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Environmental Improvements of 'The Dunes Course' in Messinia, Greece

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Abstract

Activities occupying large areas of land inevitably affect the environment to some extent. For golf courses, one of the most negative impacts is the extensive use of pesticides and fertilizers. The sport is expanding and so is the awareness of degradation of the environment and decline in biodiversity. Alternative ways to reduce chemical use is therefore of great interest for a more sustainable management. Depending on what kind of landscape golf courses are replacing and whether correct management is in use, they could actually contribute to positive effects on the environment, like increased biodiversity. Former studies with trials of the relatively new technique with effective microorganisms (EM) in agriculture and at golf courses have shown positive results such as improvement of the soil quality, which is fundamental to reach a stable soil ecosystem and to increase nutrient uptake and the defense against pathogens. In this study the golf course The Dunes Course, in Messinia, Greece were subject of investigation and a compound of information from literature studies, observations and interviews was made to get an overview of current management to identify what could be improved and what role EM could have. The results show that the management at The Dunes Course already has environmental adaptions in place, though in several aspects measures could be done, e.g., to increase biodiversity by reducing conventional pesticides and fertilizers and make nature conservation plans for non-playable areas. There is a great potential for EM to contribute to successful effects of several of these measures.

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Introduction

Background

Golf

Golf courses occupy large green areas, an average 18-hole golf course covers about 54 ha of land (Salgot et al*.,* 2012). In terms of total economic expenditure, golf is the leading sport in the world and has run a period of remarkable growth. The sport attracts a wide audience and in 2003 it exceeded 61 million players worldwide. There are over 25 000 courses in the world and in Europe there are over 5 000 (year 2006). Due to the large number of overlapping businesses, for example entertainment, construction, agriculture, marketing, advertising and hospitality and because of the expenditure in interest and the worldwide participation, the golf has become a multi-billion dollar industry (Wheeler & Nauright, 2006).

Golf and the Environment

Golf in resemblance to other human activities affects the environment in different ways (Tanner & Gange, 2005; The Swedish Golf Federation [SGF], 1999). Some of the most obvious negative impacts are conflict of interest due to land utilization, use of pesticides and fertilizers, impact on biodiversity, energy consumption and extensive irrigation, use of energy in belonging clubhouses, and greenhouse gas emissions from machines used at the course (SGF, 1999; Wheeler & Nauright, 2006).

Though, by responsive construction and management, potential for positive impact on the environment with increased biodiversity could occur as well. For example, the course could function as a sewage treatment facility if sewage water is used for irrigation, and it could also promote potential establishment of habitats for animal and plants (SGF, 1999). Considering the quantity of area that a golf course occupies, correct management is likely to count as nature conservation (Colding & Folke, 2008).

As courses often are constructed and integrated in the surrounding landscape, their relationship with nature is long-standing and it embodies both wildlife and vegetation (Tanner & Gange, 2005; Wheeler & Nauright, 2006). Activities of this range therefore have a great responsibility to reduce negative impact on the environment. Challenges consist in reducing the negative impact and increasing the positive ones without lowering the quality of the game (Dodson, 2000; SGF, 1999).

The ideal look of a golf course that many golfers visualizes as the perceived perfection has become known as the ‘Augusta National Syndrome’, named after a legendary course in Georgia, USA, hosting the Masters Tournament each spring. The televised images with verdant short-cut greens are what many golf course designers want to imitate (Wheeler & Nauright, 2006). To maintain the expectations of a golf course appearance, the management often involves excessive use of irrigation and chemicals. The intensive use of the greens along with continuously mowing makes the grass less stress tolerant and more susceptible of diseases, and to suppress this, heavy amounts of different pesticides and herbicides are applied as a consequence. One improvement of great importance is therefore to reduce the use of chemicals, since they have a direct negative impact on biodiversity.

Besides the actual golf course area an improving environmental management also should concern the surrounding landscape, since adjacent areas are likely to be affected by leaching of nutrients and pesticides (Salgot & Tapias, 2006). To examine how measures can be done to reduce this is of great importance in order to get a reduced environmental impact in a larger ecosystem point of view.

The potential for a golf course to have ecological values is primary determined by what kind of landscape that is replaced. Golf courses that are well planned in design and management and mainly replace ecologically impoverished landscapes could enhance biodiversity through the landscape diversity increase. Conversely, regional decline in biodiversity is more likely when golf courses replace native habitats (Colding & Folke, 2008; Gange et al*.,* 2003). Adaptions that can be applied to reduce the environmental impact and enhance the local biodiversity are therefore considerable already at the construction stage. An extensive agricultural area with an extensive chemical based monoculture without any small biotopes doesn't require the same amount of landscape transformations as a native. Hence, the location for establishing a new golf course should be on former managed landscapes (SGF, 1999; Gange et al*.,* 2003).

An increase in heterogeneity in contrast to adjacent areas makes the golf course a source for habitats, which have the potential to support different groups of organisms functional for critical ecosystem services, like pollination (Colding & Folke, 2008; Tanner & Gange, 2005).

Some areas at a golf course, e.g., the greens, could count as monocultures similar to croplands existing in extensive agriculture (Dell et al*.,* 2010; Salgot & Tapias, 2006). Due to heavy mechanical processing of the soil in croplands the risk of nutrient leaching is smaller at a golf course that is permanently covered by vegetation. However, compared to pastures in long lasting treads, the levels of fertilizers are considerably higher on a golf course and the grass generally has less root depth and cannot assimilate the entire amount of nutrients that are applied. The fact that the course is permanently covered also makes the risk for erosion lower (SGF, 1999). This is the reason why a depleted cropland converted to a golf course has the potential to sequester atmospheric carbon and function as a soil organic carbon pool, another essential ecosystem service (Selhorst & Lal, 2011).

Despite the fact that they are anthropogenically created and governed, fragmented urban green areas like golf courses and small biotopes in an agriculture landscape do have the potential to function as refuges (Barthel et al., 2013; Hodgkison et al., 2007a; Yasuda & Koike, 2004). Within the context of a degraded urban landscape it is possible for both urban avoiders, urban adapters and even relict species to find shelter (Barthel et al., 2013; Hodgkison et al., 2007b).

There are areas at the golf course that are defined as 'non-playable' (e.g., parts of the roughs and general sites surrounding the course), which consist of mostly wild nature that with the right management could function as nature conservation (Tanner & Gange, 2005). These sites have potential to work as patches where populations could move between. The golf course could also count as a patch itself, contributing to metapopulation dynamics in a more complex view, when looking at the course in a larger ecosystem perspective on a landscape scale, integrating with other potential patches (Colding, 2006; Gange et al*.,* 2003).

The Modern Agriculture

The modern agriculture with rationalized arrangements such as monocultures has increased the demand for pesticides and fertilizers by heavy machines, which poses a threat to the environment by leaching and emissions. The excessive use of land due to large areas of single cultivated crops also causes habitat loss and fragmentation in the landscape, which in turn leads to degradation in biodiversity (Benton et al., 2003; Krebs et al*.,* 1999; Stoate et al., 2001).

With increased awareness, alternative methods and ways to reduce the negative impacts have evolved, for example organic farming, with traditional ways of managing croplands, such as crop rotations and pasture treads, all with minimum or no conventional methods (Mayer et al*.,* 2010). Ways to improve soil quality and to reduce the needs of pesticides and fertilizers are of constant interest to be investigated, and microorganisms have for a long time been understood to have fundamental abilities for such purposes. Besides in agriculture, microorganisms have also traditionally been used in medicine, food processing and composting (Higa & Parr, 1994).

The relatively new technique with effective microorganisms (EM) has been used successfully as an alternative to conventional methods in agriculture (Hu & Qi, 2012). The technique is also showing positive indicators on being useful in golf courses management (Kremer et al., 2000).

Microorganisms

Microorganisms maintain soil fertility and play an essential role in the soil ecosystem by cycling nutrients and promoting their availability, improving soil structure, supporting nourishing health plant growth and degrading organic pollutants (Singh & Mishra, 2013).

Certain microbial groups, like fungi and bacteria, have more potential for proliferation in the rhizosphere, hence creating a larger activity in that zone compared to the bulk soil. Since the symbiosis of mycorrhizal fungi and the roots is important for N uptake in the soil, fungicides are detrimental to this service and could cause an indirect increase in greenhouse gas emissions (ibid.). Responses that function as plant defense can be induced by soil organisms to aboveground herbivores and pests. These interactions create a feedback-system that can contribute to biodiversity in several ways (Van Tol et al*.,* 2001).

None of the microbe groups are able to accomplish their services with maximum efficiency during all kinds of condition. For important soil processes to continue, diverse populations are needed. Their qualities are also influenced by climate, pH, soil texture and structure and soil salinity. The activity and growth of soil organisms increases at higher temperatures, changes in pH can affect the metabolism and nutrient availability. Medium-textured loam and clay soils are more favorable compared to fine textured sandy soils. Climate influence the physiology of soil organisms, such that their activity and growth increases at higher temperatures (Singh & Mishra, 2013).

Effective Microorganisms (EM)

Effective microorganisms (EM) as a concept, was developed in 1991 by Teruo Higa at the University of Ryukyus, Okinawa, Japan (Higa, 1991). EM is a mixed culture that contains about 80 different coexisting kinds of microorganisms, including lactic acid bacteria, different kinds of microbes and yeasts, which will work together to improve resistance against pathogens. The main process these microorganisms are using is fermentation (ibid.).

According to Dr. Higa's theory one could divide microorganisms into three groups:

1. Regenerative/fermentative
2. Degenerative/decomposing
3. Opportunists

He also observed soils and distinguished them into four categories depending on predominant microorganisms and their activities and functions:

1. **Disease-inducing soils**
   The microorganisms in this kind of soil consist mainly of pathogens. Due to addition of high-N organic matter from fresh manure for example, incomplete oxidation may occur, which could lead to malodorous and substances that are toxic for the plants. The properties of this kind of soil are often unfortunate physically. Further, the nutrients easily bond into inaccessible forms for the plants. Higa concludes that 90 % of all agricultural land holds this type of soil.

2. **Disease-suppressive soils**
   These soils produce large amounts of antibiotics and contain mainly antagonistic microbes. These soils have good water permeability and preservation qualities. The microflora is generally aerobic and the decomposing generates a pleasant earthy odor.

3. **Zymogenic soils**
   These soils contribute to an enhanced plant growth by generating amino acids, vitamins and antioxidants through beneficial fermentation decomposing of complex organic molecules and inorganic nutrients. The physical properties are favorable and have a characterized pleasant fermentative odor. The microbes are mainly anaerobic

but a few pathogenic fungi or bacteria exist. The methane, carbon dioxide and ammonia production are minimized in these soils.

4. **Synthetic soils/soils**
   Rhizobium, Phycomycetes and Cyanobacteria, are the main groups from which the microorganisms in these soils belong to. These populations of microbes have the ability to fix nitrogen and carbon dioxide from the atmosphere and convert it to carbohydrates and proteins contributing to the soil and plant health, and these soils only require minor additions of organic matter to maintain their fertility.

EM contains mainly the regenerative types of microorganisms. If this culture is added into the soil and to a point where it is dominant, the opportunistic types will follow them due to the dominance principle, which will lead to a soil environment predominantly consisting of fermentation processes (Higa & Parr, 1994).

By inoculating a soil with effective microorganisms in mixed cultures, the soil could transform into disease-suppressing, zymogenic and synthetic soils (ibid.). A composite soil that is highly zymogenic and synthetic with disease-suppressive capacity is the most suitable agricultural soil for optimum growth, and therefore the desire to find ways and measures to control the microflora is of great interest (Singh & Mishra, 2013).

Despite the theoretical knowledge of how the physiological capabilities in microorganisms can function, suppressing pathogens by their antagonistic and competitive activities, the results in several scientific studies have not been consistent. The reason for this is partly because many trials only have involved one single isolate at the time and because the microorganisms are hard to culture in laboratory. More studies are necessary to understand their growth, nutritional and ecological needs but also their ecological relationship and interactions with other microorganisms to understand the weight of diversity (Higa & Parr 1994).

EM and Golf

At Svartinge Golf in Sollentuna, Sweden (59°29'12.1"N 17°52'20.8"E), there is a 3-years trial with EM in progress, and so far the results are solely positive. For example, the growth has been good and regular, which has reduced the need of added mowing. Further, the greens show great luster and the thatch is decomposed naturally by the microorganisms, which has reduced the need of chemicals and expensive techniques like wetting agents (Jan Röed, 2014).

Aim of the Study

The aim of this study is to create an overview of current management, problematic, measures and visions to be able to make suggestions for environmental improvements for The Dunes

Course. An investigation is also made concerning the possibilities to introduce the EM-technique and what the positive effects could be.

The research questions for this study are:

- How can ’The Dunes Course’ become more environmentally adapted?
- How can EM contribute to this adaption?

A minor part of this study will also take in consideration the purpose of environmental improvements on a landscape-level perspective.

Limitations

The term ‘environment’ spans over a lot of subjects and can refer to natural, economical and social aspects. In the golf course section, which this study is linked to, all these aspects are possible to investigate. Due to restricted time and range of this study the scope of subjects had to be limited. The chosen focus is mainly the impact on biodiversity, and the results have been distinguished into the following categories: irrigation, pesticides/fertilizers, biodiversity/nature conservation, organization/education and machines. Example of subjects that were not taken into account in this study was: use of energy (e.g., in clubhouses), conflict of interest with outdoor life, socio-economics and ethical or sustainability related aspects (e.g., produce of golf equipment).

Method

Literature Studies

Literature studies was conducted in April 2014 and have consisted of scientific articles about both positive and negative environmental impact of golf courses with focus on biodiversity and ecological management, conventional and organic farming with focus on soil quality and soil carbon sequestration, the EM-technique and field experiments with EM, mainly in agriculture. Most of the articles have been located at the website for the library of Stockholm University, Google Scholar and Web of Science. A full list of literature used for this project can be found under ‘References’ on page 22.

Interviews

An interview with Will Righton, Head of Golf Course Agronomy at The Dunes Course was made 13th of May 2014 at The Dunes Course. Complementary interviews were made by email both in advance via Giorgos Maneas, the Station Manager at Navarino Environmental Observatory (NEO) and afterwards directly with Will Righton.

An interview with Jan Röed, Environmental Consultant with focus on microbial technique at the company Botanic Culture, was made 8th of May 2014, to gather basic information about the EM-technique and trials, primarily the one at Svartinge Golf. Complementary interviews were also made via telephone and by email during the work process of this study.

Observations

During the interview with Will Righton a tour around The Dunes Course was made to receive general observations of the golf course's look and to take field notes.

Study Area

The Dunes Course

The Dunes Course (36°59'48.9"N 21°39'15.4"E) (Figure 1) was the first of two golf courses constructed during the last decade in Costa Navarino, and it was opened in May 2010. It is located at the seaside in Messinia in the southwest of Greece and is replacing mainly managed landscape with conventional farmed olive groves. The 18-hole course with 36 hectares playable and 65 hectares non-playable area (Figure 2) is surrounded by olive and fruit groves, and the river 'Sellas' meanders through the site. The design of the course is a collaboration between former US Masters Champion and Ryder Cup Captain, Bernhard Langer, and the European Golf Design. Like the rest of the facilities constructed in Costa Navarino, the course is developed by TEMES s.a., which has a strong sustainability approach (Costa Navarino, 2014; Costa Navarino Golf, 2014; Will Righton, 2014).

Results

All results without references are from interviews with Will Righton (Will Righton, 2014).

Irrigation

The water used for irrigating the golf course is partly from The Dunes Course river and partly from treated sewage effluent (TSE) water from the hotel. The TSE water provides about 20% of the total irrigation water, depending on hotel occupancy.

Resources for water in the area come from The Dunes Course 250 000m3 holding lake that is filled at permitted times of the year from the river. This water is then fed by gravity through the TSE station and mixed with the TSE, then pumped into the irrigation lake next to the pump room at the golf course.

The irrigation system throughout the course is operated by a central control system that is connected to a weather station. This station adjusts watering schedules through evapotranspiration (ET). The central control system is also connected to the field controllers (LTC Satellite) that receive all flow-managed programs, field changes and alerts that then relay the information to the sprinkler.

***Figure 1**. Map over The Dunes Course and the golf course's features (Will Righton, 2014). Legend, north arrow and scale division are created in Adobe Illustrator®.*

Water conservation practices in place are: using correct nozzles, hand watering when possible, converting to part circle sprinklers where possible, seasonally adapted grasses are planted, Bermuda grass (*Cynodon dactylon*) in the summer and ryegrass (*Lolium sp.*) in the winter, only native plants throughout the unmanaged areas, and adapted to preferred vegetation zones. Also, oxygen improvement is in use, which is a process that is applied regularly to encourage the roots to grow deeper to get easier access to water. A machine makes small holes in the turf to get rid of dead organic matter (thatch), and then the turf gets top-dressed with sand. This process is done every two weeks.

Pesticides/Fertilizers

The main pests on the course are mole crickets (Gryllotalpidae), pygmy mole crickets (Tridactylidae), armyworms and cutworms (larvae of several species in the family Noctuidae), white grubs (larvae of *Phyllophaga* spp.), and moles (Talpidae) that cause damage to the turf. The main fungal disease is brown patch (caused by *Rhizoctonia* spp.). The main unwanted plants are white clover (*Trifolium repens*) and annual meadow grass (*Poa* *annua*), for these the primary issue is to find a balance between the golf ball roll capacity/playability at the course and keeping the chemical applications decreased.

The pesticides used are classified as insecticides, pre-emergent herbicides, post-emergent herbicides, fungicides, growth regulators and wetting agents (all conventional).

The fertilizers in use are controlled release fertilizers, quick release fertilizers and liquids, and water-soluble products that are applied as foliar spray (conventional). The organic fertilizers are made up of poultry, brown, marine and green manures, natural seaweeds, soil amendments - gypsum.

The control release fertilizers are coated fertilizers, which disperse more slowly (over the course of about 4 months), thus keeping the nutrients for a longer timer. The fast release are applied only certain times at the cold season to make the grass grow faster. Once it is stabilized they change to control release fertilizers instead.

The Dunes Course is in the beginning of producing compost, which they wish to use as compost tea in the future, in addition to current fertilizers. Compost tea is the result from steeping compost in water. The remaining extract, the *tea*, consists of nutrients and beneficial bacteria and can be used as a fertilizer spray (Scheuerell & Mahaffee, 2002).

INTEGRATED PEST MANAGEMENT (IPM)

'Integrated Pest Management' (IPM) is a plan specific to an individual course that aims to prevent and control pests. The IPM process is outlined below:

1. Regular monitoring and record keeping is used to identify the pest problem, analyze the conditions causing it, and determine the damage threshold level below which the pest can be tolerated.
2. Strategies are laid out to change conditions to prevent or discourage recurrence of the problem. This may include using a more hardy turf grass species, or modifying the microclimate conditions.
3. If damage thresholds are met or exceeded, control strategies are selected that will cause minimal environmental impact. These include biological (predators, parasites), cultural (habitat modification), physical (soil aeration, increased air movement), mechanical (traps) and chemical (pesticides, herbicides) methods.

IPM emphasizes that non-chemical methods should be considered before resorting to chemical application. However, if chemicals must be used, the following guidelines are recommended:

- Applicators should be well educated through state licensing, professional association training and IPM certification. Non-English speaking applicators should be provided with training in their native language.

- Always follow the label directions carefully when using chemicals. Treatments should be applied in the correct doses and during the recommended conditions to ensure effectiveness and minimize environmental impact.
- Pest control and nutrient products should be stored and handled in a way that minimizes worker exposure and potential pollution. All recommendations regarding personal protective equipment should be followed.
- Soil should be monitored regularly to ensure that turf grass needs are being met but not exceeded.
- Golf courses should inform guests when chemicals have been applied. Notices can be posted on the first and tenth tee boxes, as well as informing the Golf shop, and Staging area.

BEST MANAGEMENT PRACTICES (BMP)

The nutrient leaching are not physically measured, but 'Best Management Practices' (BMP) are in place such as:

- Avoid high amounts of soluble nitrogen when temperatures are cool or during low plant uptake.
- Use of controlled release, and foliar fertilizer where possible.
- Use of efficient irrigation programs.
- Utilizing correct grasses for the environment.
- Apply frequent light rates of nitrogen.
- Avoid fertilizing at times of the year when the turf grass is naturally slowing down.
- Conservatively irrigate to both reduce consumption and reduce leaching.
- Reduce managed areas of the golf course.
- Apply optimum amounts of given nutrient necessary to sustain the desired response.

Biodiversity/Nature Conservation

The non-playable area (Figure 2, brown color) at The Dunes Course is 65 ha, originally it was 45 ha. This area is not managed, except mowing about twice a year. The whole course boundary is non-playable, thus unmanaged. These areas serve as buffer zones to reduce leaching. The roughs in the playable area are maintained with irrigation but with lower quantities of pesticides and fertilizers.

Organization/Education

At the moment there is no particular education about the environmental practices intended for the golfers. For the managers there are soil analyses and agronomy planning performed regularly.

According to the manager, the main issues concerning an ecological adaption are the golfers' and the staff's awareness, impacts on the speed of play and the golfers' expectations.

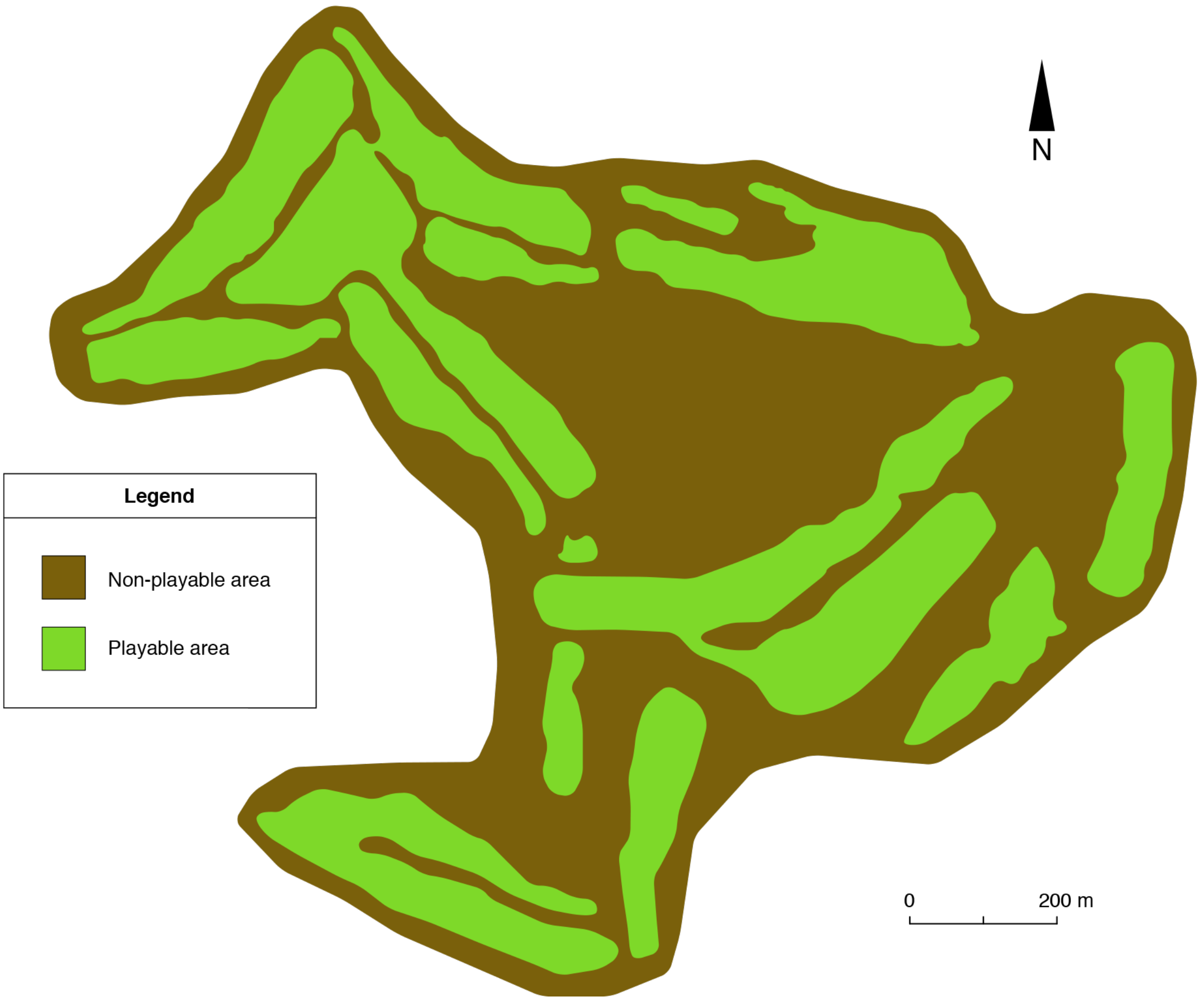

Figure 2. *Map over The Dunes Course distinguishing the Non-playable area (brown color) from the Playable area (green color). Initial map (Will Righton, 2014). Modifications are done in Adobe Illustrator®.*

Machines

Cooking oil from the hotel in Costa Navarino is being transported to a company that converts it to biodiesel. The vision is to use this in the machines at the golf course, which are currently fueled by diesel and petrol. 90 % of the machines are compatible (fueled by diesel), and the wish is to combine 20 % biodiesel in these tanks together with diesel. The golf carts are all electric.

Other Information/General Management Practices

- The grass on the greens is kept at 3 mm.
- The course is constructed on sandy loam and for the greens and tees there is a mixture of 80:20 sand/peat. The sand used at the golf courses and for top-dressing is local except the sand in the bunkers, which is Egypt sand.
- The soil pH-value in the greens is 8 and in the fairways 7.7.

Current Environmental Adaptions

***Table 1**. Summary of environmental adaptions in practice at The Dunes Course in the left column, and the managers' visions of improvements in the right column.*

ENVIRONMENTAL ADAPTIONS IN PRACTICE	VISIONS OF IMPROVEMENTS
Biodiversity/Nature conservation • Reduced managed area (Current unmanaged area is 65 ha, compared to originally 45 ha). • Native plants in their preferred vegetation zone. • Season adapted grasses.	• Reduce the use of conventional pesticides.
Irrigation • Control system/regulation for the sprinklers. • Correct nozzles are arranged. • Hand watering when possible. • Converting to part circle sprinklers where possible. • Wetting agents • Oxygen improvement • Sewage water 20% • BMP	
Fertilizers • Buffer zones (less managed area) to reduce nutrient leaching. • Oxygen improvement • BMP • IPM	• Start adding compost tea. • Reduce the use of conventional fertilizers.
Pesticides • BMP • IPM	• Reduce the use of conventional pesticides.
Location • Constructed on former cultivated olive crop land (managed area).	
Machines • 90% are compatible for biodiesel.	• Start using recycled cooking oil from the hotel.
Organization and education • Agronomy planning • Soil analyzes • No current education for the golfers.	

Impact on a Landscape-Level

This simplified map/image (Figure 3) is made to visualize the proportions of The Dunes Course in comparison to adjacent area, in this case the southwest of Messinia, Greece. This might give another perspective of the impact on the environment from The Dunes Course with more of an emphasis concerning the landscape-level. The area surrounding the course consists mainly of conventional olive groves.

Figure 3. *Map showing The Dunes Course areal in proportion to the southwest of Messinia (Google Earth, 2014). The North arrow, scale division, color modifications and the sketched distinguish of The Dunes Course position are done in Adobe Illustrator®.*

Discussion

The results show that The Dunes Course can be considered to have an environmental adaption in some aspects. Though in several aspects it is missing or could be improved. Some improvements are in a stage of planning while others still are visions (Table 1).

Irrigation
Adaptions indicate focus on irrigation improvements, which seems as an intuitive decision when situated in a climate zone with water stress during the summer season (European Environment Agency [EEA], 2014).

Pesticides/Fertilizers
The management of the golf course adheres to certain programs (IPM and BMP) that aim for an environmental adaption, though there are mainly conventional pesticides and fertilizers in use. These programs imply that certain guidelines should be followed and to accept certain preventive measures and requirements adaptions, mainly with the purpose of discouraging resistance among the plants. It can be regarded as a step towards more environmentally friendly management practices, since without these strategies chemicals are simply applied at regular intervals to ensure the control of pests, but it is not a guarantee for not using conventional methods (The Swedish Board of Agriculture [SBOA], 2014).

Managers of golf courses with an ecological approach have a responsibility to always try to keep the balance between matching the golfers' expectations and keeping the impact on the environment at a reasonable level (Dodson, 2000). This level is relative and depends on in what context it is discussed. For example, when regarding climate-change issues on a global scale, it might not even be defendable with constructions like golf courses, but when it comes to a local scale the golf courses existence could not be neglected and impact on the environment must be handled, one way or another, if improvement should occur at all. To reach environment improvements on a global scale, major sustainable measures are needed (Foley et al*.,* 2005), such as UNEP (United Nations Environment Programme, 2014).

Overall, TEMES and the employees' positive attitude concerning improved measures to a further sustainable environmental adaption mark a great potential of development in this area and the visions about adding compost tea is a good example of that.

So far, the nutrient leaching from The Dunes Course to adjacent areas has not been measured, but if such methods were initiated it would help to make preventive plans for the usage of fertilizers in the future. Though adjacent areas mostly consist of conventional plantations with already high use of chemicals there are no reasons for worsening the situation. In addition, The Dunes Course is located near the coast and also has large areas that are not maintained and can be regarded buffer zones. The river Sellas is to be considered one of these, and with reduced amount of pesticides and fertilizers, these areas in addition of acting as well-functioning buffer zones, could increase their habitat potential. All these factors put additional importance on reducing the impact on the environment.

Biodiversity/Nature Conservation
The managed areas have been reduced, which means chemicals and irrigation are affecting a smaller area. Mowing is almost entirely reduced as well; the grass here only gets cut about

twice a year. Since the plants all over the course are native, this reduced management could contribute to natural regeneration in these areas (Dodson, 2000).

It doesn't seem like the management for The Dunes Course have any other active nature conservative measures concerning biotopes, beside the fact that they have reduced their managed area. Though the course already has a lot of environmental adaptions, it doesn't infer that improvements aren't needed. Current conditions make a great fundament for even better ways to improve existence and wellness for organisms at the course. With more stable populations in existing patches the likeliness for increasing colonization in adjacent patches (both inside and outside the course) are much greater, which emphasize the importance of improvements like this (Gange et al*.,* 2003; Hanski & Hanski, 1999).

Besides the current actions such as reduced management and exclusively planting native species, there are several future possible measures regarding nature conservation that could be done. An inventory of the vegetation and animals at the non-playable areas (including the water areas) would make a great starting-point and should give an overview of dominating species and insight in what kind of nature conservation that could be accomplished (Burgin & Wotherspoon, 2008). An inventory would also be useful to create information signs about the nature at the golf course.

Possible measures at the non-playable areas (Figure 2) could exist in leaving dead trees, fallen logs and snags, which all have essential functions for certain insects and thus, in extension, certain birds. If the vegetation has to be mowed, preferably wait until after flowering season, to ensure pollination as far as possible. Another example of possible measures is to place out nesting boxes at the course (Dodson, 2000; SGF, 1999). Further, it should be considered to reduce the management of the roughs even more, if possible.

Location

Since The Dunes Course is constructed on former olive groves, i.e. urban managed landscape, the course could contribute to a larger heterogeneity and the potential to increase local biodiversity (Tanner & Gange, 2005).

Machines

When it comes to the fuel section there are a lot of things that can be improved. Environment friendly fuel alternatives could be considered for the machines in use at the course. Fortunately this is something that the managers of The Dunes Course are being aware of and the vision is that cooking oil from the hotel converted to biodiesel could be used in 20 % of the golf cars mixed with regular diesel. This is planned to be implemented in the next year. The cooking oil from the hotel is already being recycled to biodiesel but not for the count of the golf course yet.

If trials with EM are successful, it would reduce the chemical application, hence the use of machines, which in turn would reduce greenhouse gas emissions from the golf course.

Organization/Education

To reach sustainability with an environmental adaption it is important to inform and educate the golfers and the staff and also the hotel's visitors and other people visiting the area. If the insight in certain questions is increased, it should be easier to evoke curiosity and interest, which in turn could encourage a greater acceptance for new ways to manage golf courses. The traditional image most golfers have of how a golf course should look like, may in some ways need to be changed (Brennan, 1996; Dodson, 2000; Hammond & Hudson, 2007).

The golfers at The Dunes Course are mostly tourists and temporary guests, therefore it is not as easy to distribute information, e.g., via newsletters, as it would be if the golfers were permanent members. Though, some sort of brochure could be handed to the guest when arriving or by e-mail when booking. Other measures to improve in this subject could exist in constructing signs with information about the environmental approach and management, where explanations are found about how and why certain measures are done. Also, information signs about vegetation and animals could be placed in non-playable areas at the golf course.

Impact on a Landscape-Level

The management of the golf course might be more environmental friendly than that of the surrounding landscape, but constructing a facility with such great demands requires a lot of responsibility and since The Dunes Course is located near the coast (Figure 3), hence not only surrounded by conventional farming, it puts additional importance on reducing the impact on the environment.

The positive effects that come with a golf course constructed in a landscape mostly consisting of monocultures may never compensate for all the negative effects that follow. The extreme amount of heavy emissions that comes from airplanes, cars and other transports that are used for the golfers to get to the course, probably causes much larger negative impacts on the environment than the positive impacts of constructing a golf course in an extensive managed landscape, at least in a larger ecosystem view (Foley et al*.*, 2005). Both the golf and agriculture industry give the locals work and income, but the end product is in a different manner. When farming you contribute to the food security in the world (ibid.). In a larger ecosystem point of view the best thing for the environment would be if more conventional plantations could be converted to be organic and to ensure more of the benefits for the locals. Still, some might have the opinion that the job and economic growth need to increase before nature can be considered, which makes it a conflict of interest and also an ideological conflict.

However, subjects like these are to be further investigated. Considering the golf course as an ecosystem itself or as part in a larger ecosystem might have impact on how the management should be done. More powerful interferences might be necessary to make improvements in a larger perspective, but the effects of improvements for the environment at a local scale hopefully could make up a stable ground with effects that could proliferate to adjacent areas.

EM

Considering the results there is a positive attitude concerning the will to reduce the use of chemicals at the golf course. For example there is a wish to use compost tea as a complement or alternative to present fertilizers in use. Former studies show that compost and EM could be used together with satisfying results that significantly increased biomass, grain yields, and straw and grain nutrition in wheat (Hu & Qi, 2012). Since wheat belongs to the grass family (Poaceae), it might also enhance the possibilities for satisfying results at the golf course turf. Another aspect to take into account is that the current pH-value in the soil at The Dunes Course is between 7-8 and the fermentative process that EM creates should lead to a lowered pH with conditions that are disfavored by pathogens. Also, a higher temperature is more suitable for the activity and growth of microorganisms (Singh & Mishra, 2013). This suggests chances would be greater for the EM technique to show positive results at The Dunes Course, compared to the golf courses in Sweden.

EM could contribute to a reduced chemical use by improving the quality of the soil, thereby strengthening the protection against pathogens and causing the roots to grow further down. This will make it easier for the greens to restore nutrients, which will reduce the need of fertilizers (Higa & Parr, 1994). If the possible effects of EM would be accomplished, it would also decrease the need of machines applying the chemicals, which in turn would reduce the fuel use and indirectly reduce greenhouse gas emissions to the atmosphere. The potential for golf courses to work as soil carbon pools should also improve if EM were applied, since the culture contains several microorganisms that contribute to increased fixation of carbon dioxide (Higa & Parr, 1994; Sing & Mishra, 2013; Wheeler & Nauright, 2006).

Though e.g., pests and climate may differ, golf courses are generally constructed in similar ways and the problems are usually comparable (Hawtree, 2005). The challenge often consists in keeping the course in a playable condition without too much impact on the environment (Dodson, 2000; SGF, 1999). Thatch is among the most common issues for golf course managers, since it generates drainage problems that initiate irregular growing greens and fungal diseases (Jan Röed, 2014; Will Righton, 2014). EM could contribute to a natural breakdown of the thatch by its decomposing abilities (Higa, 1991; Higa & Parr, 1994), which would make expensive methods like oxygen improvement unnecessary. If the thatch gets reduced, the insects connected to it would decrease as well, since a lot of the problem insects depend on the thatch for digging and nesting (Potter & Braman, 1991).

Strengthening the existing ecosystem in ways that are more organic should make it both more sustainable and more profitable than conventional short-term measures (Higa & Wididana, 1991; Pimentel et al., 2005). Conventional methods might get quick responses but in the long term it might lead to depleted landscapes (Foley et al., 2005). Biodiversity is as critical for the soil ecosystem as for any other ecosystem to improve resilience (Higa & Parr, 1994). Improving the soil microbial activities should increase the potential for a sustainable soil ecosystem since a well functioning microflora in the soil could contribute to a larger heterogeneity. This in turn could contribute to synergy effects, improving biodiversity in a wider perspective (Colding, 2006; Higa & Parr, 1994; Wagg et al*.,* 2014).

Conclusions

Proposed Measures

This study suggests the following measures for environmental improvements of The Dunes Course:

- Reduce the use of conventional pesticides and fertilizers as much as possible.
- Reduce the management on the roughs further, if possible.
- Make an inventory at the non-playable areas for a nature conservation plan.
- Gather residues of grass, branches and brushwood for compost and/or for animals.
- Leave dead trees, fallen logs and snags to improve existence for insects and birds.
- Place out nesting boxes.
- Mow the roughs and non-playable areas after the flowering season if possible, to improve pollination.
- Increase the education and information about the golf course environmental improvements for the employees and the golfers, for example by creating information signs at the course.
- Measure the leaching to prevent and make plans for future fertilize usage.
- Try to make the vision about fuel change to biodiesel realized to reduce greenhouse gas emissions.
- Initiate an EM trial (perhaps together with compost tea).

EM Trial

There are no particular signs indicating that a trial with EM at The Dunes Course should *not* work, but there is insufficient research done in general concerning EM at golf courses to give adequate predictions. However, since EM has the ability to effect fundamental processes like soil quality, the technique make a great potential to have impact in several of the environmental adaptions at The Dunes Course. Improved soil quality would reduce the need of pesticides and fertilizers, which could lead to increased biodiversity and a more sustainable ecosystem.

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Figures

Figure 1. Will Righton, 2014-05-13, Head of Golf Course Agronomy at The Dunes Course.
Figure 2. Will Righton, 2014-05-13, Head of Golf Course Agronomy at The Dunes Course.
Figure 3. Google Earth. The southwest of Messinia, Greece. 2014-06-26.

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