkinson's Disease for the people working in and around the golf course, but also lessen the disproportionate amount of chemical burden that communities of color have to bear. A good example of this would be Vineyard Golf Club in Massachusetts, which is the only golf course in the United States that is 100% organic (24). They prohibit the use of any synthetic pesticides and fertilizers, and rely on compost-based fertilizers, native vegetation, and natural pest control such as companion planting and beneficial insects. Furthermore, golf courses should partner with organizations such as Audubon International and USGA to integrate certified sanctuary programs in their golf course to encourage water conservation and reduced chemical use (25). Golf courses should also be required to integrate natural hiking paths and design walking paths along golf holes to provide public land use to local communities (18). This way, not only will golf courses be more inclusive towards local communities, but those communities will also be able to enjoy nature without paying expensive membership fees. And when golf courses inevitably fail or are no longer in use, they should follow China's example, where abandoned golf courses lands are returned to nature or revamped for agriculture use, restoring ecological value and benefitting the community (26).

CONCLUSION

Modern golf courses, built to represent wealth and green havens, in reality, represent a significant contrast between environmental sustainability and social injustice. In the points mentioned above, golf courses significantly contribute to environmental degradation through deforestation, chemical pollution, water overuse, and carbon dioxide emissions from constant maintenance. These practices in turn disrupt ecosystems, harm native habitats and vegetation, and contaminate water sources that are important to not only the environment and humans as well. Satellite imagery and environmental audits show that some golf courses consume disproportionate amounts of resources such as water in especially arid states like California, and pump out toxic chemicals at a rate more than triple the amount used for agriculture. Moreover, these environmental impacts aren't felt equally, with communities of color more likely to experience health risks, groundwater contamination, and restrictions to green space while golf courses remain privatized and accessible to only the wealthy and privileged.

Moving forward, more research should be put towards long-term ecological monitoring of golf courses. Using satellite data, soil testing, and water samples golf courses should evaluate their environmental impact and make changes accordingly. Studies should also be put towards how golf courses can be more inclusive and examine how the land can be used for different purposes such as public parks, hiking trails, or rewilded space. Stricter policies should also be made and implemented for chemical and water use, especially in groundwater sensitive areas and communities of close proximity. Native vegetation should also be replanted, and golf courses publish their chemical and water use to the government to monitor as the year goes by. If these actions could be taken, golf courses can begin to peel away from the symbol of wealth and exclusivity into spaces of sustainable and nondiscriminatory land use.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this work.

REFERENCES

1. James I. Desert golf courses, fake lakes and the Colorado River crisis. The Los Angeles Times. Available from: https://www.latimes.com/environment/story/2023-01-29/colorado-river-in-crisis-desert-lakes-and-golf-courses(accessed on 2026-5-25)
2. Wurl J. Competition for water: Consumption of golf courses in the tourist corridor of Los Cabos, BCS, Mexico. *Environ Earth Sci*. 2019; 78 (24): 674. https://doi.org/10.1007/s12665-019-8689-y
3. Government | City of Bloomingdale, Georgia. City of Bloomingdale. Available from: https://www.bloomingdale-ga.gov/water-use (accessed on 2026-5-25)
4. Brown B. Cover story: A centuryold forest gets wiped out for a golf course. Grid Magazine. Available from: https://gridphilly.com/blog-home/2022/03/27/cover-story-a-century-old-forest-gets-wiped-out-for-a-golf-course/(accessed on 2026-5-25)
5. Selbig WR, Loheide SP, II, Shuster W, et al. Quantifying the stormwater runoff volume reduction benefits of urban street tree canopy. *Sci Total Environ*. 2022; 806 (Pt 6): 151296. https://doi.org/10.1016/j.scitotenv.2021.151296
6. Colding J, Folke C. The Role of Golf Courses in Biodiversity Conservation and Ecosystem Management. *Ecosystems*. 2009; 12 (2): 191-206. https://doi.org/10.1007/s10021-008-9217-1
7. Nguyen TT, Barber P, Harper R, Linh TVK, Dell B. Vegetation trends associated with urban development: The role of golf courses. *PLOS One*. 2020; 15 (2): e0228090. https://doi.org/10.1371/journal.pone.0228090
8. Krčmář D, Marschalko M, Yilmaz I, Patschová A, Chalupková K, Kovács T. Potential pollution risk in natural environment of golf courses: An example from Rusovce (Slovakia). *Environ Earth Sci*. 2014; 72 (10): 4075-4084. https://doi.org/10.1007/s12665-014-3296-4
9. Pesticides B. Pesticide Dangers at Golf Courses Much Higher in the U.S. than Europe, Study Finds. Beyond Pesticides Daily News Blog. Available from: https://beyondpesticides.org/dailynewsblog/2023/03/pesticide-dangers-at-golf-courses-much-higher-in-the-us-than-europe-study-finds/ (accessed on 2026-5-25)
10. New York State Office of the Attorney General. Toxic Fairways: Risking Groundwater Contamination From Pesticides on Long Island Golf Courses. Environmental Protection Bureau. Available from: www.beyondpesticides.org/assets/media/documents/documents/toxic-fairways-1995.pdf (accessed on 2026-5-25)
11. Baris RD, Cohen SZ, Barnes NL, Lam J, Ma Q. Quantitative analysis of over 20 years of golf course monitoring studies. *Environ Toxicol Chem*. 2010; 29 (6): 1224-1236. https://doi.org/10.1002/etc.185
12. Tidåker P, Wesström T, Kätterer T. Energy use and greenhouse gas emissions from turf management of two Swedish golf courses. *Urban For Urban Green*.

2017; 21: 1-11. https://doi.org/10.1016/j.ufug.2016.11.009
13. US EPA. "US Indoor Water Use | WaterSense | US EPA." Epa.gov, 19 Jan. 2017, 19january2017snapshot.epa.gov/www3/watersense/pubs/indoor.html.
14. Lurie J. Here's how much water golf courses, ski resorts, and pools are using in California: The truth about California's dwindling water supply. Mother Jones. Available from: https://www.pvwater.org/images/media-room/news-releases/2015/20150803_CA_WaterUse_MotherJones.pdf (accessed on 2026-5-25)
15. Krzyzanowski B, Mullan AF, Dorsey ER, et al. Proximity to Golf Courses and Risk of Parkinson Disease. *JAMA Netw Open*. 2025; 8 (5): e259198. https://doi.org/10.1001/jamanetworkopen.2025.9198
16. Boos M. The Links to Cancer: How Golf Became Dangerous and What We Can do to Save the Game. Available from: https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=1433&context=utpp (accessed on 2026-5-25)
17. Donley N, Bullard RD, Economos J, Figueroa I, Lee J, Liebman AK, Martinez DN, Shafiei F. Pesticides and environmental injustice in the USA: root causes, current regulatory reinforcement and a path forward. *BMC Public Health*. 2022; 22 (1): 708. https://doi.org/10.1186/s12889-022-13057-4
18. Ryan JC. Do Urban Golf Courses Provide Barriers to Equitable Greenspace Access in the United States? *Ann Am Assoc Geogr*. 2023; 113 (5): 1139-1157. https://doi.org/10.1080/24694452.2023.2166011
19. Steuteville R. Failing golf communities not on par with neighborhoods. Public Square: A CNU Journal. Available from: https://www.cnu.org/publicsquare/2019/01/22/failing-golf-communities-not-par-neighborhoods (accessed on 2026-5-25)
20. Merrick B. Better Golf Using Less Water: The Transformation of Pinehurst No. 2. USGA. Available from: https://www.usga.org/content/usga/home-page/course-care/green-section-record/62/issue-10/better-golf-using-less-water--the-transformation-of-pinehurst-no.html (accessed on 2026-5-25)
21. The Pinehurst No. 2 Restoration - A Hole-by-Hole Tour. Pinehurst Resort. Available from: https://www.pinehurst.com/news/the-pinehurst-no-2-restoration-a-hole-by-hole-tour/ (accessed on 2026-5-25)
22. Rhodan M. Obama Hits the Links in California Amid Drought. TIME. Available from: https://time.com/3929077/barack-obama-california-golf-drought/ (accessed on 2026-5-25)
23. Bekken MAH, Soldat DJ, Koch PL, Schimenti CS, Rossi FS, Aamlid TS, Hesselsøe KJ, Petersen TK, Straw CM, Unruh JB, Kowalewski AR, Spring C. Analyzing golf course pesticide risk across the US and Europe-The importance of regulatory environment. *Sci Total Environ*. 2023; 874: 162498. https://doi.org/10.1016/j.scitotenv.2023.162498
24. Pesticides B. Fully Organic Golf Course Set for Return of President. Beyond Pesticides Daily News Blog. Available from: https://beyondpesticides.org/dailynewsblog/2010/08/fully-organic-golf-course-set-for-return-of-president/(accessed on 2026-5-25)
25. Dodson RG. An assessment of the Audubon Cooperative Sanctuary Program for golf courses. *Environ Manage*. 2000; 24 (1): 1-11.
26. Reuters. China Bans More Than 100 Golf Courses to Safeguard Resources. Voice of America. Available from: https://www.voanews.com/a/china-bans-more-than-100-gold-courses-to-safeguard-resources/3686982.html (accessed on 2026-5-25)