INTERNATIONAL CONFERENCE •GOOD GOVERNANCE IN SPORT•

SPORTS TURF SURFACES GOVERNANCE BY USING PERSISTENT VISUAL AND THERMAL IMAGE DATA

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INTRODUCTION



The health of athletes must always be our first priority. An in-depth study to the limits of research and innovation is needed to design, create and maintain modern turf ground systems for the sports industry. Although injuries do happen in sports, we must continue to look for new ways to minimize the risk.

Using persistent thermal and visual imaging data to measure the sports grounds turf canopy allows the turf to tell us about the stress it is experiencing and the water content in it. A stress study looks for deviations in the surface where the quality is not raised to the desired standard. Homogeneity of the sports turf surfaces is key.

Transpiration is calculated from observations from a meteorological station and is applied to the sport turf with a correlation coefficient. This is an estimate of the water used by the sports grounds so we know how much to irrigate. Soil moisture sensors measure the water in the soil so we know, based on the accuracy of the network, where and how much to irrigate. Looking and touching the turf, then applying intuition and experience to know when and where to irrigate is important. Persistent visual and thermal image data is processed to illuminate changes in surface energy and lawn temperature.

SPORTS TURF SURFACES GOVERNANCE PROBLEM



The technical and physical parameters for playing in elite sports grounds have increased significantly in recent years. Players now make more passes per game, more explosive sprints and cover larger perimeters.

One of the factors that has contributed to such a rapid development in the game lies in the creation and maintenance of playgrounds with natural grass cover. Wet and muddy clay soils from the past on a soil basis have been replaced by modern soils on a sand base, reinforced with artificial fibers covering drainage systems of crushed fraction.

The result - more consistent mechanical properties for interaction between player and surface (adhesion and energy absorption) and between ball and surface (ball bounce), which are less affected by climatic conditions or change over time. Whereas before we witnessed the interruption of a match due to poor quality of the field, now it is much more likely to see a perfect playing surface regardless of the weather conditions.

This is great for the spectators, but is it so important for the players ?!

While we rejoice at how the striker of your favorite team dribbles with the ball in the opponent's half on a wet autumn afternoon, there are real fears that changes in the mechanical properties of the ground surface caused by the studs of his boots may increase the risk of lower limb injuries.

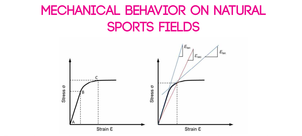
SPORTS GROUNDS RELATED INJURIES



A review of the football injury literature cannot conclusively confirm that the hardness of the pitch can be seen as an important external risk factor. There are methodological concerns about objectivity in site assessment and uniformity in the nature of injuries. Future studies are needed that use objective assessment tools to draw more definitive conclusions about the hardness of the terrain as an external factor for injury in football. The knee is one of the most frequently injured anatomical sites in elite athletes. The main factor for this is the condition of the terrain.
There is a higher risk of injury due to increased surface hardness when performing one-leg landing tasks.
For better interpretation and comparison of results, it is necessary for the studies to fully describe the characteristics of the terrain and management practices. It is important to coordinate the methods for collecting data for the field and from the athletes. Athletes surface needs new technologies. Non-professional athletes should also be tested. There needs to be more in-depth cooperation between biologists, sports field managers, sports scientists and sports medicine clinicians.
This information is valuable for conducting precise practices for the management of natural sports grounds: for the potential improvement of multiple field properties, to support effective follow-up sampling, for future spatial map creation.
Terrain-specific model are essential for the application of precision control of the ground conditions. Uniform spatiotemporal variations in the properties of the surface can be detected and mapped in a non-destructive manner in real time. This is due to the connection between soil composition and soil stress from moisture or drought and the identification of specific deficiency areas in the field.

Conclusions, based on an analysis of the available literature on the prevention of injury risk
in the management of natural sports fields:
1. Optimal interaction and risk of injury may be related to certain surface conditions and shoe characteristics.
This plays a major role in the widespread spread of lower limb injuries in football.
2. It is important to understand the variations in grass species, hybrid methods, soil composition, root zone density and soil moisture content in grass pitches and how these properties can affect the resulting adhesion to the surface and thus reduce the risk of injury to players.
3. For better interpretation and comparison of results, it is necessary for the studies to fully describe the characteristics of the terrain and management practices.
4. Research on interactions: Athlete–surface requires new technologies. Deeper cooperation between biologists and managers is needed on sports fields, sports scientists and clinicians in sports medicine.

MECHANICAL BEHAVIOR ON NATURAL SPORTS FIELDS



The mechanical behavior of natural terrain is largely determined by the behavior of the surface. Soil strength refers to the plastic behavior and represents the ability of the soil to withstand loads without experiencing plastic failure. Soil forces are caused by slip resistance between particles created by friction and cohesion and unsuccessful soil reactions created by changes in volume or shape.

The most common forms of force on the surface of natural grassland are vertical compression and horizontal shear forces. The behavior of soil elasticity determines the dynamic behavior of the natural grass surface during the impact. The energy is dissipated and absorbed by the natural grass surface through the plasticity of the soil. This is important to reduce peak forces, increase ground contact time for players and ensure that the risk of injury is reduced.

Surfaces that are very hard will not allow rough penetration into the surface when athletes connect to the surface through their buttons. This reduced penetration has the effect of reducing traction, as the smaller area of spikes and shoe sole is in contact with the grass. Insufficient resistance to cutting the grass during these movements leads to excessive horizontal movement of spikes and loading determined by soil particles sliding on top of each other and can lead to players slipping.

The viscosity of the sports field is important for surface durability; the energy is dissipated by deformation during loading, which allows this section of soil to regain its original shape. Viscosity is time dependent and is not affected by the return of energy to the players or the ball and related to the soil: stiffness or elasticity

The soil is compacted as a result of increased density and optimal particle targeting and as a result of greater soil stability. This behavior is related to the effect of wear on the turf of the game, as some areas of the field are compacted repeatedly and the mechanical behavior may vary.

GRASS PITCH QUALITY PERFORMANCE STANDARD

Natural Grass Construction Upgrade Performance Quality Standard

Element	Units	Method of use
Sound Height mm	20-60 PS 30-100	BS 7370: PT4.E
Hardness g	70-200	12Kg method of test using a 0.5kg Clegg Impact Hammer dropped a distance of 0.55m
Water infiltration rate mm/hr	5	BS 7370: PT4.M
Evenness - 2 meter straight edge	< 20mm	BS 7370: PT4.H
Slope – direction of Play Across Play Ground Cover %	< 1.5% < 2.5% > 90 or 04:35-35 < 90 for 04:35-35	BS 7370: PT4.G BS 7370: PT4.G

The Performance Quality Standard provides a recommended minimum quality standard for the maintenance and construction of pitches. Specifically, it sets the basic standard recommended for natural grass pitches, which may be located at a variety of locations including a Club site, within a park or recreational ground. Principally, this recommends that a natural grass pitch must:
- **Have adequate grass cover**
- **Low level of weed coverage**
- **Be flat**
- **Have the ability to drain water**

If met, the PQS ensures a flat drained surface suitable for 'recreational' and competitive football activities up to Step 1 of the Non-League pyramid.
There has been no commonly recognized basic technical standard for a natural grass pitch. In order to ensure that any funding produces pitches of sufficient quality for community and non-league competitive use, it is recognized that a performance quality standard has needed to be developed for all future projects. Tolerances were set as a direct result of input from the voluntary technical consultants. This body was established to agree on a common technical approach to be utilised under the programme. This included the development of the PQS.
Sport England is currently undertaking a data gathering exercise, in order to quantify the technical aspects of pitch improvement/ construction. This technical data will be an important 'legacy', which will be passed onto The FA. This will allow us to benefit from the 'lessons learned' under the programme, particularly with reference to the implementation and measurement of the PQS.

CONVENTIONAL SPORTS SURFACES MEASURING

One way to measure some of the most important terrain characteristics is by using testing devices. These devices allow routine and objective measurement of surface parameters, including: adhesion and surface hardness (energy absorption).
Although these devices do not provide an accurate representation of the forces applied by players when they are in a real game situation, they allow tracking of surface properties over time and comparison of different surfaces. This means that maintenance staff can prepare the ground surface with similar training and match characteristics.
When testing different surfaces, maintenance staff are interested in answering three simple questions:

. Is the surface too hard or too soft?
. Is there enough, but not too much, grip between the buttons and the ground?
. Is the interaction between the ball and the surface optimal?

In order to optimize the efficiency and reduce the risk of injuries in the interaction between the player and the surface, various measurements are performed. It is assumed that there is an optimal zone of adhesion and surface hardness. Surface testing of terrains with mechanical devices provides information that can be used to assess the development of the properties of sports fields. This is done without waiting for further results or planning test methods specific to laboratory or bio mechanical analyzes. There are a number of test devices, each with its own strengths and weaknesses. A review of the literature shows that testing methods can be divided into two main categories:

I. Method providing a view of the general condition of the surface
Data of an informational nature is collected and is not specifically applicable to the interaction: athlete-surface. These devices are typically used to compare surfaces or data over the entire field or over time. Initially, some devices were developed for use in other industries, but accepted for use on sports playgrounds due to their duration and cost-effectiveness in their application.

II. Method that reproduces or gives an idea of the interaction between an athlete and a surface
Reproduces a certain aspect of the sports load: e.g. replication of specific boundary conditions, rotational angles, leg positions, magnitude and speed of voltage applications. Some devices aim to replicate exact load conditions, thus examining the risk of injury from surfaces.

DISADVANTAGES THROUGH METHOD PROVIDING AN OVERVIEW OF THE GENERAL CONDITION OF THE SURFACES

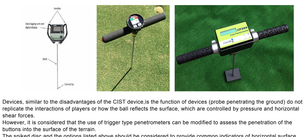
Data of an informational nature is collected and is not specifically applicable to the interaction: surface-athlete. These devices are typically used to compare surfaces or data over the entire field or over time. Initially, some devices were developed for use in other industries, but accepted for use on sports playgrounds due to their duration and cost-effectiveness in their application.

VERTICAL LOWER DEVICES



Editing the study is possible, as the CIST load conditions are not in line with those of a sport and devices that can not be used for this purpose.
However, if CIST offers only one surface parameter (peak deceleration), another parameter is offered: time.
Synthetic surfaces are modified in a similar way by changing the peak velocity data. This variable is not sufficient to characterize the surface.
Data CIST can be compared between grass and postal tests, taking reports reproduction by the effect of the leaves of the third. Like CIST, penetrometer devices are easy to use, relatively affordable, portable, provide easy to interpret data - penetration depth has been used as an indicator to compare surfaces in Australian football.

PENETROMETRIC DEVICES



Devices, similar to the disadvantages of the CIST device,is the function of devices (probe penetrating the ground) do not replicate the interactions of players or how the ball reflects the surface, which are controlled by pressure and horizontal shear forces.
However, it is considered that the use of trigger type penetrometers can be modified to assess the penetration of the buttons into the surface of the terrain.
The spiked disc and the options listed above should be considered to provide common indicators of horizontal surface shear resistance.
Although they measure the forces applied to grass spikes, the boundary conditions (Spike configuration, slab / spike materials) and loading conditions (Orientation, speed and magnitude of effort) do not constitute movements of athletes and cannot be used, to predict the exact grip.
These conditions are considered paramount to provide accurate traction readings on sports surfaces.

DEVICES DETERMINING THE STABILITY OF HORIZONTAL CUTTING



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These conditions are considered paramount to provide accurate traction readings on sports surfaces.
The use of these devices is also hampered by the requirement to use 40 kg of weight as normal force during operation which is necessary, which means that testing with the device is difficult and time consuming.

DISADVANTAGES THROUGH METHOD REPRODUCING OR GIVING AN IDEA OF THE INTERACTION BETWEEN THE ATHLETE AND THE SURFACE

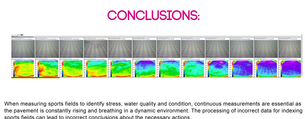
Reproduces a certain aspect of the sports load: e.g. replication of specific boundary conditions, rotational angles, leg positions, magnitude and speed of voltage applications. Some devices aim to replicate specific load conditions and thus investigate the risk of injury from surfaces.

DEVICES SIMULATING IMPACTS: PLAYER - SURFACE.



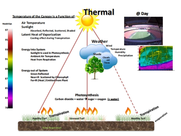
More work is needed to characterize the specific impact forces of athletes and their duration on natural grass in order to replicate their specific movements.
Despite their widespread acceptance and application of synthetic turf, the use of artificial sports devices on natural grass is limited. They are used to assess the deformation of natural grass surfaces of different grass species; the reduction of the strength and deformation of natural and synthetic grass surfaces is assessed. AAB is difficult to transport and cannot be used in wet weather due to the electrical components of the device.
A similar device of artificial athletes to assess specific athlete-surface impacts is lacking for use on natural grass sports fields. This limits the direct comparison of the behavior of natural and artificial grass material and the understanding of the ratio of elastic and plastic deformation that occurred on
natural grass under the specific load of the athlete.

TRACTION MEASUREMENT OF SURFACES

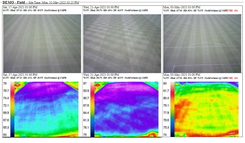


The permissible deviations of the human body from external forces must be further studied. The disadvantage is that there is no standardized approach to the use of this method, and cross-comparison of results is difficult.
Data on its use "in the field" on lawns is limited to synthetic. This is due to the difficulty of transporting the devices, the labor-intensive nature of testing with them and the requirement for trained operators.
The cost of developing these devices shows that they are often built as "disposable", and the possibilities are limited to further data collection on different physical and climatic conditions

METHOD FOR MEASURING THE REFLECTION OF COLOR FROM TURF PLANT SPORS GROUNDS SURFACES



With the help of radiometric thermal imaging (8,000 - 13,500 nanometers) it is possible to measure the temperature of the grass cover on sports fields.
The grass photosynthesizes during the light part of the day and breathes at night. Both processes release water vapor as a by-product and the evaporation cools off the surface. The lower the standard deviation, the better the quality. When a "typical" value of the change in deviation is established, it illuminates a change in energy that is directly related to health.
Another indicator of a decline in energy is a change in the degree of hue outside the range of green to yellow and brown. This value calculated at each image data collection may also be known as the Quality Index. The daily visual or quality index is the average value of the standard deviation of the hue, +/- one hour of sunny lunch; or for 2 hours without shade during daylight hours.
A stress study looks for deviations in the grass cover, where the quality is not raised to the desired standard. Sport turf surface homogeneity is key.
Given the relationship between leaf temperature and grass stress, the potential of thermal imaging to track the condition of natural grass sports fields is obvious.

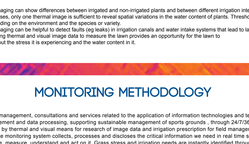


Thermal imaging can show differences between irrigated and non-irrigated plants and between different irrigation intensities. In some cases, only one thermal image is sufficient to reveal spatial variations in the water content of plants. Thresholds may vary depending on the environment and the species or variety.
Thermal imaging can be helpful to detect faults (eg leaks) in irrigation canals and water intake systems that lead to large water losses. Using thermal and visual image data to measure the lawn provides an opportunity for the lawn to tell you about the stress it is experiencing and the water content in it.

THE VALUE OF THE HUE

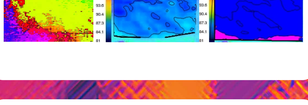


The color of the grass is processed to show the average value of the hue (the hue is measured by the degree of each pixel contained in the defined area) and the standard deviation of the average value of the hue. For grass, this is a representation of the environment and the quality of the surface. The lower the standard deviation, the better the quality. When a "typical" value of the change in deviation is established, it illuminates a change in energy that is directly related to health.
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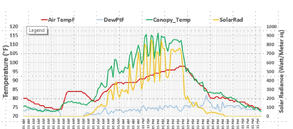
MONITORING METHODOLOGY

Technical management, consultations and services related to the application of information technologies and techniques for management and data processing, supporting sustainable management of sports grounds , through 24/7/365 monitoring by thermal and visual means for research of image data and irrigation prescription for field managers.
This remote monitoring and extern collects, processes and discloses the critical information we need in real time so that we can see, measure, understand and act on it. Grass stress and irrigation needs are instantly identified through the applied stress and irrigation indices.
Lawn health is crucial to play, safety and good looks. We influence it with our decisions on irrigation, disease and pest management and cultivation practices. It is essential to know the effects on the turf surface in real time so that the right decisions become apparent.
By monitoring grassland temperatures and color variations, it is possible to quickly identify types of stress and take immediate action to mitigate the problems before they become unmanageable.

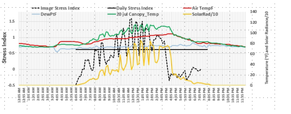


HEALTH, QUALITY, STRESS, AND IRRIGATION INDEX

In 1981, Dr. Ray D. Jackson developed methods used worldwide to evaluate crop health, determined that the difference between a plant's temperature to air temperature (Tcanopy – Tair) depends on vapor pressure deficit.
Under non-limiting water conditions, healthy plants transpire at the maximum rate. Maximum evapotranspiration increases with increasing vapor pressure deficit. When plant health and water availability is not limiting there is a linear relationship between Tcanopy – Tair and vapor pressure deficit.



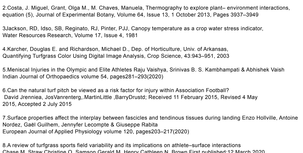
Jackson called this linear relationship the theoretical 'non-water-stressed baseline' and used the idea of upper and lower baselines, to create a crop water stress index (CWSI). This CWSI allows one to relate a crop's temperature to the maximum and minimum extents of stress that the crop can experience under similar environmental conditions.
The higher the CWSI, the greater the crop stress is assumed to be. It has since been shown that thermal image data make it possible to measure turf canopy temperature, pair it with air temperature measured by a local weather station, and measure daily upper and lower canopy temperature limits to inform a Stress Index.
The turf's canopy temperature is the biotic integrator of the many variables: humidity, pressure, water availability, wind, solar intensity, and sky conditions which contribute to the turf's health and water status.
Stress values can be calculated over designated areas from an image frequently. From individual images this is known as the Image Stress Index.
The Daily Stress Index is the average of the Image Stress Indexes from sunrise to sunset.



In 2003, Drs. Douglas Karcher and Michael Richardson showed that an analysis of digital visual images provide a reliable method to measure the reflectance of color from vegetated surfaces and that the color can be measured and expressed as the hue degree.
By establishing an area of interest and then averaging the measured hue values in each of the visual image pixels an average hue and the standard deviation of the hue in each area can be determined.
The signals obtained from visual image data of the canopy hue infer chlorophyll content and its standard deviation gives a measure density/homogeneity of the turf. Taken together these values describe quality.
They comprise a Quality Index.



When paired with the Stress Indices over the period of several days the change of the Quality Index will significantly contribute to the assessment of plant health. A stable hue and a low standard deviation (high degree of uniformity) not only represents high quality but also conditions favorable for thermal stress assessments. Low quality (wandering hue and large standard deviation of the hue) usually follow consecutive days of high stress.
When measuring turf for identification of stress, quality, and water status; persistent measurements are essential because the turf is continuously transpiring and respiring in a dynamic environment (see figures 1 & 2). Settling on any one image for a single point in time or over more days before water is called for by the turf.
Irrigation Indexing is possible by evaluating and tracking the Daily Stress Index and Quality Index.
The daily call for irrigation is signaled when the Daily Stress Index value exceeds a threshold established and indicates it needs water. When the Daily Irrigation Index crosses the turf's threshold that day, irrigation is applied in a predetermined amount. The Index threshold and water amount applied is a constant that is specific to the location and is based on a typical amount of irrigation that might be applied. Daily Irrigation Index measurements continue every day. If the next day the Irrigation Index crosses the threshold, water is applied again. The goal is to put water into the root zone, then irrigate again when called for and not until. There are periods where the Irrigation Index may call for irrigation two or three days in a row or it could go six or more days before water is called for by the turf.
The daily irrigation guidance is checked by evaluating the Quality Index at solar noon.
Withrespect to the signal to irrigate, the greatest weight is given to the Daily Stress Index. But when the quality is seen to wander, i.e. the standard deviation is growing and/or the hue is changing, a close examination of the data is needed.
This check is important because too little irrigation may not be the cause of decreased quality. When there have been long periods of rain, cool air temperatures, and frequent cloudy sky conditions, it is important to look closely for disease rather than adding water if the Daily Stress Index measures high.



CONCLUSIONS:

When measuring sports fields to identify stress, water quality and condition, continuous measurements are essential as the pavement is constantly rising and breathing in a dynamic environment. The processing of incorrect data for indexing sports fields can lead to incorrect conclusions about the necessary actions.
Irrigation indexing is possible by assessing and tracking the daily stress index and the quality index.
Daily irrigation signal when the value of the daily stress index exceeds the established threshold for water needs.
When the daily irrigation index exceeds the threshold, irrigation can be applied in a predetermined amount for the same day.
The applied index threshold and the amount of water is a constant that is specific to the location of the sports field and is based on a typical amount of irrigation that can be applied. Measurements of the daily irrigation index continue every day. If the irrigation index crosses the threshold the next day, the water can be adjusted.
The goal is to deliver water to the root zone and then re-irrigate it when required, not when it comes.
There are periods in which the Irrigation Index may require irrigation two or three days in a row or it may be six or more days before the grass requires water.
The guidelines for daily irrigation can be checked by evaluating the quality index at sunny noon. In terms of the irrigation signal, the greatest weight is given to the daily stress index. But when you see that the quality is wandering, the standard deviation increases and / or the hue changes, careful examination of the lawn is required.
This check is important, as too little irrigation may not be a cause of poor quality. When there are long periods of rain, cool air temperatures and frequent cloudy conditions, it is important to look carefully for disease instead of adding water if the daily stress index measures high.
The use of remote monitoring to control natural sports fields is complex and requires large amounts of measurements and calculations of image data, 24/7/365. Such systems, which collect, measure and calculate autonomously, can notify users of the system of a given activity and be alerted if there is something that requires attention.

DISCUSSION



There is something to learn by monitoring the sports fields day and night. We can test the data from the images with the portable instruments for spot samples (shear blade, Clegg Hammer Soil Tester, soil moisture sensor, etc.). This can lead to a quick and reliable way to assess the sports field and eliminate the problem where necessary before the start of the game.
Machine learning is an ability that needs to be explored, because we will have data based on the thermal and visual image and the measured nature of the grass cover and the time on site and incidental solar radiation.
One of the challenges we take from the personal observations is recognizing patterns that the machine can learn and make an intelligent statement using the database.
If all the data is in the cloud, it is possible to build an algorithm that recognizes constant variations in homogeneity and applies other data to it to extract statements about what has been learned.
Evaluations can be more than counting colors and using a person's experience, but there are other subtle details that will be important.
The systems will autonomously and persistently measure the grass area of the spotted terrain and will inform us in real time when the color or temperature indicates that there is something to tell us, which is important for the health and condition of the grass surface. Analysis tools will give us a detailed idea of the lawn and what it wants to tell about itself.
One of them is an index that will send an SMS to a phone at the end of daylight, announcing that the grass wants water (or not). Real-time results are available from anywhere in the world at any time, and the archive is easy to view.
We can go much further. Through temperature monitoring on the bodies of athletes during a match, the system can assess the risk of injury and signal to the coach before reaching critical levels.

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