RESEARCH AND DEVELOPMENT YEARBOOK 2023

RESEARCH AND DEVELOPMENT YEARBOOK 2023. STERF, SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION

CLIMATE CHANGE CALLS FOR COOPERATION

In 2023, Planet Earth reached a turning point. It was the warmest year ever recorded, breaking records for all types of climate-related nature catastrophes, including severe rainstorms, hurricanes, droughts and floods. The extinction rate of species is increasing, causing biodiversity loss with unknown ecological consequences. For golf and other turf sports that use land and nature as their sports arena, these changes will strongly affect future operations. New research, competence and modification of standard approaches in the turf sports sector are needed to conquer these challenges.

STERF continues to deliver ready-to-use research. In 2023, two of its largest projects ever were completed. Results from the joint R&A/STERF IPM project "*Integrated management of important turfgrass diseases and insect pests on European golf courses*", with many international participants and sponsors, was presented at the R&A/STERF symposium in Sigtuna, Sweden. The project has produced a substantial body of data on growing practices and new technologies for prevention and control of important turfgrass diseases on putting greens and insect pests on golf courses, with minimum use of pesticides.

A closing seminar for the other major project, ICE-BREAKER, funded together with the Norwegian Research Council, was held in Oslo, Norway. Four years of research resulted in a better understanding and improved strategies to prevent and repair damage caused by prolonged ice cover and meltwater on golf courses and other grasslands.

The findings from these two projects have increased the capacity of the turf sector to build resilience to climate change. The results are reported in scientific papers, handbooks, factsheets, videos etc.

During 2023, STERF initiated four new projects to ensure that we have the knowledge needed to build and maintain sustainable golf courses and sports fields while meeting global challenges. These are:

- **SCANGREEN 2023-26**, on turfgrass species and varieties for integrated pest management of Scandinavian putting greens.
- **FAIRWAYS4FUTURE**, dealing with managing high-quality golf course fairways and semi-roughs without herbicides and with lower emissions of greenhouse gases.

- **FAIR-WATER I,** working towards better drought resistance and reduced water consumption.
- **GOLF LANDSCAPE**, on increasing biodiversity and multifunctionality of golf landscapes on golf course fairways.

All four projects are presented in this yearbook.

However, these efforts are not enough to overcome the problems we face in the future.

Therefore in 2023, STERF approached the R&A and USGA to explore interest in joint funding of research projects of global significance. The very first meeting revealed mutual understanding of the need for increased research efforts and a planning group for the "*Global Turfgrass Research Initiative - A Cooperative Effort by the STERF, R&A and USGA*" was formed. Sustainable agronomy is the most prevalent area of interest.

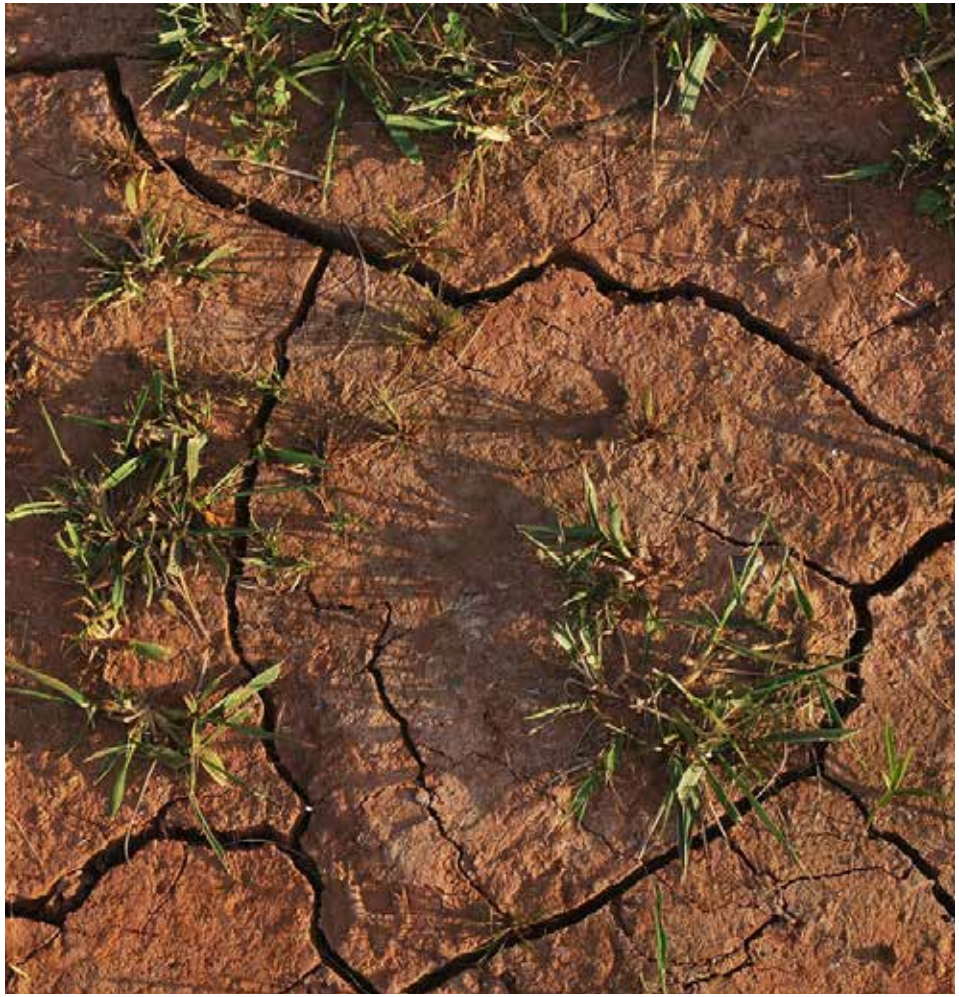
Against a background of increasingly stringent pesticide regulations and recurring droughts, all parties agreed that integrated pest management and water conservation will likely be important foci of the initiative. Biodiversity research in turfgrass management globally is essential to foster ecological balance within turfgrass landscapes. A better understanding of the carbon balance in turfgrass management globally is crucial for understanding the impact of turfgrass on greenhouse gas emissions and carbon sequestration. The highest priority research topics so far are:

- Integrated pest/turfgrass management
- Water conservation
- Biodiversity and landscape perspective
- Climate (Carbon balance)

Planning will continue through 2024 and our goal is to circulate a joint two-phase Request for Proposals in late 2024. From a STERF viewpoint, we consider this to be a highly important step for increased turfgrass research, globally.

Finally, we welcome the decision by the European Golf Association to intensify its sustainability work and to take leadership for golf and sustainability in Europe. We look forward to future cooperation.

Bruno Hedlund
STERF Chairman



IMPORTANT EVENTS IN 2023

FOUR NEW PROJECTS HAVE STARTED

The past decade was critical for Planet Earth, with more record-breaking temperatures and more severe rainstorms, hurricanes, droughts and floods than ever before. The rate of biodiversity loss accelerated and more species came under threat. All this has consequences for the golf and turfgrass industry and requires more research and knowledge building to conquer these challenges. During 2023, STERF started four new projects to obtain the knowledge needed to build and maintain sustainable golf courses and sports fields and meet global challenges:

- SCANGREEN Turfgrass species and varieties for integrated pest management of Scandinavian putting greens 2023-26
- FAIRWAYS4FUTURE: Managing high-quality golf course fairways and semi-roughs without herbicides and with lower emissions of greenhouse gases.
- FAIR-WATER I: Towards better drought resistance and reduced water consumption on golf course fairways.
- GOLF LANDSCAPES: Biodiversity and multifunctionality of golf landscapes.

All four projects are presented in this yearbook.

GLOBAL TURFGRASS RESEARCH INITIATIVE - A COOPERATIVE EFFORT BY STERF, R&A AND USGA

Development and sustainability were the theme of the 14th International Turfgrass Research Conference (ITRC 2022) hosted by STERF in Copenhagen, Denmark, in July 2022. Global challenges and challenges within the turfgrass industry related to the United Nations sustainable development goals set out in Agenda 2030 were the focus of many presentations and discussions amongst delegates. STERF feels that investing in turfgrass research would the most appropriate legacy from ITRC 2022. STERF's preference is to develop research projects with global significance and we inquired about interest in a collaborative effort with R&A and USGA early in 2023.

Representatives from each organisation initially met in May 2023. R&A and USGA representatives supported an approach to further develop the initiative and a planning group was formed and began meeting approximately monthly to define the best path forward.

The aims of the Global Turfgrass Research Initiative are:

1. To agree on the most important global research topics for turfgrass management.
2. To solicit and select research proposals to advance these topics through a competitive request for proposals (RFP).
3. To initiate two or three globally cooperative and applicable projects with international research teams.
4. To model global research cooperation and learn from the initiative for even better future efforts.

Research topics discussed

Sustainable agronomy is the most prevalent area of interest. In light of increasing pesticide regulations and increasingly hot, dry weather, droughts and irrigation bans in many parts of the world, all parties agreed that integrated pest management (IPM) and water conservation will likely be important

foci of the initiative. Biodiversity research in turfgrass management globally is essential to foster ecological balance by understanding and preserving diverse ecosystems within turfgrass landscapes. IPM promotes resilient turfgrass systems by supporting beneficial organisms that contribute to natural pest control, soil health, and overall ecosystem stability. A better understanding of the carbon balance in turfgrass management globally is crucial for understanding the impact of turfgrass on greenhouse gas emissions and carbon sequestration. The following specific topics have been suggested so far:

- Integrated pest/turfgrass management
- Water conservation
- Biodiversity and landscape perspective
- Climate (carbon balance)

Planning will continue through 2024 and our hope is to circulate a two-phase Request for Proposals in late 2024.

The initiative will have two important committees. A **steering committee**, consisting of representatives of the funding organisations (STERF, USGA and R&A) will continue to plan and execute the initiative, appropriately representing the interests of the organisations funding the work. The steering committee will nominate, select and oversee the work of 10-12 people (scientists, agronomists and industry practitioners) serving on a **proposal review committee**.

Field Day at Sigtuna Golf Club, presenting their successful biodiversity programme and sustainable course management. Photo: Ola Jennersten.

SUSTAINABLE GOLF COURSES – JOINT STERF AND R&A SYMPOSIUM

The symposium 'Sustainable golf course management- Integrated turf management' was a joint R&A and STERF initiative and part of the Golf Course 2030 programme. It brought together researchers, greenkeepers, superintendents, technical experts, consultants and top industry delegates. This provided excellent opportunities to improve and extend important international collaboration, which is the only viable strategy to overcome the current challenges and create a sustainable future. Production of healthy turf while safeguarding environmental quality and providing a toxin-free environment is a high priority within the European Union (EU). The golf and turfgrass industry must play its part in this task by providing high playing quality and at the same time reducing dependence on chemical pesticides.

The aim of the symposium was to establish an arena to exchange knowledge and experiences with the best experts in the field, and to inspire the golf sector to take the initiative, work proactively and create an integrated approach to pest and disease management as the driving force for producing healthy turf and to reduced use and dependence on pesticides. More than 80 delegates from 12 countries participated in the symposium.

The event started on September 18th with an afternoon Field Day at Sigtuna Golf Club, which inspired us with a successful biodiversity programme and sustainable course management. The Symposium on September 19th was a full-day event comprising a number of short and sharp presentations. Results from the joint STERF and

R&A IPM project "Integrated management of important turfgrass diseases and insect pests on European golf courses" was an important part of the symposium. New and ongoing IPM projects and practical experiences of implementing IPM were presented and discussed. The programme also included a presentation of the European Golf Turfgrass Sustainability Roadmap 2023-2030.

Doug Soldat , University of Wisconsin

Turfgrass Field Day Lunch. Photo: Thomas Björn.

STERF NEW BOARD MEMBER DOUG SOLDAT

Doug Soldat is a professor, turfgrass extension specialist and chair of the Department of Soil Science at the University of Wisconsin in Madison, Wisconsin, USA. Doug completed his B.S. and M.S. degrees in Soil Science from the University of Wisconsin and earned a Ph.D. in Plant Science from Cornell University in Ithaca, New York, USA. His research and outreach programmes are focused on improving turfgrass nutrient and water use efficiency. Doug teaches courses on turfgrass management and soil science at the University of Wisconsin. As a scientific board member for STERF, he has participated in a joint programme with STERF, USGA and R&A to fund collaborative research projects to advance turfgrass sustainability globally. He also provides input and advice to the STERF board regarding scientific proposals and reports, and seeks to facilitate more communication and cooperation about sustainable turfgrass management between North America and the Nordic countries.

NIBIO INTERNATIONAL TURFGRASS FIELD DAYS

On June 20-21 2023, around 90 scientists, turfgrass agronomists, company representatives and practitioners from nine countries gathered for the NIBIO International Turfgrass Field Days at Landvik Research Center on the south coast of Norway. After a three-year pause due to Covid 19, NIBIO Turfgrass Group is now planning for these field days to become a biannual meeting point, with the next event in June 2025. Since STERF is a major funding body for NIBIO's turfgrass research projects, the STERF board combined the 2023 field days with its annual summer meeting.

On June 20, guided tours to NIBIOs turfgrass field trials were organised by dividing participants into five groups, thus allowing more time for questions and discussions among participants. The programme also included an interesting update by Niels Dokkuma from the European Golf Association about the ongoing revision of the EU Directive regarding pesticide use.

The second day was devoted to presentations from the STERF-funded projects IPM-GOLF, ROBO-GOLF and ICEBREAKER, all coming to an end in 2023-2024. As an introduction to the IPM session, Dr. Bruce Clarke, former director of turfgrass research at Rutgers University,

Turfgrass Field Day. Photo: Thomas Björn.

Maria Strandberg heading the panel discussion at the ICE BREAKER Final Seminar. Photo: Sigridur Dalmannsdottir

USA, gave a highly appreciated overview of cultural control of Microdochium patch and dollar spot, two of the most important diseases of cool-season turfgrass in Europe and North America.

ICE BREAKER FINAL SEMINAR

The scientific and practical conclusions from ICE-BREAKER, one of STERF's largest ever projects, which was co-funded by the Norwegian Research Council during the past four years, were highlighted in a final seminar held in Oslo on November 3, 2023.

After a warm welcome by NGF's Pål Melbye and STERF's director Maria Strandberg, the programme started with an invited keynote by Hans Olav Hygen of the Norwegian Meteorological Institute on the implications of global warming for future winter climates and the risk of ice and water damage on golf courses in various geographical regions of the Nordic countries. The five subprojects in ICE-BREAKER were then presented by NIBIO scientists and agronomists from the Swedish Golf Federation. There was also a keynote address by turfgrass physiologist Emily Merewitz Holm of Michigan State University, who drew parallels to the large ongoing USDA-funded project WINTER TURF and showed that turfgrass winter damage is not limited to the Nordic countries. Other highlights were a presentation by course manager John Riiber on how winter damage is prevented at Norway's most prestigious golf course in Oslo, and a panel discussion by practitioners, agronomists and scientists on the pros and cons of using impermeable covers on golf course putting greens during winter.

The seminar attracted around 100 participants, mostly Norwegian but with a large delegation from Iceland.

GOLF COURSES AS AN OUTDOOR CLASSROOM

Children's learning experience can be improved if part of the teaching takes place in a natural outdoor environment. Using golf courses and the land that surrounds them as outdoor classrooms could become particularly important in an age when most of the world's population lives in urban landscapes



From left to right: Learning how to assemble a storm kitchen and boil water as part of a sports lesson on Mälarö GC. Geometry lesson and trying out golf at Stockholm GC. Photos: Thomas Björn.

and when local areas suitable for outdoor activities are becoming scarce. In STERF´s pilot project at Motala Golf Club in collaboration with Smedsby School in Motala, methods for outdoor teaching on golf courses and the most suitable areas of the golf course for use as an outdoor classroom were investigated.

The concept, 'The golf course as an outdoor classroom', has now (2023/2024) been implemented in the Swedish municipalities of Stockholm and Jönköping. Using funding from the Swedish Outdoor Association, the municipalities of Sölvesborg and Göteborg will soon also adopt the concept. The aim is to offer over 400 pupils outdoor teaching on golf courses during 2024. STERF´s inspirational handbook and its descriptions of experiences, ideas and practical activities that can be performed in everyday outdoor teaching will be used. The video 'Outdoor teaching at Motala Golf Club' is also widely used by schools and golf clubs. Dialogue about potential collaboration has been initiated with the Golf Course Superintendent Association of America (GCSAA) programme of outdoor teaching, 'First Green', established back in 1997.

A LOT OF VIDEOS

More videos than ever before were produced during 2023. Here are some examples:

- 21 videos were produced in connection with the R&A and STERF IPM symposium in Sigtuna. All 14 presentations were recorded, as well as seven short personal interviews. They can all be found at https://www.youtube.com/playlist?list=PLKaPDBMLBJMKu-P0MNiWQbMR-QnuX5G8C

- Five videos were produced at NIBIO International Turfgrass Field Days in Landvik. They can be found at https://www.klubbtv.nu/#provider_channels/1293

ABOUT STERF

SCANDINAVIAN TURFGRASS AND ENVIRONMENT RESEARCH FOUNDATION, STERF

STERF is an independent research foundation that supports existing and future R&D efforts and delivers 'ready-to-use' research results that benefit the golf and turfgrass sector. STERF was set up in 2006 by the golf federations in Sweden, Denmark, Norway, Finland and Iceland and the Nordic Greenkeepers' Associations. Research funded by STERF is carried out at universities or research institutes (or equivalent), where most relevant research capacity is concentrated. STERF helps to strengthen research capacity by encouraging and supporting networks and collaborating actively with international key organisations in the field of turfgrass management. STERF also arranges innovation workshops to help identify the golf and turfgrass industry´s future research needs, where researchers and industry representatives contribute to the planning process. STERF receives funding from participating golf associations, complemented by funding from other sources.

STERF's vision is to be the leading international centre of expertise in sustainable golf course management. To achieve this vision, STERF focuses on:

- Making the turfgrass industry in the Nordic countries a role model regarding responsibility for sustainable societal development, i.e. in producing managed turfgrass areas of a high standard while at the same time ensuring sustainable use of natural resources and contributing to functioning ecosystems and providing recreation areas that are open to the public and to outdoor activities.

- Ensuring that Nordic turfgrass research and development focuses on internationally important areas where concerted research and industrial efforts are required. These include the pressures generated by government demands for greater environmental regulation, the increasing pressure on natural resources (notably water, energy and land), the emerging role of turf management in supporting ecosystem services and enhancing biodiversity, the continued need to promote integrated pest management, and the looming challenges posed by a changing climate and the urgent need

to adapt. Activities within the focus areas must contribute to fulfilment of nine of the 17 sustainable development goals (SDGs) set in the United Nations Agenda 2030.

- Establishing a successful international research and development collaboration, including research facilities and expertise in all five Nordic countries. STERF will continue to initiate inter-disciplinary and multi-disciplinary research and support collaborations in Europe, Canada and USA involving researchers and stakeholders interested in land used for managed turfgrass areas.

- Developing and expanding the STERF industrial scientific partner programme by collaborating with leading international companies within the sector to further strengthen the strategy that research and development should be integrated from producer to end-user.

- Taking a lead in making research results and new knowledge easily accessible to end-users and providing support to implement changes, a prerequisite for achieving progress in sustainable management of golf courses and other turfgrass areas.

STERF´s activities must contribute to fulfilment of nine of the 17 SDGs set out in Agenda 2030. STERF has divided these into six categories:

1. Sustainable use of natural resources and chemicals (SDGs 6, 11, 12, 14, 15).
2. Ecosystem services and enhanced biodiversity (SDGs 14,15).
3. Adapting to a changing climate and minimising factors affecting climate change (SDG 13).
4. Sustainable cities and communities (SDG 11).
5. Healthy lives and well-being for people of all ages (SDG 3).
6. Partnership for sustainable development and for new regulations (SDG 17).

These categories and goals are closely related to the golf and turfgrass industry´s everyday challenges and to STERF's programmes, projects and dissemination efforts.

BACKGROUND

Managed turfgrass areas, such as golf courses, sports fields, landscaped amenity areas and public parks, together act as an important social, environmental and economic resource for both urban and rural communities. These areas serve a multifunctional purpose by offering valuable open spaces for recreation, helping to improve the health and quality of life for individuals and, when designed and managed appropriately, enhancing biodiversity and supporting regulatory targets for environmental protection. Conversely, where turfgrass management practices are inadequate or inappropriate, their services to society are reduced and their impacts on the natural environment can be damaging and costly.

The future challenges for turfgrass and golf course management are many and diverse. They include increasing demands on natural resources (notably land use, water resources and energy) driven by economic development and population growth, coupled with government demands for greater environmental protection, which are creating conflicts at the interface between land management (including turfgrass) and the environment. The situation is particularly acute in peri-urban areas, where the majority of managed turfgrass facilities are concentrated. Population growth, migration and climate change will exacerbate the current situation, by increasing competition for resources between individual sectors, including agriculture, urban development, tourism and the environment.

Many golf courses, sport facilities and stadiums are under economic pressure due to economic recession in many parts of the world. In many countries there has also been a decrease in the number of registered golf players. It is common for golf courses to base their financial stability on a constant inflow of members, rather than a static membership. However, they are now facing the challenge of balancing this approach against the new concept of fewer members and new conditions in a more variable and more competitive market.

The keys to success in future golf course and turfgrass management will be to increase resource use efficiency, reduce maintenance costs and minimise the environmental impact. In this context, protection and enhancement of ecosystem services will need to be fully integrated into the planning, design, construction and management of all golf and turfgrass facilities.

The Nordic Golf Federations have approximately 900 000 members, playing golf on more than 900 courses that occupy a total area of more than 60 000 hectares. Any societal activity as significant as golf must take responsibility for building knowledge through research and development (R&D). There are several important reasons why Nordic R&D is necessary. In Central Scandinavia, Oslo, Stockholm and Helsinki lie at the same latitude as the southern tip of Greenland (~60oN). This gives a unique climate resulting from a combination of factors such as light, temperature and precipitation during the playing season and particularly during the winter season. The Nordic climate creates conditions for plant growth and construction and management of golf courses, sports fields etc. that are not found anywhere else in the world.

R&D will continue to be a necessary and strategically important investment for the golf sector in achieving economically and environmentally sustainable golf facilities of a high standard and in establishing the credibility of golf as an environmentally friendly sport. Golf facilities that are already using new knowledge are achieving cost savings through more efficient management strategies, while also enhancing their golf course, raising the profile of their golf facility and improving the environment.

The financial resources allocated to R&D in each country are very limited and the number of scientists actively working within each priority R&D area is also quite limited compared with agricultural and forestry research. The financial resources and efforts of these researchers should therefore be coordinated through STERF, to optimise R&D within the golf and turfgrass sector.

RESEARCH OBJECTIVES AND R&D SUB-PROGRAMMES

Screening of turgfrass species and cultivars for resistance to diseases at Landvik. Photo: T. Espevig.

STRATEGIC RESEARCH OBJECTIVES

The golf and turfgrass industry, like other land-based industries, must take responsibility for sustainable societal development, i.e. it must produce golf courses and other turfgrass areas of a high standard while at the same time ensuring sustainable use of natural resources and contributing to functioning ecosystems.

The aim of STERF is to support R&D that can help the golf industry to fulfil these ambitions. The activities of STERF are intended to lead to improvements in the quality of golf courses, as well as economic and environmental gains for the industry and society as a whole.

The strategic objectives for STERF-funded R&D activities are that:

- The design, construction, management and administration of golf courses provide optimal conditions for playing quality, degree of utilisation of the course and management inputs.
- The design, construction, management and administration of golf courses are economically and environmentally sustainable, for example with respect to plant nutrient requirements, water and energy use, drainage and control of weeds and plant diseases.
- Golf courses contribute to production of biological diversity, conservation of natural and cultural envi¬ronments and retention and expansion of ecosystem services, and to improving the conditions for good quality of life and health, e.g. through providing a broa¬der active outdoor life, experiences of nature and better climate adaptation in the everyday landscape.

R&D SUB-PROGRAMMES

It is evident that the golf and turfgrass industry faces a number of local and international challenges, all of which will need concerted and collective solutions, underpinned by robust, applied science. To meet the challenges facing the sector, STERF has created four international and transdisciplinary R&D programmes:

- Integrated pest management
- Sustainable water management
- Turfgrass winter stress management
- Multifunctional use of golf facilities and ecosystem services.

Progress in these programme areas will collectively lead to improvements in the quality of managed turfgrass areas, as well as economic and environmental gains for the industry.

The key objectives of the programmes are to coordinate the design and running of R&D activities and to ensure effective dissemination of outputs (new knowledge) through channels and formats which are easily accessible to end-users. STERF will play a key role in expanding the programmes on international level.

Integrated pest management

New regulations at national and international level relating to the turfgrass industry are becoming more demanding. A good example is the EU Green Deal and the proposed Sustainable Use of Pesticides Regulation, which includes strategies for integrated pest management (IPM) and drastic reductions in pesticide use. STERF, together with the Nordic park and golf sector, universities, research institutions and authorities, will take responsibility for ensuring that R&D activities important for IPM and pesticide reduction are coordinated and executed and that new knowledge is delivered.

Sustainable water management

Water is essential to secure the future of the turf industry and the livelihoods of many rural communities that depend upon it. Working with industry and leading research institutes, STERF's goal is to provide science-based information to practitioners and stakeholders on integrated water management in turf. This will improve management practices relating to both irrigation and drainage systems, help protect environmental water quality and support the industry in adapting to the effects of future changes in rainfall and climate variability on water resources.

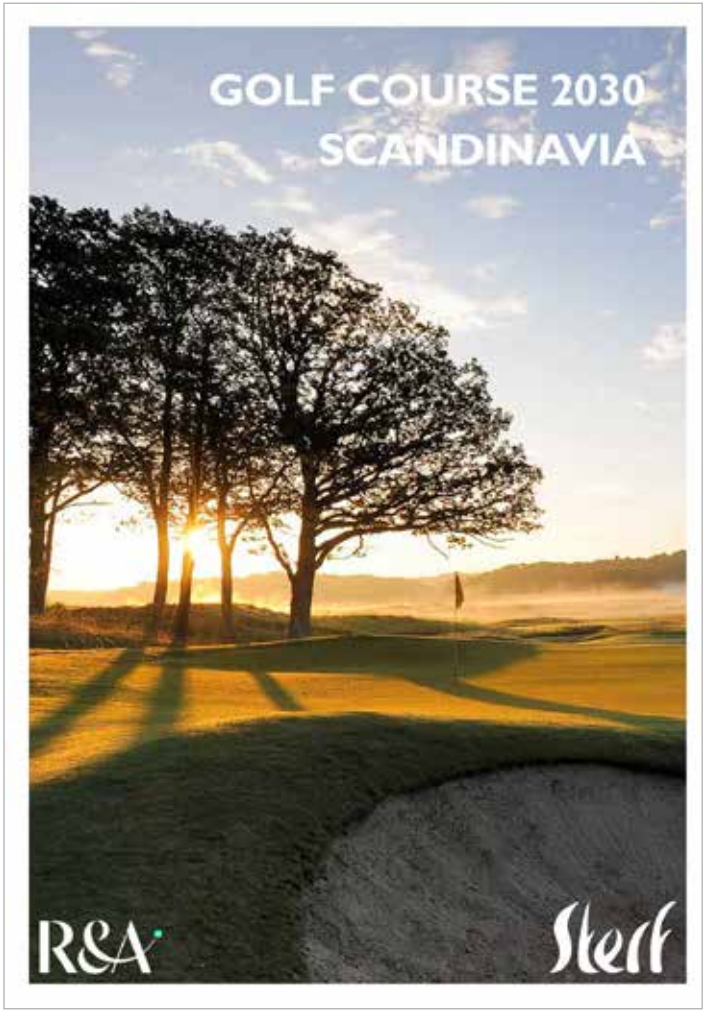
Turfgrass winter stress management

Winter damage is the foremost reason for dead grass, reducing the aesthetic and functional value of turf. UN-IPCC climate scenarios predict that, due to high precipitation and unstable temperature, ice and water damage will become the most important cause of winter damage in the future. This is a complex but high-priority area for STERF, as an estimated 70% of Nordic golf courses suffer from winter damage each year, with associated average annual costs per golf course of €35 000-40 000. STERF will take responsibility for developing strategic expertise and new knowledge to avoid and manage such damage.

Multifunctional use of golf facilities and ecosystem services

Multifunctional golf courses can contribute to increased biological diversity, conservation of na¬tural and cultural environments, and retention and expansion of ecosystem services. They can also help to improve people's health and quality of life by providing facilities for active outdoor recreation and outdoor teaching. Through STERF´s R&D programme within multifunctional facilities, the societal benefits of golf can be improved and the Nordic area can become a model region as regards multifunctional golf courses and collaborations between different interests in society. Four central research and development areas have been identified: (1) The everyday landscape and peri-urban nature, (2) Nature and culture, (3) Dialogue and cooperation, and (4) Business promotion.

GOLF COURSE 2030 SCANDINAVIA



To achieve maximum future impact from the turfgrass sector´s sustainability work, it is of the utmost importance to establish international interdisciplinary collaborations where all stakeholders make efforts to cooperate and align their resources and efforts using the United Nations 2030 Agenda for Sustainable Development with its 17 sustai¬nable development goals (SDGs) as a steering document.

The R&A Golf Course 2030, established by the Royal & Ancient (R&A) in 2018, is a significant initiative to support and stimulate golf industry stakeholders to agree on a roadmap that secures optimal golf course condition and playability for current and future generations. The roadmap is also intended to highlight the potential for golf courses to be designed and managed to promote critical ecosystem services, and to restore and enhance biodiversity in ecologically simplified lands¬capes.

As part of the R&A Golf Course 2030 initiative, STERF has created Golf Course 2030 Scandinavia. This collaboration between STERF and the R&A regards ready-to-use research as an important tool to help prevent negative impacts on the planet and aims to develop new knowledge that is neces¬sary to change the mindset and attitudes of people world¬wide.

The joint R&A and STERF IPM-project "*Integrated management of important turfgrass diseases, and insect pests on European golf courses*" was completed during 2023. Research results and new knowledge have been presented in scientific publications and in practical advice and recommendations provided in demonstration videos, fact sheets, popular scientific articles and presentations at seminars and workshops, for example at the symposium 'Sustainable golf course management Integrated turf management' held in Sigtuna in September by STERF and R&A.

A new joint STERF-R&A project, "*GOLF LANDSCAPES: Biodiversity and multifunctionality of golf landscapes*", was started in 2023.

Vallda GC. Photo: Peter Corden

SCANGREEN: TURFGRASS SPECIES AND VARIETIES FOR INTEGRATED PEST MANAGEMENT OF SCANDINAVIAN PUTTING GREENS, 2019-2022

PROJECT PERIOD: 2019 - 2023

FUNDING (kSEK)

	2019	2020	2021	2022	2023	Total
STERF	500	375	500	300	200	1875
Other sources	153[1]	0	264[2]	0	153[1]	570
Total	653	375	764	300	353	2445

1) DLF Seeds, Barenbrug, DSV, Scandinavian Seeds, Mountain View Seeds, Graminor, Svensk Jordelit, Semillas Fito, Landmark Seeds, ICL/Everris, PGM, Tempo Verde, Germinal.
2) Extra funding from DGU, Solum, Agrometer and NIBIO.

PRINCIPAL INVESTIGATOR / CONTACT PERSON

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Anne F. Borchert, Trygve S. Aamlid, Tatsiana Espevig, Trond Petterson and **Jørgen Hornslien,** NIBIO, Norway.

PROJECT OBJECTIVES

- To screen in the field and clarify which varieties of *Agrostis, Festuca, Poa* and *Lolium* are most winter-hardy, most stress-tolerant and most disease-resistant on putting greens at four experimental sites representing the two major climate zones in the Nordic countries.
- To create meeting places for discussions between plant breeders, seed companies and greenkeepers in order to encourage variety awareness, integrated pest management and continued efforts in turfgrass breeding for high-latitude environments.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023

15 January: NGA Gresskurs, Malaga, Spain. 'Arter og sorter til greener. Resultater fra SCANGREEN 2019-22'. T.S. Aamlid.
12 April: Smørum. Field walk with ERFA group visiting the experimental green. P.Rasmussen.
20 June: NIBIO-Landvik, Norway. International Turfgrass Field Day. Field walk at experimental plots before renovation of the trial. K.J. Hesselsøe.
19 September: Sigtuna, Stockholm, Sweden. Integrated Turf Management, Golf Course 2030 and STERF Symposium, 'Varieties and mixtures for integrated management of putting greens, results from SCANGREEN 2019-2022'. K.J. Hesselsøe
13 November: Stockholm, Sweden. 'Grasarter og sorter til golfbaner i Norden', Lecture at 'Högare Greenkeeperutbildning' for Svenska Golfförbundet, T.S.Aamlid.
15 November: Svendborg, Denmark, Danish Greenkeepers Association Conference. 'Arter, sorter og blandinger til greens i Norden. Resultater fra SCANGREEN 2019–2022'. Karin Juul Hesselsøe.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

In ranking of species across three test sites in the Nordic countries (Reykjavik, Apelsvoll and Landvik, Smørum not included because of a shorter test period), creeping bentgrass and velvet bentgrass gave the best overall impression, significantly better than slender creeping red fescue, Kentucky bluegrass and chewing's fescue, which were all equal. Perennial ryegrass and rough bluegrass were rated lowest or second lowest at all sites except Smørum, where perennial ryegrass showed intermediate performance. Among varieties of chewing's fescue (*Festuca rubra commutata*) across all Nordic sites and years, the new variety 'Euro Carina' performed best, in line with the control variety 'Barlineus', followed by the two new varieties 'Orionette' and 'Gima' and the control variety 'Musica'. Among

Delegates at NIBIO International Turfgrass Field days at Landvik on 20 June 2023 during a field walk in SCANGREEN 2019-2022 plots. Photo: Morten Günther.

varieties of slender creeping red fescue (*Festuca rubra litoralis*) across the three sites, 'Sybille' performed best, followed by the control variety 'Cezanne'. Among varieties of colonial bentgrass (*Agrostis capillaris*) across the three sites, there was no difference between the varieties in overall turfgrass quality, but 'Jorvik' had the lowest overall winter damage and the least microdocium patch across all years. Among varieties of creeping bentgrass (*Agrostis stolonifera*) across the three test sites, the new varieties 'Matchplay', 'L-93 XD' and '777 Triple Seven' performed best, closely followed by 'Piranha' and 'Valderrama' which were in line with the control variety 'Luminary'. Among varieties of velvet bentgrass (*Agrostis canina*), 'Villa' remains the top variety for the Nordic countries. Among varieties of Kentucky bluegrass (*Poa pratensis*), the control variety 'Limousine' had higher turfgrass quality, higher tiller density, finer leaves and less in-season disease than the candidate 'Professor' on average for the Reykjavik, Apelsvoll and Landvik sites.

Only a few clear differences were found between the mixtures and blends. At 3 mm mowing height and a fertiliser rate of 17 g N m^{-2} yr^{-1}, the mixture of fescue (blend of 'Barineus', 'Musica' and 'Cezanne') and creeping bentgrass ('Pure Distinction') performed better than the traditional mixture of fescue and colonial bentgrass ('Greenspeed') at Landvik and Smørum, because of better winter survival and less microdochium patch, but there was a risk of fescue being outcompeted by creeping bentgrass. Varieties of creeping bentgrass with lower tiller density than 'Pure Distinction' should be used for mixtures with fescue. The mixture of creeping bentgrass and perennial ryegrass established significantly faster than the other seed blends and mixtures, but turfgrass quality after winter was lower than for the other blends.

SCANGREEN: TURFGRASS SPECIES AND VARIETIES FOR INTEGRATED PEST MANAGEMENT OF SCANDINAVIAN PUTTING GREENS, 2023-26

PROJECT PERIOD: FEBRUARY 2023 - MARCH 2027

FUNDING (kSEK)

	2023	2024	2025	2026	Total
STERF	529	669	635	510[1]	2343
Other sources[2]	232	47	47	207	533
Total	761	716	682	717	2876

1) Reserved, not granted;
2) Companies: Barenbrug (The Netherlands), DLF (Denmark), Landmark Seeds Company and Mountain View Seeds (Oregon, USA). In kind: Smørum GC, Reykjavik GC/Golf Union of Iceland, Danish Golf Union

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PROJECT OBJECTIVES

- To screen in the field and clarify which varieties of *Agrostis, Festuca, Poa* and *Lolium* are most winter-hardy, most stress-tolerant and most disease-resistant on putting greens at four experimental sites representing the two major climate zones in the Nordic countries.
- To create meeting places for discussions between plant breeders, seed companies and greenkeepers in order to encourage variety awareness, integrated pest management and continued efforts into turfgrass breeding for northern environment

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023
12 April: Teams meeting (Project core group). PPT by Karin J. Hesselsøe
12 May: Teams meeting (Project core group). PPT by Karin J. Hesselsøe
31 August: Field walk at Reykjavik GC, Bjarni Hannesson.
14 September: Evaluators meeting and field walk at newly established green at Smørum Golf Club, Denmark. PPT by Karin J. Hesselsøe, field walk by Per Rasmussen.
21 November: Teams meeting (Project core group). PPT by Karin J. Hesselsøe.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024
This project is a continuation of SCANGREEN variety testing that has been going on for more than 20 years. Varieties are assessed on sand-based greens at NIBIO-Landvik, Norway, and Smørum GC, Denmark, in the southern zone and at NIBIO-Apelsvoll, Norway, and Reykjavik GC, Iceland, in the northern zone. The on-going test round started in 2023 and includes an additional test site in Minnesota, USA.

The project comprises seven species (chewings and slender creeping fescue, colonial and creeping bentgrass, perennial ryegrass, Kentucky bluegrass and smaller cat's-tail) with 20 new varieties for comparison with the references. Mixtures of fescue and bentgrass are also being tested. Experimental plots are evaluated monthly and varieties are ranked for turf quality, winter tolerance, diseases and invasion of moss and annual bluegrass. The test sites are used for field days according to a predetermined schedule and results are communicated at www.sterf.org, www.scanturf.org and in greenkeeper magazines and in the booklet '*Turfgrass seed for the Nordic countries*', which is updated every second year.

Removing turf from the old SCANGREEN. Landvik, July 2023. Photo Trygve Aamlid.

New experimental greens were established at Apelsvoll and Smørum in June, and at Reykjavik and Landvik in July. Establishment was most successful at Reykjavik, while many of the plots had to be reseeded at Landvik in August and September. At Apelsvoll, plots with Kentucky bluegrass were also reseeded. At Smørum, most of the green was reseeded in August. In October, some of the plots with Kentucky bluegrass and smaller cat's-tail were still not fully covered at Landvik, Apelsvoll and Smørum. The challenges with establishment are likely explained by the very dry weather in Norway and Denmark in June. At Minnesota, the experimental green was established in early September due to problems with delivery of the seed package from Norway.

Field walk at Reykjavik GC, August 2023 Photo Bjarni Hannesson.

INTEGRATED MANAGEMENT OF IMPORTANT TURFGRASS DISEASES AND INSECT PESTS ON EUROPEAN GOLF COURSES

PROJECT PERIOD: FEBRUARY 2020 - DECEMBER 2023

FUNDING (kSEK)

	2020	2021	2022	2023	Total
STERF	386	322	288	178	1 174
The R&A	386	322	288	178	1 174
Other sources	697	692	583	110	2 082
Total	1469	1336	1159	466	4430

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PROJECT OBJECTIVES
The overall aim of the project is to investigate cultural practices and new technologies for prevention and control of the two most important turfgrass diseases on golf course putting greens and insect pests on golf courses with minimum use of pesticides. Specific objectives are:

- To investigate the effect of cultural approaches such as rolling (microdochium patch only), UV-C radiation and alternative products against microdochium patch and dollar spot.
- To identify the fungal species causing dollar spot in Northern and Central Europe and investigate immonoassay for identification of *Clarireedia* spp. and *Microdochium nivale* in plant tissue and *Clarireedia* spp. in commercial seeds.
- Compile a review of the management and potential innovation options of monitoring, warning and control of chafer grubs and leatherjackets on golf courses.
- Provide technology transfer to the golf course industry, to disseminate the results from the project through popular and scientific publications, videos and fact sheets, and to participate in international seminars and meetings, which will provide exchange of knowledge and experience among scientists, superintendents, the industry, turfgrass agronomists and consultants.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023
11 January: Malaga, Spain. Gresskurs NGA, 'Integrated management of important turfgrass diseases and insect pests on European golf courses (IPM-Golf 2020-2023)' T. S. Aamlid, A.F. Borchert, and T. Espevig.
25 January: Harrogate, UK, BTME - BIGGA Turf Management Exhibition. 'Integrated Disease and Pest Management in Europe: Research Results'. T.Espevig.
21 June: NIBIO International Turfgrass Field Days, Landvik, Norway:
'Introduction to IPM GOLF'. 2020-23, T.Espevig.
'Alternative methods to prevent and control microdochium patch on annual bluegrass predominant putting greens'. A. F. Borchert, K..J. Hesselsøe, A. Beisland, . T.O. Pettersen, T. Espevig.
'ITM in Practice - a UK Perspective'. C. Spring.
'Effect on rolling on microdochium patch. Field trial at Royal Copenhagen GC'. M.Nilsson.
'Use of biostimulants in ITM programs on golf greens with microdochium patch pressure'.

T. Espevig, T.O. Pettersen, C. Spring, M.Ferguson, and C.A. Frisk.
'Development of immunoassay for detection of microdochium fungus in grass'. Y. Lebedin.
'An overall strategy for using alternative pest management techniques in turfgrass'. H. MT Hokkanen.
'Experiences on using insect pathogenic nematodes for controlling leatherjackets and other Diptera on golf courses in Finland'. I. Menzler Hokkanen.

19 September: A Golf Course 2030 and STERF IPM Symposium, Sigtuna, Sweden.
'Introduction to IPM research programme – today and in the future'. T. Espevig
'Managing important turfgrass diseases microdochium patch and dollar spot using less fungicides'. T. Espevig
'Insect pests on Scandinavian golf courses: An update on integrated management'. K. J. Hesselsøe.
'Effects of UV-C radiation and Suståne slow-release fertiliser on turfgrass diseases on golf greens'. W. Prämaßing.

15 November: Les 48h du Gazon Sport Pro, Paris, France. 'Effects of UV-C radiation and Suståne slow-release fertiliser on turfgrass diseases on golf greens'. W. Prämaßing.

Fertilising experimental golf green at Landvik on 14 October 2021. Photo: K.J. Hesselsøe.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

This project is a concerted effort by researchers and greenkeepers from the Nordic countries, Germany, Portugal, the UK, Finland and Russia, suppliers (ICL, Syngenta, Suståne, Aqua-Yield), Golf Federations in Germany and Netherlands and the Danish Environmental Protection Agency to investigate cultural practices, alternative products and new technologies for managing the important diseases microdochium patch (MP) and dollar spot (DS) with no or strongly reduced pesticide inputs. Seven field trials were conducted, in Denmark (1), Norway (2), the UK (2) and Germany (2).

The main conclusion from the field studies at Landvik and Bingley on alternative methods for preventing MP on annual bluegrass-dominated golf greens is that fungicides are the most effective method, with MP disease reduction of 66-85%, compared with 43% or less by other methods. At Landvik, the most effective methods were 33%-reduced N rate, alone or in combination with rolling, bi-weekly nutrition and use of the slow-release organic fertiliser Suståne 5-2-4+Fe. At Bingley, with low disease pressure (<13%), iron sulphate at a rate of 4 or 8 kg/ha was effective in reducing MP incidence when used preventatively and during early disease pressure. Additional N application in late autumn increased MP in spring at Landvik, but not at Bingley.

Studies at Landvik and Bingley on incorporation of a pigment (Ryder, Syngenta) and a biostimulant (Hicure, Syngenta) into an IPM programme showed that it allowed the number of fungicide applications against MP to be decreased from three to two without loss of efficiency in treating MP.

A study on the Golf Course Osnabrück Bissendorf showed that UV-C dosages of 35-40 and 70-80 mJ/cm² successfully suppressed DS infestation at low disease pressure (<5%). *Microdochium* ELISA acted as a simple and practical method for early detection of latent *Microdochium* infection in turfgrass, and can be integrated into the overall plant disease control strategy. *Clarireedia* affinity polyclonal antibodies did not form a sandwich immunoassay, and this species requires continued efforts in obtaining mouse monoclonal antibodies.

Studies on causal species for DS in Europe identified *Clarireedia jacksonii* and *C. homoeocarpa* at least as the main cause species. However, DS symptoms can be confused with the symptoms of other turfgrass diseases, such as yellow patch caused by *Ceratobasidium cereale*, fusarium patch caused by *Fusarium culmorum* or *F. oxysporum*, pink patch caused by *Limonomyces roseipellis*, *Microdochium bolleyi* basal rot or brown ring patch caused by *Waitea circinata*.

The main conclusion from literature reviews and studies on insect pests was that control of leatherjackets, chafer grubs and other pest insects in turf needs more research on improving the efficacy and reliability of entomopathogenic nematodes. Golf course managers and greenkeepers must also improve their skills to become experts in using alternative and biological methods.

ROBO-GOLF: ROBOTIC MOWERS FOR BETTER TURF QUALITY, REDUCED FERTILISER COST AND LESS USE OF FOSSIL ENERGY ON GOLF COURSE FAIRWAYS AND SEMI-ROUGHS

PROJECT PERIOD: JANUARY 2020 - JULY 2023

FUNDING (kSEK)

	2020	2021	2022	2023	Total
STERF	250	326	336	160	1072
Husqvarna	952	376	396	304	2028
Other sources	81	83	83	0	250
Total	1283	785	818	464	3350

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Marcus Rehnström, Jönköpings GK, Sweden
Janne Lehto, Hirsala Golf, Finland
Bjarni Hannesson, Ness GC, Iceland

PROJECT OBJECTIVES

- To generate and disseminate knowledge about implications for turfgrass quality, fertiliser requirement, weed encroachment and susceptibility to various diseases of switching from conventional manual mowers to robotic mowers on fairways and semi-roughs with grass species typical for Nordic golf courses.
- To generate and disseminate knowledge about implications for labour and energy use, CO_2-emissions and soil compaction of switching from conventional manual mowers to robotic mowers on fairways and semi-roughs with grass species typical for Nordic golf courses.
- To generate and disseminate knowledge about implications for player and greenkeeper satisfaction of switching from conventional manual mowers to robotic mowers on fairways and semi-roughs with grass species typical for Nordic golf courses.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023

7 June: Stockholm, Husqvarna Conference, PPT-presentation about ROBOGOLF 2020-23, Karin Juul Hesselsøe
20 June: NIBIO Landvik, International Turfgrass Field Days. Field walk at experimental site, Karin Juul Hesselsøe and Trond Pettersen
21 June: NIBIO Landvik, International Turfgrass Field Days. PPT-presentation about WP 1 and 3, Karin Juul Hesselsøe
21 June: NIBIO Landvik, International Turfgrass Field Days. PPT-presentation about WP2, Anne F. Borchert
21 September: Svendborg, Denmark, GAD (Groundsman Association of Denmark) conference, PPT-presentation in Danish about ROBOGOLF results, Karin J. Hesselsøe
7 December: Stockholm, HGU (Høgere Greenkeeper utbildning), Lecture/PPT-presentation about ROBOGOLF in Danish/Swedish, Karin J. Hesselsøe

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

Field trials comparing robotic and manual mowing were continued at NIBIO Landvik, Norway, with robotic (Husqvarna 550) and cylinder mowers on fairway (mowing height 15 mm). On semi-rough (mowing height 35 mm), the same robotic mowers were compared with rotary mowers. Similarly high turfgrass quality on fairway and semi-rough was found with robotic and manual mowing. On some observation dates, less disease was found with robotic mowing, which could be explained by more frequent dew removal by the robots. Less white clover was found on robotic-mown fairway, while more white clover was found in robotic-mown semi-rough.

The N fertiliser effect of return of clippings in robotic vs. manual mowing was studied on fairway with annual N rates of 0, 3, 6, 9, and 12 g/m^2/yr applied over the season. There was no evidence that daily robotic mowing, compared with manual mowing three times a week with clippings returned, reduced fertiliser requirements on fairways due to better utilisation of nitrogen (N) in the smaller clippings volume. Overall, there were only small and insignificant differences in turfgrass visual quality and N utilisation between robotic and manual mowing that both returned clippings, but manual mowing with removal of clippings reduced turfgrass quality. However the results indicated a trend for more benefit from robotic mowing compared with manual mowing at high fertility resulting in high turfgrass growth rates. Under dry condtions and with insufficient fertilisation, weeds, especially white clover, increased more on robotic-mown fairways than on manually mown fairways.

The contradictory results obtained on encroachment of white clover on fairway in robotic and manual mowing call for further research. For robotic mowing to be recommended as a more sustainable mowing system than conventional mowing, it is important to know whether white clover increases or decreases with robotic mowing, which depends on factors such as grass mixture, fertiliser rate, water availability/irrigation and mowing height. Large-scale demonstration trials with robotic mowers in comparison with cylinder mowers on fairways and rotary mowers on semi-roughs were laid out at five golf courses in Scandinavia. Turfgrass quality, coverage of broadleaved weeds and energy use were recorded monthly by the course managers. In these trials, turfgrass quality was mostly similar for robotic and manual mowing on fairways and semi-roughs, but the robots were superior at high growth rates. Course managers reported less soil compaction with robots, resulting in improved water drainage on areas with robotic mowing for 2-3 years. Robotic mowing also resulted in less soil compaction in the experimental semi-rough at Landvik.

A surveys of golfers indicated that they were positive or neutral to robot mowing, but they wanted local rules when robots interfere with the game. Unfortunately, due to malfunction of loggers, the ROBO-GOLF project was unable to assess changes in energy use and CO_2 footprint on switching from traditional (manual) to robotic mowing. Further research is needed to answer these questions.

Conventional fairway mower and robot at Landvik. Photo Karin Hesselsøe.

FAIRWAYS4FUTURE: MANAGING HIGH QUALITY GOLF COURSE FAIRWAYS AND SEMI ROUGHS WITHOUT HERBICIDES AND LESS EMISSION OF GREENHOUSE GASES

PROJECT PERIOD: MARCH 2023 - DECEMBER 2025

FUNDING (kSEK)

	2023	2024	2025	Total
STERF	413	329	343	1085
Other sources	2044	374	388	2806
Total	2457	703	731	3891

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PROJECT OBJECTIVES
- To investigate management strategies for fairways and semi-roughs (robotic vs. manual mowing, mowing height and fertiliser level) that result in high turfgrass and playing quality with as low input of energy and fertiliser as possible.
- To elucidate the long-term effect of robotic mowing on soil physical conditions affecting greenhouse gas (GHG) emissions from golf course fairways and semi-roughs.
- To investigate how the combination of mowing system (robotic vs. manual), mowing height and fertiliser rate affects infestation by individual weed species and other aspects of turfgrass quality on fairways and semi-roughs.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023
16 March: Teams meeting (Project core group). PPT by Karin J. Hesselsøe
21 April: Teams meeting (Project core group). PPT by Karin J. Hesselsøe
10 October: Teams meeting (Project core group and Husqvarna). PPT on preliminary work and results in WP1 by Anne F. Borchert.
13 October: Teams meeting (Project core group and Husqvarna). PPT by K. J. Hesselsøe.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024
The long-term impact of robotic mowing on soil compaction and water infiltration rate, fairways, and roughs on golf courses in the ROBO-GOLF project (2020-23) (Bærheim (Norway), Grenå (Denmark) and Hirsala (Finland)) will be further examined. In September 2023, NIBIO started collecting soil samples to determine soil density, texture, and carbon content of the experimental fairways used in ROBO-GOLF at Bærheim. Penetrometer and soil moisture measurements were also made. In 2024, comparable samplings and measurements will be performed at Grenå and Hirsala.

At NIBIO-Landvik, Norway, conventional rotary mowing is being compared with systematic robotic mowing using the GPS-based Ceora EPOS system from Husqvarna. In the two mowing systems, two mowing heights 30 and 45 mm (which are believed to have an impact on weed encroachment) are compared. In 2024, plugs of fairway-type

white clover (*Trifolium repens*) will be transplanted into subplots in the plots with different combinations of mowing height and mowing system.

The following characters will be recorded monthly: Turfgrass overall impression, turfgrass colour and NDVI, turfgrass height and coverage of white clover using digital imaging.

The same Ceora robotic mower as used at NIBIO-Landvik will be programmed to mow different plots at the two mowing heights, 10 and 15 mm, in factorial combination with three fertiliser levels (0, 60 and 120 kg N/ha/yr). Plugs of white clover, daisies (*Bellis perennis*) and other broadleaved weeds will be transplanted into subplots to study the combined effect of different mowing heights and fertiliser levels on encroachment by the different weed species.

Demonstration trials will be established at five golf courses: Hills near Gothenburg in Sweden, Hirsala near Helsinki in Finland, Brøndby near Copenhagen in Denmark, Haus Bey near Düsseldorf, and St. Eurach near Munich in Germany. At each golf course, a Ceora robotic mower will be installed on a designated area including both fairway and semi-rough. Conventionally mown neighbouring fairways and semi-roughs of similar soil type will serve as control treatments. On fairways, two fertiliser levels will be assessed: 'Common practice' (100%) and reduced (50%). In Germany, course managers in collaboration with turfgrass agronomist Daniel Hahn and turfgrass scientist Wolfgang Prämaßing will be responsible for the trials. Golf playing quality of the turf will be assessed by Daniel Hahn.

Monica Jayesingha taking undisturbed soil samples for soil density analysis at Bærheim GC in September 2023. Photo: Anne F. Borchert.

FAIR-WATER I: TOWARDS BETTER DROUGHT RESISTANCE AND REDUCED WATER CONSUMPTION ON GOLF COURSE FAIRWAYS

PROJECT PERIOD: JANUARY 2023 - APRIL 2026

FUNDING (kSEK)

	2023	2024	2025	2026	Total
STERF	567	572	580	0	1719
Other sources	629	491	250	0	1370
Total	1196	1063	830	0	3089

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Bernd Leinauer, New Mexico State University

PROJECT OBJECTIVES
The main aim is to develop management strategies for resilient GC fairways that retain acceptable quality with no or strongly reduced consumption of potable irrigation water. Specific objectives are to:

- Identify the most drought-resistant cultivars of turfgrass species/subspecies commonly seeded on fairways in Northern Europe, including mixtures of species.
- Screen seven soil surfactants for their potential to prevent drought stress, reduce water consumption and enhance recovery after drought.
- Validate in field trials in Norway and Germany the two most drought-tolerant blends/mixtures and the two best-performing surfactants identified in previous steps to optimise fairway quality under drought.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023
20 June: Project presented at NIBIO International Turfgrass Field Day, Landvik
14 November: Project presented briefly at SGF's course: Higher Greenkeeper Education

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024
During the past decade, many golf courses (GCs) have experienced more frequent and more severe droughts due to climate change. Scarcity of potable water for irrigation is now an issue even in the Nordic countries. This project is studying methods to reduce irrigation while retaining turf quality on golf course fairways. The project has three work packages (WPs), of which two started in 2023:

In WP1, turfgrass breeders and seed companies throughout Europe and North America were invited to submit seed of their most drought-resistant varieties. The invitation resulted in 42 varieties representing 10 species which were sown on a sandy soil in mid-May 2023. The original plan was to impose drought under a rain shelter in July. However, due to slow grow-in, notably of some fine fescues, the varieties were allowed to develop mature canopies with more and deeper roots and an extended drought period will be initiated in 2024.

In WP2, we are currently testing the capacity of soil surfactants to retain fairway quality, while minimising irrigation inputs in a trial under a mobile rain shelter operated by a rain sensor. Seven surfactants were applied according to their label (two applications 3 weeks

Experiment with 42 varieties representing 10 drought-resistant species/subspecies.Photo: T.S. Aamlid.

apart for most) to a Kentucky bluegrass/red fescue stand before imposing drought from 14 July to 8 September 2023. The products (and collaborating company) were: H2PRO Trismart (ICL), Qualibra (Syngenta), Magnum 357 Calibre (Indigrow), PBS 150 Liquid (Aqua Aid), Hydra 30+ (Aqua Aid), ProWet Evolve (RhizoSolutions/Turf Care), and Revolution. Additional treatments included a negative control (same drought period, but no surfactant) and a positive control that was irrigated to field capacity three times a week. Digital images were taken of each plot three times a week and analysed using the software Turf Analyzer (https://turfanalyzer.com). Plots were hand-irrigated with 8 mm every time turf coverage was <70%. There were no significant differences in turf quality, turf coverage or water use between the surfactant treatments. On average for the seven products, water use during the 8-week period was 54 mm on surfactant-treated plots and 70 mm on untreated plots with reference evapotranspiration of 136 mm. This experiment will be repeated in early summer 2024.

In WP3, we are planning parallel trials to be conducted at NIBIO Landvik, Norway, and Osnabrück University, Germany, in 2025 (and perhaps 2026), combining the most drought-resistant varieties from WP1 with the best surfactants from WP2.

Taking digital images in a light box. Photo: T. S. Aamlid.

ICE-BREAKER: REDUCING THE AGRONOMIC AND ECONOMIC IMPACT OF ICE DAMAGE ON GOLF COURSES AND OTHER GRASSLANDS

PROJECT PERIOD: JANUARY 2020 - MAY 2024

FUNDING (kSEK)

	2020	2021	2022	2023	Total
STERF	314	549	397	379	1639
Research Council of Norway	964	1666	1296	589	4515
Other sources	834	1195	1210	821	4060
Total	2112	3410	2903	1789	10214

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Carl Johan Lönnberg and **Håkan Blusi,** Swedish Golf Federation.
Michelle DaCosta, University of Massachusetts.
Eric Watkins, University of Minnesota.

PROJECT OBJECTIVES
The overall aim is to obtain a better understanding and improve strategies to prevent and repair damage caused by prolonged ice cover and meltwater on golf courses and other grasslands. Specific objectives are to:

- Screen turfgrass cultivars for tolerance to anoxia, i.e. no O_2 and and high CO_2.
- Explore whether plastic covers or snow/ice removal during all or parts of the winter prevent ice and water damage in creeping bentgrass, red fescue and annual bluegrass or whether the grass will suffer from hypoxia.
- Evaluate whether sensors can be used to determine if ice layers should be crushed or the need for ventilation under the plastic covers.
- Explore whether free oxygen radicals impair photosynthesis when newly sown grass or grass that has been under ice is exposed to normal O_2 levels at low temperature and high light intensity, and if such damage can be avoided by the use of shade covers in spring.
- Identify growth-inhibiting substances than can form on ice-covered greens and explore means to eliminate these before reseeding.
- Evaluate cultivars of creeping bentgrass, tarps and biostimulants for faster re-establishment of greens killed by ice.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023
16 January: Norwegian Greenkeeper Association Winter Course, Malaga, Spain. 'Resulater fra ICE_BREAKER'. T. S. Aamlid.
24 January: Lectures at Sandmoseskolen, Denmark: 'Vinterpleje, græs'. Education course for course managers. K. J. Hesselsøe.
21 April: Oral presentation at WINTER TURF annual meeting, University of Massachusetts, Amherst, USA. 'NIBIO Turfgrass Research Group, STERF and ICE-BREAKER'. T. S. Aamlid.
28 April: Field day presentation at WinterTurf Field Day, Univeristy of Minnesota, St. Paul, MN, USA. 'Species survival under extended ice cover'. Andrew Hollman.
1 June: Oral pesentation at seminar for NIBIO CEO and board: 'Grovfôrforskning i NIBIO, Tromsø'. S. Dalmannsdottir, M. Jørgensen & E. Elverland
20 -21 June: NIBIO International Turfgrass Field Days:
'Impact of winter covers on the need for fungicide applications on putting greens'. T. S. Aamlid.
'Re-establishment rate and competition from Poa on winter-killed putting greens as affected by creeping bentgrass cultivar and soil temperature at reseeding'. T. Espevig and T.Pettersen

'ICE-BREAKER 2020-2023: Reducing the agronomic and economic impact of ice damage on golf courses and other grasslands'. T. S. Aamlid.
'Transitioning from winter to spring: Understanding factors impacting turfgrass recovery following ice cover. M. DaCosta.
'Strategies for enhancing creeping bentgrass re-establishment following winterkill'. M.DaCosta.
'Cool season turfgrass survival under prolonged ice cover. E.Watkins
31 Aug: Oral presentation at 100-year anniversary for NIBIO Holt, Tromsø. 'Ikke trø i graset – vi tester det nemlig'. S. Dalmannsdottir, E. Elverland & M. Jørgensen
7 Sept: Oral presentation at the 11th Circumpolar Agricultural Conference, Tórshavn, Faroe Islands 5-7. September 2023: 'Future prospects for agriculture in Northern-Norway. S. Dalmannsdottir.
28 Sept: Visit to Landvik by Danish Greenkeeper Students from AMU-Sandmosen, Denmark: 'NIBIO Turfgrass Research Group and the project ICE-BREAKER'. T. S. Aamlid.
18-20 Oct: Poster at The 3rd Nordic Metabolomics Conference, Trondheim, Norway: 'Metabolomic study of metabolites in winter damaged soils that can impact plant growth'. M.Almvik
3 November: ICE BREAKER Final Seminar, Oslo Quality Oslo Airport Hotel:
'ICE-BREAKER: Background, overview and project team'. Trygve S. Aamlid.
'The risk for ice and water damage: IPCC predictions for future winter climates'. Hans Olav Hygen, Norwegian Meteorologial Institute.
'The two main types of ice and water damage: Anoxia vs. crown hydration/freezing'. T. S. Aamlid
'What's going on at the turfgrass crown level? Freeze/thaw cycles and crown hydration – why could impermeable plastic be better than ice ?' E. Merewitz Holm, Michigan State University.
'The critical spring transition: Bleaching and reduced photosynthesis as the turf comes out of ice'. S. Dalmannsdottir.
'Practical experiences with coverage in Sweden'. H. Blusi.
'From snow removal to plastic coverage at Oslo GC:'. J. Riiber.
'Two years comparison of snow/ice removal vs. plastic sheets at NIBIO Apelsvoll'. W. Waalen.
'Refinement of the cover technology: The need for ventilation and undercovers'. T. S. Aamlid.
'The adoption of cover technology on Norwegian GCs'. M.Thers.
'The genetic component: Screening of species and varieties for tolerance to ice encasement. K. Juul Hesselsøe.
'Identification and elimination of inhibitors to germination and seedling growth when reestablishing greens after ice encasement'. P. Heltoft, K. Juul Hesselsøe, M.Almvik.
'Creeping bentgrass varieties, spring covers and biostimulants for faster reestablishment of winter-killed greens'. T. S. Aamlid.
'Optimal machines for reseeding / faster reestablishment using unprimed and GA3-primed seed of creeping bentgrass varieties on golf courses in Sweden. CJ Lönnberg.
'Main conclusions from a four year project'. T. S. Aamlid.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

All experiments in ICE-BREAKER were completed in 2023 and results were presented at a final seminar in Oslo on 3 November. STERF and the Research Council of Norway have granted an extension of the project until 31 May 2024 for remaining publications to be completed. The 10 main conclusions from the project are that:

1. Ice and water damage in future winter climates will probably be caused by meltwater and repeated freeze/thaw rather than anoxia, but long winters with anoxia may occur every 5-10 years.
2. Because of this, the need for properly designed and well-drained greens and green areas will become even more important in the future.
3. We recommend coverage with a tarp + plastic to prevent ice and water damage. Ventilation under the covers is needed as insurance in years with a long winter, especially on Poa greens.
4. Plastic covers neither increase nor decrease the need for fungicide applications in autumn.
5. Poa is by far the least winter-hardy species on Nordic putting greens. New varieties of chewings fescue from Northern Europe may be at least as tolerant to ice encasement as new varieties of creeping bentgrass from USA.
6. All species, and especially Poa, may suffer from photoinhibition after release from ice encasement and/or plastic covers in spring. We recommend not exposing turf to intense sunlight after being covered through the winter; risk of damage can be decreased by removing plastic on a cloudy day.
7. Fast re-establishment of winter-killed greens from seed in spring is primarily a question of soil temperature, adequate water supply, good seed-soil contact, sufficient phosphorus supply and ample nitrogen supply.
8. Creeping bentgrass varieties differ in their ability to re-establish at low soil temperatures, but these differences also depend on the seed lot used and are altogether less important than the varieties' overall turfgrass quality over several years. The most slowly germinating varieties, such as 'Independence' and 'Memorial', should be avoided.
9. Spring covers are important to accelerate germination and seedling growth after reseeding in spring. Their effect is primarily due to higher soil temperature, but they also protect against hard rains, desiccation and high light intensity.
10. Growth-inhibiting concentrations of butyric or acetic acid or other compounds were not detected in winter-killed greens after up to 115 days of ice encasement. Since these acids are volatile and tend to evaporate in a few days, their role in inhibiting germination and seedling growth after ice encasement may have been overrated in the past.

CARBON PAR: ESTIMATING CARBON STATUS OF LAND USED BY ICELANDIC GOLF COURSES AND MEASURING CARBON SEQUESTRATION AND SOIL CONSERVATION POTENTIAL OF TURFGRASS ON GOLF FAIRWAYS AND MOWN ROUGHS

PROJECT PERIOD: JANUARY 2020 - MARCH 2024

FUNDING (kSEK)

	2020	2021	2022	2023	Total
STERF	150	300	0	0	450
Other sources	345	156	171	276	948
Total	495	456	171	276	1 398

PRINCIPAL INVESTIGATOR / CONTACT PERSON

Edwin Roald, Eureka Golf ehf., Stekkjarflöt 23, 210 Garðabær, Iceland, , edwin@carbonpar.com, +354 693 0075.

CO-APPLICANTS

Jón Guðmundsson, Agricultural University of Iceland.

PROJECT OBJECTIVES

- Estimate CO_2 losses and carbon storage from land use of cultivated and managed areas on Icelandic golf courses, in total and by facility.
- Discuss whether/how the estimation process can be streamlined further.
- Determine what is required in terms of funding, time and other resources to produce a similar estimation for other Scandinavian countries.
- Identify marked trends, if any, revealing or suggesting how golf facilities can, in a general sense, easily improve their carbon status from land use without negatively influencing the playing experience.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023

5 July: Live morning interview on Channel 2 Radio, part of Iceland's public service broadcasting, about Carbon Par.
7 November: Interview on CNN's Living Golf.
24 November: Meeting with the President of Iceland, Guðni Th. Jóhannesson, discussing how Carbon Par is helping Icelandic golf lead climate action in global golf, by estimating land carbon flows and stocks in all of Iceland's sixty golf course sites.
December: Successful title and short abstract submission to the International Turfgrass Society's call for papers in connection with the 2025 International Turfgrass Research Conference in Japan.

Project Information is provided on its website, http://www.carbonpar.org, and in mainstream social media under @carbonpar.
Social media in 2022 included:
Facebook: 9 posts. Page likes to date: 149. Followers to date: 165.
Instagram: 6 posts. Followers to date: 413.
X (formerly Twitter): 9 tweets. Followers to date: 384.
LinkedIn: 5 posts. Followers to date: 189.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

The development of some golf courses has involved wetland drainage or the use of previously drained wetlands. Through this, many clubs have unintentionally caused large emissions of greenhouse gases, since emissions from golf courses on drained organic soils can be very high, while courses on mineral soils can sequester carbon. Grass can sequester considerable levels of carbon. Furthermore, managed grasslands, or turf, can sequester more carbon than unmanaged. This indicates that well located golf courses, thoughtfully planned, designed and built, have a reasonable chance of becoming net carbon sinks.

To estimate the carbon status of land used by all golf courses within the Golf Union of Iceland, a variety of methods were used, including mapping, references to national soil databases, soil sampling, interviews, and analysis. Perimeters of various golf course land use elements, such as fairways, managed roughs and native areas, were drafted up in GIS and CAD-software, using underlying georeferenced aerial photographs. Each golf course area was broken down into 3-4 basic soil types. Soil samples were collected from a selection of golf facilities and analysed by dry combustion, delivering %C and %N content.

Collection of soil samples from all 60 golf course sites was completed in November 2022. Laboratory analysis was completed in May 2023. Interpretation of results and development of a scoring system for carbon sequestration and/or land use emissions on each golf course are underway.

Preliminary results indicate considerable sequestration potential in mineral soils, although depending on land use history, and some emissions hotspots in organic soils.

María Svavarsdóttir from the Agricultural University of Iceland loading samples into the carbon analyser in the laboratory.

PRACTICAL MEASURES TO INCREASE BIODIVERSITY ON GOLF COURSES

PROJECT PERIOD: MAY 2020 - JUNE 2024

FUNDING (kSEK)

	2020	2021	2022	2023	Total
STERF	0	0	0	0	0
Other sources	790	390	197	200	1577*
Total	790	390	197	200	1577*

** 50% in SEK and 50% in in-kind funding*

PRINCIPAL INVESTIGATOR / CONTACT PERSON

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CO-APPLICANTS AND COLLABORATORS

Ingela Danielsson, Falkenberg Municipality. Email: ingela.danielsson@falkenberg.se

PROJECT OBJECTIVES

- To create a model for local collabo¬ration between golf clubs, municipalities and other actors in the community with the aim of creating rich plant and animal life.
- To improve biodiversity on golf cour¬ses through increased knowledge of how different measures and mainte¬nance routines on the golf course can contribute to creating rich plant and animal life.
- To study the effects of different care routines to increase the number of pollinating insects and the playability of golf course roughs.
- To evaluate how different care routi¬nes benefit specific insect species.
- To spread knowledge and experience to golf clubs, municipalities and other organisations in society nationally and internationally.

TALKS AT CONFERENCES, SEMINARS, MEETINGS ETC. IN 2023

Falkenbergs GC:
28 March: Checking up the maintenance plan and check the work with trees.
14 April: Work with sand beds. **23 May:** Information meeting and nature walk with 30 persons from Ljungbyhed GC, which works much with biodiversity on its course.
4 September: Follow-up of the season. Nature Walk on the golf course. Participants from the public, club members and representatives from local conservation organisations took part in the event.
Ullared Flädje GC:
11 January: Check on the maintenance plan and work with sand beds. **24 April:** Check on the results of burning. **14 December**: Follow-up of the season.
Vinbergs GC:
3 May: Check on the maintenance plan and work with sand beds. **18 September:** Follow-up of the season. Nature walk on the golf course. Participants from the general public, club members and representatives from local conservation organisations took part in the event.
Hofgårds GC:
5 May: Check on the results of burning. **31 May:** Information meeting and nature walk at Hofgårds GC with an international IPM network group (from Scandinavia, Netherlands and Germany). **21 August:** Follow-up on grass cutting and removal.
Harabäckens GC:
28 April: Check on the result of burning. **11 September:** Follow-up on grass cutting, removal and "sand areas", follow-up of the season. Nature walk on the golf course. Participants from the general public, club members and representatives from local conservation organisations took part in the event.
13 November: Presentation of the project at seminars/meetings with WWF and Östergötlands Golf district organisation.
Information spread in SGF courses GUB 10/11, VUB 25/1, 1/12, VUB (NGA Norge) 13/2 and HGU 6 /12, as well as at GAF (golf administrators) training 15/11.
Signs have been placed with habitat types (10 (A3) signs per course) on the courses and a larger information board (about Biodiversity) has been placed at each clubhouse.

Grass surfaces were burned off on some courses.

Signs have been placed at different habitat types.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

Biodiversity loss and ecosystem collapse are among the greatest threats humanity faces in the next decade. The EU Biodiversity Strategy for 2030 proposes a more holistic approach to biodiversity policy. Protecting and restoring nature cannot be solely imposed by regulation and must include all relevant actors in the peri-urban and rural landscape. Golf courses could contribute to produc¬tion of biological diversity, conservation of na¬tural and cultural environments and retention and expansion of ecosystem services in peri-urban environments and the cultivated landscape.

The project tested several measures to promote biodiversity, adapted to each golf club's con¬ditions. Measures to benefit insects involved creating flower-rich soils with exposed sand. The selection of measures and maintenance efforts tested can be adapted to a golf course anywhere in the municipality, region or country. The goal is that the final inventories for 2023 will show improved flora and insect diversity on the golf courses.

Individual action plans have been drawn up for five golf courses: Falkenbergs GC, Ullared Flädje GC, Harabäckens GC, Hofgårds GC and Vinbergs GC. These action plans describe what, where and when measures for biological diversity can take place on each individual course and include an assessment of the time required and costs.

A dialogue has been held with the Golf Federation and golf course staff to make sure that the action proposals can be coordinated with the golf game itself. Work has started on summarising the experiment and writing a project report, manuals and checklists for different biotopes.

The following activities were conducted on the golf courses in 2023:

- During the growing season, individual plans were implemented in practice. In autumn, each facility was visited, the season was reviewed and the individual care plans for 2023 were adjusted.
- Grass surfaces were burned off on some courses.
- Grass surfaces were cut and the material was removed. A challenge encountered, and which will be a problem when these measures are implemented on a larger scale, is to get rid of this grass material in an economically and environmentally correct way.
- Sand areas were produced by excavating and/or supplying sand to support seed and establish new meadow plants that have a good function for pollinating insects.
- Release of larger solitary trees and brow environments (thinning and clearing).
- Parts of bunkers are managed and executed so that certain insects will find a place to live in edge zones.
- Information material, such as signs etc., has been placed at different habitat types (10 (A3) signs per course) on the courses and a larger information board has been placed at each clubhouse.

GOLF LANDSCAPES: BIODIVERSITY AND MULTIFUNCTIONALITY OF GOLF LANDSCAPES

PROJECT PERIOD: FEBRUARY 2023 - DECEMBER 2025

FUNDING (kSEK)

	2023	2024	2025	Total
STERF	300	300	300	900
R&A	225	225	225	675
NIBIO	0	100	100	200
Total	525	625	625	1775

PRINCIPAL INVESTIGATOR / CONTACT PERSON
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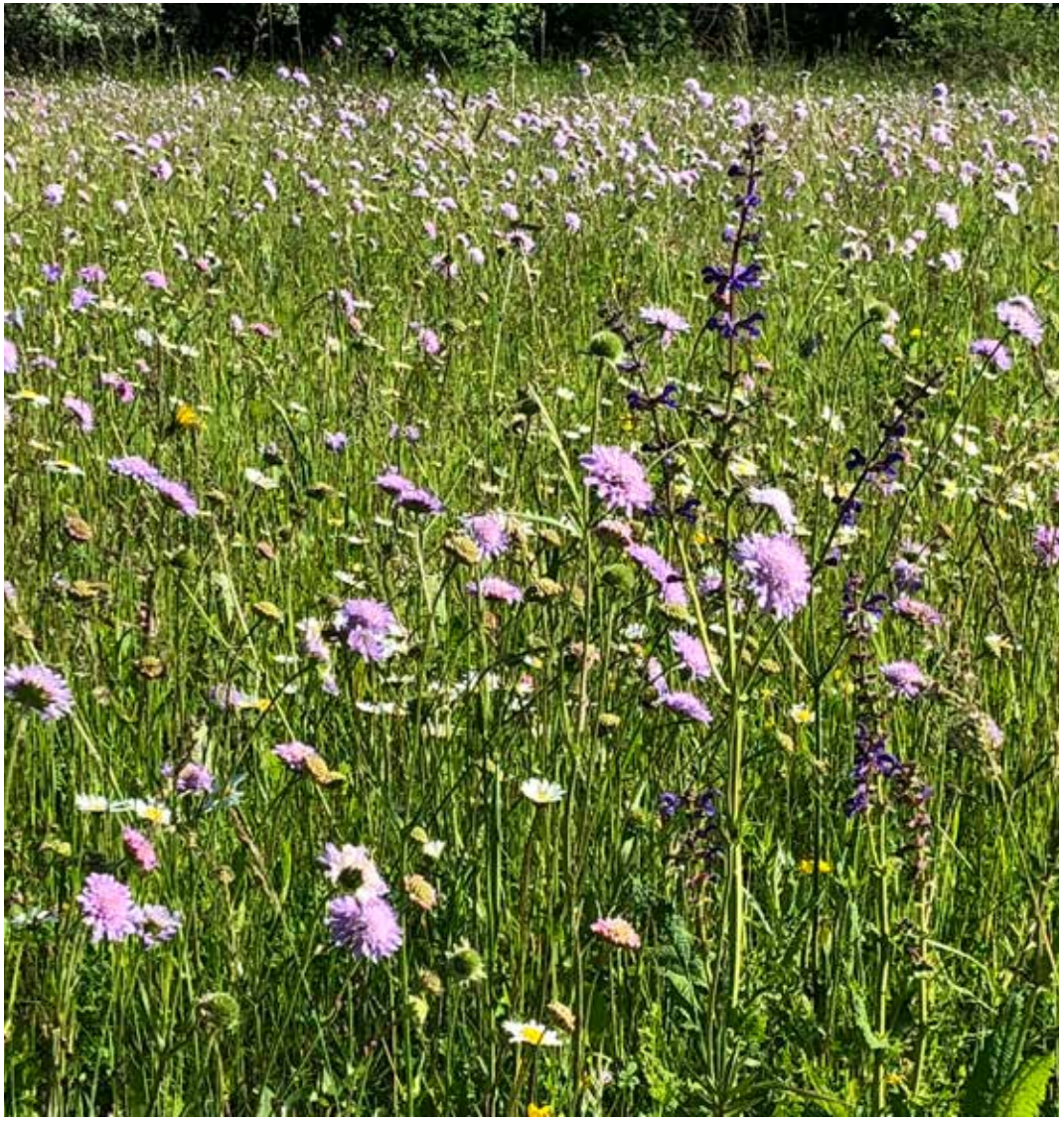
CO-APPLICANTS AND COLLABORATORS
Trygve Aamlid, NIBIO, Dept of Urban Greening and Vegetation Ecology, Norway
Wendy Fjellstad, NIBIO, Dept. of Landscape Monitoring, Norway
Johannes Kollmann, NIBIO and Technical University Munich, Germany
Tommy Lennartsson, Swedish Biodiversity Centre, SLU, Sweden
Christopher Marston, UK Centre for Ecology & Hydrology, UK.

PROJECT OBJECTIVES
- To provide knowledge of how golf courses can be designed and managed to improve their contributions to biodiversity and multifunctionality at the landscape scale.
- To identify approaches to assess and document existing qualities and biodiversity potential, prioritise approaches and recommend methods to monitor development based on golf course potential and landscape context.
- To provide simple indicators of golf course contributions to landscape functions, to be used in design and management, such as connectivity, species pool, and structural and habitat diversity.
- To provide methods to estimate multifunctionality for the courses and landscapes.
- To prescribe principles of design to improve biodiversity and ecological functioning, the quality of golf course habitats for biodiversity and their contributions to biodiversity in the wider landscape while retaining playability and quality of the game.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024
Golf courses are often established in highly fragmented and at least partly degraded landscapes, resulting in positive effects on biodiversity and ecosystem functions. However, there are few studies on ecological effects within and beyond golf courses.

In this project, landscape ecological analysis is being performed on 40 courses along an urbanisation gradient, in Munich (Germany), Manchester (UK), Stockholm (Sweden), Copenhagen (Denmark) and Oslo (Norway). Landscape analysis is based on mapped information to estimate landscape indicators for biodiversity, such as size and shape of landscape elements, edge effects, landscape diversity and landscape heterogeneity based on land cover types. We are using methods to automate this for larger landscapes. Patterns within the golf courses will be related to the surrounding landscape, and results will be verified by fieldwork on a subset of the courses. This will provide knowledge of how golf courses can be designed and managed to improve their contributions to biodiversity and ecological functions at the landscape scale, also given the context dependence of each course. The main findings of the project will be disseminated to the golf industry through guidelines, workshops, and webinars.

Restored water course GC Eichenried.



Restored meadow at Hangenham.

ARTIFICIAL INTELLIGENCE-POWERED GOLF TURF MAINTENANCE (ADORE)

PROJECT PERIOD: JANUARY 2024 - SEPTEMBER 2024

FUNDING (kSEK)

		2024	Total
STERF		250	250
Other sources		107	107
Total		357	357

PRINCIPAL INVESTIGATOR / CONTACT PERSON
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CO-APPLICANTS AND COLLABORATORS
Felix Rios, AI Consultant Frilans Finans Sverige AB
Viktor Österberg, Data Scientist Nordic AI Technology AB

PROJECT OBJECTIVES

- The project objective is to evaluate artificial intelligence (AI)-based time-series modelling techniques for simulation of turf metrics and to answer the research questions: i) what types of data are required and ii) what volume if data is needed to simulate turf quality with sufficient accuracy.
- Given sufficient simulation accuracy, cost and sustainability drivers can be defined for each maintenance action. Combining the AI models, cost and sustainability functions, a generative AI layer can be applied, targeting a future app for generation of optimised turf maintenance prescription taking turf quality, sustainability and maintenance cost into consideration.
- Since successful validation of stand-alone local AI models is a prerequisite, the project scope will not encompass the generative layer or evaluation of transfer learning, i.e. the project will not evaluate to what extent data from one golf course can be leveraged on other golf courses. Domain experts state that properties of the underlying turf soil physics can be extrapolated, given i.a. common grass, geo and soil characteristics, which brings a solid case for evaluating transfer learning in future projects.

PROJECT SUMMARY AND STATUS AS OF 1 JANUARY 2024

Despite rising turf maintenance challenges, related to e.g. climate change, fungicide and pesticide restrictions and cost inflation, turf maintenance is to a large extent a manual and non-optimised process. Turf care optimisation is complex and multivariate, i.e. it depends on multiple and co-varying parameters, including maintenance, soil properties and environmental parameters. Hence, optimisation of turf maintenance using domain knowledge and physical experiments alone is unfeasible.

A digital and data-driven approach, powered by AI will be evaluated for identification of sustainability and playability optimal turf maintenance prescription in the endless space of possible maintenance configuration combinations. AI modelling will be applied for simulation of future turf properties, including playability and stress metrics, as a function of current turf state, a maintenance scheme and environmental data. Since continuous data collection is resource-consuming, the project aims to identify the data type/s and data volume required to make accurate predictions and to assess whether AI-generated turf maintenance prescription is viable.

COMPLETED PROJECTS

The projects listed below were funded by STERF during the period 1999-2022. More information about the projects can be found on the STERF website www.sterf.org

1. The effects of soil organic matter, content, and quality on soil biological activity and turfgrass root development in sand dominated golf greens. Karin Blombäck, Swedish University of Agricultural Sciences (1999–2001)

2. Nitrogen utilisation efficiency in different golf green constructions of Creeping Bentgrass golf greens. Karin Blombäck, Swedish University of Agricultural Sciences (2001-2004).

3. Effects of demand-driven fertilisation on growth, appearance and nitrogen use efficiency of turfgrass. Tom Ericsson, Swedish University of Agricultural Sciences (2003-2004).

4. Leaching of fungicides from golf greens: Quantification and risk assessment. Nicholas Jarvis, Swedish University of Agricultural Sciences (2004-2005).

5. Benefits and environmental risks of fungicide use on Scandinavian golf greens. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2004-2005).

6. Evaluation of *Agrostis* and *Festuca* varieties for use on Scandinavian golf greens. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2004- 2007).

7. Environmental management programmes for golf facilities - a case study in the Stockholm golf district. Mårten Wallberg, Swedish Society of Nature Conservation, Stockholm (2005-2007)

8. Evaluation of Agrostis and Festuca varieties (Nordisk sortguide). Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2007).

9. Evaluation of biodiversity and nature conservation on golf courses in Scandinavia. Bente Mortensen, GreenProject (2006-2007).

10. Effects of organic amendments and surfactants on hydro-phobicity and fungicide leaching from ageing golf greens. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2006-2007).

11. The role of golf course management in the support of wetland-associated organisms in greater metropolitan Stockholm. Johan Colding, Beijer Institute of Ecological Economics, Royal Swedish Academy of Science (2006-2008).

12. Ageing of a sand-based rootzone. Karin Blombäck, Swedish University of Agricultural Sciences (2006-2008).

13. Turfgrass demonstration trials in Dalarna. Erik Svärd, Swedish Golf Federation (2006-2008).

14. Improved strategy for control of *Microdochium nivale* on golf courses. Anne Marte Tronsmo, Department of Plant and Environmental Sciences, Norwegian University of Life Sciences (2006-2008).

15. The influence of golf on nature and environment – analyses and evaluation of the environmental performance in Scandinavia. Bente Mortensen, GreenProject (2006-2008).

16. Evaluation of the plant growth regulator trinexapac-ethyl (Primo MAXX®) on Nordic golf courses. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2007-2009).

17. Development, evaluation and implementation of playing quality parameters in a continuous golf course evaluation concept – user survey. Anne Mette Dahl Jensen, Forest & Landscape, University of Copenhagen (2007-2009).

18. Prediction of turf growth as a function of light and temperature under Nordic conditions. Karin Blombäck, Swedish University of Agricultural Science (2007-2009)

19. Re-establishment of green turfgrass after winter damage, spring 2009. Agnar Kvalbein, Norwegian Greenkeepers' Association (2008-2009).

20. Impact of mowing height and late autumn fertilisation on winter survival of golf greens in the Nordic countries. Agnar Kvalbein, Norwegian Greenkeepers' Association (2008 -2010)

21. Multifunctional golf course with unique natural and cultural values. Carina Wettemark, Kristianstads Vattenrike Biosphere Reserve, Kristianstads kommun (2008 – 2010)

22. Evaluation of turfgrass varieties for use on Scandinavian golf greens, 2007-2010. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2007-2010)

23. Demonstration trials with winter cover protection. Boel Sandström, Swedish Golf Federation (2007-2010)

24. Breeding of winterhardy turgrass varieties for central and northern Scandinavia. Petter Marum, Graminor AS, Bjørke Research Station (2007-2010)

25. VELVET GREEN: Winter hardiness and management of velvet bentgrass (*Agrostis canina*) on putting greens in northern environments. T. Espevig, Norwegian Institute for Agricultural and Environmental Research (2007-2011)

26. Fertiliser strategies for golf turf: Implications for physiology-driven fertilization. Tom Ericsson, Department of Urban and Rural Development. Swedish University of Agricultural Sciences. (2007- 2011)

27. Nordic cooperation between authorities and non-governmental organisations for creating multifunctional golf courses and healthy ecosystems. Maria Strandberg, Scandinavian Turfgrass and Environment Research FoundationJanuary (2010–2011)

28. The Nordic Turfgrass Guide 2012 and Variety Lists. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2011-2013)

29. Optimal maintenance for hardening and early spring growth of green turfgrass. Karin Blombäck, Department of Soil and Environment, Swedish University of Agricultural Sciences (2006-2013)

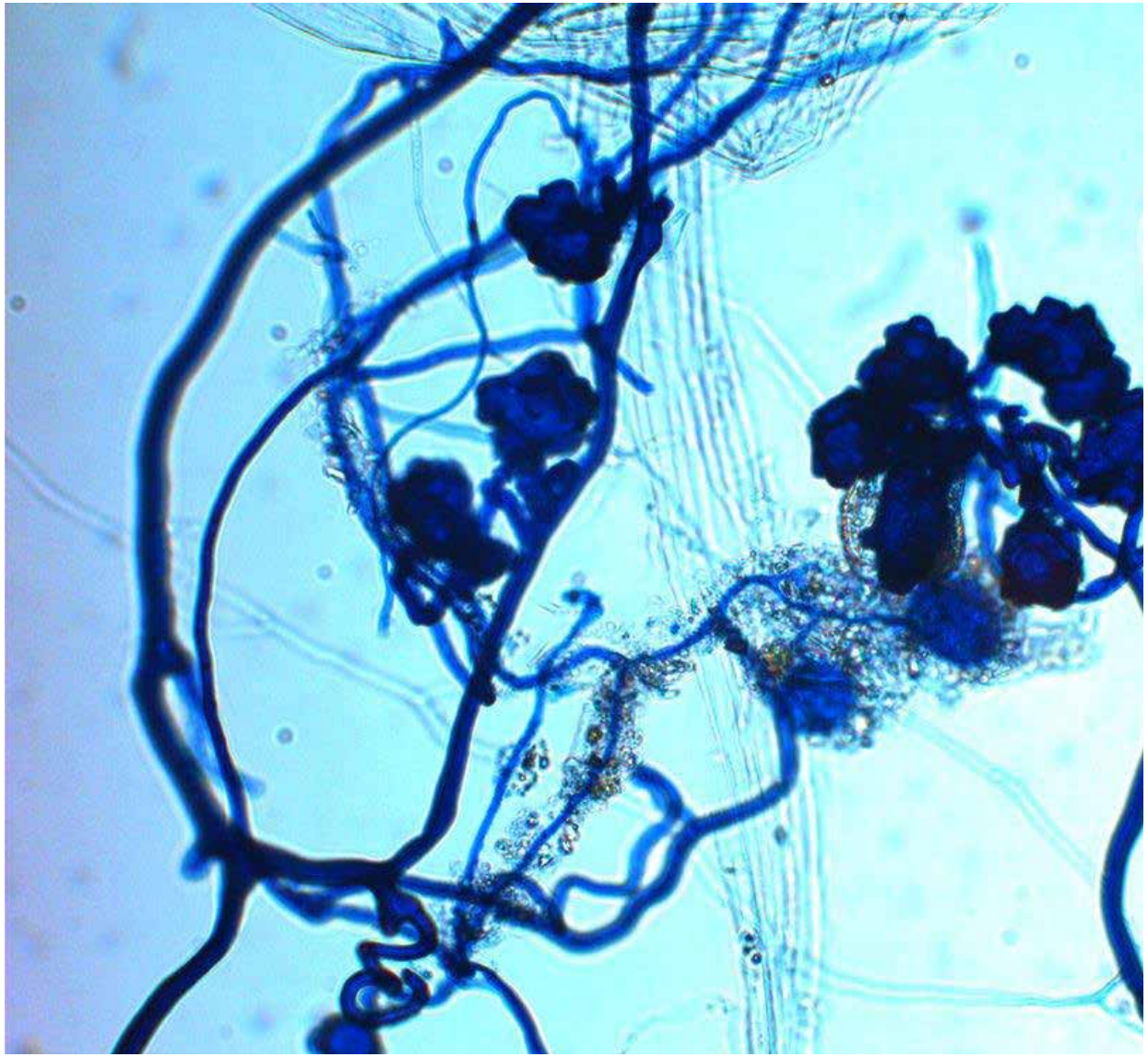
30. Development of methods for non-pesticide weed control on golf fairways. Anne Mette Dahl Jensen, Forest & Landscape, University of Copenhagen-LIFE (2008-2013)

31. Preservation of cultural landscapes and cultural heritage elements on golf courses. Ole R. Sandberg, Department of Landscape Architecture and Spatial Planning, Norwegian University of Life Sciences (2009-2013)

32. Interactive map with navigation to learn and understand environmental work and impacts at a golf course. Magnus Enell, Enell Sustainable Business AB (2011-2013)

33. Integrated pest management - communication project within the park and golf sector. Maria Strandberg, Scandinavian Turfgrass and Environment Research Foundation (2011-2013)

34. Evaporative demands and deficit irrigation on sand-based golf greens. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2008-2014)



Often referred to as the 'roots of roots', the symbiotic relationship with mycorrhiza extends the root system of turfgrasses, thus enabling them to absorb more nutrients, especially P. Photo: Tina E. Andersen.

35. Large-scale demonstration trials: Silvery thread moss on greens. Mikael Frisk, Swedish Golf Federation (2011-2014)

36. SCANGREEN: Turfgrass species and varieties for integrated pest management of Scandinavian putting greens. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2011-2015)

37. Increasing rates of the current and a new formulation of Primo MAXX® for plant growth regulation on greens and fairways. Ingunn M. Vågen, Norwegian Institute for Agricultural and Environmental Research (2013-2015)

38. Effects of mowing height, N-rate and P-rate/ mycorrhiza on quality and competition against annual meadowgrass on putting greens with red fescue as predominant species. Tatsiana Espevig, Norwegian Institute for Agriculture and Environmental Research (2011-2015)

39. Validation of the GreenCast prediction model for microdochium patch on golf greens in the Nordic region. Tatsiana Espevig, Norwegian Institute for Agricultural and Environmental Research (2012-2015)

40. Testing of alternative plant production products for the control of *Microdochium nivale* and other diseases on golf greens.Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2011-2015)

41. Better turfgrass survival in a changing winter climate Tatsiana Espevig, Norwegian Institute for Agriculture and Environmental Research (2011-2015)

42. A comparison of the soil surfactant Qualibra and Revolution on creeping bentgrass greens varying in water availability. Trygve S. Aamlid, Norwegian Institute for Agricultural and Environmental Research (2014-2015)

43. GreenCast validation of anthracnose (*Colletotrichum graminicola)* on golf greens in the Nordic region. Tatsiana Espevig, Norwegian Institute for Agricultural and Environmental Research (2014-2015)

44. FESCUE-GREEN: Best management of red fescue (Festuca rubra) golf greens for high sustainability and playability. Trygve Aamlid, NIBIO (2011-2016)

45. Overseeding of Fairways - A strategy for finer turf with less broad-leaved weeds and Poa annua. Anne-Mette Dahl Jensen, University of Copenhagen (2011-2016)

46. Identification and risk assessment for dollar spot on Scandinavian golf courses. Tanja Espevig, NIBIO (2014-2016)

47. Experience mapping and multifunctional golf course development - enhanced possibilities of increased and more varied use of golf courses. Ole Hjorth Caspersen, University of Copenhagen (2011-2016)

48. Multifunctionality in golf courses – effects of different management practices on the ecosystem services carbon sequestration and biodiversity. Thomas Kätterer and Jörgen Wissman, SLU (2014-2016)

49. Optimal application of nitrogen and sulfur in autumn for better winter survival. Agnar Kvalbein, NIBIO (2014-2017)

50. Successful reestablishment of golf greens following winter damages. Wendy Waalen, NIBIO (2014-2017)
51. Fairy rings and thatch collapse, Tatsiana Espevig, NIBIO (2016-2017)

52. Evaluation of the soil surfactant Qualibra on sand-based putting greens. Trygve S. Aamlid, NIBIO (2015-2016)

53. Evaluation of Aquatrols experimental biostimulant formulations on fine turfgrass subjected to wear, drought (nutrient) and winter stress. Agnar Kvalbein, NIBIO (2015-2016)

54. Sustainable fairway management. Trygve S. Aamlid, NIBIO (2014-2016)

55. Evaluation of fungicides for Nordic golf courses. Trygve S. Aamlid (2016-2017)

56. Evaluation of a phosphite pigment, alone and in combination with fungicides, for control of turfgrass winter diseases on green and fairway. Trygve S. Aamlid, (2016-2017)

57. Optimal application of nitrogen and sulphur in autumn for better winter survival of perennial grasses – with emphasis on turf. Bert Sandell, NIBIO, (2014-2017)

58. Dandelion management at Värpinge golf course Håkan Rasmusson, Värpinge golf course (2014-2018)

59. Engineering better irrigation in turf - Quantifying impacts of application uniformity on turf quality in golf. – Jerry Knox, Cranfield University (2014-2019)

60. Effect of fertiliser type, silicon and copper on turf quality and Microdochium infection on Poa annua putting greens. Tanja Espevig, NIBIO (2016-2019)

61. Effect of irrigation, fertiliser type and soil amendment on turf quality and organic matter accumulation/thatch control on creeping bentgrass greens. Bert Sandell, NIBIO (2017-2019)

62. Testing the effect of AlgeaGreen® on winter stress tolerance. Bert Sandell, NIBIO (2016-2019)

63. Selection and management of bentgrass cultivars for genetic and induced resistance to microdochium patch and pink snow mould. Trygve Aamlid, NIBIO (2014-2019)

64. Practical re-establishment of golf greens following winter damage – a field study. Carl-Johan Lönnberg, Swedish Golf Federation (2017-2019)

65. Winter damage to golf greens in the Nordic countries: Survey of causes and economic consequences (part II). Tanja Espevig, NIBIO (2017-2019)

66. Golf clubs as landscape players – Establishment of collaboration networks in the landscape for enhanced contribution to the 2030 Agenda on sustainable development. Anders Esselin, Man & Nature (2017-2019)

67. SCANGREEN: Turfgrass species, varieties and seed blends and mixtures for integrated pest management of Scandinavian putting greens, Trygve Aamlid, NIBIO (2015-2020)

68. Risks for surface runoff and leaching of fungicides from golf greens varying in rootzone composition and amount of thatch, Trygve Aamlid, NIBIO (2016-2020)

69. Invite the starling to help the greenkeeper, Henning Heldbjerg, DOF Birdlife Denmark (2018-2020)

70. Go outdoors and use the Golf area in a pedagogical way – creativity, learning and health in the unlimited classroom, Anders Szczepanski, Linköping University/ Spetsa (2017-2020)

71. From dense swards to biodiverse roughs. Hans Martin Hanslin, NIBIO, (2017-2020)

72. Risk assessment, management and control of dollar spot caused by *Clarireedia* spp. on Scandinavian golf courses. Tatsiana Espevig, NIBIO, (2017-2020)

73. SUSPHOS: Sustainable phosphorus (P) fertilization on golf courses. Trygve S. Aamlid, NIBIO, (2017-2022)

STERF KEY INDICATORS 2006 - 2023

Year	Funding (kSEK)		Applications		Ongoing projects	Scientific publications		Popular publi-cations	Presen-tations at seminars, webinars, conferences	Handbooks, Fact sheets, videos Programmes	Subscribers to STERF newsletters		
	STERF	Match-funding	Received	Approved for funding									
2006	1 500		17	7	12	7		23	46				
2007	4 900		1	1	13	3		12	26	1			
2008	4 500		22	6	18	11		29	42	2			
2009	5 500		1	1	15	16		20	49	1			
2010	3 000		16	9	13	7		29	46	1			
2011	3 700				19	4		32	50	25			
						Peer-reviewed papers	Publications and reports				English	Swedish	Finnish
2012	3 400				18	9	12	24	98	25			
2013	4 100				14	2	11	36	71	11			
2014	6 300		19	8	22	13	18	33	84	12			
2015	4 400				17	6	7	23	77	9			
2016	4 100		15		19	14	6	25	86	126			
2017	4 700	3 682		7	18	10	3	50	92	16	893	1233	
2018	3 300	4 711	3	1	15	10	7	48	114	19	898	1238	
2019	2 412	4 129	17	6	7	2	4	49	122	5	1303	1271	
2020	2 900	5 952			9	7	1	88	85	13	1374	1293	
2021	2 900	5 467			7	5	8	57	103	26	1452	1397	
2022	1 321	4 224	9	4	6	6	5	44	106	35	1465	1428	250
2023	2b600	5 414	1	1	11	2	13	60	118	30	1465*	1428*	250*

These key indicators are based on information in annual project reports. STERF issues an open call for proposals approximately every three years. If there are specific reasons, a project application in between the open call for proposals may be approved for funding by the STERF board. *The values are not updated for 2023 as the STERF website was unavailable owing to a ransomware attack on several Tietoevry data centres in Sweden.

FINANCIAL SUMMARY

INCOME STATEMENT	01/01/2022 12/31/2022	01/01/2023 12/31/2023
Revenue		
Net revenue	4 985 214	4 217 367
	4 985 214	4 217 367
Expenses		
Other external expenses	-29 526	-106 251
	4 955 688	**4 111 116**
Income from financial items		
Interest	44 373	325 996
Surplus	**5 000 061**	**4 437 112**

BALANCE SHEET	2022	2023
Other receivable	0	0
Cash and bank balances	**9 227 437**	**10 732 549**
Total assets	**9 227 437**	**10 732 549**
Liabilities and equity		
Equity		
Restricted reserves	262 719	262 719
Non restricted reserves	8 964 718	10 469 830
Total equity	**9 227 437**	**10 732 549**
Current liabilities		
Other current liabilities	0	0
Total current liabilities	**0**	**0**
Total liabilities and equity	**9 227 437**	**10 732 549**

LIST OF PUBLICATIONS 2023

The links below to material at www.sterf.org will probably not be available as the website was destroyed owing to a ransomware attack on several Tietoevry data centres in Sweden in January 2024.

PAPERS IN INTERNATIONAL PEER REVIEWED JOURNALS / CONFERENCE PROCEEDINGS

Borchert, A. F., Aamlid, T. S. & K. J. Hesselsøe 2023. Einblick in die Rasenforschung am NIBIO. European Journal of Turfgrass Science, 54 (3): 57-58.

Almvik, M., M. Fongen, P.Heltoft, K.J. Hesselsøe, J. Hornslien & T.S. Aamlid 2023. Metabolomic study of metabolites in winter damaged soils that can impact plant growth. 3rd Nordic Metabolomics Conference 2023, Trondheim, Norway, 18-20 October 2023 https://www.researchgate.net/publication/377499700_Metabolomic_study_of_metabolites in_winter_damaged_soils_that_can_impact_plant_growth

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Espevig T. 2023. Introduction to IPM research programme – today and in the future. p. 18-19. In Sustainable Golf Courses: Integrated Turf Management. Book of abstracts, A Golf Course 2030 and STERF IPM Symposium, Sigtuna, Sweden, 18-19 Sept. 2023.

Espevig T. 2023. Managing important turfgrass diseases microdochium patch and dollar spot using less fungicides. P.24-25. In Sustainable Golf Courses: Integrated Turf Management. Book of abstracts, A Golf Course 2030 and STERF IPM Symposium, Sigtuna, Sweden, 18-19 Sept. 2023.

Frisk, C. A., M. Ferguson, C. Spring, T.O. Pettersen, T. Espevig. 2023. Evaluation of different integrate turf management programs to reduce microdochium patch. NIBIO Report 9(56). 26 p. https://hdl.handle.net/11250/3067790

Hesselsøe, Karin J., Anne F. Borchert, Trygve S. Aamlid, Bjarni Hannesson, Per Rasmussen, Karin Normann, Tatsiana Espevig, Michelle DaCosta, Eric Watkins, Andrew Hollman, Jørgen Hornslien, Trond Pettersen and Pia Heltoft (2023): SCANGREEN 2019-2022: Turfgrass species, varieties and seed mixtures for Scandinavian putting greens. Final results from a four-year testing period. NIBIO Report, vol. 9, Nr. 62, p. 1-100. https://hdl.handle.net/11250/3065144

Hesselsøe, Karin J., Anne F. Borchert, Trygve S. Aamlid, Bjarni Hannesson, Per Rasmussen, Karin Normann, Tatsiana Espevig, Michelle DaCosta, Eric Watkins, Andrew Hollman, Jørgen Hornslien, Trond Pettersen and Pia Heltoft (2023): SCANGREEN 2019-2022: Turfgrass species, varieties and seed mixtures for Scandinavian putting greens. Final results from a four-year testing period. Final Report for STERF, p. 1-15. http://www.sterf.org/Media/Get/4042/scangreen-2019-22_final-report

Hesselsøe, Karin Juul & Lars T. Havstad (2023): Turfgrass Seed for the Nordic Countries 2023-2024. Results from Scanturf and Scangreen variety testing, updated April 2023, p. 1-32. http://www.sterf.org/Media/Get/4082/turfgrass-seed-for-the-nordic-countries-2023-24

Hesselsøe K.J. 2023. Insect pests on Scandinavian golf courses: An update on integrated management. p.23. In Sustainable Golf Courses: Integrated Turf Management. Book of abstracts, A Golf Course 2030 and STERF IPM Symposium, Sigtuna, Sweden, 18-19 Sept. 2023. (2) Hesselsøe K.J., A. F. Borchert, T. O. Pettersen, A. Beisland, K. Sundsdal, V. Stornes Moen, E. Lysøe, M. Skogen, C. A. Frisk, T. Espevig, C. Spring, M. Ferguson, M. Clark, L. Hargreaves, M. Nilsson, W. Prämaßing, L. Borrink, D.R. Hunt, J. Siebert, A. Städler, Y. Lebedin, V. Maygurova, A. Antropova, T. Gagkaeva, M. Usoltseva, K. Entwistle, S. Braitmaier, C. Guerrero, I. M. Hokkanen, H. Hokkanen. 2024. Integrated management of important turfgrass diseases and insect pests on European golf courses (2020-23). Final report to STERF. 43 pp.

Hesselsøe, K. J., Borchert, A. F., Pettersen, T., Beisland, A., Hannesson, B, Nielsen, L., Hansen, A. R., Rehnström, M., Lehto, J. and Aamlid, T. S. (2023): ROBO-GOLF: Robotic mowers for better turf quality on golf course fairways and semi-roughs. Final results from 2020-2023. Final report to STERF http://www.sterf.org/Media/Get/4258/robo-golf_final-report

Kemp J., A. F. Borchert, K. J. Hesselsøe, and T. Espevig. 2023. Integrated management of turfgrass diseases and insect pests on European golf courses. Project Update 2023. Golf Course 2030. 5 p.

Prämaßing W, D. Hunt, L. Borrink, Bonn Jan Van, Siebert Julian, Espevig Tatsiana. 2023. Effect of UV-C-radiation and Sustane 5-2-4+Fe on Dollar spot and Microdochium patch; field trials (Germany). FINAL REPORT IPM-PROJECT GOLF STERF/R&A. Osnabrück University. 29 pp. http://www.sterf.org/Media/Get/4166/effect-of-uv-c-radiation-and-sustane-on-dollar-spot-and-microdochium-patch-field-trials-v2

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Strandberg. M. 2023. STERF yearbook 2023. European Turfgrass Society newsletter 02/2023 p 3. https://turfsociety.com/wp-content/uploads/2023/05/2023-05-itsnd.pdf

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Aamlid, T.S., K.J. Hesselsøe, A.F. Borchert, T. Espevig og H.M. Hanslin: 4 nye STERF-projekter starter i 2023. Greenkeeperen nr. 1, side 58-59.

Aamlid, T.S., K.J. Hesselsøe, A.F. Borchert, T. Espevig & H.M. Hanslin 2023. Fire nye STERF-forsøk starter i 2023. Gressforum 2023(1): 28-29.

Aamlid, T.S., K.J. Hesselsøe, A.F. Borchert, T. Espevig, H.M. Hanslin & P. Edman 2023. Fyra nya STERF-fôrsøk 2023. Greenbladet 40(2): 40-41.

Aamlid, T.S., K.J. Hesselsøe, A.F. Borchert & P. Heltoft 2023. Assessment of turfgrass species and varieties for tolerance to winter stress on golf course putting greens. Winter Turf Newsletter April 2023. https://winterturf.umn.edu/assessment-turfgrass-species-and-varieties-tolerance-winter-stress-golf-course-putting-greens

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Aamlid, T.S., A.F. Borchert, I. Eik, T. Pettersen & K.J. Hesselsøe 2023. FAIR-WATER: Nytt STERF prosjekt skal gjøre fairwayer mer motstandsyktige mot tørke. Gressforum 2023 (3): 28-33.

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Excellent survival after ventilation under plastic covers on green 4, Holtsmark GK. Project: ICE-BREAKER , 27 April 2023. Photo: Trygve S. Aamlid

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