Climate Change and Scottish Golf Courses

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Cover Photograph: The sky captured as it was on 11th June 2004 by Allan Roberts (Skipton, North Yorkshire)

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INTRODUCTION

The climate is the overriding influence on the conditioning, playing quality and presentation of the golf course.

The extremes of weather experienced in recent years have posed new and significant problems for golf clubs, relating to the presentation and playability of courses. In the worst cases it has had a negative effect on the financial health of many clubs. In view of the latest climate change predictions, it seems likely this trend will continue unless appropriate action is taken.

To minimise the impact of these climate change predictions, it is important that the decision makers at every golf club in Scotland appreciate the climatic changes that are occurring, understand the potential impacts on their course and develop long-term management strategies which adapt to those changes. They should:

- Evaluate the potential effects of climate change on the playing quality and agronomic condition of the course.
- Devise, adapt and implement sustainable management strategies to minimise the threat of climate change on the course, as recommended by The R&A, SGU, SEPA and the Scottish Executive.
- Devise long-term plans to provide direction and continuity, which may include appropriate investment in staff and modern turf maintenance machinery to implement adequate cultural and mechanical operations.
- Communicate to golfers the importance and rationale behind these sustainable maintenance practices.

This report describes the changes we are likely to experience and the potential impacts they will have on golf courses in Scotland. It provides best practice advice on how to minimise these impacts. A checklist is provided at the end of each chapter to enable decision makers to quickly assess where action is required on their course.

Providing and, more importantly, implementing best practice advice on minimising the impact of climate change will help retain and, possibly, improve the turf condition and playing quality of golf courses for future generations. It will also play a part in ensuring that Scotland’s golf courses are managed as effectively and efficiently as possible.

1

Climate Change

1 Climate Change

1.1 WHAT IS CLIMATE CHANGE?

Climate refers to the average weather experienced in a region over a long period, typically thirty years. This includes temperature, wind and rainfall patterns. Our climate is not static and has changed many times in the past in response to a variety of natural causes.

These changes in global climate are due to a combination of natural and human causes. The climate varies naturally as a result of interactions between the ocean and the atmosphere, changes in the Earth's orbit, fluctuations in energy received from the sun and volcanic eruptions. The main human influence on global climate is through emissions of greenhouse gases such as carbon dioxide and methane, i.e. the greenhouse effect. At present, approximately 6.5 billion tonnes of carbon are emitted globally into the atmosphere each year, mostly through the combustion of coal, oil and gas for energy. Changes in land use result in a further net annual emission of between 1 and 2 billion tonnes of carbon. Increasing concentrations of so-called greenhouse gases in the atmosphere over the last two hundred years have trapped more energy in the lower atmosphere, thereby altering global climate. Changes in global climate drive changes in national and regional climates.

The Intergovernmental Panel on Climate Change (IPCC) concluded in their Third Assessment Report that, *"...most of the warming observed over the last 50 years is likely to have been due to increasing concentrations of greenhouse gases."* Essentially, the activity of man has been the overriding influence in the climate changes we have seen over this period of time.

In April 2002, the Department for Environment, Food and Rural Affairs (DEFRA) for the UK Climate Impacts Programme (UKCIP) published the latest predictions regarding climate change in a document entitled "Climate Change Scenarios for the United Kingdom" (see **www.ukcip02.org.uk/scenarios**). The UKCIP02 scenarios are the most detailed and accurate yet as they are based on new global CO_2 emissions scenarios published in 2000 by the IPCC in their Special Report on Emissions Scenarios. The scenarios describe four alternative climates for the UK, labelled Low, Medium-Low, Medium-High and High for the periods up until 2020, 2050 and 2080. There is no probability attached to these four scenarios, i.e. one is considered no more likely than any other.

1.2 OUR PAST AND FUTURE CLIMATE

Some will doubt the reality of "Climate Change", putting the changes down to natural weather cycles. However, over the past couple of decades we have experienced definite changes in weather patterns, with wetter, milder conditions being the clearest aspect. To highlight these changes, data collated from the Met Office (**www.metoffice.co.uk**) shows the differences experienced between 1970-2000 for rainfall (Figure 1) and raindays (Figure 2), and 1999-2003 for maximum and minimum temperature (Figure 3), against the 1961-1990 averages. Regional differences can be ascertained as the Met Office has divided the country into north, west and east.

The climate change predictions suggest a continuation of these trends towards warmer, wetter autumns and winters and hotter, drier summers. The main predictions through to 2080, made in the document entitled "Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report", are summarised below.

Past rainfall changes

Over the period 1970-2000, the whole of Scotland received 9% more rainfall during late autumn to early spring (October-March inclusive) compared to the period 1961-1990, with biggest differences experienced through the winter period (December-February inclusive); February receiving 16% more rainfall. There is a regional difference, with the west receiving 10% more rain, the north 9% and the east 7%. Summer rainfall (April-September inclusive) decreased by 3% across all regions of Scotland, with greatest reductions being noted in May and August, with 8% less rain in both these months. Recent years have seen extremely wet winters, e.g. between October-March 1999/2000 there was 90% more rain in the west compared to the 1961-1990 average. In contrast, there have also been extremely dry summers, such as 2003, when 40% less rain fell during April-September in the east.

Past rainday changes

Across Scotland there have been 3% more raindays (i.e. the number of days receiving more than 1 mm of rain) each late autumn to early spring (October-March), during the period 1971-2000 compared to 1961-1990; with most of these being concentrated between February and March. In the summer, there has been a 3% reduction in raindays, with most of these concentrated into the months of May, August and September. During the winter, the extra average rainfall is not due to an increase in raindays, but an increase in the intensity of rain on each rainday, i.e. when it rains, it rains harder. Conversely, the reduction in raindays may account for the reduction in summer rainfall.

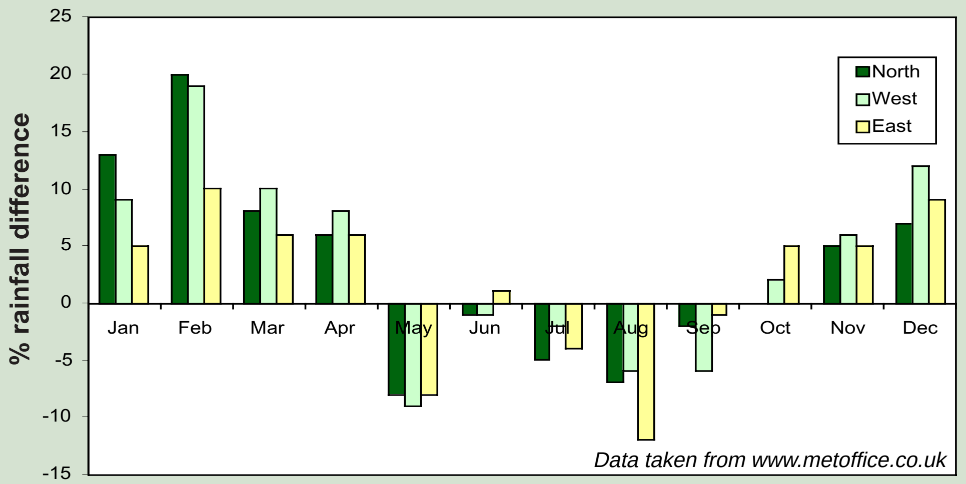


FIGURE 1. The regional percentage difference in mean monthly rainfall (mm) between 1961-1990 compared to 1971-2000 in Scotland.

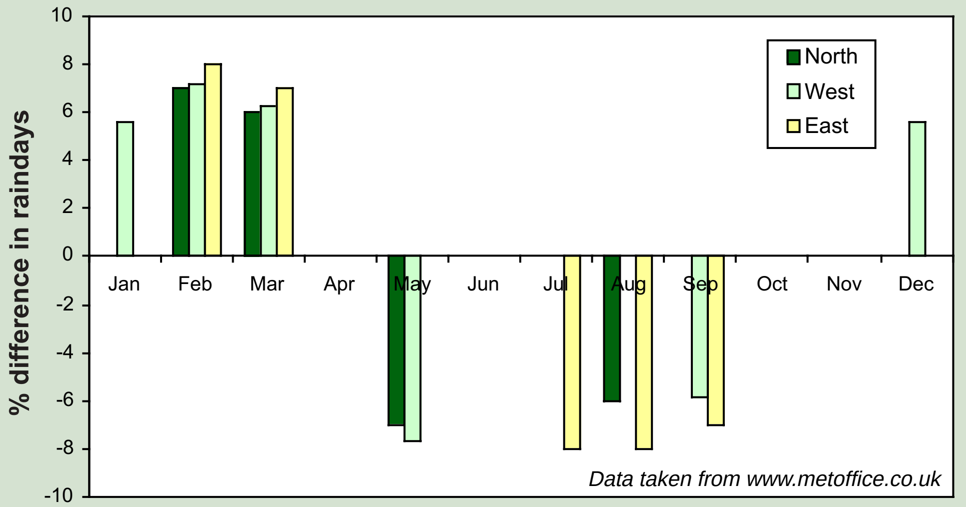


FIGURE 2. The regional percentage difference in mean monthly raindays (>1 mm per day) between 1961-1990 compared to 1971-2000 in Scotland.

Future precipitation predictions

- Average annual rainfall across the UK will remain at current levels or reduce slightly.
- Winters will become wetter by approximately 5-15% for the Low Emissions scenario and more than 30% for the Medium-High or High Emissions scenario. Very wet winters like 1994/95 may occur on average almost once every decade for the Medium-High Emissions scenario.
- Summers will become substantially drier by approximately 20% for the Low Emissions scenario, rising to more than 40% for the High Emissions scenario. Very dry summers, e.g. 1995, may occur on average every other year by the 2080s for the Medium-High Emissions scenario.
- Spring precipitation will decrease over inland areas of the UK, with more modest decreases around coastal areas. Autumn displays a strong southeast-northwest gradient across the UK, with the southeast drying by between 5-20% (depending upon the scenario) and the northwest of Scotland increasing slightly under all scenarios.
- The greatest percentage changes in winter and summer precipitation are likely to be experienced in the eastern and southern parts of the country, with northwest Scotland experiencing the least change.
- The intensity of winter precipitation will increase. By the 2080s, heavy winter precipitation intensities currently experienced once every two years or so may become between 5% (Low Emissions) and 20% (High Emissions) heavier. This will result in more flood occurrences.
- Snowfall amounts will decrease throughout the UK, with average snowfall over Scotland being 60-90% less (depending on region) by the 2080s for the High Emissions scenario.

Past temperature changes

Throughout Scotland the average annual maximum temperature has increased by 1.0ºC over the period 1999-2003, compared to 1961-1990, with 1.1ºC, 1.0ºC and 0.8ºC increases experienced in the north, west and east respectively. The greatest increases in average monthly maximum temperatures have been experienced during November (1.6ºC) and May (1.2ºC), the smallest increases during June (0.5ºC) and October (0.3ºC). Minimum temperatures have increased by 0.73ºC across Scotland, with 0.8ºC, 0.6ºC and 0.8ºC increases experienced in the north, west and east respectively. There have also been extreme monthly increases, e.g. a 2.4ºC increase, in maximum temperature and a 2.1ºC increase in minimum temperature for November 2003 in the north.

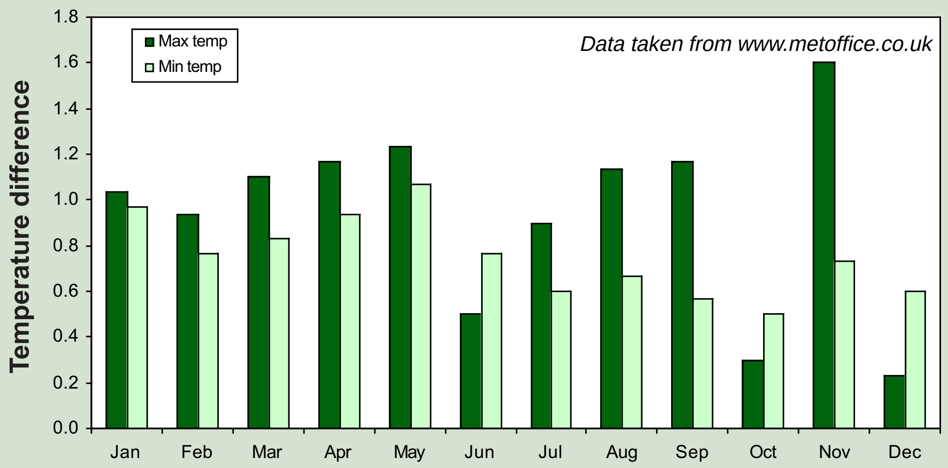


FIGURE 3. The difference in maximum and minimum temperature between 1961-1990 compared to 1999-2003 in Scotland.

Future temperature predictions

- The UK climate will become warmer, with average temperatures increasing by approximately 2.0-3.5ºC. Each decade, the warming may vary across the UK by 0.1-0.3ºC for the Low Emissions scenario compared to 0.3-0.5ºC for the High Emissions scenario. In general, there will be greater warming in the southeast than the northwest. Furthermore, there may be greater warming in the summer and autumn than in the spring and winter.
- High summer temperatures will become more frequent and very cold winters will become increasingly rare. There will also be more 'extreme' high temperature days, e.g. the probability of the Scottish Highlands receiving one day with a temperature of 23ºC will increase from 1% to 15% by 2080.

- This increase in temperature will increase the 'thermal growing season' for plants thus continuing the trend of recent years (since 1900 the growing season has increased by one month). By the 2050s, typical spring temperatures may occur between one and three weeks earlier than at present and the onset of present winter temperatures may be delayed by a similar time period.

Future soil moisture predictions

- Higher temperatures and lower summer rainfall are predicted to reduce average soil moisture across the UK. The southeast will be most affected, with reductions of 40% for the High Emission scenario and 20% for the Low Emission scenario.
- In the winter, there will be an increase in soil moisture for all scenarios in Scotland.

Future sea level predictions

- Relative sea level will continue to rise around most of the UK's shoreline. By the 2080s, sea level may be between 2 cm (Low Emissions) below and 58 cm (High Emissions) above the current level in western Scotland, but between 26 cm and 86 cm above the current level in southeast England.
- High sea levels will be experienced more frequently. For the east coast, a water level that at present has a 2% probability of occurring in any given year may have a probability of 33% by the 2080s for the Medium-High Emissions scenario.

1.3 NATURAL VARIABILITY

We can expect to see long-term warming in the summer and winter, with wetter winters and drier summers. However, it is vital to remember there will be much variability in the day-to-day, year-to-year and decade-to-decade weather we experience. This means there may be long periods in the future that show relatively little warming, or perhaps even cooling for a few years. There may also be trends in precipitation over a few years which are opposite to what we expect, e.g. the wet summer of 2002. New records will not be set every year, or even every decade, but a few records may fall in consecutive years.

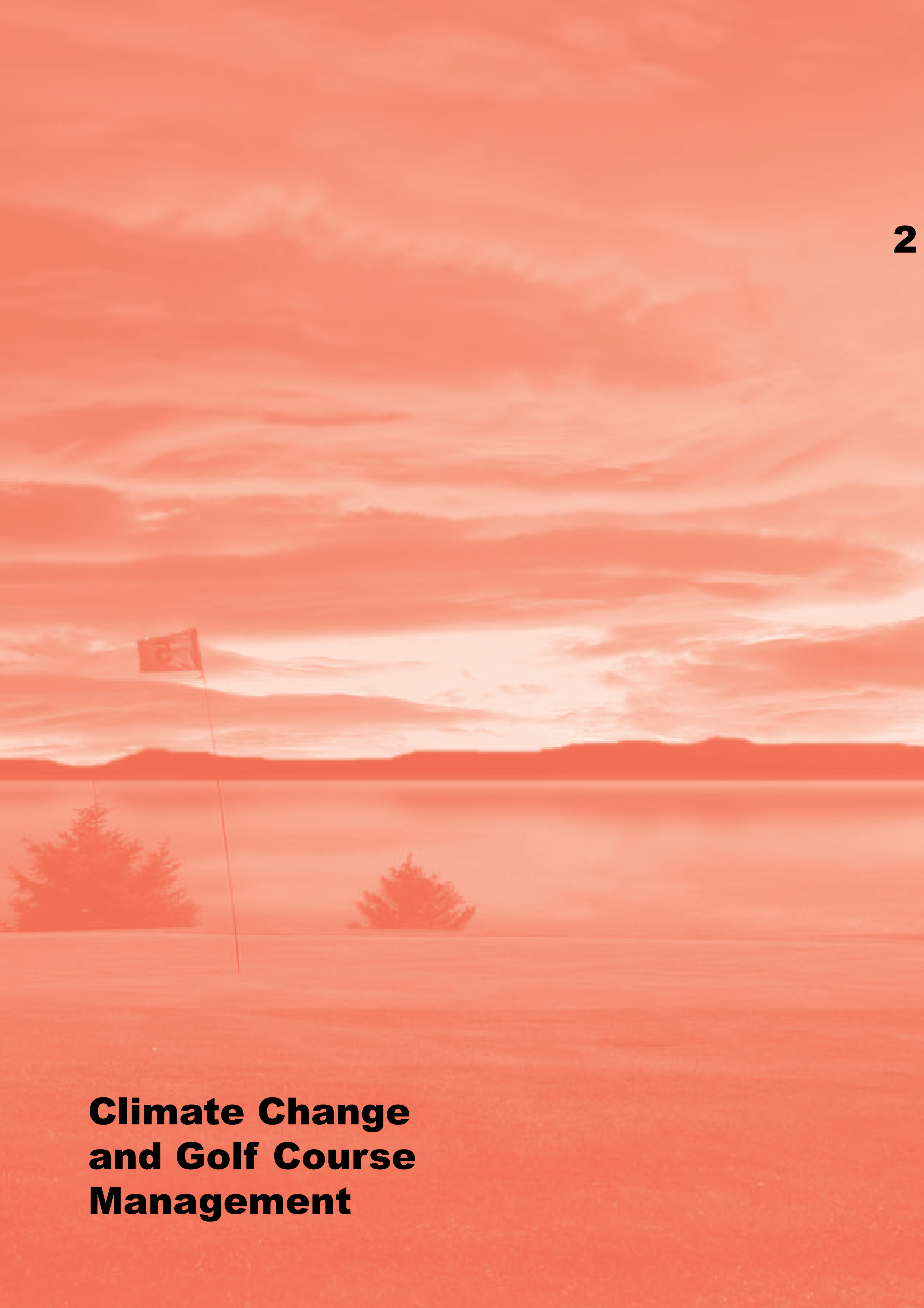
1.4 BE PREPARED

Some degree of climate change by 2080 has already been determined by historic emissions and the inertia of the climate system and we will have to adapt to some change in climate regardless of whether the amount of emissions are reduced now or in the future. Even if global emissions fall below today's level, as assumed in the Low Emissions scenario, the future rate of global warming this century may be about four times that experienced during the last century due to historic emissions. If the rate of emissions rises to approximately four times today's level, as assumed in the High Emissions scenario, the future warming may be about eight times that experienced in the last century.

In order to ensure your club is best placed to overcome the risks of climate change and create new opportunities, its decision makers should heed the following advice from Barbara Young, Chief Executive of the Environment Agency, *"...some climate change is already inevitable, so we will need to adapt."*

1.4 CHECKLIST: Climate Change

- Ensure your club is aware of recent climate changes.
- Scotland has recently seen more extremely wet winters and extremely dry summers.
- Scotland has received 9% more rainfall in the autumn and winter and 3% less rainfall in the summer and spring over the past thirty years.
- Total annual rainfall will stay constant. However, autumns and winters will become wetter with more days of intense rainfall, thus more flood occurrences, and summers and springs will become drier.
- Temperatures have become warmer by 1.0ºC during the period 1999-2003 compared to the period between 1961-1990.
- In the future, the climate will become warmer. Each decade will see an increase of 0.1-0.5ºC, with hotter summers and milder winters, which will increase the growing season of plants.
- Sea levels will rise.
- The climate has changed and will continue to change—be prepared to adapt.



2

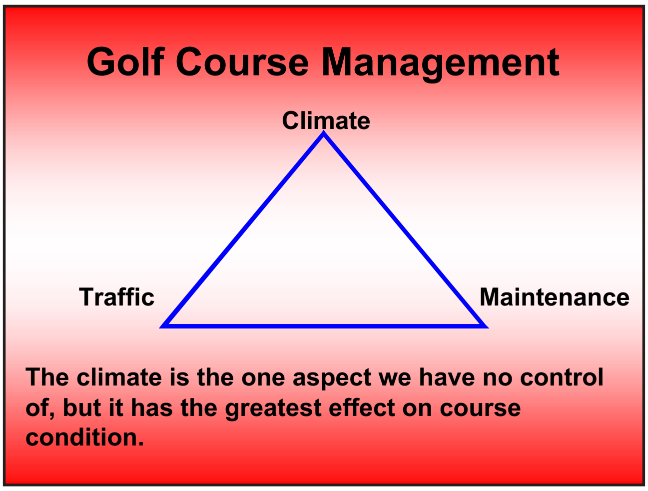
Climate Change and Golf Course Management

2 Climate Change and Golf Course Management

2.1 CLIMATE CHANGE AND GOLF COURSE MANAGEMENT

Regardless of course type, the aims of course management are:

- To produce firm, smooth, true putting surfaces of an acceptable pace using sustainable management strategies.
- To produce consistent and playable surfaces for as long as possible through the year.
- Through the greens, these principles still apply but the main emphasis is on surface firmness, durability and resilience, rather than smoothness and pace.
- Outwith these areas, the rough on our courses frames the playing surfaces, characterises the course and 'finishes' the golfing environment; the greater the biodiversity of the rough—the more pleasurable the golfing environment.



Producing and maintaining such playing surfaces requires great skill from greenstaff, using appropriate procedures at the correct time of the year. As golf is played outdoors, playing quality and presentation are affected by many things. However, the overriding influences on golf course management can be described as:

- Climate
- Maintenance
- Traffic

We have some control over maintenance and traffic inputs. For instance, maintenance intensities are determined by the amount of staff, machinery and materials, time on the golf course and the efficiency of the maintenance crew. Traffic levels can be controlled by setting the interval between tee-off times, limiting the number of visitor rounds and limiting the number of members, etc. However, we have no such influence over the climate. For this reason, the climate has the greatest influence on the presentation and playing quality of the golf course at any particular moment in time.

Dealing with short, medium and long-term weather patterns is a critical element of the course manager's professional duty, which is going to be increasingly important as we experience more climatic extremes. Therefore, the course management programme must be sufficiently flexible, proactive and yet reactive to climatic conditions to optimise playing surface condition and performance.

2.2 PREDICTING THE IMPACT

Golf facilities are well placed to predict the impact of climate change as they have experienced some of the predicted negative effects over the past decade. We are therefore in a position to predict:

What the impacts of climate change, both positive and negative, will be on the playing quality and agronomic condition of specific parts of the course.

Impacts need to be considered for:

- Greens
- Green approaches and fairways
- Tees
- Rough
- Bunkers

When considering responses to these impacts, management strategies can be targeted towards:

- Water management, i.e. drainage and irrigation
- Species selection/promotion
- Disease and pest management
- Fertiliser management

Throughout this report reference will be made as to how specific areas of the course will be affected by climate change, with particular attention to the impact on the playing quality and agronomic condition of each area.

2.3 ADOPTING BEST PRACTICE

Climate change will have many impacts on the management and maintenance of Scottish golf courses in the future, but it is impossible to predict exactly what will happen. It is also not possible, in this report, to prescribe a specific management programme for each course. However, it is possible to suggest principles and broad strategies on how specific threats can be minimised whilst maximising turf health.

The basic principles follow the best practice guidelines described by The R&A on their website **www.bestcourseforgolf.org**. In this report, these guidelines will be described in more detail, with particular emphasis on the requirement for their adoption to overcome the threat from climate change.

2.4 CHECKLIST: Climate Change and Golf Course Management

- Climate change will impact upon golf course management.
- Make sure your club is aware what the impacts will be on your course.
- Establish/predict the effect climate change will have on course maintenance and traffic.

3

Basic Principles of Turf Management

3 Basic Principles of Turf Management

3.1 TRADITIONAL AND SUSTAINABLE GREENKEEPING PRINCIPLES

Golf was developed in Scotland and is where the art of greenkeeping was born. Ever since, the theories and principles of good greenkeeping have barely changed, except of course the standard, efficiency, frequency and quality of the practices that are implemented. Such traditional principles are based upon cultural and mechanical operations to produce turf surfaces on which to play golf. These principles have stood the test of time and will always do so, as long as they are correctly adhered to in the future.

The implementation of traditional greenkeeping principles will ensure the turf surface that is produced is done so in the most economically sustainable and environmentally friendly manner possible, i.e. with minimal inputs of fertiliser, water and pesticides. By doing this, we are producing playing surfaces that fulfil the requirements of golfers as well as ensuring the turf is best adapted to climatic extremes—a very important attribute considering the changes we have seen and will continue to see.

Producing turf playing surfaces in a sustainable and environmentally sound manner relies upon the correct management of the soil/turf system by cultural and mechanical operations. It is the aim of this chapter to describe the basic principles of sustainable turf management.

3.2 THE IMPACT OF CLIMATE CHANGE ON GOLF COURSE MANAGEMENT

The maintenance of the golf course is complex and requires a great deal of skill to produce the surface that golfers desire. Invariably, the implementation of one maintenance task has knock-on effects to the playing quality and agronomic condition of the turf. For instance, aeration improves drainage and underfoot firmness as well as improving root development and drought tolerance.

Any change in the weather is likely to have effects on turf condition and playing quality. For instance, wetter/milder autumns and winters will result in greater moisture retention on the turf/in the soil, which will encourage more disease activity as well as softer surfaces.

Some aspects of climate change, in certain degrees, may have beneficial effects on the playing quality or turf condition of our golf courses. For example, drier summer weather will help present firmer golf courses. This is exemplified by the excellent summer condition of many courses during 2003. However, extremes of dry weather will cause difficulties in retaining turf health and uniformity.

3.3 SPECIES SELECTION

Golf, especially putting, is extraordinarily sensitive to the quality of turf that it is performed upon. There is overwhelming evidence to suggest that blends of fine-leaved browntop bent (*Agrostis capillaris*) with fescues, i.e. Chewings fescue (*Festuca rubra* ssp. *commutata*) and slender creeping red fescue (*Festuca rubra* ssp. *litoralis*, also known as ssp. *trichophylla*), provide the best playing surfaces for golf and fulfil the demands of economic and environmental sustainability on golf courses. Best practice dictates that management programmes should be designed to favour these species.

Under the terms of environmental and economic sustainability, and with the prospect of climate change, annual meadow-grass (*Poa annua*) is not a sustainable grass and best practice will always aim to minimise its presence in any sward. However, some courses which are based on heavy soil and receive high levels of play will find it more difficult to produce turf dominated by these desirable species, but, if sustainable and sensible greenkeeping principles are adhered to, the finer grasses are promoted and a healthier turf results. A sward more capable of coping with the extremes of wet and dry weather is thus produced and the threat of climate change is minimised.

In certain circumstances away from putting surfaces, such as areas of concentrated wear, other species can be introduced such as smooth-stalked meadow-grass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*).

TABLE 1. Comparison of bent and fescue versus annual meadow-grass and the desirability of their promotion with regard to future climate change predictions.

Bent and fescue		Annual meadow-grass	
Attribute	**Desirability**	**Attribute**	**Desirability**
Deeper root development	Better drought tolerance, thus less irrigation requirement.	Shallow root development	More drought susceptible, increased irrigation and fertiliser requirement.
Greater disease tolerance, especially against fusarium	Less scarring, less loss in surface uniformity and less fungicide applications.	More disease susceptible, especially to fusarium	More scarring, more uniformity loss and more fungicide applications.
Slower growth rates	Less thatch accumulations, thus less removal operations required and firmer surfaces.	More rapid growth rates	More rapid thatch accumulations, thus more removal operations required and softer surfaces.

3.4 SOIL MANAGEMENT

To produce the desirable conditions for fine grasses and healthy turf to thrive, it is essential to manage the growing medium correctly.

Theoretically, a unit volume of an ideal soil should comprise approximately 50% solid matter, 25% air and 25% water. Water and air are found in the pore spaces between the solid particles and it is through this network of pores that drainage and root growth occur.

Any compression of the pore space will adversely affect drainage and root development. This is known as compaction and is an inevitable consequence of play and traffic. To alleviate this compaction, aeration must be undertaken. This creates fissures and cracks in the soil which correct any imbalance in the air/water ratio in the soil pores, improving water infiltration and root development. This in turn enhances drainage through the soil and drought tolerance of the turf. Furthermore, a well-aerated soil will support a strong microbial population, which helps optimise nutrient cycling (via the nitrogen cycle) and the digestion of organic matter (thatch).

3.5 THATCH MANAGEMENT

Thatch is an organic material which naturally accumulates to the turf base as a result of the continuous process of senescence and death of grass leaves, stems, shoots and roots. Microbial action breaks down this organic 'litter', but when the production of dead plant tissue exceeds microbial digestion, thatch accumulates. Thatch decomposition is inhibited by anaerobic conditions, such as those that occur in compacted or waterlogged soils.

Thatch absorbs and holds water in a similar manner to a sponge, thus reducing drainage. Dense/thick accumulations of thatch will result in soft conditions underfoot.

Moisture and nutrient retention in the spongy thatch encourages shallow root development. In periods of dry weather, thatch dries out and becomes very difficult to re-wet—similar to a peat-based potting compost. This combination of effects increases the drought susceptibility of the turf and the occurrence of hydrophobic dry patch, both of which have a negative impact on surface uniformity and playing quality.

Image 1. *Thatch layers in a soil profile under a putting green.*

TABLE 2. The negative effect of excessive thatch and compaction on the playing quality and agronomic condition of golf courses.

Thatch		Compaction	
Playing quality	**Agronomic effect**	**Playing quality**	**Agronomic effect**
Soft, spongy underfoot conditions when wet. Hard, unreceptive surfaces when dry. Reduces turf uniformity and smoothness when wet and dry.	Harbour for disease pathogens, e.g. fusarium patch (*Microdochium nivale*). Promotes shallow root development, favouring annual meadow-grass over desirable species. Reduces drought tolerance of turf and increases hydrophobic dry patch incidence, thus uniformity loss of sward.	Inconsistency of turf vigour, firmness and thus receptiveness to the golf ball. Hard when dry, soft when wet. Poor moisture penetration leads to prolonged wetness following rain and inconsistent penetration of rain/ irrigation water.	Poor, weak grass growth. Shallow root development, thus increased requirement for fertiliser and water input. Increased thatch accumulation. Annual meadow-grass (*Poa annua*) promotion.

3.6 THE RELATIONSHIP BETWEEN THATCH AND COMPACTION

From Table 2 we can see the agronomic and playing quality problems caused by thatch and compaction. Many of the problems are interrelated, e.g. compaction causes wet soils, which in turn results in more rapid thatch accumulation. To ensure playing surfaces are best adapted to climate change, thatch accumulations must be minimised and compaction should be adequately alleviated.

3.7 WATER MANAGEMENT

The production of quality putting surfaces is largely reliant upon getting soil water management right. If we get it wrong, play will not be sustained in wet periods, as playing surfaces will be excessively soft. Conversely, in dry periods the turf will become droughted and surface uniformity or even grass cover will be lost.

Maintenance operations that are designed to improve drainage also enhance root development/depth and the infiltration of water (from rain or irrigation), thus increasing the drought tolerance of the turf. Optimising irrigation efficiency promotes healthy turf.

3.8 INFLUENCES ON WATER MANAGEMENT

There are many influences on water management. Each different influence can affect the quality and turf condition of all the playing surfaces on the golf course. The main influences are described below.

Severely contoured surfaces are problematic to maintain in dry periods, as retaining grass cover on these more drought-prone areas is more difficult.

Soil condition

Many courses throughout Scotland, particularly those situated inland, have been built upon heavy soil or even clay. Such soils drain slowly which often results in surfaces to become soft in wet weather. Wet soils promote more rapid thatch production which further accentuates surface softness. With the climate predictions and the requirement for year-round play in mind, these types of courses are particularly vulnerable to the prediction of wetter autumns and winters.

Topography/situation

The design of some courses, or playing surfaces, means that they naturally hold water, or receive water from the surrounding higher ground. Concave or cut and fill greens are good examples. Such surfaces cause problems in wet periods.

Courses that are built on floodplains are also vulnerable during wet winter weather, as rivers are more likely to flood.

Image 2. *This clay pot was constructed from material beneath an Edinburgh green! Its concave shape and poor drainage qualities replicate many putting greens through Scotland. It also highlights the slow drainage rates of clay soils.*

Thatch and compaction

The main threats to the production of free-draining, healthy year-round surfaces is the presence of excessive thatch and soil compaction. The implementation of sound thatch and compaction management operations is essential to minimise the impact of climate change.

Traffic

Compression of air spaces in the soil results in compaction. Play leads to compaction. For example, one four ball results in over five hundred footprints across one green (with most being concentrated into a 6 foot radius from the pin; *Pelz Putting Bible* 2002).

As our autumns and winters are likely to become milder, our golf courses may well receive more year-round play, thus more foot traffic and more compaction. Without sufficient compaction alleviation, the soil will become consolidated, drainage will be impaired and turf health will be reduced. With wetter winter weather, this compaction effect will be accentuated.

Compacted soils limit the depth and density of root development, so turf growing on such soils is more likely to become drought stressed during dry periods.

Shade

Air movement across playing surfaces greatly increases evaporation. In sunny conditions, such water loss is further increased through the process of evapotranspiration. Given the threat of wetter autumns and winters, it is essential that the drying effects of the wind and sun be optimised on golfing surfaces. The presence of trees or dense vegetation close to playing surfaces (mainly greens and tees) can compromise this and result in surface moisture retention, poor root development and softer surfaces.

In predicted hotter, drier summers the process of evapotranspiration will help to cool the grass plant and reduce stress, but dense vegetation, interrupting airflow, can restrict this process.

Image 3. *Heavy traffic results in soil compaction and poor turf health, as seen on this walk-on/walk-off area.*

Image 4. *Shade results in more moisture retention in the soil and on the surface which leads to greater compaction, thatch development, softer surfaces and increased disease activity.*

3.9 DISEASE/PEST MANAGEMENT

Milder, wetter autumn and winter conditions may result in playing surfaces, especially greens and tees, experiencing a wider range of fungal diseases, or more frequent attacks of diseases and greater problems from pest damage, particularly from worm casting.

3.10 FERTILISER AND IRRIGATION MANAGEMENT

Fertiliser is applied to present a playing surface of good quality and provide adequate growth to encourage recovery from wear and tear. Irrigation is required to retain turf uniformity during periods of dry weather. Our aim with fertiliser application and irrigation should always be to minimise supply to achieve adequate growth and retain surface uniformity. Applying water and fertiliser to produce green, lush surfaces should never be allowed as this will promote annual meadow-grass, more rapid thatch production and poor quality, soft surfaces.

3.11 CHECKLIST: The Principles of Turf Management

- Ensure traditional principles of greenkeeping, involving cultural and mechanical operations with minimal use of pesticides, fertiliser and water, are adhered to at all times on your course.
- Understand the need to manage the soil/turf system correctly to produce the desired playing surfaces and minimise the impacts of climate change in the future.
- Ensure appropriate soil compaction and thatch management techniques are adopted to promote good drainage, strong root development and healthy turf.
- Be aware of the desirability of the finer grasses over annual meadow-grass in their adaptation to climatic extremes. Always look to minimise the amount of annual meadow-grass in the sward by appropriate management techniques.
- Understand the different influences on water management and the importance of getting it right in order to optimise the performance of the playing surface and health of the turf.
- Always minimise fertiliser and water application.

4

Greens

4 Greens

4.1 MANAGEMENT OBJECTIVES

Greens are the most important areas on the course and should receive the most maintenance. Our aim must be to produce a surface that is firm underfoot and refined to enable the ball to roll fast, smooth and true.

Now golf has evolved into a year-round game, it is no longer acceptable for the golfer to be playing to temporary greens for extended periods. The promotion of firm, free-draining surfaces, available year round (bar frost and snow) should therefore be a fundamental objective for clubs.

4.2 THE IMPACT OF CLIMATE CHANGE ON PUTTING GREENS

Wetter, milder autumns and winters

Wetter weather is likely to result in putting surfaces to be softer underfoot and could result in more regular green closure. This scenario is more likely if excessive accumulations of thatch are present beneath the greens or soil compaction is a problem as drainage rates will be reduced.

As the soils beneath the greens will contain more moisture during periods of wet weather, they will be more prone to compaction and surface sealing which both reduce drainage rates. With milder autumns and winters, it is likely there may be more play which will accentuate this problem.

Soils that contain more moisture take longer to warm up in the spring which means early season growth rates and the production of summer surfaces will be less rapid.

Compacted and wet soils encourage the ingress, or proliferation of annual meadow-grass and moisture-loving species such as moss and toad rush.

Milder, wetter autumn and winter conditions may result in putting greens experiencing a wider range of fungal diseases or more frequent attacks of diseases. Disease activity such as fusarium patch, anthracnose and take-all patch can have devastating effects on putting greens as dense, smooth, evenly textured turf can be severely compromised by disease scars. Turf dominated by annual meadow-grass and surfaces supporting excessive accumulations of thatch and soil compaction will be more susceptible to disease attack. For a description of the symptoms of the main diseases and their prevalence on putting surfaces please refer to Section 11.2—Disease monitoring.

Image 5. *Wetter, milder autumns and winters will place greater importance on effective greens drainage.*

Hotter, drier summers and springs

Hotter and drier weather will have a positive impact on the playing quality of putting greens, as the surfaces will be firmer underfoot, will grow less rapidly, produce less thatch and be less susceptible to disease outbreaks. However, during extended dry periods it is likely there will be more drought stress on the turf which will affect surface uniformity and, in severe cases, may result in turf loss. In order to combat these effects, more regular irrigation will be required.

Image 6. *Hotter, drier summers will increase the need for irrigation and may threaten the uniformity of putting surfaces.*

TABLE 3. The likely outcome of future climate change predictions on the playing quality and agronomic condition of putting greens.

Prediction	Positive impact		Negative impact	
	Playing quality	Agronomic effect	Playing quality	Agronomic effect
Wetter autumns/ winters	• None	• None	• Softer surfaces. • Standing water. • Green closure. • Muddy conditions. • More pitch marks. • Poorer spring condition and greater time for greens to reach summer condition.	• More compaction. • More rapid thatch accumulation. • More turf disease. • Increased sealing of surface. • Reduction in turf health. • Annual meadow-grass promotion. • Moss ingress
Milder autumns/ winters	• More play. • Longer playing season.	• Longer growing season. • More growth. • More recovery.	• More disruption to surfaces from disease scars. • More wear	• More pest and disease activity. • Greater variety of disease and more severe attacks. • More compaction. • More thatch accumulation. • More wear. • Annual meadow-grass promotion.
Drier summers	• Firmer surfaces. • More play. • More pleasurable play. • Less summer closure. • Better presentation.	• Aids promotion of fine grasses. • Slower growth. • Less thatch accumu-lation. • More rapid thatch digestion.	• Reduction in uniformity and quality of surface from drought in terms of receptiveness and trueness.	• More turf stress. • More stress on annual meadow-grass. • Greater irrigation requirement. • More signs of wear.
Less frost and snow	• Less winter green closure. • More play.	• Reduction in ice damage to turf. • Reduction in disease activity beneath snow. • Reduced risk of foot damage on frosted greens.	• More wear.	• More pest and disease activity. • Greater variety of disease and more severe attacks. • More compaction. • More thatch • Annual meadow-grass promotion.

4.3 CHECKLIST: The Impact on Greens

- Climate change will have positive and negative impacts on the year-round playing quality of putting surfaces. To optimise the positive impacts and minimise the negative impacts, appropriate adaptation of maintenance (both intensity and type) and play is required.
- Identify how climate change will affect the year-round playing quality of your greens, and then adapt the greens management package accordingly to minimise its impact.
- Greens management objectives should be to promote firm, free-draining surfaces that run smooth and true.

5

Adapting Greens Management

5 Adapting Greens Management

5.1 MAINTAINING TRADITIONAL QUALITY

Maintaining turf in the traditional way promotes sustainably firm, fast, smooth and true putting surfaces for as long as possible through the year. By doing this, a deep-rooted, healthy turf is produced that grows slowly and produces a firm surface. Furthermore, limited amounts of organic matter (thatch) are produced and resistance against disease is relatively high.

Adapting to Climate Change?

FOLLOW THE BIG SIX

Minimal water
Minimal fertiliser
Plenty of aeration
Plenty of top dressing
Optimise the growing environment
Implement sustainable surface refinement

Promote finer grasses and strong, healthy turf

5.2 SUFFICIENT AERATION

Aeration is vital and is the most important turf management operation to undertake. Implementing the correct balance of aeration treatments will alleviate compaction, thereby improving drainage and ensuring deep root development. Consequently, surfaces will be firm during periods of wet weather and turf will be more tolerant of drought in dry weather.

Aeration also optimises the effects of other maintenance tasks, e.g. fertiliser and water application. For example, regular summer aeration will ensure that water will be able to penetrate into the soil. In this way, water is more likely to reach the turfgrass roots and less is wasted in run-off or evaporation.

Increasing the air in the soil profile increases the amount of beneficial soil microbes, which are important in nutrient cycling (i.e. the nitrogen cycle) and the digestion of thatch.

The actual amount of aeration required is dependent upon many factors such as the weather conditions, type of soil and the amount of play. It is also course, or even green, specific. For instance, an inland course based on heavy soil with 50,000 rounds of golf per year will require more aeration than a free-draining sandy links which receives less than 20,000 a year.

TABLE 4. The positive effect aeration has on the playing quality and agronomic condition of golf greens.

Playing quality	Agronomic effect
• Promotes firmer surfaces. • Promotes greater uniformity. • Reduces disease scarring. • Improves drainage. • Extends playing season.	• Relieves compaction. • Promotes deep root development. • Promotes strong, healthy turf. • Increases microbial activity, helping digest thatch. • Promotes finer grasses. • Reduces fertiliser and irrigation input. • Increases infiltration of rain/irrigation water. • Minimises thatch accumulation.

Image 7. *Scarification removes thatch from the upper soil profile. This fairly new concept, known as linear aeration, affects a larger surface area than coring.*

Image 8. *Hollow core aeration physically removes plugs of thatch.*

Image 9. *The value of aeration. Fresh, deeper root development and better drainage.*

Aeration should be seen as a package of treatments, which incorporates forms of scarification and top dressing. The objectives of an aeration programme are to improve the oxygen balance of the rootzone, to optimise sward health and improve drainage. Different forms of aeration will be required at various depths to achieve these objectives.

Aeration should be considered a year-round operation, with some minimally disruptive aeration being achieved during the main playing season. Historically, when equipment to achieve this was not available, aeration tended to involve using large tines during the late autumn and winter months, which resulted in inconsistency in surfaces, great seasonal variation in root development and significant surface disruption.

The correct timing of aeration should ensure the maximum benefits of the operation are achieved, but at the same time the least possible disruption to golf. Many clubs are now choosing to implement the main autumn aeration operations earlier in the year (i.e. spring, midsummer or late summer/early autumn) to fulfil these aims.

Case Study

Early aeration work—Hilton Park Golf Club

In the past, the greenstaff at Hilton Park have always hollow cored their greens during mid-late October at the end of the main playing season. Unfortunately, at this time of the year the weather is often wet and growth rates have slowed significantly. Consequently, sub-optimal results from the work were obtained and recovery was slow—sometimes the holes remaining open at the surface well into the spring.

The Course Manager, Mr. John Robertson, with the backing of the Club, decided to move this operation to Glasgow Fair week in July as the course at this time is relatively quiet. Ten millimetre tines were used and all greens were cored and top dressed in two days with four staff, allowing the rest of the team to continue more general course maintenance.

The results were excellent. Recovery was rapid; it only took two weeks to restore the surfaces to normal summer condition. The turf was invigorated going into the late summer and autumn period and surfaces remained smoother and firmer through the late autumn and winter months. However, it is the reaction of the members which gives a true measure of the success of this switch in timing as they have requested this to be a permanent feature of the green maintenance calendar.

5.3 SUFFICIENT TOP DRESSING

Top dressing is another fundamental part of greens maintenance for the following reasons:

TABLE 5. The positive effects of top dressing on the playing quality and agronomic condition of golf greens.

Playing quality	Agronomic effect
• Promotes firmer surfaces. • Improves surface smoothness and trueness. • Improves drainage.	• Dilutes thatch accumulations. • Increases depth of quality growing medium. • Increases infiltration rate of rain/irrigation water. • Knock-on effects of deeper root development, healthy turf promotion and less disease activity.

Top dressing should be undertaken in conjunction with aeration, scarification or verticutting to ensure the fresh material is integrated into the soil profile. Failure to do this may result in layering to the soil profile, which affects moisture movement and root development.

The selection of top dressing material is very important and should follow the guidelines outlined below:

- Select material that is compatible with the underlying growing medium. Do not use material that is finer or more water retentive than the underlying growing medium. For instance, on sand-based greens, built to USGA recommendations, the top dressing material should consist of sand with the same particle size as the underlying rootzone. When top dressing greens built on indigenous soil, a material dominated by medium grade (0.25-0.5 mm) sand should be used.
- Ensure the applied material is consistent from one application to the next so a uniform soil profile develops. Remember, the top dressing of today is the rootzone of tomorrow. To ensure quality, ask for specification sheets from your supplier and regularly test the material at an approved independent laboratory.
- Be careful with the amount of organic matter in the mix, as too much will result in surface water retention and soft surfaces.
- If pure sand is used, stick to this policy and do not revert back to a more moisture retentive material.

It is important to apply top dressing at the right time:

- Only apply material when there is growth. This will ensure the dressing can be absorbed. Applications outside the growing season may smother the turf and/or promote sappy growth, both of which can result in disease activity.
- Apply at a rate to match the rate of turf growth and thatch accumulation. This will avoid layers developing in the profile which will affect even moisture movement and root development through the profile. This will require light but frequent applications.
- Avoid applications that exceed the growth rate of the turf (i.e. too heavy a treatment when turf growth is slow) and applying material during periods of turf stress, as this may result in turf thinning and loss of uniformity. This is especially important during periods of drought.

The amount of top dressing applied is dependent upon the specific objective, the rate of turf growth and the composition of the underlying material. For instance, inland parkland courses on indigenous heavy soil should be applying in the region of 80-100 tonnes of top dressing to all eighteen greens each year. Unfortunately, this is often compromised due to a lack of appropriate machinery, resources and cost. However, clubs that do achieve regular top dressing and hit this target have better, firmer, smoother playing surfaces for longer through the year. Links courses may apply less, but nonetheless at rates that match the growth rate of the turf. Under such circumstances, these applications are often considered a smoothing operation rather than rootzone improvement.

Image 10. *Top dressing using a spinning disc top dresser. Such equipment has made it easier to apply more frequent, lighter dressings and minimised disruption to play.*

5.4 MINIMAL FERTILISER APPLICATION

Why apply fertiliser?

Regular removal of clippings by mowing removes plant tissue and stimulates more rapid growth. The grass plant needs to regenerate the lost tissue. Energy from photosynthesis contributes to this regeneration capability but the plant also has to take on board other nutrients. All soils have some natural nutrient reserve but this is not adequate to sustain the growth rates that are necessary to support the mowing frequency applied to the closer cut areas of the golf course such as greens, green surrounds and tees. This is why additional feeding of the turf is required.

Nutrient requirements

Nitrogen (N), phosphate (P) and potassium (K) are the major nutrients that support most growth functions and the metabolism of the growing plant. These three nutrients have differing levels of mobility (i.e. the rate of leaching) within different types of soil.

Nitrogen is by far and hence the most mobile nutrient of the group, phosphate virtually immobile in most instances, with potassium somewhere in between. Soils with a high clay, silt or organic content hold onto nutrients more readily than sandy soils. High mobility equals more rapid loss through the soil system by leaching. This is why in any fertiliser programme nitrogen is the most commonly, and sometimes only, added nutrient.

In most cases, all other nutrients including phosphate and so-called micronutrients such as calcium, iron, magnesium and sulphur are obtained in adequate quantities via the atmosphere, weathering of mineral material or decay of organic matter. To USGA or other high sand content constructions in which natural nutrient reserves are low, there may be a need for occasional inputs of nutrients other than nitrogen that leach through the soil profile rapidly, e.g. potassium and magnesium.

In the context of predicted climate change, it is even more important to stick to these principles of minimal inputs as there will be far more agronomic damage from over-feeding than from under-supply. If you aim to supply the minimum requirement, you can always add a little extra when needed. Once fertiliser is applied you cannot take it away. Some of the consequences of over-feeding are shown in Table 6. From these effects, it is clear to see why the application of fertiliser should be minimised in order to respond effectively to the threat of climate change.

Fertiliser programmes

The type of fertiliser used, the amount of fertiliser applied and the timing of application will be dependent on many factors, but there are a few basic principles that should be followed.

Source of component nutrients

- This is often overlooked but will affect the reaction of the turf and could, over long-term use, radically alter soil chemistry. For example, to acidify the soil to help control disease and annual meadow-grass ingress, an acidifying source of nitrogen such as sulphate of ammonia should be used. However, it is possible to develop too acid a soil through the use of such fertilisers which can result in a weak-rooted turf that struggles to grow well in the spring. There are fertilisers based on neutral and alkaline nitrogen sources which can be useful for stabilising or raising pH, but beware of the latter course of action as too rapid a rise can lead to increased problems with annual meadow-grass, disease incidence, weed ingress and worm casting. High sand-content rootzones have far less of a buffering capacity against fluctuations in pH (i.e. pH changes occur more rapidly) which has implications not only for those managing such constructions, but also those building up a depth of sandy material above indigenous soil.
- The type of nutrient in a fertiliser such as organic or inorganic, along with other aspects of the product such as biodegradable coatings, will determine the longevity of release of the nutrient. Sources therefore should be selected to meet each courses/greens specific requirements. Timescales should also be taken into account here; is an immediate response required, or a longer term more gradual effect? Note that microbial activity and/or temperature/moisture may affect the nutrient gain to the plant from controlled release products.

Rates of application

Always avoid applying too much and always look to minimise growth, otherwise you are simply wasting time and money.

A 'light and often' fertiliser regime may provide the most consistent results, with liquid formulations at the appropriate time offering the simplest means of supplying the nutrients that the turf requires.

Annual application rates vary considerably and are dependent upon turf composition, type of construction, amount of play and weather conditions.

Time of application

Only apply fertiliser in calm and dry conditions to avoid loss to wind or run-off. Avoid applying fertiliser in very dry conditions as some can scorch unless watered in.

A balanced diet

Nitrogen will always be the main nutrient required in a turf fertiliser regime. There will be a need for other supplemental feeding from time to time, e.g. potassium is known to provide a degree of disease resistance and manganese has been cited as being of potential benefit in the control of take-all patch.

Depending on your situation, devise a balanced programme using inorganic and organic sources of nitrogen. Use different formulations, powder or granular when a growth boost is required, possibly turning to liquid over the main summer period.

Use chemical soil analysis to monitor pH and nutrient status over the long-term. A single analysis tells you little; it is the fluctuations in the trends of nutrient levels and pH that cause variation in turf quality and vigour.

TABLE 6. The potential agronomic and playing quality impacts of excessive fertiliser application to putting surfaces.

Playing quality	Agronomic effect
• Soft surfaces. • Slow surfaces. • More disease scars.	• More rapid thatch accumulation. • Increased maintenance inputs to deal with thatch. • Lush, sappy growth which is more susceptible to disease attack. • Shoot growth at the expense of root development. • Greater requirement for irrigation. • Less durable and wear resistant turf. • Propensity to shave the turf to obtain decent pace which is not sustainable.

5.5 MINIMISING IRRIGATION APPLICATION

The adaptation of sound aeration, fertiliser and top dressing programmes will increase the natural tolerance of turf to drought and minimise the need for irrigation. Overwatering will lead to shallow-rooted turf which increases the need for more regular applications of water. A classic 'vicious circle'. This management will promote the growth of annual meadow-grass (*Poa annua*), resulting in all the problems associated with this species.

Why irrigate?

During dry summer periods, water losses from the soil can be as high as 3.5 mm a day through evapotranspiration. When there is no rainfall to compensate for this, soil moisture reserves become depleted which can result in drought-stressed turf and a decline in surface quality/uniformity. In extreme cases, grass can be lost. In prolonged dry periods the application of irrigation water by artificial means is required to maintain turf uniformity as well as ensuring the turf can withstand wear.

How much to apply

Maintaining soil moisture levels somewhere between field capacity (constant saturation) and the permanent wilting point (drought stress) should be the aim. A visual assessment of the turf and/or the moisture content of the soil is the most common way of determining whether irrigation is needed and is reliant on the experience of the individual turf manager. More scientific methods involve the use of a water balance sheet (essentially a profit/loss account, with losses through evapotranspiration and gains through natural precipitation/irrigation), or the use of tensiometers, which give an indication of soil moisture tension (i.e. the amount of work which grass roots must do to extract water from the soil).

Image 11. *A lack of adequate irrigation can result in a reduction in turf uniformity or, even worse, turf loss.*

The ability to correctly calculate the irrigation input is necessary to maintain a quality sward and conserve water. The amount of water given at any one application should retain moisture in the top 150 mm or so of the soil profile. This may need applications on a daily basis or at two to three day intervals (longer intervals in less droughty conditions), allowing a period in between for the surface 50-75 mm to dry out slightly and let in air.

It is very important when irrigating to ensure the rate of water application does not exceed the infiltration rate of the turf. If it does, run-off occurs which wastes an increasingly valuable resource and needlessly increases maintenance costs. Thatch management, regular aeration and sensible use of wetting agents ensure the rapid and uniform infiltration of water into the turf.

When to irrigate

Watering during the heat of the day will lead to greater evaporation losses. The best time to water is during the late evening or overnight. Watering at this time means play is not interfered with and the soil has had time to dry out slightly before play commences. In periods of intense heat, occasional and extremely light irrigation during the day may be called for to help cool down the turf. This operation, often referred to as 'syringing', is currently rare in Scotland, but may become more common given the prediction of warmer, drier summers.

Irrigation water source

As mains water becomes more expensive, more sustainable and less expensive sources of water for irrigation are required. This may involve obtaining water from:

- Underground aquifers
- Streams and rivers
- Recycled water, i.e. waste water from the clubhouse
- Harvested rainfall
- Drainage systems

Water from underground aquifers and rivers/streams is cheaper than mains water, but such sources do not provide a finite supply. Future licensing is likely to impose stricter regulation on the abstraction of such water, especially during drought periods when it will be needed most. The most sustainable source of water for irrigation is recycled water from rainfall and drainage systems. Ideally, the water from such sources should be harvested and stored on the course in lagoons or ponds for subsequent use in the summer. Linking any course drainage systems into new or existing water stores will further enhance the efficiency and sustainability of these systems. With wetter, milder autumns and winters and hotter, drier summers predicted this approach will have to be considered by those having the land to accommodate such a storage facility.

Image 12. *The construction of winter storage ponds will provide a more sustainable irrigation supply in the future, at the same time as providing useful outlets for drainage systems.*

Water quality

Before any water is used, especially from aquifers or recycled sources, it is vital to test its quality in a laboratory. This should cover:

- pH
- Alkalinity
- Salinity
- Industrial/agricultural pollution

If water quality of the source is an issue, corrective measures are possible, e.g. action can be taken to reduce alkalinity by the installation of acid injection systems.

Automatic irrigation systems

Many clubs have automatic irrigation systems on greens and tees and some have them on fairways. If correctly maintained and operated, these provide an efficient means of water application. However, when using these systems the following guidelines should be adopted:

- It is vital they are not overused as this will result in soft surfaces, more compaction and annual meadow-grass promotion. It is imperative the demands of golfers to water greens to enhance receptiveness or colour is strongly resisted.
- Sufficient hand watering of areas prone to drought may reduce the need for larger scale irrigation to the whole surface, thus minimising the wider use of the automatic system. By doing this, surface firmness, uniformity and playing quality are optimised and water use is minimised. If the automatic system is relied upon to supply sufficient water to higher, more elevated areas or areas that are more prone to droughting, too much water will be supplied to lower, receptive areas, resulting in the development of soft, over-watered areas.
- Minimise irrigation application by using water injection machines to ensure water reaches the roots. This operation is especially useful on links courses.
- Service and maintain systems regularly to optimise performance.

Image 13. *Irrigation systems are an efficient means of supplying water to greens, but it is essential they are not overused.*

5.6 DISEASE MANAGEMENT

The climate change predictions of milder, wetter autumns and winters are likely to increase the incidence of disease on putting surfaces, resulting in more scarring which will reduce playing quality.

To minimise this threat, it is vital action is taken to reduce the potential for disease to occur. Achieve this by promoting year-round healthy turf and the finer grasses such as bent and fescue which are far more resistant to disease. The conditions that promote disease, i.e. poor drainage, turf stress, shade and excessive thatch accumulations, are addressed by implementing the 'BIG SIX'.

5.7 PESTICIDE USAGE

What is a pesticide?

The Food and Environmental Protection Act (1985) defines a pesticide as any substance, preparation or organism prepared or used, among other uses, to protect plants or wood or other plant products from harmful organisms; to regulate the growth of plants; to give protection against harmful creatures; or to render such creatures harmless. The term pesticide has a very broad definition which embraces herbicides, fungicides, insecticides, rodenticides, lumbricides, soil-sterilants, wood preservatives and surface biocides among others.

Pesticide application—a last resort

On the golf course, the application of a pesticide should be considered a last resort and made only after appropriate cultural control methods have been implemented. By adopting good agronomic practices to promote a strong, healthy turf, the need for pesticide application will be minimised.

Pesticide legislation

If pesticide use is deemed to be required, it is imperative current pesticide legislation is strictly adhered to. All employers and employees must be fully aware of their responsibilities under the terms of the current applicable legislation. The main areas covered by legislation are:

- Risk assessment
- Reduction of exposure to hazardous substances
- Recording exposure to hazardous substances
- Information and training
- The protection of the environment
- The safe, effective and humane methods of controlling pests
- The storage of pesticides

Some of the specific issues to address within these broad headings are:

- Employers must ensure employees have received adequate training and are competent to use pesticides. Note: competence means certification.
- No product may be used unless it has been given provisional or full approval on the grounds of safety and efficacy by Government ministers and they have consented to its use.
- Users should take all reasonable precautions to protect the health of human beings, creatures and plants, to safeguard the environment and in particular avoid pollution of water.
- Records on the safe storage, disposal and application of a pesticide should always be made.
- The employer is required to provide appropriate (recommended) protective clothing which must be worn by the employee.
- It is mandatory to follow all the instructions printed on the label of the particular pesticide.

The future of pesticide usage

It is uncertain at present what will happen in terms of future pesticide legislation in Scotland. It cannot be ruled out that severe restrictions in their availability and use will be introduced, as has happened in other parts of Europe (e.g. The Netherlands, Germany and Denmark).

Regardless of this, it is important to overcome any reliance on pesticide application as this is simply unsustainable. What must be reinforced is the need to adopt sensible management strategies designed to promote strong, healthy turf that is more resistant to pest and disease attack. This will prepare for any changes in future pesticide legislation as well as any climate change we may experience.

Case Study

Sustainable management 1—Glencorse Golf Club

Glencorse Golf Club is a mature parkland course on the outskirts of Edinburgh, with natural soil/clay-based greens. Over the past eight or nine years, Mr Ian Bell, the Head Greenkeeper, has improved the quality of the greens by implementing a sound, sensible management strategy.

In 1994, the club received its first advisory report from STRI, in which the greens were reported to be 'over-fertilised and watered'. Consequently, the putting surfaces were excessively soft underfoot due to dense accumulations of thatch (up to 50 mm in places), dominated by annual meadow-grass, suffered regular outbreaks of fusarium patch that required applications of fungicide to limit its damage, and green closure was all too frequent.

Since 1995, the greens have received a far more intensive and sustainable maintenance programme involving more regular aeration and top dressing, in addition to receiving far less fertiliser and irrigation (see Table 7), which has seen a dramatic reduction in disease incidence. Consequently, the members have reported firmer, faster and smoother putting surfaces which sustain far more winter play. Agronomically, the surfaces are now dominated by bentgrass, support better soil structure, minimal thatch accumulations and stronger, deeper root development.

By implementing this sensible programme, the greens will be best able to withstand the effects of climate change, in addition to providing high quality putting surfaces that are environmentally and economically sustainable.

TABLE 7. The reduction in days closed, disease incidence and frequency of fungicide applied by adopting a sensible programme of regular aeration, top dressing and minimal fertiliser application.

	Days greens closed	Disease incidence	Frequency fungicide applied	Frequency aeration	Frequency top dressing	Nitrogen applied (g)
1995	36	7	7	2	2	7.2
1996	24	3	1	2	4	7.2
1997	17	3	2	2	3	7.2
1998	38	1	0	6	3	10.0
1999	33	3	2	7	7	7.2
2000	36	0	0	6	3	8.1
2001	14	0	0	7	5	8.9
2002	16	0	0	7	5	6.8
2003	7	1	0	7	6	4.2

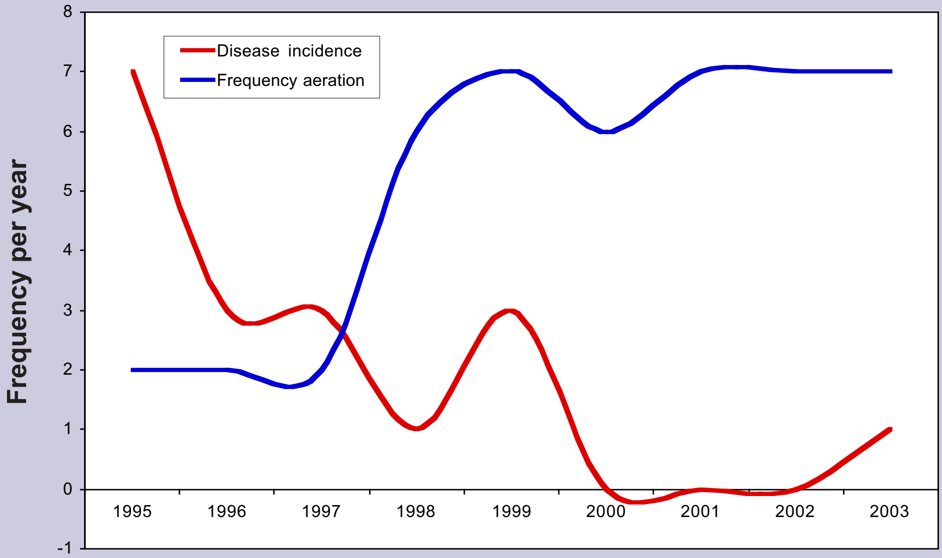


FIGURE 4. The correlation between disease incidence reduction and regular aeration at Glencorse Golf Club.

Case Study

Sustainable management 2—Gullane Golf Club

Gullane Golf Club supports three links golf courses; the No. 1 is a Final Qualifying course for the Open Championship when it is played at Muirfield.

The management programme implemented by the Course Manager, Mr. Paul Seago, and his team promotes the indigenous links grasses by adopting traditional, sustainable and environmentally sound greenkeeping practices.

Maintenance essentially revolves around plenty of aeration and top dressing to promote smooth, true and firm putting surfaces. The main thrust of aeration work is achieved in August when the greens are scarified, micro-tined, overseeded and top dressed. This timing means recovery is rapid and the turf is invigorated going into the autumn and winter months.

Irrigation and fertiliser application is kept to an absolute minimum. Regular hand watering ensures only areas that require water are irrigated. Wetting agents are also applied to ensure rain or irrigation can readily penetrate into the turf. Sulphate of ammonia is the main source of nitrogen applied to the greens to promote the finer grasses. Cutting heights are maintained at sensible levels. Surface refinement involving lightweight rolling and verticutting is implemented to polish the surfaces and provide smooth, true, acceptably paced greens.

This programme is aimed at, and achieves, retention of the native fine grasses which are resistant to common diseases.

5.8 SENSIBLE SURFACE REFINEMENT

As golfers demand yet faster surfaces, there is great pressure on greenkeepers to shave greens to excessively low cutting heights which imparts great stress on the turf. To sustain such low cutting heights, more frequent inputs are required of fertiliser, water and pesticides, especially fungicides as more regular outbreaks of disease are likely. Implementing such techniques provides the ideal conditions for annual meadow-grass to flourish. Consequently, this type of management is environmentally and economically unsustainable. It also compromises the aim of producing putting surfaces that can sustain year-round play.

In order to rise to the challenge of climate change, stricter pesticide legislation and tighter regulation of water usage, it is essential to select sustainable refinement operations to minimise stress on the turf at the same time as fulfilling the requirement of the golfer by providing consistently true and slick putting surfaces. To do this, sensible heights of cut should be selected and modern turf refinement techniques should be utilised, such as rolling, brushing, grooming, top dressing, verticutting and hand mowing.

The following describes these refinement operations in more detail.

Mowing

Height of cut

This directly affects the density and texture of the turf, thus the smoothness and pace of greens. Overly close mowing can scalp and cause turf thinning. Optimum cutting heights are dependent upon the sward species composition, firmness of the surface, resources available (i.e. machinery, staff and time) and design limitations. The objective is to maintain surface uniformity at a height that provides sufficient pace but at the same time does not result in excessive turf stress.

Frequency of cut

The closer turf is mown, the more often you have to cut it to retain consistency of surface. This explains why greens are the most often mown area on the golf course and the rough the least mown. Turf can, of course, be mown too often, although the damage seen is often caused by tyre tracking from machinery rather than the direct effect of the clipping action.

Top dressing

Top dressing helps produce a smooth and true surface which improves green pace and general playing quality.

Rolling

The use of lightweight units has brought rolling back into vogue. Research work in the US has shown no ill-effects on soil or sand-based greens when used appropriately. An initial trial carried out at STRI showed that an extra 10% ball roll was obtained after a double pass across a green. Used correctly, rolling may increase green speed whilst allowing slightly more leaf to be left on the plant, thus reducing stress and minimising inputs of fertiliser and irrigation. Rollers are particularly good for settling the surfaces back down after aeration and for vibrating top dressing off the surface and into the base of the turf.

Image 14. *Using lightweight rollers helps to provide extra pace without stressing the turf.*

Verticutting

Verticutting is essentially vertical mowing. It thins out the sward, improves its texture, removes lateral growth and controls the accumulation of organic matter at the base of the turf. It therefore improves smoothness, firmness and pace. New verticutting units achieve this essential task to a better standard and with more efficiency than older units. Verticutting must be carried out during periods of strong growth to avoid excessive stress and thinning of the turf.

Grooming

Grooming attachments can be fitted to cutting units, allowing greens to be cut and groomed in one operation. The light vertical cutting encourages an upright growth habit and fines down coarser growth which produces faster and smoother greens. Grooming should be limited to periods of strong growth, as overly frequent or aggressive operations weaken the turf. Groomers are not a replacement for verticutting, but should be considered as an additional refinement tool.

Brushing

The positive effects of brushing are often forgotten. The operation makes the grass blades stand up, thereby minimising lateral growth and improving smoothness and pace. This conditioning operation should be more widely used than it currently is on most courses, particularly during times of stress when verticutting and grooming need to be postponed.

5.9 PROMOTING HEALTHY ENVIRONMENTAL CONDITIONS

In some circumstances maintenance operations may not always be sufficient to produce quality surfaces. This is often due to inadequacies in the growing environment around specific greens, e.g:

- Excessive shade and poor air movement across putting surfaces from surrounding dense vegetation and undergrowth.
- Water being shed from surrounding higher ground.
- Heavy, concentrated traffic, i.e. due to limited pin positions, or limited entry and exit points to greens.
- Poor underlying drainage, either from heavy soils or poor green design.

Each of these problems could individually, or collectively, have a negative effect on the playing quality and agronomic condition of your putting surfaces.

In order to sustain play, improve the playing quality of your greens and minimise the threat from climate change, it is important to optimise the growing environment around greens.

Excessive shade and poor air movement

Greens cast in shade often exhibit the following problems:

- Turf more susceptible to wear
- Greater incidence of disease
- Weaker, thinner growth
- More surface moisture retention
- Slower to thaw after frost or snow
- Poorer root development
- Greater drought susceptibility
- More heat stress

Effective tree management will increase the amount of light reaching the turf and air flow across the surface. Priority trees for removal, or pruning, are usually those to the southeast of greens to allow the morning sun to reach the surface and those to the southwest to allow the prevailing wind to blow across the turf.

When planning which trees to remove it is important to recognise the following:

- Advice—consult professional ecologists and arboriculturists before any action is taken. This may also help provide the rationale to your membership for the removal of the trees.
- Planning—decide which trees require removal, or pruning, giving priority to those that reduce the penetration of morning sunlight as well as those that shelter surfaces from the prevailing wind.
- Communication—to avoid controversy inside the clubhouse ensure the reasoning for any removal is clearly understood by your membership.
- Licence—as a general rule you require a licence from the Forestry Commission before you fell growing trees.

Case Study

Tree removal—Milngavie Golf Club

Milngavie Golf Club, to the north of Glasgow, was one of the many clubs seeing the introduction of large-scale, densely packed conifer plantations during the 1960/70s. Unfortunately, the plantations were not thinned appropriately so dense copses, with trees of narrow girth, surround many greens, tees and fairways. This has had a detrimental effect on turf quality, especially on greens where increased disease incidence and softer surfaces have been reported.

To rectify this problem, the Course Manager, Mr. Wallace Wilson, with the support of the club, initiated a programme of tree removal with some excellent results.

One of the best success stories was on the 13th green. Here, trees shaded the green and frequent applications of fungicide were required to keep disease in check. The green was always soft underfoot and closed during periods of wet weather. To counteract the problem, 109 trees were removed and an intensive soil exchange programme was implemented.

Consequently, the health of the turf is much improved, minimal (if any) disease outbreaks have occurred, the surface has remained far firmer underfoot and the green has been closed far less.

Water being shed from surrounding higher ground

Greens that receive surface run-off from surrounding higher ground often exhibit surfaces that are soft underfoot; the wetter soil then results in more rapid thatch accumulation and more disease incidence.

The answer to this problem can be fairly simple, involving the installation of cut-off drainage to intercept water before it reaches the playing surface. Such drains should be installed at the foot of slopes and for full effect catchwater drain trenches should be filled with perme-able material up to 25 mm of ground level. The proximity of the drain to the putting surface may dictate that a turf

Image 15. *Water being shed from surrounding higher ground results in softer playing surfaces.*

cover is maintained above the drain so that play is not interfered with.

Poor underlying drainage/poor green design

For inland courses built on heavy soil, appropriate aeration and top dressing is the first step towards improving their drainage and year-round playing quality.

The combination of more winter play and wetter weather means that additional action may be required to improve the drainage qualities of such greens. By doing this, golfers' demands for firmer year-round surfaces will be fulfilled and a response to climate change will be made. Examples of appropriate action may include:

Gravel and sand banding

This process involves the introduction of free-draining aggregates such as sand, gravel or Lytag at close spacings across the green. To be effective, the bands need to tap a positive drain outlet. Such an approach has been common on fairways and winter games pitches for some time now, but has become increasingly common on putting greens in recent years.

These types of system will improve surface drainage in the short-term, but there is concern regarding their long-term performance. In addition, the lines are likely to show up and disrupt surface uniformity in dry summer weather, and there is also a question mark over their interference with hole cutting and other routine operations such as aeration.

Pipe drainage installation

This operation involves the excavation of drain trenches in the green, followed by the installation of a plastic pipe, free-draining gravel backfill and good quality sandy rootzone. The drains evacuate excess water from the soil beneath the green, i.e. they empty the bathtub. Through their installation, positive responses to aeration and top dressing operations are achieved and firmer, better quality year-round surfaces can result.

When installing drains, it is good practice to cut thin strips of turf from the green where the drains will be situated. The turves should then be stored for replacement after the work has been completed. Drains should be cut using a suitable chained trencher, run on boards to avoid damage to turf around the drain lines. Drain trenches should have a fall of at least 1:200, lead to a positive outlet and be backfilled using quality materials. Once the work is complete, the re-laid turf must be adequately aerated and top dressed to ensure it does not 'cap' or 'seal' the drain. Regular light top dressing will also restore surface levels.

TABLE 8. The advantages and disadvantages of gravel banding greens.

Advantages	Disadvantages
• Inexpensive. • Quick.	• Possible inconsistencies within the surface. • Disruption during installation. • Limitations on future aeration operations and pin positioning. • Short-term solution.

TABLE 9. The advantages and disadvantages of pipe drainage installation on putting surfaces.

Advantages	Disadvantages
• Inexpensive. • Potentially long-term solution. • Non-disruptive in the long-term. • Quick.	• Settlement along drain lines may occur. • Drain lines may dry out in summer. • Can only be done when soil is dry.

Reconstruction and/or redesign

If increased maintenance and drainage installation have failed or are deemed inappropriate, the final step should be green reconstruction. There are various methods of green reconstruction for inland courses not naturally based on sand or gravel. Due to the complex nature of such construction and the extent of available options, best practice would be to consult an experienced agronomist to identify the best type of construction for your course. The size of a green should ideally be 500 m^2.

When designing the green, it is important to ensure that at least 75% of the surface is available for pin placements and high quality materials are used in its construction.

TABLE 10. The advantages and disadvantages of green reconstruction.

Advantages	Disadvantages
• Long-term solution. • Year-round surfaces (bar frost and snow).	• Expensive. • Reconstruction in isolation may lead to inconsistencies with original greens. • High quality, efficient irrigation required. • Different maintenance required.

Case Study

Improving greens drainage—Cowglen Golf Club

Cowglen Golf Club, to the south side of Glasgow, has mainly soil/clay-based greens. Over the past few years, the Course Manager, Mr. Scott Ballantyne, and his staff, have improved the year-round playing quality of the greens by implementing a maintenance programme involving regular aeration and top dressing.

However, some the surfaces showed less of a response to this intensive programme of work. These were closed more regularly in periods of wet weather, were generally softer underfoot, in addition to supporting more rapid thatch accumulation and greater proportions of annual meadow-grass.

Before going to the expense of green reconstruction, it was decided to make one final attempt to improve their quality by the installation of pipe drains. The first hole to receive the work was the 4th, then the 6th, 9th, 11th and 17th.

As the club own their own trenching machine, the operation to install the drains was simple. The design and layout of the optimal drainage system was decided and the turf where the drain lines would be excavated was cut as thinly as possible and removed. The trenches were excavated, pipes, gravel, a blinding layer and rootzone were installed and the original turf replaced over the drain lines. The whole process took a few days and cost less than £1,000 per green.

The result has been very positive, as the greens now remain playable for longer during the year and are barely closed. The surfaces are much firmer and more consistent to the other greens and a far better response from aeration is experienced. Furthermore, due to drier soils, the ingress of bentgrass is already evident.

When installing pipe drains in greens, there is always the concern that drain lines will be evident (especially during dry weather) and surface levels will be disrupted. At Cowglen, neither of these problems were encountered due to the excellent aftercare work once the drains had been installed. Even through 2003's very dry summer the drain lines were not evident. However, it is worth pointing out that the installation of pipe drains into a green without a gravel carpet in the drier east of the country may be more problematic and those installing them into greens should be made aware of the potential problems that may occur.

Case Study

Green reconstruction—Peebles Golf Club

Peebles Golf Club in the Borders has original push-up greens on heavy clay soil. A good quality management programme based on sound principles has been adopted for several years, initially by Mr Donald Menzies, and now by the new Head Greenkeeper, Mr Colin Noble.

Unfortunately, three to four of the greens have shown a less positive response to the implementation of this work. They were always softer underfoot and closed the first, and for the longest, in periods of wet weather. The membership wanted better quality year-round putting surfaces.

Therefore, the club decided to initiate a programme of in-house green reconstruction, following recommendations from STRI to implement the USGA guidelines for putting green construction. Materials were submitted to the laboratory for analysis and once approved were delivered for use. Stone roadways were installed to minimise disruption to the course. Over the past two to three winters, three greens have been rebuilt. A local contractor was commissioned to do the excavation, installation of drains, gravel carpet, blinding layer and rootzone, with the greenstaff undertaking the handwork and the returfing, using the turf from the original greens.

The turf was laid by Christmas on all greens. Due to good aftercare, each green was ready for play again the following April, and consistent surfaces were presented by midsummer. Regular hollow coring is being carried out to ensure the thatch to the original turf is removed and diluted.

As a result of their good drainage, the greens remain open and playable during periods of wet weather in both winter and summer.

As all the work was done in-house, the cost of the construction of each green was kept below £10,000.

It must be remembered that sports turf contractors can also undertake green reconstruction and the full range of options should be explored before making a decision on who will carry out the construction process.

Image 16. ***Green reconstruction underway. Here the rootzone is being placed over the grit blinding layer.***

Heavily concentrated traffic

One of the largest pressures on many courses is the increased popularity of winter golf. With more year-round play, the common traffic routes onto and off greens bear the brunt of this extra traffic. The result is far greater soil compaction, which at best supports weaker/thinner meadow-grass dominated turf, or at worst no turf at all. With milder winters predicted, the likelihood is that winter play will increase. With wetter weather also predicted, the soils on greens will be more prone to compaction which will accentuate these problems.

The four main solutions to tackle these problems are:

- **Alleviating compaction through appropriate aeration operations.**
  It is important for golfers to appreciate that more play necessitates more aeration work.
- **Altering winter and summer traffic routes, both onto and off greens, and also from the green to the next tee.**
  By doing this, wear is spread over a greater area and provides time for the turf to recover. This can be achieved by marking walkways through the use of white lines, ropes and hoops. In addition, other action such as the construction of different winter tees or the rerouting of the course may be a possibility.
- **Maximising the area for pin positions and number of entry and exit points on greens.**
  The number of pin positions and entry and exit points is usually governed by the design of the green and its surrounds. If severe contours, small greens and bunkering around greens reduces the number of entry and exit points, then traffic problems will be accentuated. Initial action should be to undertake aeration and traffic management. If these have been carried out or are not feasible, then a more drastic approach is possibly required. This may involve the reconstruction or redesign of the green to increase the number of pin positions and/or the number of entry and exit points. If greenside bunkering or contouring is the problem, then these will have to be addressed. The aim should be to spread traffic and wear over the largest possible area.
- **Correct repair of pitch marks.**
  There is no doubt pitch marks reduce the playing quality of greens. By bruising the turf, they increase the likelihood of disease incidence. They also provide a gap in the turf for annual meadow-grass to ingress. More play will lead to more pitch marks. Wetter winters will lead to softer surfaces that are more prone to pitch mark damage. To reduce the problems caused by pitch marks, it is imperative for golfers to adhere to the etiquette of the game and repair their pitch marks properly.

If your greens are struggling to cope with the amount of play now, they will suffer even more from the predicted increase in future play.

Image 17. *Traffic management in practice. Notice better turf health inside the ropes compared to outside.*

Image 18. *Pitch marks should be repaired properly at all times.*

Case Study

Traffic management—West Kilbride Golf Club

The links course at West Kilbride is managed traditionally by Mr Jim Paton, the Course Manager, to promote firm, smooth putting surfaces which are dominated by the finer grasses.

Over the past decade, more and more golf has been played during the autumn and winter months at West Kilbride, but during this time many golfers have not wished to play a full eighteen holes. The layout of the course enables golfers to play a loop of six holes, i.e. three out and three back. Consequently, these six holes receive approximately 300-400% more winter traffic compared to the other twelve on the course. This extra play has had a negative effect on turf quality, with thinner turf through the green centres, more pitch mark damage and more meadow-grass being present in the turf compared to the other greens.

In response to this problem, the club this winter (2003/4) has taken the positive step of rerouting the winter course. This action has improved the turf health and quality to the holes formerly used, with denser swards already being noted and far less pitch marks also being evident. As there is a stronger grass cover now, the production of 'summer' surfaces will be more rapid in the spring.

Of course, the layout of West Kilbride lends itself to this rerouting strategy, but it does highlight what can be achieved with a little thought.

In addition to these measures, the club, like many others, has adopted more stringent traffic management strategies around green complexes (i.e. greens, green surrounds and bunkers) by installing ropes around the circumference of these sensitive areas. By doing this, the turf is given a rest which results in better playing surfaces in the spring and summer.

With more winter golf, many courses, especially our fragile links, should adopt such measures.

5.10 CHECKLIST: Adapting Greens Management

- Follow the BIG SIX at all times, as this will ensure you can adapt to a changing climate.
- Evaluate your aeration programme. Ensure sufficient aeration is being implemented for the soil type and level of play when the soil conditions are most conducive to the operation.
- Evaluate your top dressing programme. Ensure the correct quality and consistency of material is applied at the right time of the year, and at the necessary frequency.
- Never over-apply fertiliser. Ensure a strict minimalist policy is adhered to.
- Never over-apply water. Apply only to keep the turf alive and the surface uniform, never to produce soft and receptive green surfaces.
- Evaluate your surface refinement package. Ensure sensible, turf friendly techniques are adopted to minimise turf stress and optimise putting surface performance.
- Evaluate the growing environment around greens and beneath their surface. Remove trees, install cut-off drains, alter traffic routes and improve underlying drainage as necessary to improve growing conditions and optimise year-round playing quality.
- Encourage the finer grasses and healthy turf at all times.

6

Green Approaches and Fairways

6 Green Approaches and Fairways

6.1 MANAGEMENT OBJECTIVES

The traditional Scottish game requires firm, running fairways and approaches, with tight lies to ensure a crisp strike of the ball. In addition, today's golfer demands good presentation. To fulfil these objectives, effective drainage is imperative and a strong, resilient grass cover is required.

6.2 THE IMPACTS OF CLIMATE CHANGE

In recent wet years, saturation of these areas has probably caused the greatest problems to golf clubs as they have been the most common reason for course closure. However, with prolonged dry periods of weather predicted, it is likely we will also see problems caused by drought in the future.

Wetter autumns and winters

Wetter autumn and winter weather over the past few years has resulted in many courses being soft underfoot, causing surfaces to become muddy and poorly presented. In many cases, courses have been closed for extended periods. Although increased rainfall has been experienced for several years now, the big impact on clubs came from the wet summer of 2002. When courses were closed for long periods, competitions were cancelled, fairways were being mown with pedestrian rotary mowers and in some cases were not mown at all.

The summer of 2002 provided clubs with a warning as it highlighted green approaches and fairways to be the playing surfaces that require the most attention to keep the course playable in periods of wet weather.

Drier summers

Over the past few years there have not been too many dry summers, except for 2003. Drier summers will, to some extent, provide positive improvements to the conditioning and playing quality of our fairways and approaches. Drier weather produces firmer surfaces and slower growth which means less mowing.

The greatest impacts from drier summers will stem from more play and thus more compaction on all courses. Extended periods of dry weather will reduce recovery of divot damage, could result in grass loss and the invasion of ephemeral species. Sandy links courses will be the worst affected by these potential problems.

The combined effect of dry summers and wetter autumns may result in the potential for serious surface drainage issues as heavy rainfall meets with hard, impermeable surfaces.

TABLE 11. Impacts of climate change on the playing quality and agronomic condition of approaches and fairways.

Prediction	Positive impact		Negative impact	
	Playing quality	**Agronomic effect**	**Playing quality**	**Agronomic effect**
Wetter autumns/ winters	• None	• None	• Softer surfaces. • Standing water. • Course closure. • Muddy conditions. • More pest activity, especially worm casting.	• More compaction. • More rapid thatch accumulation. • Increased sealing of surface. • Reduction in turf health. • Moss ingress. • Weed ingress. • Poor drainage.
Milder autumns/ winters	• More play. • Longer playing season.	• Longer growing season. • More growth. • More recovery.		• More compaction. • More thatch accumulation. • More wear. • Moss ingress. • More mowing. • More clippings. • More divot damage.
Drier summers	• Firmer surfaces. • More play. • More pleasurable play. • Less summer closure. • Better presentation.	• Slower growth. • Less thatch accumulation. • More rapid thatch digestion.	• Reduction in uniformity and quality of surface from drought.	• Turf loss. • Greater irrigation requirement. • More wear from traffic.

6.3 CHECKLIST: The Impacts on Green Approaches and Fairways

- Your club's fairway and approach management objectives should be to promote firm, running surfaces with tight lies.
- Identify how climate change will affect the year-round playing quality of fairways and approaches and the fulfilment of desired management objectives.
- Make the necessary adaptations to ensure fairways and green approaches are best placed to cope with wetter and drier conditions.

7

Adapting Green Approach and Fairway Management

7 Adapting Green Approach and Fairway Management

7.1 THE ADAPTATION REQUIRED

As firmness, drainage and presentation of these areas are more critical than smoothness and trueness, the main aspects of maintenance required to overcome the threat of climate change on fairways and approaches must be effective soil water management.

Bear in mind, any management should aim to produce firm, free-draining, resilient and well-presented surfaces.

7.2 ADAPTING TO WETTER AUTUMNS AND WINTERS

Over the past few years, course closure has been the result of poor drainage on approaches and fairways rather than greens and tees. The difference in drainage rates on the greens compared to wider areas of the course is simply due to the greens receiving more intensive maintenance work, involving aeration and top dressing. Greens also sometimes have better underlying drainage systems.

In the past, maintenance practices implemented on approaches and fairways generally only involved mowing, occasional slit tine aeration and the odd application of fertiliser. With wetter weather, more traffic and the desire for better year-round surfaces, such simple techniques are no longer sufficient to provide the quality of playing surfaces demanded. As with greens, more intensive maintenance practices must be implemented—the main issue for attention being improved drainage.

Effective drainage of fairways and green approaches is a three-step process and entails:

- Efficient removal of surface water
- Efficient movement of water through the soil
- Efficient evacuation of water from the soil and away from the playing area

In some cases all of these aspects will need attention, but in many cases improving the efficiency and rate of surface water removal may be all that is required.

Images 19 and 20. *Scenes like these have been common on our courses over the past few years.*

Improving surface drainage and water movement through the soil

Surface water retention and soft surfaces are not necessarily due to poor underlying drainage, as many may think. Often, the problem is due to the slow infiltration of water from the surface and through the soil.

Such problems are invariably caused by excessive accumulations of thatch combined with compacted soils. These parts of the course have typically received little maintenance with nothing being done to manage thatch or alleviate compaction. The recent combination of wetter weather, more play and more mowing has highlighted these underlying problems—the result being greater surface water retention.

Thatch holds water like a sponge. On fairways and approaches it is common to see accumulations of 30-50 mm, perhaps even up to 100 mm deep. Usually the soil beneath such accumulations of thatch remains dry when the thatch is saturated, highlighting the lack of water movement through the thatch.

A compacted soil has few air spaces through which water can pass. The more compacted the soil, the slower the drainage will be. Soil compaction has become an increasing problem due to more maintenance traffic, more golf and the limited aeration work undertaken in the past. This is accentuated by the type of heavy soils our fairways are grown on.

Soil compaction and dense thatch accumulations usually go hand-in-hand, as soil compaction reduces drainage through the soil which then results in water becoming trapped in the upper soil profile. A wet soil means microbial digestion of organic matter is reduced which in turn means thatch accumulation is accelerated. Without alleviating the compaction, this process continues. Over a number of years dense thatch accumulates beneath the sward.

Inland courses are not only affected as these symptoms can also be seen on many links courses. The results are similar with softer, stickier playing surfaces being evident.

The solution to the problem is similar to the programme required for excessive thatch accumulation and compaction on greens and is centred around thatch removal (i.e. scarification and hollow coring), aeration and top dressing operations.

Image 21. *Thatch holds water like a sponge, resulting in soft, poorly draining surfaces.*

Image 22. *Compaction restricts water movement through the soil, resulting in poor drainage and the accumulation of thatch.*

There is clearly a logistical problem when considering implementing wider aeration and top dressing work due to the size of the area that requires treatment. However, action must be taken to solve poor surface drainage. It is therefore important for clubs to devise cost-effective and time-efficient solutions to improve surface drainage and enhance year-round playing quality. One such solution would be to focus time and resources into specific 'priority' areas of the course, such as green approaches, fairway landing zones and traffic routes, rather than entire fairways.

Image 23. *12-15 mm fibrous organic matter at the turf base beneath links fairways results in surface moisture retention and softer, less links-like playing surfaces.*

Case Study

Fairway scarification and sanding—Glencorse Golf Club

Dense thatch accumulations and severe water retention across the fairways and approaches have been a problem over the past few wet years at Glencorse Golf Club. Some fairways had supported accumulations of 50 mm, but on average 35 mm of thatch was present.

The Head Greenkeeper, Mr. Ian Bell, and his team initiated a programme of fairway thatch management and sand top dressing to all green approaches and selected fairways.

Scarification was initially undertaken by a contractor, at a cost of £3,000 for 3.6 hectares. The club have now purchased their own machine which has improved the cost effectiveness of the operation. Approximately 160 tonnes of sand is spread annually over six fairways and green approaches, at a cost of £2,300 per year.

As a result of the work, less surface water has been noted on these areas and all green approaches are now considerably firmer underfoot. The key to obtaining further improvement is sustaining this maintenance input which will ensure the existing thatch is removed and replaced with sand top dressing.

Evacuating water from the soil

Many of our inland courses are built on heavy soils with high proportions of silt and clay which means natural percolation is slow. The pH and particle size distribution of the three courses used for the fairway thatch management trial are shown opposite. These can be deemed representative of inland courses in Scotland.

Category	Diameter	Glenbervie	Cowglen	Glencorse
Stones + gravel	>2.0	T	2	0
Very coarse sand	2.0-1.0	2	0	0
Coarse sand	1.0-0.5	5	2	2
Medium sand	0.50-0.25	10	9	9
Fine sand	0.250 0.125	21	20	20
Very fine sand	0.125-0.050	20	18	18
Silt	0.050-0.002	25	29	29
Clay	<0.002	17	22	22
pH		4.9	4.7	5.0

Many inland soils contain high proportions of fines; very fine sand, silt and clay. This can result in slow natural drainage.

When many of our courses were built, some over a hundred years ago, a primitive form of land drainage may have been installed, which may have been perfectly adequate to cope with weather conditions and levels of play. The effectiveness of these drains may have depreciated due to land settlement, tree root blockage, soil contamination, silting up or damage by later irrigation system installation.

In many circumstances, poor drainage may be due to a combination of problems such as dense thatch accumulations, compacted soils and poor or inadequate underlying drainage. If this is the case, pipe drainage is required to evacuate water from the heavily saturated soil but this must be dovetailed with additional maintenance in the form of thatch removal and compaction alleviation to ensure the water can actually reach the drain. For most situations, one without the other will result in only limited improvement.

Clubs considering renewing or upgrading their drainage systems should ensure the problem has been properly identified. For instance, it would be of no benefit to install pipe drainage into an area of ground that is suffering from rising groundwater levels or an area that suffers from surface water run-off when the installation of ditches, swales, etc. would be more beneficial, straightforward and cheaper.

Whatever the problem, the starting point for improving drainage should always involve more surface work, involving thatch removal and compaction alleviation. The continuation of this work will be required even after new drains have been installed.

If a thorough investigation into the drainage problem (perhaps by a qualified drainage consultant) determines water evacuation from the soil is required, the next step should be to consider how the drains will be installed:

Image 24. *Many old clay pipe drains have become blocked.*

Image 25. *Pipe drains being installed using a tractor mounted drainage trencher.*

Image 26. *Using a dedicated drainage trencher produces clean trenches and minimum disruption to the playing surfaces.*

- **Utilise latest equipment**
  Regardless of whether the work is done in-house or by contractor, it is important that good quality equipment is used. In most cases, tracked trenchers will limit disruption and the size of the trench which will minimise the amount of expensive backfill required.

- **Use quality materials and backfill properly**
  Often, the imported material used to backfill the drainage trench is poor and sometimes the previously excavated poor-draining material is put back. This will totally compromise the results obtained as the rate of water movement to the drain will be limited. Quality and approved materials should always be used.

  In most cases the backfill should comprise a 6-9 mm pea gravel to within 150 mm of the surface, followed by a 50 mm deep blinding layer of coarse sand/grit, finished off with 100 mm depth of sandy rootzone/sandy loam. To ensure maximum infiltration and effectiveness from the drains, grass should be established over the trenches with seed, but in some cases turf can be used. If turf is used, it is important sufficient aftercare (e.g. hollow coring) is carried out to avoid the turf sealing the surface of the drain.

- **Lead to a positive outlet**
  Before any system is designed, it is important to find suitable outlets to take water away from the playing surfaces. The more available positive outlets there are, the faster and more effective the drainage system will be. Too few outlets will lead to water backing up the drainage pipe (known as surcharging) which reduces the effectiveness of the system.

  Positive outlets for drainage can take the form of open ditches, wetlands, soakaways and ponds. For soakaways to be successful, the underlying subsoil must be sufficiently permeable for water to percolate away, e.g. chalk or gravel. Open ditches and swales provide very good positive outlets and require no expensive pipework or backfill for construction, making them a most sustainable method of drainage.

  Improving the drainage of the main in-play areas is the priority, so a sensible and cost-effective approach would be to lead drainage water into out of play areas in the rough. This provides local solutions to local drainage problems and minimises the installation of pipework which reduces the cost of drainage.

Image 27. *Backfilling a drainage trench using a purpose made gravel hopper.* Picture courtesy of Souters Sports Ltd.

With the predictions of drier summers and wetter winters, the removal of water in the winter and the re-use of the same water for summer irrigation will provide the most sustainable and cost-effective systems. When designing new drainage systems, such an approach should be considered wherever possible by excavating water storage ponds in appropriate out of play areas and using them as positive outlets for any pipework.

Install to sufficient depth and provide a good fall

Pipe drains should be laid to a uniform minimum fall of 1:200. Installing drains to a shallower fall than 1:200 may result in water backing up along the pipe (surcharging) and silting up.

The use of a laser beam when installing drains ensures a smooth gradient, which is especially useful on undulating ground or when gradients are very gentle.

Drains should be installed to a sufficient depth to avoid damage from surface traffic or subsequent mechanical operations, particularly Verti-Draining. Lateral drains should be no shallower than 450 mm, but 600 mm is probably the optimum depth in terms of cost of excavation, efficiency and backfill. Main carrier drains are normally installed at depths no shallower than 700 mm, with catchwater drains being installed to depths of 1000-1500 mm.

Timing of works

Optimum results from drainage and minimum disruption from installation is obtained during periods when the ground is dry. The summer months or the early autumn are ideal.

Working on wet or saturated soils should be avoided as this will cause more damage from drainage machinery and compaction of the surrounding soil, as well as sealing the side of the trench which will reduce the rate of lateral water movement into the drains.

Mapping drainage

It is important that the location of existing drains is recorded for future decision makers. Modern GPS techniques are very effective at recording drainage lines as they are installed.

Case Study

Drainage installation by contractor—Auchterarder Golf Club

The horrendously wet year of 2002 took its toll on the golf course at Auchterarder, which was closed for ninety-six days, forty-two of which were in the main playing season from April to September. Clearly, this had an impact on the income of the club, with estimations of at least £500 in revenue being lost each weekday the course was closed and £1,000 of revenue being lost each day if the course was closed at weekends.

The holes worst affected were the 7th, 10th and 11th which are based on very heavy clay soils, with dense accumulations of thatch lying beneath the surface. During periods of rain, the soils became saturated resulting in unplayable conditions.

To overcome the problems, the club commissioned a sports turf drainage contractor to install a pipe and secondary (slit) drainage system to these three fairways. To get the best possible results, the club took the proactive action of installing the drains in early September when the soil was relatively dry.

The cost of this work was in the region of £40,000 and was completed with minimal disruption to the golf course.

The improvement from the work has been encouraging, with only two days of golf being lost due to rainfall in 2003. Of course, this year has been much drier but even after heavy rainfall during November to January the drained areas remained relatively firm underfoot and, most importantly, playable. Work to these areas will now involve deep aeration, scarification and sand top dressing to retain optimum performance of the pipe and slit drainage system.

Case Study

In-house drainage installation—Cowglen Golf Club

Several years ago the club rebuilt three new holes. The soil used in their construction was very heavy and, as a result, severe waterlogging through October-April was common. During this period, the holes were closed and the fairways were impossible to maintain. Growth was weak and grass cover was poor.

To rectify the problem, regular Verti-Draining and hollow coring was undertaken, but no discernable improvements were obtained. It was decided to install pipe drains.

Quotes from contractors were provided and the cost to drain two holes amounted to £60,000, with 1 metre of 100 mm lateral drainage costing £11.50. To achieve the work more cost effectively, the Course Manager, Mr Scott Ballantyne, with the support of the club purchased a tractor mounted trencher which cost £10,500 and included a gravel banding unit, chain and gravel hopper. The purchase of the trencher allowed the greenstaff to complete the work during optimum weather and ground conditions and when it suited the maintenance schedule and golfing calendar.

The first project was a par 3 carry. One tractor, mounted with the trencher, and two tractors with trailers were required to do the job. Six members of staff were involved in the operation; one person trenching, two removing the spoil from site, two cleaning the sides and base of the trench and one starting to layout/cut the pipe and make the connections. Once the trenches were cut and the pipes installed, good quality 6-9 mm gravel was placed in the trench which was then finished off with rootzone and seed.

With each successive job, the efficiency and speed of the operation has increased. The first took from December to April to complete 800 metres of drainage; the last on a par 5 fairway took thirteen working days to complete 3000 metres of drainage. In general, 250 metres of drain can be installed per day. The cost per linear metre of drainage is considered to be approximately £2.90, which is a substantial cost saving when compared with quotes from drainage contractors.

The result from all the work has been excellent. The drained fairways are now firmer, grass cover is stronger and winter play is now supported.

Secondary drainage

In areas of concentrated play, the rate of water movement through the soil and to the piped drain can be accelerated by the installation of secondary drainage, involving sand slits and gravel bands. Green approaches and landing zones are primary areas for this work. Sand slits are usually introduced at 60-100 cm spacings and should connect into the aggregate of the underlying pipe drain at 90º to the direction of the pipe run.

After secondary drainage has been installed, sufficient aftercare must be achieved, involving thatch removal, aeration and sand top dressing. Insufficient aftercare is a common cause of deteriorating performance and undermines the initial investment.

7.3 IMPROVING GRASS QUALITY

Many fairways are showing another problem associated with the wetter weather—the ingress of moisture-loving species. These are coarse in nature, difficult to cut and reduce playing quality by providing a 'tufty' lie. Drying out the soil in these areas is the best way to favour the finer grasses. Physical refinement of these coarser species should also be considered by scarification and verticutting. Patches of such species were found in recent fairway thatch trial plots and have nearly been eliminated in one year as a result of scarification work.

Image 28. *Moisture-loving grass species, e.g. Juncus spp. and Deschampsia spp., provide coarse textured turf and poor lies.*

7.4 ADAPTING TO DRIER SUMMERS

Hotter, drier summers will have some positive impacts on the playing quality of golf courses as surfaces will be firmer, growth will be slower and less mowing will be required.

The most profound negative impact is likely to be on links courses—most prominently those on the drier East Coast. The drier summer of 2003 has highlighted some of the potential impacts, with grass being weakened on mounds and south-facing slopes.

To minimise these impacts, ensure the turf is as naturally resistant to drought as possible. Deep and dense root development should be encouraged by sufficient aeration work, involving deep aeration (Verti-Draining) and slit tining during the autumn and winter, with shallower solid tining and surface aeration during the spring and summer. As a result, the finer bent and fescue grasses, which are naturally more resistant to drought, will be promoted. It is also important that any rain or irrigation can penetrate into the ground by keeping the surfaces open through aeration and sensible use of wetting agents. Also consider top dressing with a more moisture-retentive material such as fensoil or compost. This is especially useful in areas where topsoil depths are shallow.

The implementation of such work will minimise the need for irrigation, but as an insurance policy for courses most prone to potential damage, the provision of automatic irrigation to fairways and approaches will avoid droughting of the turf and subsequent loss of turf cover. As with greens, such a system should only be used as a tool to keep the turf alive.

With prolonged periods of drought, similar symptoms may be experienced on inland courses. The most vulnerable courses will be those that support dense accumulations of thatch and compacted soils as root development will be shallow and water penetration into the soil will be impaired. To minimise the impact on these areas, appropriate thatch management and compaction alleviation operations should be implemented which may well negate the need for irrigation.

Case Study

Fairway irrigation installation—Glasgow Golf Club, Gailes Course

This Championship course in Ayrshire is a superb example of a links managed by Mr. Brian Dickson, the Course Manager, in the traditional way to promote firm, running playing surfaces dominated by the finer grasses.

However, over the past decade Glasgow Gailes has seen significant grass loss through the fairways, and resultant poor turf condition, due to the effect of prolonged periods of drought.

The main underlying problem that has made the fairway surfaces vulnerable to drought was shallow depths of organic topsoil, with some places only supporting 25-50 mm over the native sand. Without a means of applying irrigation to these areas in dry weather, they suffered cycles of decline through the summer months. Recovery from divot damage was reliant upon weather conditions and autumn renovation was generally only beneficial in the short term as there was no guarantee of sustaining the sown species in subsequent dry springs. Consequently, the swards contained a high population of ephemeral species such as parsley piert and early hairgrass, in addition to various mosses and sorrel.

To break this boom-and-bust cycle of fairway condition and quality, the club commissioned the installation of a new fairway irrigation system at an approximate cost of £230,000.

Thanks to this significant investment, the club can manage the turf more effectively and overseeding and top dressing programmes can gradually strengthen soil profiles and improve sward composition. Consequently, the content of ephemeral weeds and moss will be reduced and the growth of the traditional links grasses (that are so important to the game) will be encouraged through appropriate use of water, all of which will improve the playing quality of the fairways in the future.

7.5 ADAPTING TO MORE YEAR-ROUND PLAY

One of the major impacts on courses is increasing levels of play due to the desire for more year-round golf. For fairways and approaches this means more divot damage. On inland courses, growth is relatively vigorous and this does not pose such a problem. On slower-growing, more ‘fragile’ links courses, damage from divoting is more problematic. The immediate solution may appear to be an increase in water and fertiliser application or increase the frequency of divot repair. However, the former solution would reduce the agronomic quality of our courses and the latter would not improve autumn, winter and early spring recovery as there will no, or very limited, germination and establishment of seed at this time. Therefore, the preferred option is fairway protection through periods of dormant growth during November-March.

Fairway protection options include:

- Picking from the fairway and placing in the semi-rough.
- Teeing up on the fairways.
- Playing off mats for periods during the winter.
- If resources allow, patch-plugging divots with fresh turf in areas of high wear is another possible alternative.

More play, especially when the course is wetter, also means more compaction. To alleviate this compaction, particularly on traffic routes, regular deep aeration will be required. Retaining grass cover on these high wear areas could be aided with the use of rubber crumb and perhaps overseeding with fine-leaved ryegrass. If rubber crumb is used, it must be applied to a strong grass cover.

Image 29. *More winter play will result in more divot damage. These scars do not recover until growth returns in the spring. However, a longer growing season may help increase recovery rates but this benefit is likely to be offset against milder winters encouraging more winter golf.*

7.6 MORE WORM CASTING

With wetter, milder conditions during the autumn and winter, the trend over recent years of greater worm casting is likely to continue. Perhaps the greatest problems from worm casting occur on fairways, approaches and tees. Excessive worm casting affects the playing quality in the following ways:

- Muddier surfaces.
- Reduction in surface drainage due to casts smearing the surface.
- More opportunities for weed ingress, particularly daisy, as the smeared cast provides an ideal seedbed.

Over the past few years this has worsened due to climate change (see figures collected from the thirty selected trial sites in the research section of this report) and the lack of genuine cost-effective chemical control. The only remaining chemical worm suppressant is the fungicide carbendazim. The regularity of application required and the sheer size of area to be treated makes it a costly operation.

To minimise worm casting in the future, a more culturally based worm casting management programme will be required, which should incorporate the following:

- **Reduce the food source:** Boxing off grass clippings and limiting fertility will reduce the food supply to worms. However, boxing off clippings from large areas such as fairways is impractical for many, not only in terms of time but also due to implications for the disposal of grass clippings. Reduction of thatch and organic matter in the soil by regular aeration and scarification techniques will also reduce the food supply further.
- **Reduce soil pH:** We can manipulate soil pH on alkaline soils by using an acidifying agent such as iron sulphate or, in some circumstances, sulphur. Producing more acidic soil conditions discourages earthworms.
- **Sand top dressing:** The application of sand as top dressing reduces the effects of surface casting. Sand particles are irritable to the worm on passage through its gut. This forces the worm to migrate away from the sand top dressed area, further from the playing surface. In the event of casting, the sandier cast is much easier to disperse. Sanding also has the benefit of diluting thatch, thereby improving surface drainage.
- **Recycled glass top dressing:** Research into the application of recycled glass for top dressing (in a similar manner to sand) is underway and has given some positive interim results. The advantage of this material over sand is reduced cost, in addition to recycled glass being a more sustainable resource. See SGEG Waste Management Toolkit for further reference.
- **Use chemicals where necessary:** Whilst chemical products currently remain available they should be used sensibly and only to high priority areas. Bear in mind that overuse of any chemical is likely to increase the chances of their withdrawal from use.

The best option when controlling worm casting is a combination of the above. However, even with cultural management, climate change may result in increased casting. Whilst it may be possible to limit this to an acceptable level, this may be higher than that currently considered tolerable. Golfers should be prepared for this possible scenario.

Image 30. *Worm casting on fairways has increased.*

7.7 MORE PEST DAMAGE

It is likely we will see more pest damage on our golf courses from leatherjackets, fever fly and chafer grubs in the future. It is uncertain to what extent this increase in pest incidence will be induced directly by climate change and how it could be influenced by potential future insecticide restrictions.

Mild winters will increase the number of larvae that appear in spring and may increase the potential for feeding damage over the winter period as the larvae will remain closer to the surface in milder, frost-free conditions. This will coincide with slow-growing grass prolonging the time taken for recovery.

However, climate change may also reduce outbreaks of insects. Dry periods in late summer and autumn (especially during the egg laying and hatching period) can reduce the population of leatherjackets leading to less damage over the following winter.

It is, therefore, difficult to predict what will happen with regard to pest damage on our golf courses in the future.

The key response must be to implement as many cultural practices as possible to promote deep-rooted, healthy turf to minimise the effect of any pest damage and optimise the recovery rate of the turf.

7.8 CHECKLIST: Adapting Green Approach and Fairway Management

- Assess drainage qualities of your fairways and approaches, identify problem areas and correctly identify causes.
- To enhance drainage, the first step should be to improve surface drainage and water movement through the soil by implementing appropriate thatch removal and dilution measures combined with compaction alleviation. By doing this, sufficient improvements may be realised.
- Correctly identify the need for pipe drainage installation, then install drains using tried and tested techniques and use quality, free-draining aggregate/backfill. Consider less costly, more sustainable options as part of any scheme.
- Compare the feasibility of achieving drainage in-house against using appropriately qualified sports turf drainage contractors.
- Identify areas of your fairways and approaches prone to drought stress/grass loss in periods of prolonged dry weather.
- Implement appropriate action to improve drought tolerance of vulnerable areas and investigate the feasibility of fairway irrigation.
- Assess the potential effect of extra traffic on your course from both increasing summer and winter play.
- Implement course protection measures as necessary, e.g. restrict traffic across sensitive areas and alter summer and winter traffic routes.
- Identify areas of the fairways and approaches that are prone to worm casting and other pests and implement appropriate control measures.

8

Teeing Grounds

8 Teeing Grounds

8.1 MANAGEMENT OBJECTIVES

To promote, firm, free-draining and level playing surfaces that support a dense cover of grass, maintenance should centre on the implementation of good greenkeeping practices that have already been described for the greens. Sufficient aeration, top dressing and surface refinement must be implemented whilst supplying the minimum amounts of fertiliser and irrigation to achieve sufficiently rapid recovery from wear.

8.2 THE IMPACT OF CLIMATE CHANGE ON TEES

The impact of climate change on tees is much the same as for greens. Broadly speaking, the management package should be the same. The only difference is that there will be less emphasis on surface smoothness and trueness as there is less turf to ball contact.

8.3 COPING WITH MORE PLAY

In the summer

It is likely the greatest impact from climate change on tees will arise from greater usage, resulting from more year-round play.

To cope with these pressures, it is important the size of tees is adequate for the amount of play they will receive. For par 3 holes, teeing grounds should be 400-450 m^2; for par 4 and par 5 holes this can be reduced to 300-350 m^2. Where separate tees are provided, the ladies tee should be sufficiently sized at 50 m^2; the general 'box' tee 200 m^2 and the medal tee 100 m^2. Tees should be wide enough to allow for two to three lateral shifts of the tee boxes, and 14-20 metres is considered ideal.

Tee boxes should be moved regularly to spread wear evenly across the surface. Divots should be filled with a soil/seed mix regularly to achieve rapid recovery. Full renovation should be undertaken in the late summer or early autumn to restore a strong grass cover for the following season.

In the winter

It would be most desirable to play off the main tees all year. However, few courses will have such low year-round playing levels or sufficiently big tees to accommodate this. Year-round play on insufficiently sized tees will result in poor spring condition and late season condition. With increasing levels of play combined with drier summers and wetter winters, it is perhaps less likely that the main tees will be able to sustain year-round use.

To cope with these demands, the best approach should be to provide separate winter tees. This has three main benefits:

- To allow early enough closure of the main tees to permit effective renovation.
- To limit further damage to the summer traffic routes, i.e. from green to tee, and tee to fairway.
- To provide alternative sight lines and fairway landing zones, thereby spreading wear, traffic and divot damage.

To ensure these tees are playable in the winter, especially in the wetter west, the installation of pipe drains with a gravel carpet should be considered. After all, there is little point in having a winter tee if it cannot be used in the winter months.

Image 31. *Playing off the main tees all winter may result in poor surfaces in the early spring and summer.*

No space for new or enlarged tees

Some clubs do not have sufficient space to construct separate winter tees or enlarge existing surfaces. In these cases, other action can be taken which can involve the use of more durable, hard-wearing grasses that recover more rapidly, e.g. dwarf perennial ryegrass. Whilst the promotion of fescue and bent turf should be the primary aim, in certain circumstances, if managed correctly, this species of grass provides a sufficiently good turf for teeing grounds.

If any type of grass is proving difficult to retain on the tees, especially in the winter, then serious consideration to the installation of purpose made artificial teeing grounds should be made. Many clubs have small mats that are placed on a flat area of ground. Whilst these are acceptable, far better surfaces are now available which can be installed permanently in an appropriate location. These provide a more realistic surface to play from and have generally been received positively where they are installed.

Image 32. *Purpose built artificial tees provide a superior winter teeing ground and are particularly useful on par 3 holes.*

8.4 SHADE REDUCTION—PROMOTING YEAR-ROUND TURF HEALTH

The presence of dense, surrounding vegetation has a major impact on the year-round condition of tees. As with greens, this reduces the vigour and recovery of the sward and results in thin, weak turf. A lack of air flow means evapotranspiration is reduced which in turn results in softer, less playable surfaces.

The solution is usually quite simple and involves the removal of trees (with an appropriate licence) or underlying vegetation to increase light to the turf and air flow across the surface.

Image 33. *Shade cast from trees or dense vegetation has detrimental effects on the turf quality of teeing grounds.*

8.5 DRIER SUMMERS—INCREASING THE IRRIGATION REQUIREMENT

The requirement to irrigate tees is likely to increase due to the predicted hotter, drier summers. It could be argued that irrigation of tees is just as important as greens, with more rapid growth required to ensure the turf recovers from wear. The installation of an efficient, possibly automated irrigation system, providing even application of water to ensure good presentation and vigour across the whole teeing ground may be necessary.

Image 34. *It is important the irrigation to tees provides uniform coverage to avoid droughted areas of turf from developing.*

8.6 CHECKLIST: The Impact on Teeing Grounds

- Adhere to maintenance objectives of providing firm, level, resilient and free-draining teeing grounds.
- Extend and implement as much greens maintenance work as possible into your teeing grounds to fulfil the desired maintenance objectives.
- Manage tees to optimise the available teeing ground on each hole.
- Evaluate condition and size of tees in relation to current and potential future levels of summer and winter play.
- Increase size of teeing grounds and implement appropriate maintenance operations to promote durable turf and rapid recovery.
- Evaluate requirement for separate winter tees or permanent artificial tees if space is restricted.
- Identify tees that suffer from shade and remove trees and vegetation to optimise the growing environment. Before any trees are removed, always obtain professional advice.
- Evaluate requirement for automatic tee irrigation and/or assess quality and performance of existing system. Install or upgrade as required.

9

Other Parts of the Course

9 Other Parts of the Course

9.1 THE IMPACT ON BUNKERS

The main issues for bunkers are likely to be inadequate drainage during autumn and winter months and the potential need for irrigation to bunker faces in predicted drier summers.

Playing quality problems in bunkers generally stem from inadequate drainage. Waterlogged bunkers during periods of wet weather are unplayable and wet sand provides inconsistent and poor playing quality. With the prediction of wetter winters, the requirement for adequate drainage in bunkers will increase.

9.2 INLAND BUNKER CONSTRUCTION

On inland courses drainage of bunkers has always been a major consideration. The design and shaping of these bunkers tends to reflect this requirement as they are often built up slightly to help retain dry sand bases. The bunker floor should be shaped to follow the desired contours, with a drain installed in the lowest point which should be linked to a positive outfall. For larger expanses of sand, a herringbone system may be required to drain the bunker adequately.

Drain lines should be excavated to a depth 230 mm below the bunker with a fall of at least 1:200. Clean, hard stone aggregate such as 8-12 mm gravel should backfill the trench. Above this, a geotextile membrane can be placed over the drain run to stop the migration of the sand into the hard aggregate below. An equally effective method is to blind the aggregate with an approved grit or coarse sand, dispensing with the geotextile membrane. Thought needs to be given to ensure surface water is directed away from the top of the bunker to reduce the amount of water erosion on the sand faces. Bringing grass down the face is a design aspect that can reduce erosion, but bear in mind the mowing requirement of steep grass faces.

Image 35. *Poor drainage and subsequent water retention is a problem at many inland courses.*

Image 36. *Pipe drainage installation is the solution to poor drainage problems in bunkers.*

9.3 RETAINING GRASS COVER ON LINKS BUNKER FACES

As a consequence of sun burn to grass faces with a southern aspect and the general demand for better presentation, some East Coast links courses have installed irrigation heads into revetted bunker faces to retain grass cover, thus lengthening the period between re-facing. This measure will help in the predicted drier summers.

This strategy should only be considered for specific south-facing, heavily played bunkers. Extending irrigation into more bunkers will waste valuable water resources.

Image 37. *Irrigation installation into links revetted bunker faces helps to retain grass cover for longer.*

9.4 ROUGH MANAGEMENT

The past few wet summers have seen changes in the species composition and density of rough grasslands on the majority of Scotland's courses. The resultant vigour produces denser and thicker grassland. If this process goes unchecked for a few years, the species composition can change to become more rank, with thicker agricultural type grasses such as Yorkshire fog, cock's-foot and false oat-grass appearing. To avoid this and to retain or revert to a more open finer sward, a management programme involving mowing and clipping removal must be implemented.

The effect that climate change will have on the less intensively managed parts of the course is a complex issue. To receive more detailed advice and guidance on how climate change may affect the rough vegetation on your course contact SGEG.

Image 38. *Mowing and baling improves the texture of the sward and promotes the finer, less productive grasses.*

Case Study

Rough grassland management—Gullane Golf Club

Gullane Golf Club has been working closely with Scottish Natural Heritage (SNH) and Scottish Golf Environment Group (SGEG) to develop rough mowing practices to transform areas of coarser tussocky grasses such as cock's-foot (*Dactylis glomerata*) and Yorkshire fog (*Holcus lanatus*) back to the indigenous, finer links species of fescue and bent.

This will improve the visual impact and species composition/quality of the rough and the speed of play as golf balls are far easier to find. However, a sufficient penalty will still remain when errant shots find their way into the rough.

The programme of work involves mowing selected areas once a year, with all the arisings being collected and suitably disposed of. The removal of clippings is especially important to reduce the fertility of the stand and physically open up the sward, thus promoting the finer grasses.

The work takes a couple of months to complete during the late winter/early spring, which equates to approximately 480 man-hours per year. The limiting factor in how much can be achieved is the disposal of the clippings. At present, they are burned but investigations into composting are currently being explored.

The cost to implement the work, including man-hours (based on £7.20 per hour), is considered to be £525 per hectare of rough. At Gullane, 10 hectares have been managed to date.

Already, positive results from this work have been obtained as the texture of the grass stands has been refined and the content of fine grasses has increased.

9.5 COASTAL PROTECTION

Sandy beaches and dunes are an attractive part of Scotland's natural heritage and they are inextricably linked to the invention and subsequent development of golf. They provide the ideal landform, substrate and vegetation for golf. However, these landscapes are dynamic and susceptible to relatively rapid changes, with many tonnes of sediment often shifted within an individual storm event. The irony is that it is this dynamism that created the links land, and it is the same dynamism which occasionally threatens it.

Scotland's sand dunes relates to coastal processes which have their origins many thousands of years ago. After the last Ice Age, large volumes of sand and gravel were deposited around Scotland's coastline and reworked by wind and wave action. These deposits have not been supplemented to the same extent since, resulting in former ***surpluses*** of coastal sediment becoming ***deficits***.

There are numerous reasons why a section of coast may experience erosion. Relative sea-level rise is progressively affecting more and more of Scotland's coastline. Alongside declining sediment supply, wave heights are also increasing in the Atlantic and North Sea and storm surges (when sea levels are temporarily higher due to low atmospheric pressure) are also becoming more frequent. All of these factors may be changing at different rates and frequencies, which makes it very complicated to make future predictions about the coastline. For these reasons, it is imperative that the management of coastal golf courses works with, and not against, the natural processes that are operating on the shoreline.

Erosion is not a process that exists in isolation—the sediments which are moved around the coastline play an important role in coastal dynamics when they are transported and deposited on adjacent sections of the beach or within the near-shore area. This recycling of sediments allows beaches to respond to and, usually, absorb storm events. These are normally followed by a slower, often unnoticed, natural rebuilding of the beach over intervening periods. This freedom of sediment movement is the very essence of maintaining sandy beaches and dunes.

At a local scale, deficiency of beach sediment may be exacerbated by coastal defence of neighbouring sections of shoreline. Each protected section reduces the supply of sediment to unprotected sections, resulting in even more rapid erosion down coast. The construction of sea walls and defences leads to a steepening of the foreshore which allows ever larger waves to attack the defences, thereby increasing flood risk. Fortunately, this 'protectionist' approach is currently being replaced by a more integrated approach, which views the coastline and its hinterlands in a more holistic manner. Sediment supply is a key control on links coasts and through the local manipulation of the beach-face, management approaches can mitigate coastal erosion and also improve wider recreation and amenity value.

Conflict can arise when land uses that require stability, such as golf courses, occupy such dynamic landscapes. Unlike built structures, dune habitats may recover naturally after being eroded. This forces us to manage our built and natural landscapes together. For golf courses, this means not developing the most seaward links and dune areas in order that they can contribute to a buffer zone which provides a natural defence to changes in weather conditions. It also means to try a more flexible approach to golf course layout/design, allowing courses to be extended landward in the event of continuing erosion to the dune face.

No links course is better known than the Old Course at St Andrews. Although the West Sands have been relatively stable since the First Edition Ordnance Survey Maps was published, erosion did become a problem several years ago on the northwest flank of the adjacent Jubilee Course towards the mouth of the Eden Estuary. Careful consideration of the golf course assets and, as importantly, the environmental issues of adjacent designated sites resulted in a solution that was both environmentally sustainable and met the golf club's requirements. The use of buried gabion baskets provided the 'last line of defence' in front of a tee, while the dune face was 'recharged' with sand and replanted with marram grasses to maintain its natural characteristics. Five years on, the managed and adjacent sections are healthy and have shown signs of accretion.

Increasingly, advisers are encouraging coastal management planning over longer time scales (decades) and with whole beaches in mind. From the golf perspective, if greens and tees are to be rebuilt in the coming years, there may be an opportunity to move them inland, thereby increasing the 'life' of any future investment. Fundamentally, it is essential to manage

Image 39. *Coastal erosion from rising sea levels and more frequent storm surges may threaten many links courses.*

Image 40. *Environmentally sustainable coastal defences at St Andrews links.*

erosion by addressing the cause of the problems, not just the symptoms. If defence is absolutely essential, then a minimum requirement is to ensure that there will be positive effects on neighbouring sections of coast rather than negative ones. This will ensure that if members' fees have to be spent year-on-year on coastal management, they are at least going towards a long-term solution, rather than an expensive temporary 'stay of execution' which does nothing to address the underlying problem whilst exacerbating the problems on site and elsewhere.

A typical response to erosion is to start off with localised protection to a tee or a green. However, this usually results in beach lowering in front of the defence and increased erosion to adjacent areas as the coast surrounding the defences continues to be dynamic. The failure of this initial protection is often compounded as adjacent sections are also 'engineered'—eventually resulting in the whole section of coast being armoured, divorcing the links course from the very environment that formed it.

If your course is experiencing erosion:

- Monitor the change by setting up a number of pegs and measure to the coastal edge. This will quantify the rates of erosion and may inform us that the five days of erosion are surrounded by 360 days of gentle, unnoticed accretion.
- Get advice from a coastal geomorphologist.
- Try to work with natural processes rather than against them.
- Use natural habitats as buffer zones to protect the golf course's assets. Also, try not to locate the more expensive structures (tees and greens) in the areas of greatest risk (near the sea).
- Contact the Scottish Golf Environment Group (www.scottishgolf.com/environment) or your area SNH office (www.snh.gov.uk).
- Plan for the medium term, rather than attempting 'quick fixes'.
- Plan for expansion inland. If neighbouring land becomes available, consider the long-term development of the course.

If considering management options, think about soft solutions, like the St Andrews example mentioned earlier, or the beach recycling which has proven to be so successful for Gairloch Golf Club, Wester Ross. Severe erosion in January 1993 left a large erosional scar along the course edge. After consultation with stake holders, sand was taken from an intertidal berm and artificially moved to mimic natural processes. The sand was reprofiled, stabilised and replanted, resulting in a natural beach defending the golf course. It should be noted that this approach, like many of the alternatives, does require an ongoing commitment.

9.6 CHECKLIST: The Impacts on Other Parts of the Course

- Evaluate drainage of bunkers and improve as necessary to sustain year-round play.
- Appraise the condition of your rough grassland in conjunction with specialist advice. Develop appropriate management practices as necessary.
- Evaluate potential sea-level changes and consequences on your course and seek professional advice on options to manage problems that may arise.

10

Minimising the Impact

10 Minimising the Impact

10.1 CLIMATE CHANGE—ADAPT YOUR MANAGEMENT APPROACH

The weather we have seen in recent years, such as the wet winter of 1999/2000 and the dry summer of 2003, may provide an insight as to what we may expect from predicted climate change.

Weather patterns such as this will impact on the playing quality of courses throughout Scotland. Golf facilities need to take stock of the information available, appreciate changes that are taking place and devise strategies to overcome the potential problems that we may face.

10.2 GOVERNMENT ADVICE

Tony Blair recently said, *"Climate Change is the most important environmental issue that the world faces".*

Margaret Becket, Secretary for State for Environment, Food and Rural Affairs in 2002 said, *"Adaptation will be an essential part of the response to the threat of climate change. Everyone involved in making investment and policy decisions in the public and private sectors needs to have access to the best estimates of how climate change will affect the UK over the coming decades… All organisations should anticipate climate change—those that are well-informed and innovative will be best placed to respond to the risk and create new opportunities."*

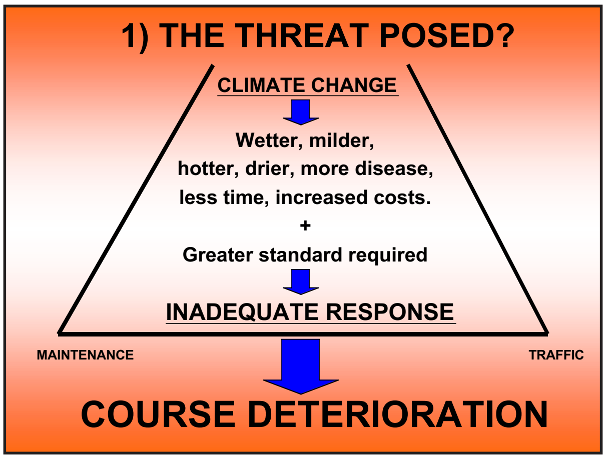
The magnitude of global and national climate change means much time and effort has and will continue to be spent in researching the scenarios and potential consequences that may occur. From these, our Government and national climate change organisations can provide advice on how to overcome the problems faced.

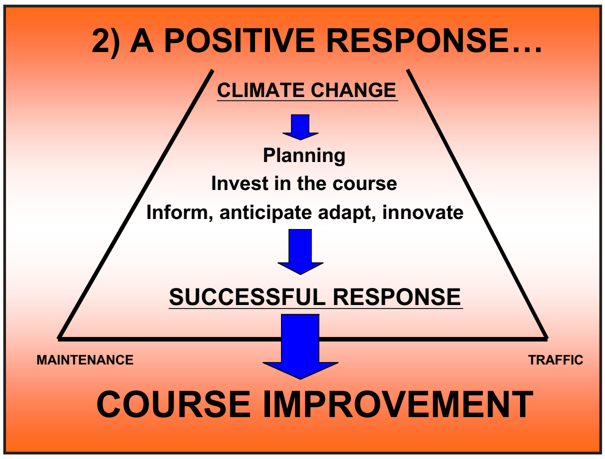
Golf facilities must take this advice seriously and adapt management practices to minimise the impact on year-round course playing quality and turf condition.

10.3 START WITH PLANNING

The key starting point for any golf facility relates to the responsibility of decision makers inside your club. Apathy is not an option. It is vital to identify the parts of your course that are vulnerable to the climate change predictions outlined in this document. You can then make a positive response to initiate appropriate programmes to minimise the effect and reduce the vulnerability of these areas. Failure to do so will result in course deterioration.

The climate change predictions are not short-term. At present, we have predictions up to 2080, and this may be considered a major challenge to golf clubs. Many club committees change every two or three years which often results in a short-term approach, only dealing with the issues of the day. Such a reactive and discontinuous approach is bad practice for course management generally and will not address the long-term implications of climate change.





10.4 LONG-TERM COURSE MANAGEMENT POLICIES

In order to provide long-term direction to course maintenance, it is important to have specific management policies in place which should be designed to achieve the management objectives outlined in this document.

To ensure future committees adhere to these policies, they must be documented in a Course Management Plan. Such a document should be a working manual which will have to be reviewed and amended from time to time. Amendments to policy should only happen after broad consultation, both within the club and with professional advisers. Adherence to the principles of the document should be non-negotiable to override changes in personnel both on committee and staff.

10.5 RESPONDING TO THE RISK AND CREATING NEW OPPORTUNITIES

Climate change will pose certain challenges to the management of golf courses and at certain times will make it harder to produce firm, free-draining surfaces and healthy turf. However, if clubs implement sufficient long-term and sustainable management strategies to promote year-round play and healthy turf, climate change may also create new opportunities. For instance, drier and hotter summers may encourage more people to play golf and milder winters may encourage more year-round golf. Both scenarios may attract more members and visitors to Scottish golf courses which will provide increased revenue to fund necessary changes in the course maintenance programme to minimise the impact of climate change.

10.6 INVEST IN THE COURSE

Much of the response to climate change will require additional investment, e.g. pipe drainage and more intensive maintenance to remove and dilute thatch and alleviate soil compaction beneath fairways. This work takes time, requires additional resources and increases course management costs.

Increasing the length of the playing season is not enough as better quality surfaces are also demanded. This is achievable but it must be remembered the implementation of the work required to provide such conditions does come at a cost. If golfers demand better playing surfaces, they need to be willing to pay for them, particularly in the context of climate change.

As with all investments, sufficient planning and regular assessment and review are required to ensure the benefits are realised and the desired outcome is achieved.

10.7 A FINAL WORD...

To put it plainly, our climate has changed and our experts are predicting further changes.

This document provides the golf facility with information about these changes, how they may affect the course and the responses you will need to make to sustain play and fulfil the playing quality potential of the course.

Decision makers in every club must anticipate the change, consult with professionals such as the course manager, agronomist, ecologist, irrigation engineer, etc. and make the necessary adaptations to the course management programme. It is vital to inform and educate your successors so the progressive strategies you implement are continued in the future, thereby sustaining course playing quality for future generations.

10.8 CHECKLIST: Minimising the Impact

- Evaluate the potential effects of climate change on the playing quality and agronomic condition of the course.
- Devise and implement appropriate sustainable management strategies to minimise the threat of climate change on the course, as recommended by The R&A, SGU, SEPA and the Scottish Executive.
- Develop long-term written course management policies to provide direction and continuity in the future.
- Invest in staff and modern turf maintenance machinery to ensure sufficient cultural and mechanical operations are achieved.
- Use this guidance, consult widely and seek professional advice to minimise the impact of climate change on the future playing quality and condition of your golf course.

11

Collation of Research

11 Collation of Research

- 11.1 Fairway thatch management trials
- 11.2 Disease monitoring
- 11.3 Worm activity
- 11.4 Fertiliser usage survey
- 11.5 Pesticide usage survey

As part of the project funding, a series of information gathering and small on-course research trials were conducted. This section of the report provides the methodologies, results and conclusions from this work.

11.1 FAIRWAY THATCH MANAGEMENT TRIALS

Rationale

Thatch tends to develop slowly on fairways in the UK, mainly due to relatively slow growth rates of the grasses present. Consequently, few have undertaken management to control this build up of organic material. Many clubs have found that decades of thatch accumulation to fairways have caused serious surface water problems through their courses in recent wetter years. Wet ground between tee and green is now probably the main factor in lost play as well as heightened maintenance difficulties, e.g. actually getting onto the course to mow.

As dense thatch accumulations beneath fairways and approaches are such a problem through Scotland, a series of trials was set up. The aim was to:

- Investigate simple cultural treatments to reduce thatch depth and improve surface drainage on fairways.
- Provide information to clubs on what results could be expected from the implementation of such maintenance regimes.
- Record data to support the programme.

Methodology

Four sites were selected through Scotland that were known to have problems with dense accumulations of thatch beneath their fairways. During the trial period one club withdrew. The three remaining courses were Glencorse (Edinburgh), Glenbervie (near Falkirk) and Cowglen (Glasgow).

The treatments applied to each of the five plots are described below and were randomised on each site:

- **Plot 1:** Control—no treatment.
- **Plot 2:** Deep scarification to 25 mm with 3 mm blades in April and September.
- **Plot 3:** Deep scarification to 25 mm with 3 mm blades in April and September, plus sand dressing with a medium to medium/coarse grade, lime-free sand applied at 6 kg/m^2 after mechanical treatments in April and September.
- **Plot 4:** Deep scarification to 25 mm with 3 mm blades, plus hollow coring with 12 mm coring tines to 75 mm depth at 50 x 75 mm spacing and sand top dressing with a medium to medium/coarse grade, lime-free sand applied at 6 kg/m^2 after mechanical treatments in April and September.
- **Plot 5:** Deep scarification to 25 mm with 3 mm blades, plus hollow coring with 12 mm coring tines to 75 mm depth at 50 x 75 mm spacing and sand top dressing with a medium to medium/coarse grade, lime-free sand applied at 6 kg/m^2 after mechanical treatments in April and September. In addition, Verti-Draining with 18 mm diameter solid tines to minimum 200 mm depth with 50% available heave in August.

Pre-treatment data recording

Before any treatments were achieved the first set of data recording was carried out during March 2003. This involved measurements for hardness using a Clegg Impact Hammer, water infiltration rate using double ring infiltrometers, and thatch depth and density by subjective recording. The standard operating procedures for these tests are described in the Appendix section of the report.

Post-treatment data recording

After the two sets of operations were carried out in April and September 2003, the post-treatment data recording was completed in March 2004. The same recording procedures were followed as described above.

Results

The following results were taken, collated together from the three trial sites and analysed. Very interesting differences have been realised. It is important however to note that these results cannot be described in true scientific terms as being ‘significant’ as the trial design, and budgetary restraints, meant insufficient replicates were made.

Image 41. *Coring work on the trial plot.*

Image 42. *Deep scarification on the trial plot.*

Image 43. *Sand top dressing work on the trial plot.*

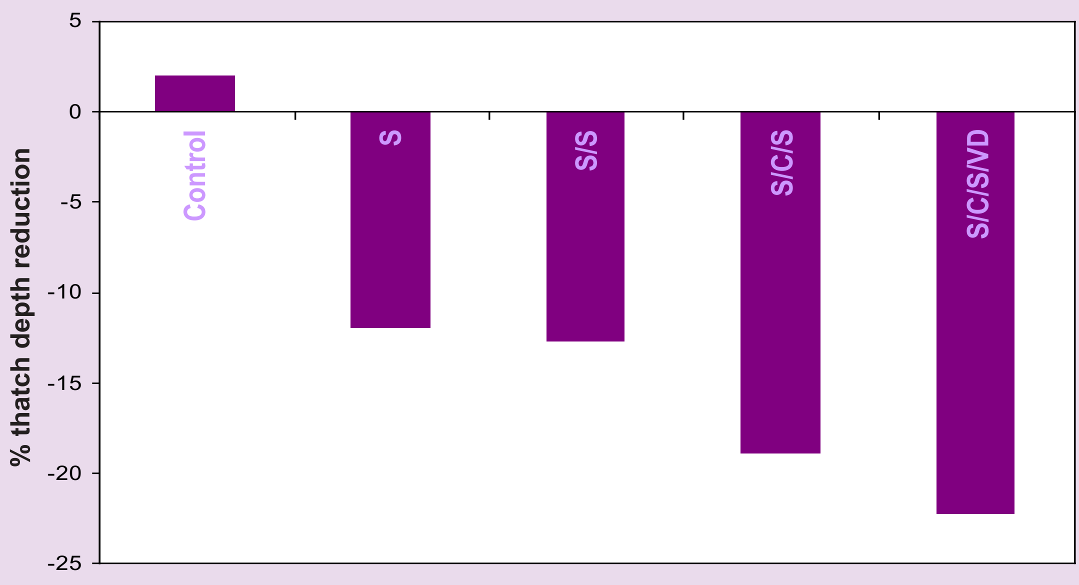
Thatch depth

On average, the thatch depth beneath the plots receiving no treatment increased in depth by 2% during the twelve month trial period. Conversely, for all of the plots receiving treatments thatch depth was reduced.

Scarification and scarification/sand had similar reductions by 12% and 13% respectively. Scarification/coring/sanding reduced thatch depth by 19%, with scarification/coring/sanding and Verti-Draining reducing thatch depth by 22%.

TABLE 12. The percentage changes in thatch depth following each of the treatments on the three different trial sites.

Plot	Glenbervie % thatch change	Cowglen % thatch change	Glencorse % thatch change	Average % change
1 Control	-6	+2	+10	+2
2 Scarify	-10	-13	-13	-12
3 Scarify/sand	-16	-16	+4	-13
4 Scarify/core/sand	-29	-23	-5	-19
5 Scarify/core/sand/ Verti-Drain	-29	-23	-15	-22



Control, S = Scarify, S/S = Scarify + Sand, S/C/S = Scarify + Core + Sand, S/C/S/VD = Scarify + Core + Sand + Verti-Drain

FIGURE 5. The average reduction in thatch depth after operations across all three trial sites for different treatments.

Water infiltration rates

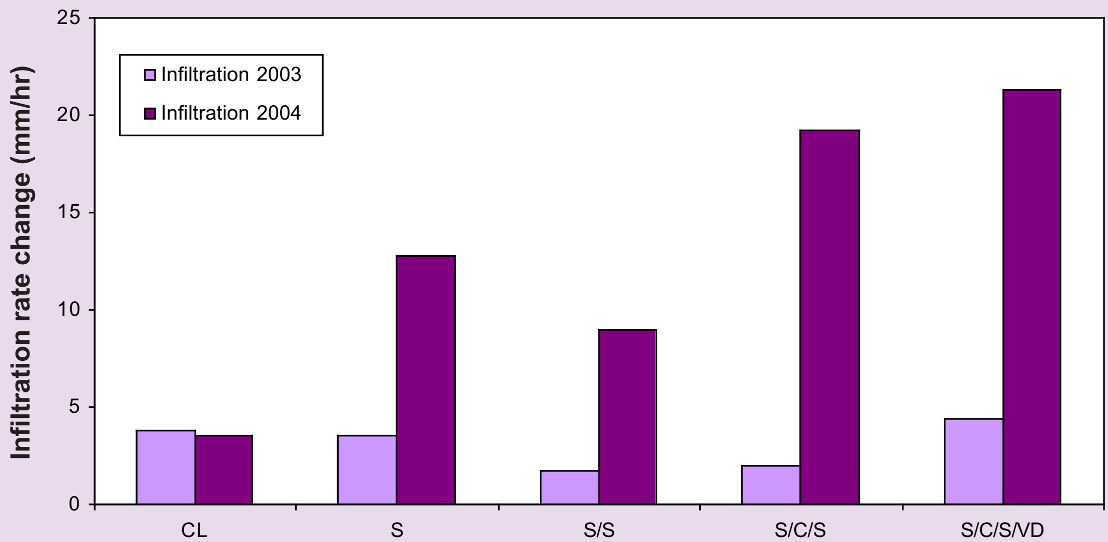
On average the infiltration rate of the control plot remained relatively constant between the two testing periods.

All the treatments increased the water infiltration rate.

From the presented data, it seems the scarification/core/sand/Verti-Drain plot had the greatest effect on water infiltration, with scarification/coring/sanding treatments supporting slightly lower infiltration rates. Scarification/sanding seems to have a lesser effect than scarification alone.

TABLE 13. The difference in water infiltration rates (mm/hour) before and after the range of treatments on the three different trial sites.

Plot	Glenbervie		Cowglen		Glencorse		Average	
	2003	2004	2003	2004	2003	2004	2003	2004
1 Control	1.1	1.5	10.4	1.5	0.0	8.3	3.8	3.5
2 Scarify	0.7	6.6	10.0	3.4	0.0	30.1	3.6	12.7
3 Scarify/sand	1.4	7.3	3.1	10.5	0.6	9.0	1.7	8.9
4 Scarify/core/sand	1.1	6.0	3.9	39.3	1.0	12.4	2.0	19.2
5 Scarify/core/sand/ Verti-Drain	0.4	8.7	10.3	44.4	2.6	10.9	4.4	21.3



CL = Control, S = Scarify, S/S = Scarify + Sand, S/C/S = Scarify + Core + Sand, S/C/S/VD = Scarify + Core + Sand + Verti-Drain

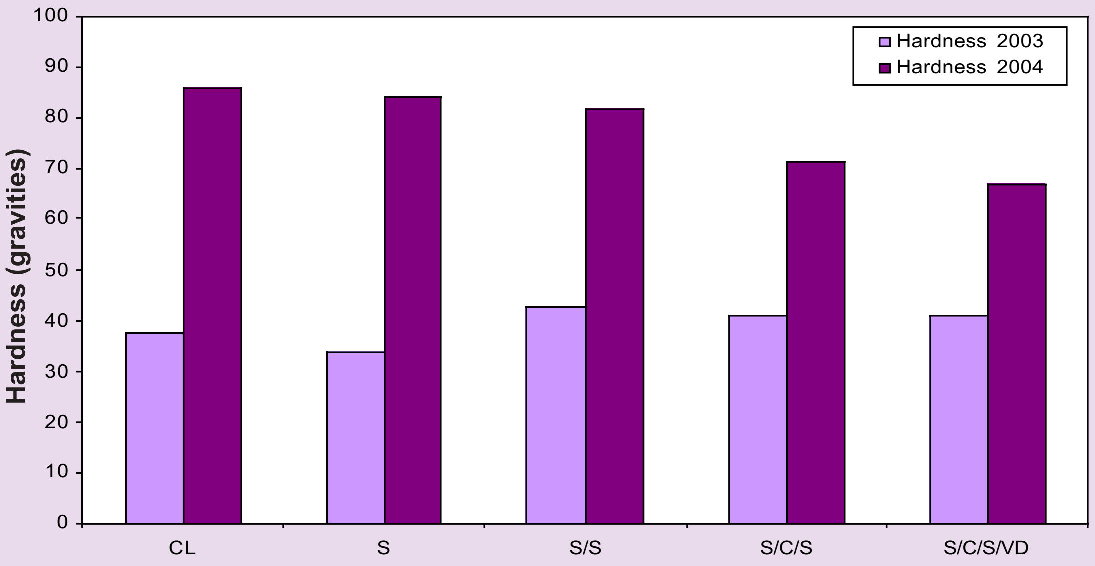
FIGURE 6. The average infiltration rate change (mm/hr) across all three thatch trial sites before (2003) and after (2004) the maintenance operations.

Hardness

The firmness of the plots in 2003 was relatively constant. It is not possible to compare the hardness results from 2003 with 2004 due to differences in soil moisture content; however it is possible to compare the effect of the different treatments on the hardness of each individual plot. Essentially, the more aggressive the operation, the softer the plots have become. Thus, the control plot has remained the firmest, with the scarification/coring/sanding and Verti-Draining plot being the softest; the difference being 19 gravities.

TABLE 14. The difference in hardness (gravities) before and after treatments across all three trial sites.

Plot	Glenbervie		Cowglen		Glencorse		Average	
	2003	2004	2003	2004	2003	2004	2003	2004
1 Control	44	100	37	89	31	69	37	86
2 Scarify	31	97	39	86	31	69	34	84
3 Scarify/sand	55	93	40	85	33	67	43	82
4 Scarify/core/sand	53	96	39	51	30	67	41	71
5 Scarify/core/sand/ Verti-Drain	48	95	40	55	35	51	41	67



CL = Control, S = Scarify, S/S = Scarify + Sand, S/C/S = Scarify + Core + Sand, S/C/S/VD = Scarify + Core + Sand + Verti-Drain

FIGURE 7. The difference in hardness (gravities) across all three trial sites before (2003) and after (2004) the maintenance operations.

Turf quality

All the plots supported turf quality and species composition similar to most inland courses with an acidic soil. Sward composition comprised on average 70-75% of bent, with moss, field woodrush, *Deschampsia* spp. and dog lichen.

After the treatments, all scarified plots supported less moss and other sward contaminants. Dog lichen was eliminated and *Deschampsia* spp. were significantly thinned. Turf density stayed the same on most plots. On plots that had the two most aggressive treatments, i.e. scarification/coring/sanding and scarification/coring/sanding/Verti-Draining, turf density was considered to be slightly reduced.

Image 44. *No treatment. Thatch depth/density remains unchanged.*

Image 45. *Scarification, coring and sanding. 10-12 mm sand accumulated in upper soil profile. This was similar for all the sanding plots.*

Due to the dry summer weather in 2003 and the instability of the turf, some disruption from deep scarification was noted on two of the trial sites.

As the treatments combinations are considered to be rather aggressive, it would seem sensible to provide small amounts of nitrogenous fertiliser to encourage rapid recovery and to improve turf density. By doing this, in conjunction with the maintenance operations, it would seem likely turf quality and texture would improve.

Discussion of results

The results from the fairway thatch management trial have certainly provided some interesting data, even after a short recording period. Due to the very encouraging differences obtained from the pilot study, it is hoped further funding will be obtained to continue the trials.

Without treatments, thatch depth increased during the trial period on average by 2%. This shows that unless managed, problems caused by dense thatch accumulations will be accentuated in the future. Each operation was shown to reduce the depth of thatch, with the most aggressive treatment involving scarification/coring/sanding/Verti-Draining removing the most, followed by scarification/coring/sanding, then scarification/sanding and scarification alone.

The slow infiltration rates ranging from 1.7-4.4 mm/hr on the control plot show the extent of the problem. Precipitation levels exceeding this infiltration rate will result in waterlogged surfaces. Such levels of precipitation occur regularly in Scotland and are likely to occur more regularly during the autumns and winters if climate change predictions come to fruition.

The results show that each treatment seems to have a positive impact on the water infiltration rates of the plots. The greatest improvement in water infiltration was gained from the most aggressive treatment involving scarification/coring/sanding/Verti-Draining, followed by scarification/coring/sanding, then scarification and scarification/sanding. It was interesting to see scarification had a greater improvement on water infiltration compared to scarification/sanding. It is likely this is a one-off occurrence; the data being skewed as the scarification-only plot at Glencorse was damaged by the operation in September due to overly dry soil conditions. This disruption could have been sufficient to cause the observed increases in water infiltration.

Between data recording periods, the hardness of all the plots increased. This is due to the lower moisture content of all the plots because of the drier weather experienced leading up to the second recording period. Essentially, due to the variables in time, the 2003 and 2004 data for firmness cannot be compared in this study. However, it is possible to compare the differences in firmness between each plot for each recording date. The difference between the plots in 2003 was only 9 gravities, essentially showing the firmness was relatively consistent regardless of the trial site. After the treatments this variation rose to 19 gravities. The firmness decreased with the increased aggression of operation, i.e. control through to scarification/coring/sanding/Verti-Draining. This result was generally unexpected. However, it is likely to be attributable to the increased air in amongst the thatch and the physical removal of material from the upper soil profile. It is considered likely that with increasing accumulations of sand top dressing, the firmness of the plots will increase in comparison to the plots that receive no work or less aggressive treatments.

There are correlations between the data. The removal of more thatch results in more rapid infiltration of water which supports the hypothesis that drainage is restricted by dense thatch accumulations. Removing thatch improves drainage rates of the areas in question. The more aggressive the operation, the more thatch is removed and the greater the infiltration improvement.

Conclusion

This pilot study has shown some very positive results from the treatments on thatch reduction and water infiltration rates, with the more aggressive treatments resulting in greater responses. However, surface firmness has shown an opposite trend.

In order to obtain more scientifically viable results between treatments, the pilot study should be developed.

11.2 DISEASE MONITORING

Rationale

There is plenty of anecdotal evidence that more disease has been seen on golf courses in Scotland in recent years due to climate change. Any programme of best practice advice has to be developed with more accurate knowledge of the problems being faced on the golf course. This initial survey is intended to gather information from the thirty participating golf clubs on the incidence of fungal diseases on greens and green surrounds.

Data collection

On accepting the invitation to participate in the project, the thirty clubs were sent a document with recording sheets. The sheets asked the club to get one recorder to note down the incidence of active disease on the same day/date each month from February 2003 to January 2004. For fusarium patch disease, both active disease and scarring were recorded so as not to underestimate the level of this disease.

The disease incidence requested was for:

- Fusarium patch (*Microdochium nivale*)
- Anthracnose (*Colletotrichum graminicola*)
- Take-all patch (*Gaeumannomyces graminis*)
- Yellow tuft (*Sclerophthora macrospora*)
- Red thread (*Laetisaria fuciformis*)

Seventy-six percent of the questionnaires were completed and returned, providing a good response from a cross-section of Scotland's course types. The results below relate to these questionnaires.

Results

Most common disease

As expected, the most common disease during the study period was fusarium patch, with 15% of all greens receiving an outbreak of fusarium, compared with 11% for anthracnose, 4% red thread and 2% yellow tuft. No greens received an outbreak of take-all patch.

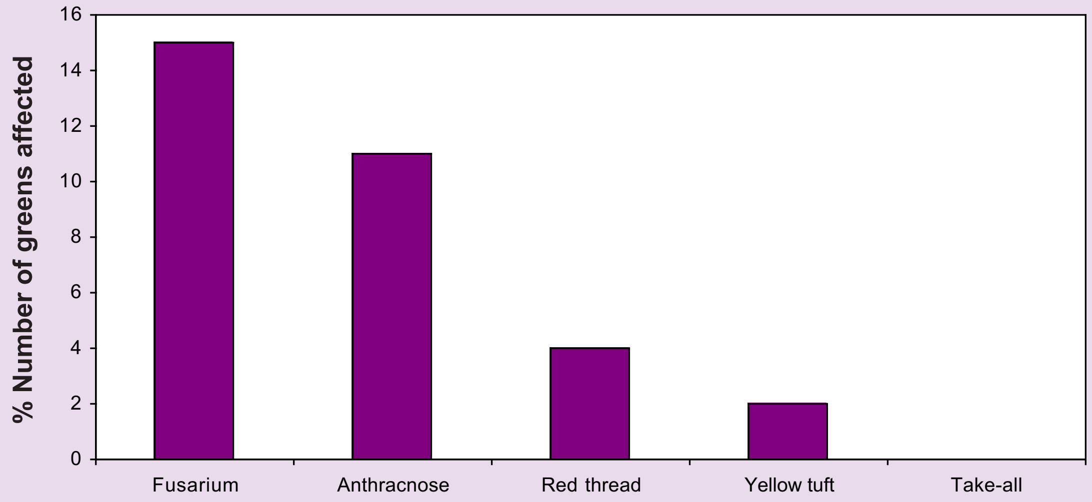


FIGURE 8. The most common turfgrass diseases on the surveyed greens.

Fusarium patch disease

Fusarium is a fungal infection of turf caused by *Microdochium nivale*. This microorganism is always present in soil but survives as dormant spores or mycelium until environmental conditions encourage it to bloom and become pathogenic to turfgrasses. Annual meadow-grass (*Poa annua)* is most susceptible to this disease, though it will attack other species, notably bentgrasses (*Agrostis* spp.). Fusarium patch is promoted by the following:

- Humid atmosphere
- Moist, poorly draining turf surface
- A rise in turf/soil pH
- Excessive nitrogen fertility
- Mis-timing of nitrogen fertiliser application
- Mis-timing of top dressing application
- Turf with a high proportion of susceptible grass
- Cool temperatures, above freezing to 10-15ºC being the optimum range

September through to December saw the most frequent occurrence on greens. The most severe outbreaks occurred during September and November, with 8% of the surveyed greens having an outbreak across more than 10% of the surface. In November, 2% of the surveyed greens saw an attack that affected over more than 50% of the surface. Outbreaks of fusarium were also recorded during the summer, with 13% and 14% of the surveyed greens receiving outbreaks in June and July respectively.

In general, fusarium activity was more common on greens dominated by annual meadow-grass. Greens dominated by the finer grasses supported very little, if any, disease. Greens that drained poorly or were cast in shade also supported more disease. For example, one club showed no disease on the majority of greens, but those cast in shade for long periods saw disease outbreaks.

Image 46. *Active fusarium on a golf green.*

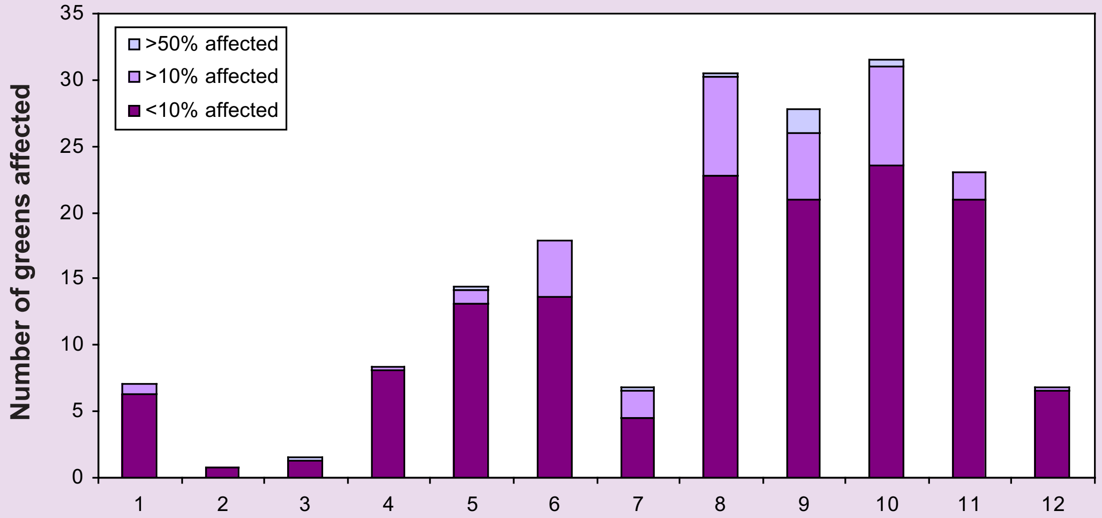


FIGURE 9. The percentage number of surveyed greens per month affected by active fusarium and the percentage area (severity) affected on each occasion.

Figure 10 shows the average length of time fusarium scars (from a previous attack and active disease) were present across the greens each year. The period of time the greens supported scars was generally between 0-4 months, with six clubs supporting scars for 0-1 months, five for 1-2 months, three for 2-3 months and two for 3-4 months.

The results from this questionnaire have confirmed that fusarium is the most common and problematic turfgrass disease on putting greens across Scotland. The mild, damp weather through the autumn and winter months encourage its activity. With climate predictions for milder and wetter autumn and winter periods, it seems likely more fusarium outbreaks will occur. Each outbreak of fusarium has a debilitating effect on the condition of the turf and thus the playing quality of the surface. As the average recovery time to restore full grass cover takes approximately 1-4 months, the disruption from fusarium on surface quality can be clearly realised.

Fusarium caused more damage to putting surfaces which were dominated by annual meadow-grass, cast in shade or drained poorly. To reduce fusarium, it is

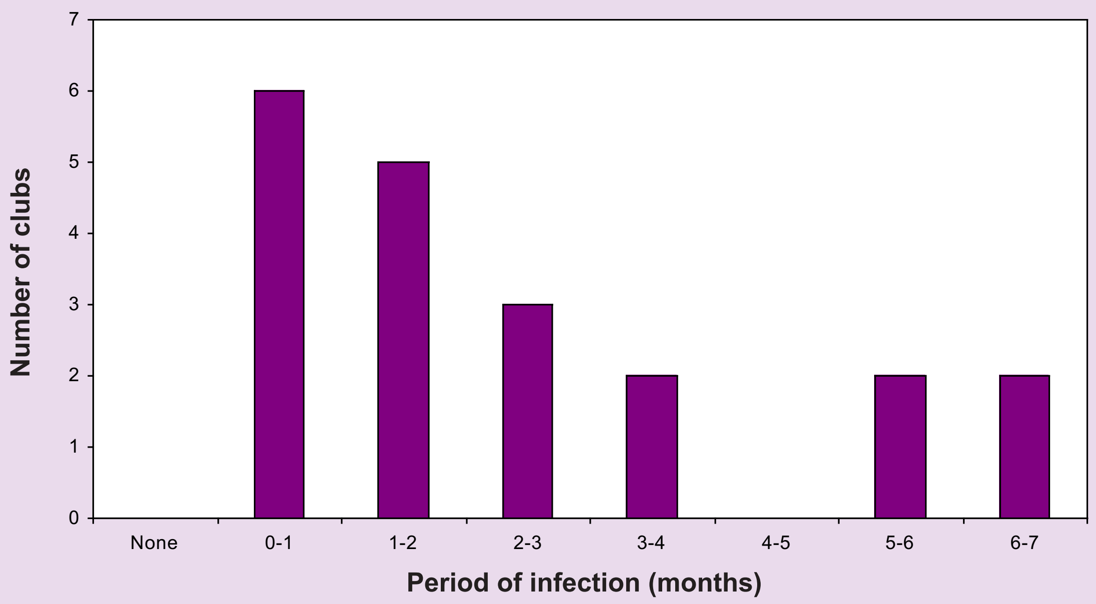


FIGURE 10. The length of time fusarium scars were present on surveyed greens during the course of the year.

therefore important to promote the finer grasses in your putting surfaces, ensure the influence of shade from surrounding trees is minimised and take action to improve drainage.

Anthracnose

Anthracnose is caused by the fungus *Colletotrichum graminicola* and only occurs on annual meadow-grass in the UK. It is usually seen between late summer and late winter, although it can persist all year round. The disease usually appears as yellowing individual meadow-grass plants which can be easily removed from the sward, often with a clear rotted black base to the stem being evident. In severe cases, it can cause patches of infected turf up to 15 cm in diameter.

Image 47. *Anthracnose disease on a golf green.*

Conditions that favour the disease are:

- Compaction
- Poor drainage
- Low fertility
- Turf stress

Outbreaks of anthracnose were most common over the autumn and winter months, with between 15% (September) and 25% (November) of greens affected. From our experience, anthracnose was slightly more problematic in 2003 due to the long, dry summer which meant many greens were 'tired' coming into the autumn and winter period. Outbreaks of anthracnose in the summer were fairly limited, with only 1-5% of greens being affected during the period May-August.

As anthracnose can be encouraged by compacted and poorly draining soils, it seems likely that milder, wetter autumns and winters in the future will continue the recent trend of more frequent attacks. Sufficient action must be taken to alleviate compaction and improve drainage to avoid the problems that cause the disease and appropriate management should be implemented to encourage resistant grasses such as bent and fescue.

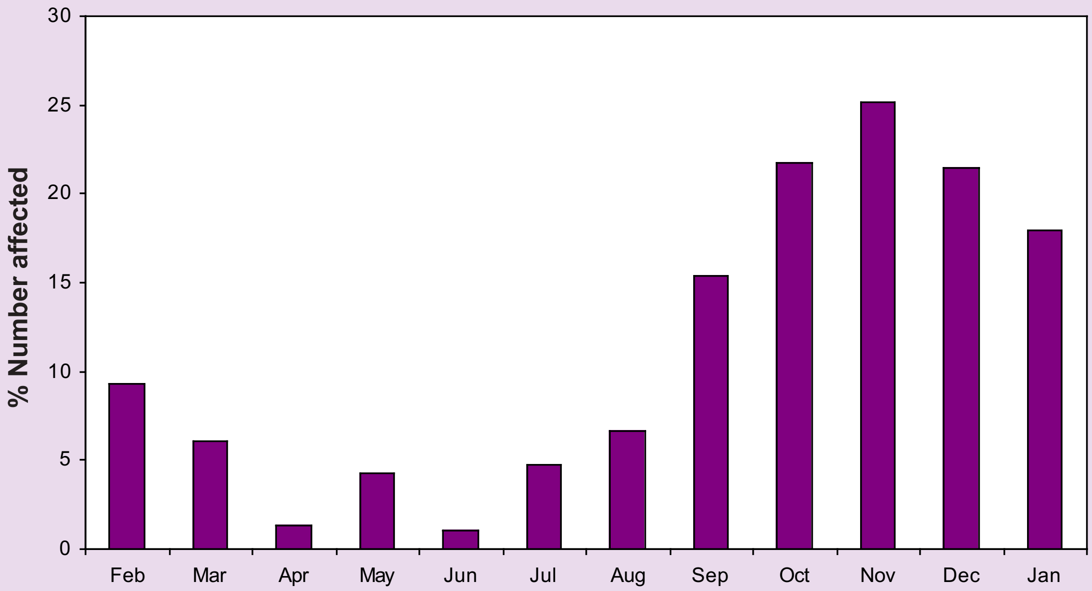


FIGURE 11. The percentage number of surveyed greens per month affected by anthracnose.

Other diseases

Clubs were asked to record outbreaks of red thread (*Laetisaria fuciformis*), take-all patch (*Gaeumannomyces graminis*) and yellow tuft (*Sclerophthora macrospora*). Red thread was recorded through the summer on 13% and 15% of greens in July and August respectively, which tended to be links courses that support high proportions of bent and fescue. Yellow tuft was present on a couple of greens on two courses, confined to water-holding depressions. There were no incidences of take-all patch.

11.3 WORM ACTIVITY

Rationale

There has been plenty of anecdotal evidence that there has been more worm casting on golf courses in Scotland in recent years due to climate change. Any programme of best practice advice has to be developed with more accurate knowledge of the problems being faced on the golf course. This initial survey is intended to provide information from the thirty participating golf clubs on the incidence of worm casting through the golf course.

Data collection

On accepting the invitation to participate in the project, the thirty clubs were sent a document with recording sheets. The sheets asked the club to get one recorder to note the incidence of worm casting on the same day/ date each month from February 2003 to January 2004. The information requested from each hole on the golf course was a simple presence or absence of casting on the four main in-play areas of the golf course, i.e. greens, green surround/apron, fairways and tees.

Results

From Figure 12 it is apparent that worm casting incidence is most significant on tees followed by fairways, green surrounds then greens.

Greens

The greatest frequency of worm casting on greens occurred during the period September-December, with between 16-25% being affected. Usually, worms are not such a problem on greens due to the sandy nature of the soil profile, as well as the generally acidic conditions. With climate change, however, the milder, damper conditions may increase the frequency and extent of worm casting on greens.

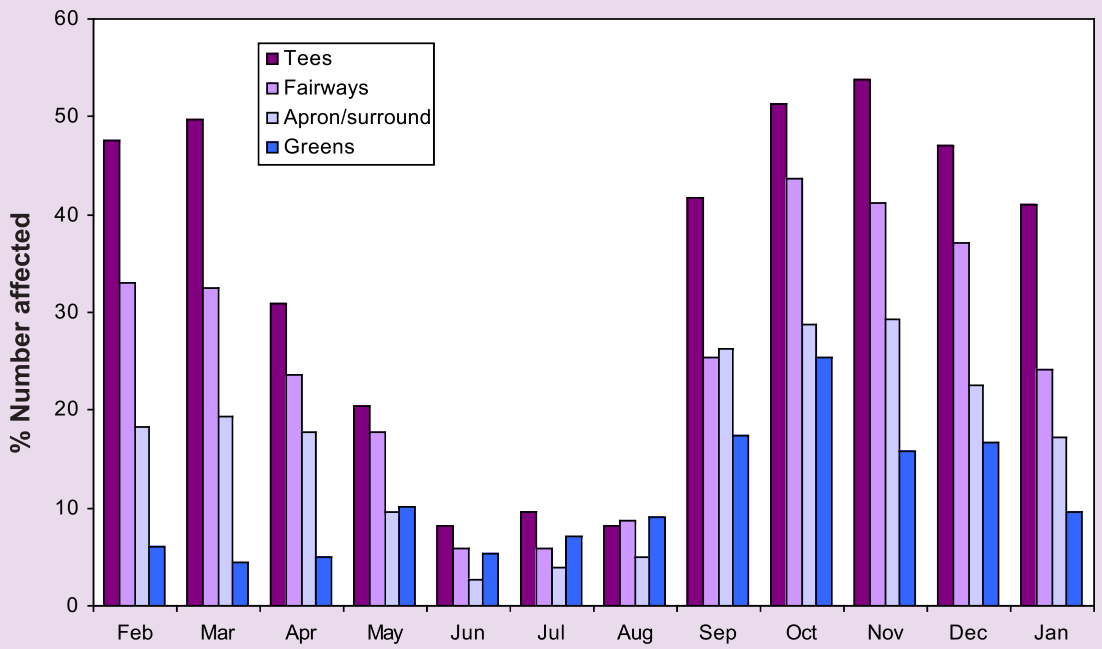


FIGURE 12. The percentage number of surveyed playing surfaces (tees, fairways, aprons/surrounds and greens) affected per month from worm casting.

Fairways

The greatest frequency occurred during the period October-December, with 45%, 41% and 37% of all fairways surveyed supporting worm casting during October, November and December respectively. Casting relaxed during January but intensified again in February. Through the summer, casting was fairly minimal with only 6% of fairways being affected in June and July and 9% in August.

Tees

On tees, the greatest frequency occurred between September-March, with 41-54% of tees surveyed supporting worm casting during this period. Through June, July and August casting was fairly minimal, with only 8% of tees being affected in June, 10% in July and 8% in August.

Summary

This data confirms earthworm casting to be most problematic during periods of mild, damp weather and least problematic in hotter, drier conditions. It therefore appears wetness overrides other factors which may reduce worm casting such as sand content and acidity.

With increasingly milder and damper autumns and winters, it is likely we will see more worm casting in the future on all playing surfaces. Casting at this time, combined with more traffic from play and maintenance, will result in greater smearing, thus greater associated problems from casting may also be experienced. To minimise casting, it is vital clubs take action to reduce casting by cultural means.

With hotter and drier summers, it is likely worm casting will become less of a problem during the summer on all playing surfaces.

11.4 FERTILISER USAGE SURVEY

Rationale and methodology

In order to provide information on the fertiliser usage from a range of clubs throughout Scotland, the thirty clubs chosen in this study were asked to record the amounts of nitrogen, phosphate and potassium applied to their greens, tees and fairways during a twelve month period. The results of the survey are described below.

Results

Greens

The average nitrogen input across all selected courses that returned the questionnaire was 11.6 g/m^2, whilst the average phosphorus (P_2O_5) input was 1.8 g/m^2 and the average potassium (K_2O) input was 9.2 g/m^2. These values are very much in line with the STRI's guidelines

TABLE 15. The annual nitrogen input of twenty-three golf clubs in Scotland.

	5-8 g/m^2	9-10 g/m^2	11-12 g/m^2	13-15 g/m^2	>16 g/m^2
Number of clubs	7	4	3	6	3

TABLE 16. The annual phosphate (P_2O_5) input of twenty-three golf clubs in Scotland.

	0 g/m^2	1 g/m^2	2-3 g/m^2	4-5 g/m^2
Number of clubs	7	6	4	5

TABLE 17. The annual potassium (K_2O) input of twenty-three golf clubs in Scotland.

	0 g/m^2	1-5 g/m^2	6-8 g/m^2	9-10 g/m^2	11-15 g/m^2	>15 g/m^2
Number of clubs	2	4	7	2	2	5

where the annual nitrogen input on soil-based golf greens would be between 8-10 g/m^2, and around 2 g/m^2 of phosphate and 6-15 g/m^2 of potassium (Lawson, 1996). The three courses with a nitrogen input of over 16 g/m^2 supported sand-based USGA greens.

Tees

The results indicate that clubs supply slightly less nitrogen to the tees than greens. Nitrogen and potassium (K_2O) are supplied at a similar ratio for greens and tees. More phosphate (P_2O_5) is applied to tees than for greens. These values are very much in line with STRI's guidelines where the annual nitrogen input on soil-based golf tees would be between 8-16 g/m^2, and around 2 g/m^2 of phosphate and 6-12 g/m^2 of potassium (Lawson, 1996). Tees that receive high levels of wear and support perennial ryegrass or smooth-stalked meadow-grass turf should receive fertiliser input to the higher end of these guidelines.

Fairways

Only seven of the surveyed clubs applied fertiliser to the fairways, five of which only applied fertiliser to weak areas. The two clubs applying fertiliser to all fairways did so to aid moss control as the material applied was lawnsand which contains sulphate of iron and sulphate of ammonia. These results confirm the general experience of STRI that very few clubs apply fertiliser to fairways.

TABLE 18. The average nitrogen (N), phosphate (P_2O_5) and potassium (K_2O) input on tees across the surveyed clubs in Scotland. The figures for fertiliser input to greens are included for comparison.

	N	P	K
Average tees (g/m^2)	9.7	3.2	7.5
Average greens (g/m^2)	11.6	1.8	9.3

11.5 PESTICIDE USAGE SURVEY

Rationale and methodology

In order to provide information on the pesticide usage from a range of clubs throughout Scotland, the thirty clubs chosen in this study were asked to record the amounts of herbicide, fungicide and insecticide they applied to their course during a twelve month period.

These results indicate the surveyed golf clubs use minimal amounts of pesticide to maintain turf condition and playing quality. Assuming clubs continue to adopt culturally based management programmes, this will be the case even in the context of climate change.

TABLE 19. The average number of pesticide applications made to the surveyed clubs in Scotland during the course of the year.

	Herbicide	Fungicide	Insecticide
Average number of applications	0.5	1.7	0.5

NB The figures above were obtained by dividing the total number of applications of herbicide, fungicide and insecticide between all the surveyed clubs.

References

References

References

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Appendix

Appendix

1. Determination of hardness
2. Determination of water infiltration rate
3. Determination of thatch depth

The following provides the standard operating procedures for the tests used as part of the fairway thatch management trials.

1. DETERMINATION OF HARDNESS

Scope

This standard operating procedure specifies a method of test for the determination hardness of turf surfaces.

Principle

A cylindrical mass is released from a standard height and its peak deceleration during impact with the turf surface is recorded.

Apparatus

A Clegg Impact Soil Tester shall be used. The apparatus consists of a cylindrical compaction hammer with a mass of 0.5 kg and a diameter of 50 mm attached to a piezoelectric accelerometer which feeds into a peak level digital meter. The peak deceleration of the hammer on impact with the ground is displayed in gravities on the liquid crystal display of the digital meter.

(Note: Available from Simon Deakin Instrumentation, PO Box 2481, Trowbridge, Wiltshire, BA14 9YJ. As delivered, the instrument reads in scale of 10 gravities. It should be modified to read in units of gravities before use on natural turf surfaces.)

Procedure

Ensure that the guide tube is held vertically and drop the compaction hammer down the tube from a height of 550 ± 10 mm for winter games surfaces and 300 ± 10 mm for golf, bowls and cricket surfaces. After the impact of the hammer on the turf surface, the peak deceleration displayed by the digital meter shall be recorded in units of gravities. After each test, the guide tube shall be moved so that the compaction hammer does not impact with the surface on the same spot twice.

Number and distribution of readings

Ten readings to be taken at random on each plot.

Expression of results

Calculate the mean hardness value for each plot.

2. DETERMINATION OF WATER INFILTRATION RATE

Foreword

This standard operating procedure is based upon a European Standard under preparation by Technical Committee CEN/217, surfaces for sports areas.

Scope

This standard operating procedure specifies a method of test for the determination of water infiltration rates on natural turf.

Principle

Water is ponded within two concentric cylinders which have been hammered into the surface. The outer cylinder is used as a buffer area to prevent the lateral flow of water from the inner cylinder and the rate of water entry into the surface from the inner cylinder is measured.

Apparatus

A double ring infiltrometer (Fig. 1) consisting of two metal cylinders, with the inner cylinder of 300 ± 25 mm diameter forming the measurement area and the outer cylinder of 500 ± 25 mm diameter forming a buffer area to prevent the lateral flow of water from the inner cylinder. (Note: a wide tolerance on the cylinder diameter is permitted to allow the cylinders to be stacked for ease of transport.)

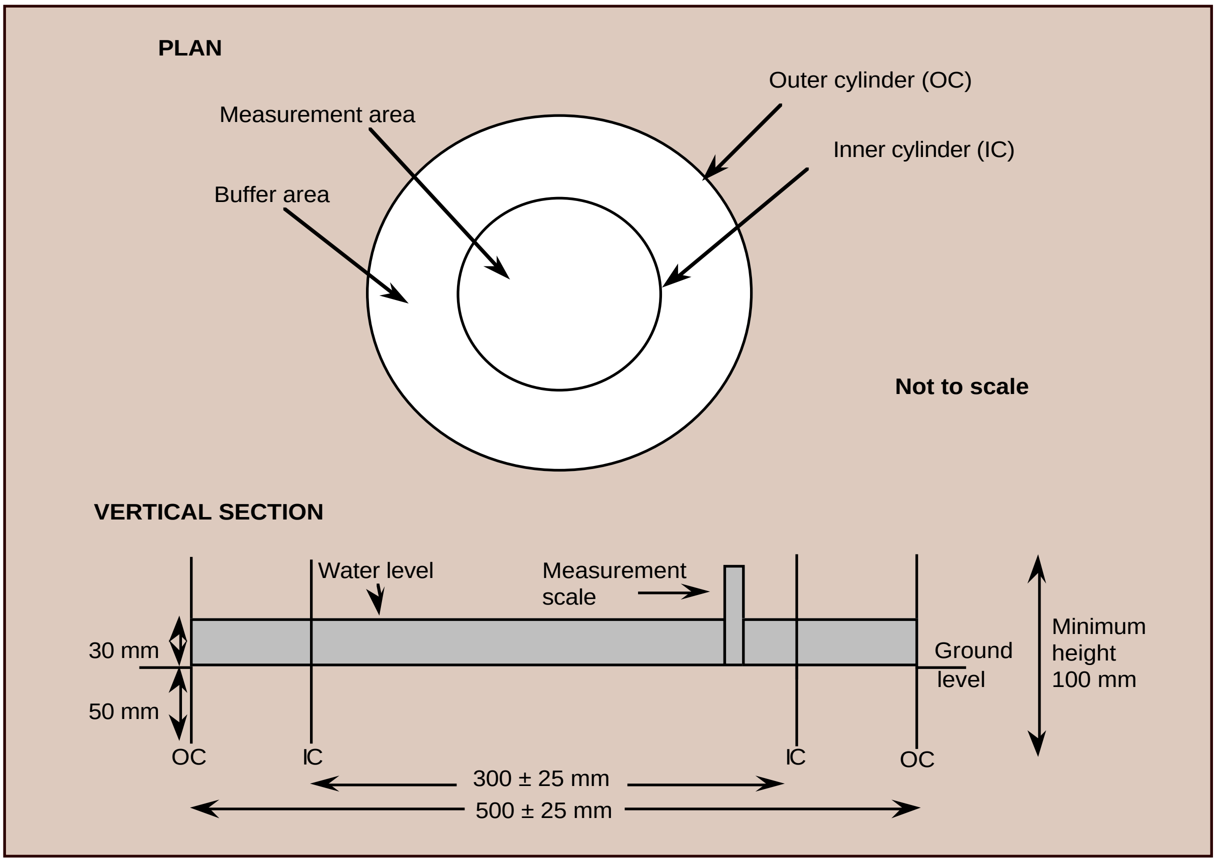

FIGURE 1. Plan and vertical section of a double ring infiltrometer.

Procedure

[a] Hammer the cylinders into the surface to a depth of 50 ± 5 mm, taking care to seal any cracking along the soil/cylinder interface by pressing down the soil around the wall of the infiltrometer.

[b] Pond water in the cylinders until infiltration approaches a steady-state value. (Note: ideally infiltration rates shall be measured when soil moisture levels are high, e.g. in March or early April, and in this case a 'wetting-up' period of 20 minutes shall be used. If tests are carried out in dry summer weather, at least one hour shall elapse between the onset of ponding and the start of measurement.)

[c] Measure the fall in water level in the inner cylinder from an initial ponding depth of 30 mm over a time of 20 minutes. In cases when drainage is more rapid, record the time for the water to fall 25 mm. In all cases ensure that the water level in the outer cylinder is within ± 2 mm of the level in the inner measurement area.

[d] Measure the water temperature in the inner cylinder during the test.

[e] Calculate the water infiltration rate as:

$$\text{Infiltration rate (mm h}^{-1}\text{)} = \frac{\text{fall of water level (mm)}}{\text{time (hours)}}$$

[f] Standardise values to a common temperature of 10°C by multiplying the resulting infiltration rate by the appropriate temperature correction factor given in Table 1.

Number and distribution of readings

Three readings to be taken per plot.

Expression of results

The individual infiltration values should be transformed logarithmically (base 10), or as $\log_{10}(x + 1)$ if some values are less than one. Calculate the mean from the log-transformed data and then back transform to give the water infiltration rate. Express the results as the back transformed value of water infiltration rate.

TABLE 1. Correction factor to standardise infiltration rate to that measured with a water temperature of 10°C.

Temperature of water in inner cylinder (°C)	Correction factor
5	1.163
6	1.128
7	1.093
8	1.058
9	1.035
10	1.000
11	0.965
12	0.942
13	0.919
14	0.895
15	0.872
16	0.849
17	0.826
19	0.791
20	0.767

3. DETERMINATION OF THATCH DEPTH

Procedure

The depth of thatch was measured in millimetres and recorded.

Number and distribution of readings

Three samples were taken from each plot at random.

Expression of results

The average thatch depth in millimetres is calculated and presented for each individual plot.