Surface Temperature Experienced and Irrigation Effects on Artificial Turf

PANAGIOTIS VYRLAS[a], MILTIADIS KOUTRAS, VASILEIOS LIAKOS
Department of Agrotechnology,
University of Thessaly,
Gaiopolis, Larissa 41500,
GREECE

[a]ORCiD: 0000-0002-3617-9976

Abstract: - Artificial turf has gained widespread use in sporting fields as it is considered a water-saving and maintenance-free alternative to natural turfgrass. However, the high surface temperatures that occur during the day are a potentially important unfavorable feature of artificial turfgrass. The objective of this study was to establish the temperatures experienced on an artificial turf surface and to evaluate the effect of irrigation on artificial turf surface temperature. Data was collected over five surfaces across a sports facility on the campus of the University of Thessaly in Larissa, Greece. Results showed surface temperatures on artificial turf (AT) as significantly higher than running track (RT), asphalt (AS), bare soil (BS), and natural grass (NG), with maximum surface temperatures of 72ºC. Solar radiation accounted for most of the variation in surface temperature of the artificial turf (r^2=0.92) as opposed to air temperature (r^2=0.38), and relative humidity (r^2=0.50). To lower surface temperature, four irrigation regimes were used (1x60 min, 1x30 min, 2x15 min, and 3x5 min water application). Irrigation reduced the surface temperature by as much as 30°C compared to the unirrigated surface, but these low temperatures were maintained for 90 to 120 minutes long. The most effective cooling effect occurred when water was applied in a 3-cycle, 5-minute duration, where the irrigated surface temperature remained below the unirrigated surface throughout the time after the first watering.

Key-Words: - Synthetic turf, natural grass, sports fields, surface temperatures, solar radiation, cycling irrigation, cooling turf, temperature amelioration.

Received: June 21, 2023. Revised: March 14, 2024. Accepted: April 17, 2024. Published: May 22, 2024.

1 Introduction

Artificial turf (also referred to as synthetic turf) is a surfacing material engineered to mimic the appearance and performance of natural grass on sports surfaces, [1]. The first-generation artificial turf made of short-pile plastic fibers was introduced in the 1960s. The improved second-generation products featuring sand infill between the fibers made artificial turf widely popular in the early 1980s. The third generation (3G) artificial turf introduced in the late 1990s is infilled with crumb rubber or a mixture of sand and crumb rubber to keep the plastic fibers upright and provide shock absorption similar to that of natural grass, [1], [2], [3].

Artificial turf is now widely used, particularly for football fields, as a replacement for grass playing surfaces in cases where natural grass cannot grow, or where maintenance of natural grass is expensive or undesired, [1]. However, the use of synthetic surfaces in sports activities has long been debated, particularly based on their negative environmental and health impacts. The introduction of black crumbed rubber infill in third-generation synthetic turf has yielded concerns over possible increases in surface radiant heat and associated heat-related illnesses, [4].

Various studies have demonstrated elevated surface temperatures on synthetic playing fields, particularly when exposed to direct sunlight, [5]. In a study conducted in Las Vegas, hazardous surface temperatures (>75ºC) were recorded on infilled synthetic turf, [6]. Artificial turf surface temperatures observed in a study conducted at the University of Tennessee Centre for Athletic Field ranged from -9.8 to 86.4ºC at ambient air temperatures ranging from -0.4 to 37.1ºC, [7].

Research on temperatures of artificial and natural turf sites in Hong Kong reported that on sunny days the synthetic surface reached 72.4ºC, [3], [8]. In a study that investigated how various structural components of AT influence temperature at the surface, during which 14 fields of artificial turf located in central Spain were sampled, a temperature variation between 57.6ºC and 61.9ºC, depending on the type of fiber, infill, and usage and the AT age, was recorded, [9]. Surface temperatures as high as 93ºC have been recorded on infilled synthetic turf, [10].

Several studies conducted field measurements to compare the thermal performance of artificial and natural grass. Surface temperature is one of the most considerable differences between AT and NT, ranging from around 30ºC to 60ºC, [5], [6], [8], [10], [11], [12].

Researchers have tried to reduce high surface temperatures on synthetic turf by watering the turf surface. The application of irrigation water can significantly lower surface temperatures, but the effects are temporary, [10], [13], [14]. At Pennsylvania State University, various methods to reduce surface temperatures have been evaluated including irrigation. The tested methods were initially successful in lowering the surface temperature of AT but could not be maintained for the length of standard sporting events, [5], [15].

The objective of this study was to establish the temperatures experienced on an artificial turf surface compared to natural grass and other surfaces and to evaluate various irrigation regimes for reducing the surface temperature of artificial turf.

2 Material and Methods

This study was conducted at the Sports Field of the Gaiopolis Campus of the University of Thessaly in the summer of 2023. The sports field used for testing was installed in June 2023.

The surface temperature was measured on a 3G artificial football pitch and four adjacent surfaces (field track, asphalt, bare soil, and natural grass) during the first week of August, where the ambient temperature ranged from 15.0 to 38.4ºC. Measurements taken on four clear sunny days were selected for analysis and presentation.

To evaluate the effects of various irrigation regimes on the surface temperature of the playing surface, water was applied through high precipitation rate sprinklers. The treatments included long-duration irrigation applied once (WAT 1x), multiple short applications (WAT 2x and WAT 3x), and no irrigation (Control).

The research plots in football pitch were circular areas of 2 m radius and were set up at a distance from the sidelines of the pitch to avoid edge effects.

Water was applied through a pop-up spray sprinkler (PS-Ultra, Hunter Industries Inc.) positioned in the center of each irrigated plot, watering a cycle. The sprinkler head equipped with an 8A nozzle was operated at 210 kPa and produced a wetted radius of 2.3 m.

At least nine surface temperature measurements were taken circularly in a 1-m distance (radius) from the center of the circular plot. Surface temperatures were collected immediately after irrigation and at regular time intervals thereafter.

The research plots in the other surfaces were also circular areas of 1 m radius. Nine surface temperature measurements were taken within the cycle. Data recording started at 09:00 and ended at 18:00.

All surface temperature data was collected using an infrared thermometer (Parkside Infrared Thermometer PTIA 1) with measuring range from -50ºC to +380ºC and accuracy ±1.5ºC or ±1.5% for T > 0ºC.

Data collection included air temperature, solar radiation, mean relative humidity, and wind speed from a meteorological station located 160 m from the sports field.

3 Results and Discussion

3.1 Surface Temperatures

Solar radiation, air temperature, mean relative humidity, wind speed, and surface temperatures are plotted in Figure 1 for a 9-hour monitoring period conducted on August 2, 2023.

The curve of solar radiation followed a bell-shaped pattern, increasing from sunrise, peaking between 13:00 and 14:30 hours, and declining toward sunset. The air temperature steadily increased over the first seven hours, peaking at 38.4ºC at around 17:00 hours. The relative humidity dropped rapidly until 14:00, as expected, then remained steady at around 22% until the late afternoon, while wind speed fluctuated at low levels, exceeding 5 km/h between 14:00 and 15:00.

The highest temperatures were recorded on the artificial turfgrass, followed by the asphalt, running track, bare soil, and natural grass. The temperatures of all surfaces reached their peak between 14:00 and 15:00 hours, displaying a clear difference ($p<0.05$) from AT in the maximum values recorded.

As early as 09:00 hours, the AT turf surface was already up to 39.2ºC. NG temperature was only a few degrees higher (30.0ºC) than ambient (27.2ºC).

At the artificial turf, moderate morning solar radiation warms the surface material rather quickly early in the day [3]. By noon, AT surface temperature reached 66.0ºC while air temperature was raised to 31.0ºC. NG temperature continued to rise slightly compared to other surfaces.

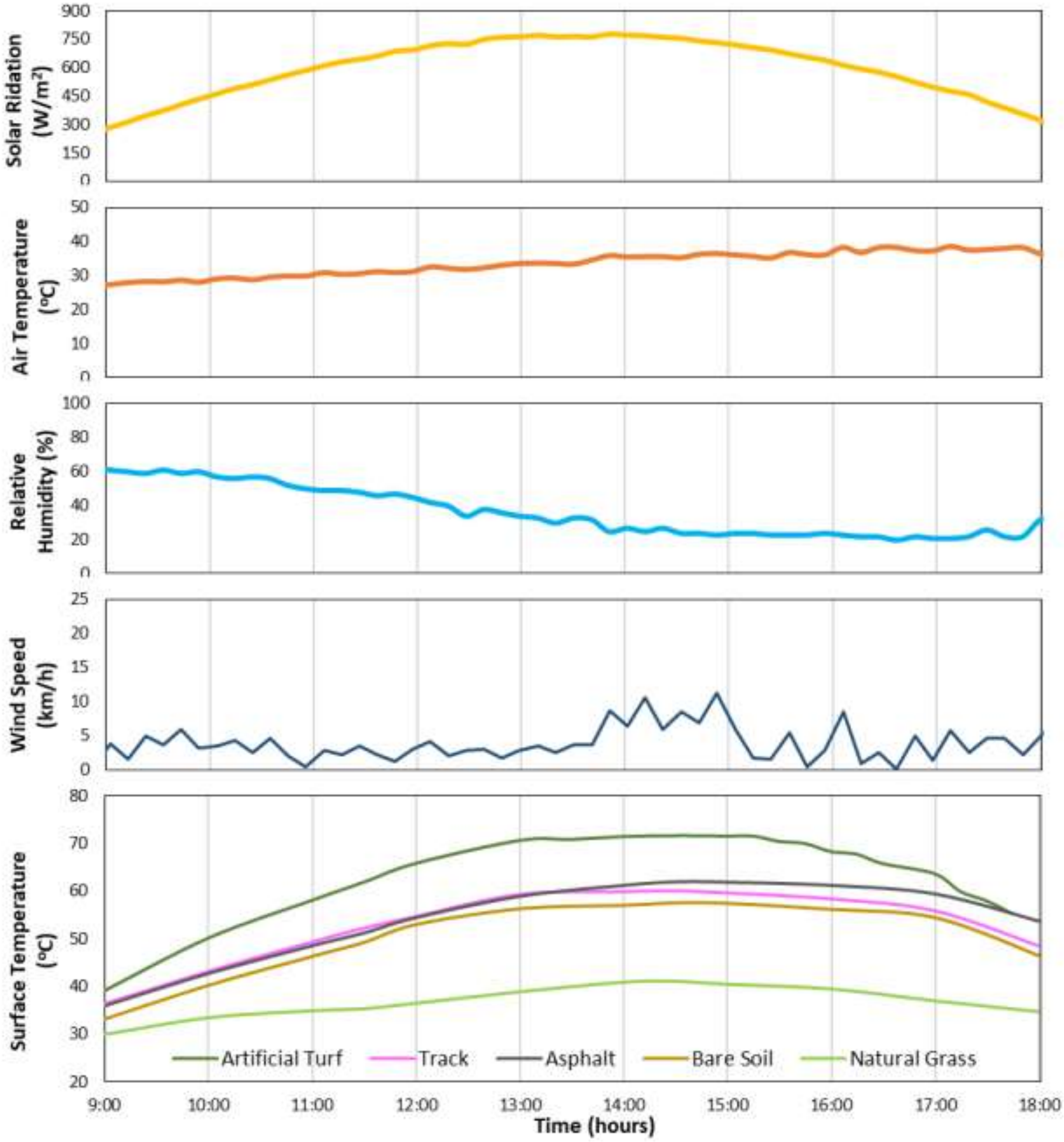

Fig. 1: Climatic parameters and surface temperatures, on August 2, 2023

The NG surface was 29.4ºC cooler than AT. At 14:00, the AT surface temperature peaked at 71.6ºC, indicating a rapid thermal response to peak solar radiation input (779 W/m^2 at 13:51) with a short time delay.

At 14:30, AT surface recorded the highest temperature at 71.8ºC surpassing asphalt (62.1ºC), running track (60.0ºC), bare soil (57.5ºC) and natural grass by 30.6 degrees. At NG, the temperature rose to its maximum of 41.2ºC and soon after, it started to fall slightly. Air temperature continued to rise to 35.5ºC. After 15:30, when solar radiation began to decrease, drastic cooling occurred at the AT surface, which dropped to 68.4ºC at 16:00 and to 63.8ºC at 17:00. All the other surfaces cooled slower than the AT surface. Air temperature continued to rise to the daily maximum of 38.4ºC at 17:08.

At the end of the measuring session (18:00), all surface temperatures dropped noticeably in comparison with 17:00. All but NG temperatures were still higher than air temperature (36.2ºC) with the former being slightly cooler (34.8ºC) than ambient. Both the climatic parameters and the temperatures of the various surfaces showed the same trend during the 4 days of measurements with a clear sky.

Results indicated that the temperature-time curves of all surfaces replicated a bell-shaped curve, with surface temperatures increasing quickly in the morning hours and decreasing in the early hours of the evening, with the maximum temperatures recorded at midafternoon for all the surfaces. The temperature on the artificial turf surface was higher than all other surfaces throughout the day. The temperature curve of grass indicates that it is less affected by environmental conditions.

Table 1 summarizes the data recorded over the four sunny days of the trial. The monitoring surfaces reached different maximum temperatures. The descending sequence of mean maximum temperature was: artificial turf (72.2ºC) > asphalt (62.3ºC) > running track (60.3ºC) > bare soil (58.6ºC) > natural grass (41.3ºC). The surface temperature of the synthetic turf was 11.1ºC higher than asphalt, 11.9ºC than running track, 14.3ºC than bare soil, and 31.8ºC hotter than natural grass.

The artificial turf surface presented extreme temperatures exceeding 70ºC after midday. Such a hot sports field surface carries a high heat-related health risk, [12], [15], [16], [17]. On infilled synthetic turf fields, temperatures ranging from 70 to 93ºC have been reported, [3], [5], [6], [7], [10], [14], [18].

The natural grass surface kept its maximum temperature below 42ºC, just 4-5 degrees higher than the ambient temperature. The recorded temperatures were 10ºC lower than AT throughout the day. Surface temperature is considered one of the most considerable microclimate differences between AT and NT.

Several studies have conducted field measurements to compare surface temperatures of artificial turf with natural grass surfaces under various conditions. The information shows that the surface temperature of artificial turf can be greater than that of natural grass, and, in some cases, artificial fields exhibited surface temperatures that were up to 38ºC higher than those on natural turf, [5], [10], [19].

The average surface temperature difference between AT and NT in this study (31.8ºC) was lower than the findings of [6] who found AT surface temperature 38.4ºC higher than irrigated natural turfgrass but higher than others that recorded 21.5ºC [10], 24.8ºC [18], and 22.2ºC [16]. On-site measurements at the sports center of the University of Hong Kong reported AT-NT maximum differences from 32.1ºC to 37.6ºC at surface temperature, on three sunny summer days, [3], [8], [12].

The reported differences in thermal effect could be attributed to variations in background weather conditions, artificial turf material and design, and natural grass species, [12]. The AT-NT difference in thermal effect is mainly due to their specific thermodynamic properties, which affect their surface thermal admittance. Unlike natural grass, which has evaporative cooling properties, artificial turf is made up of heat-retaining materials that contribute to elevated surface temperatures.

Surface temperatures were plotted as a function of solar radiation, air temperature, and relative humidity in Figure 2. It is evident that increases in solar radiation and air temperature are associated with increased surface temperatures, while relative humidity appears to be inversely related to surface temperature, with higher temperatures associated with lower humidity levels.

Solar radiation accounted for most of the variation in surface temperature of the artificial turf ($r^2 = 0.92$) as opposed to air temperature ($r^2 = 0.38$), and relative humidity ($r^2 = 0.50$). When surface temperatures were regressed against air temperature, good linear relationships existed only for asphalt ($r^2 > 0.83$). However, for the artificial turfgrass, only 38% of the variation in the surface temperature could be accounted for based on the air temperature.

Table 1. Comparison of different surfaces' temperatures with AT (ºC)

Time	AT		Track-AT		Asphalt-AT		Soil-AT		Grass-AT	
9:00	39.9	(0.65)	-3.1	(0.39)	-3.3	(0.32)	-6.3	(0.50)	-10.1	(0.78)
10:00	50.6	(0.39)	-7.2	(0.22)	-7.3	(0.23)	-9.2	(0.71)	-18.2	(1.28)
11:00	59.7	(1.36)	-9.3	(0.35)	-10.3	(0.75)	-12.0	(0.37)	-24.7	(1.37)
12:00	65.8	(0.82)	-10.9	(0.73)	-10.8	(0.83)	-12.6	(0.78)	-28.9	(1.41)
13:00	70.8	(0.23)	-11.3	(0.15)	-11.1	(0.55)	-13.7	(0.75)	-31.8	(1.11)
14:00	72.2	(1.17)	-11.9	(1.67)	-10.7	(1.27)	-14.3	(1.54)	-31.8	(1.59)
15:00	70.8	(1.01)	-11.1	(1.37)	-8.5	(1.31)	-12.2	(2.21)	-29.5	(1.39)
16:00	65.7	(2.93)	-7.6	(3.04)	-4.5	(2.99)	-9.4	(3.16)	-25.8	(3.11)
17:00	59.2	(3.96)	-5.3	(2.26)	-0.7	(3.04)	-6.3	(2.65)	-21.7	(4.34)
18:00	49.3	(2.14)	-0.7	(2.23)	4.2	(2.58)	-3.1	(2.21)	-14.8	(2.11)

In the case of natural grass, only 67% of the variation in the surface temperature can be attributed solely to the measurement of solar radiation, 68% to air temperature, and 76% to relative humidity.

Similar findings were presented by [6] who reported that solar radiation (r^2 = 0.95) accounted for the majority of the variation in infilled synthetic turf surface temperature, even more than air temperature (r^2 = 0.32).

The surface temperatures of five sport surfaces, artificial and natural turf included, increased with solar illuminance, [18]. A study by [20] aimed to compare the surface temperature of a range of 34 different synthetic turf products, revealed that the surface temperature of all the tested products was largely influenced by ambient temperature and solar radiation, with relative humidity having a medium effect.

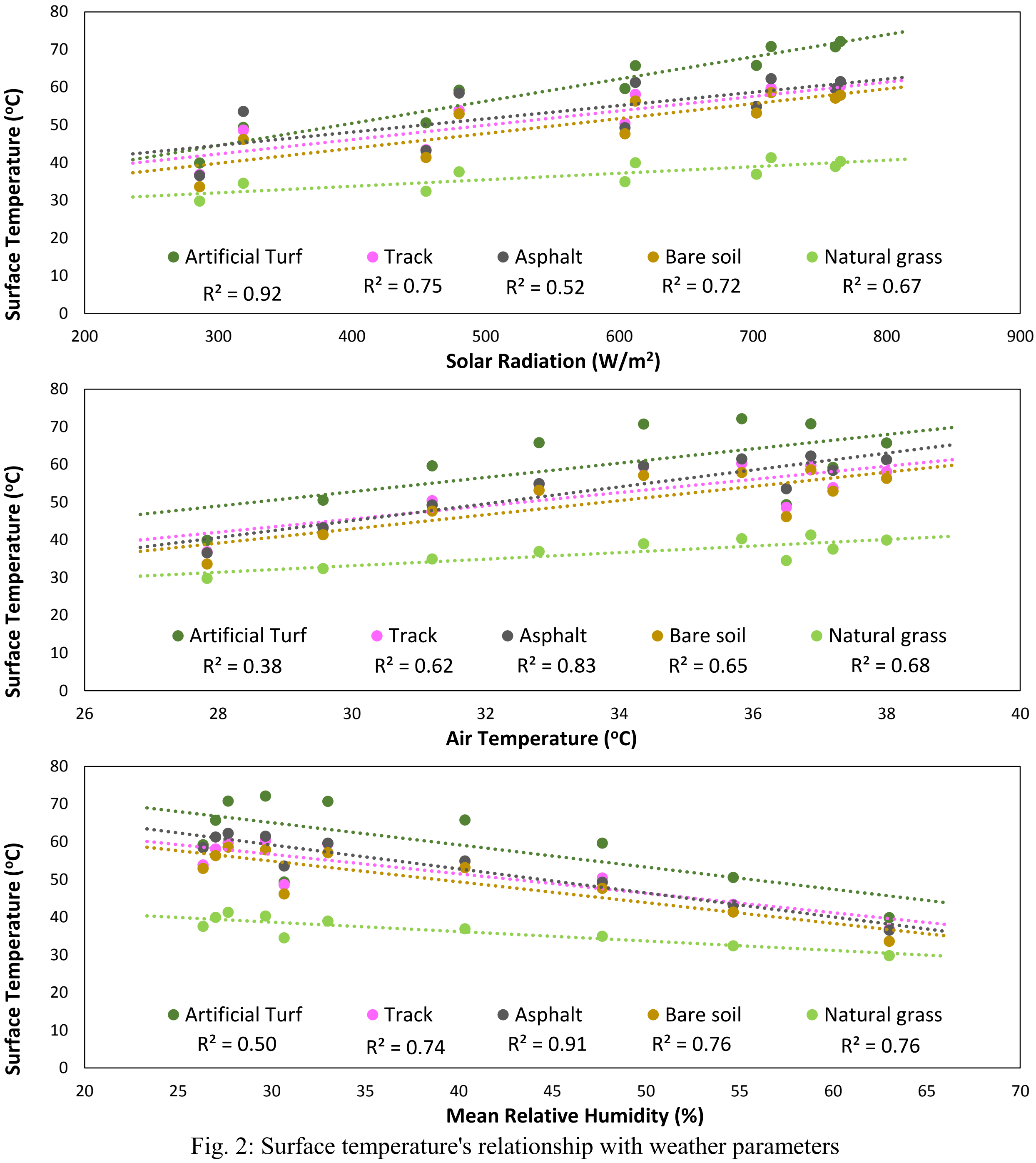

Fig. 2: Surface temperature's relationship with weather parameters

3.2 Irrigation Effects

The effects of irrigation are apparent at the post-watering temperature readings. The application of water initially lowered substantially the surface temperature in all treatments (Figure 3). The temperature of the surface after irrigation was statistically lower than the pre-irrigation one, for each rating time and all treatments, on all trial dates.

Irrigation reduced surface temperature by as much as 30ºC compared to the control. However, the temperature rebounded rather quickly, returning to control after about 90 minutes.

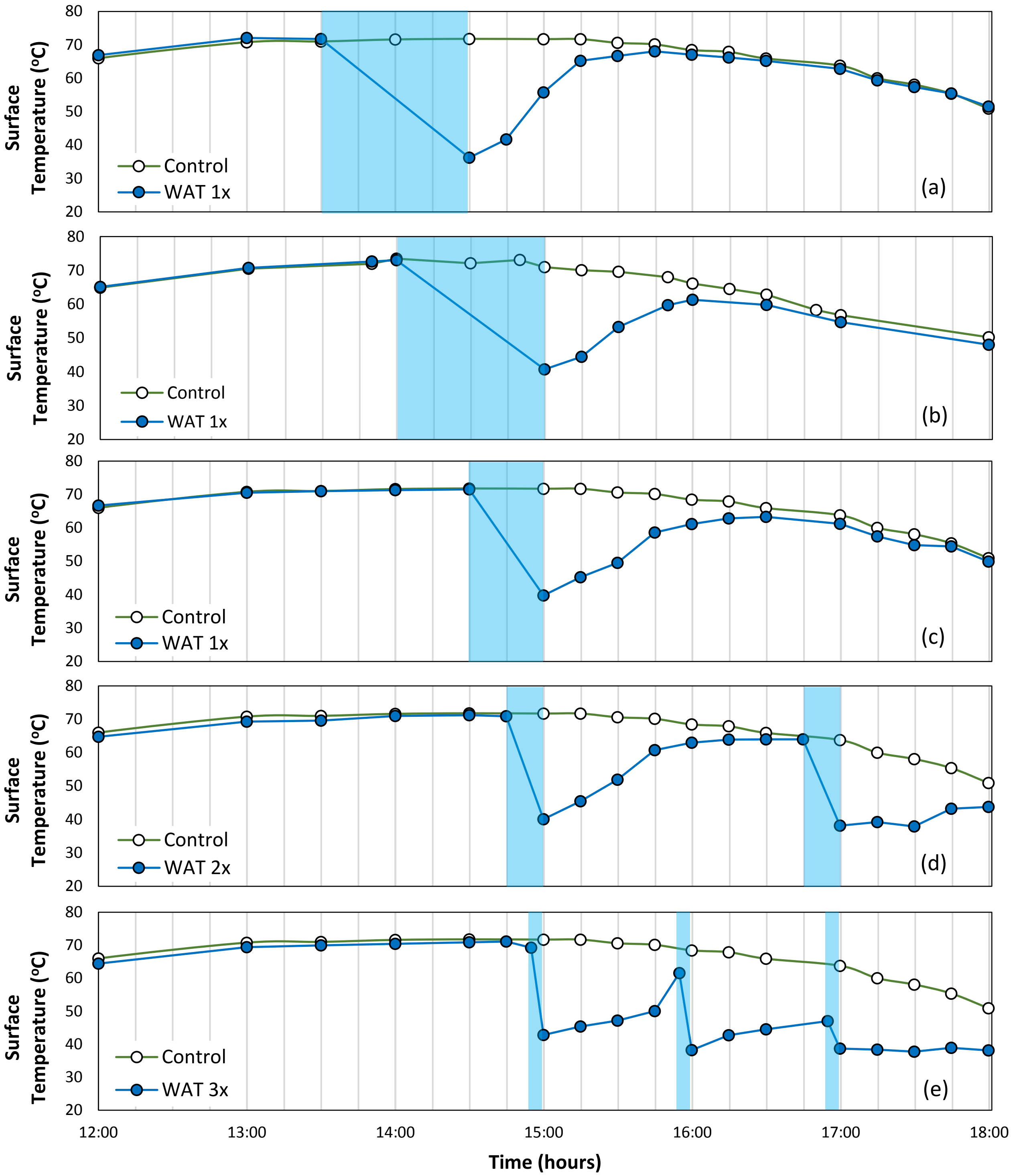

Fig. 3: Surface temperatures of non-irrigated (control) and irrigated (WAT) artificial turf as a function of time. The light blue rectangles correspond to the time interval of irrigation

Long duration (1 hour) water application at 13:30 was not effective since temperature rose to high values at the time the practice is presumed to begin (15:00) (Figure 3a).

Shifting the irrigation for 30 min (at 14:00) produced better temperature conditions at the start time of practice but the temperature recovered to 90% of the control surface temperature at that point (Figure 3b).

The 30-minute shift in irrigation timing (at 14:00) resulted in improved temperature conditions at the beginning of the practice. However, the temperature recovered to 90% of the control surface temperature by that time.

Irrigation of 30 minutes ending at 15:00 has almost the same effect as the 1-hour duration (Figure 3c), indicating that irrigation duration was not a critical factor in the cooling process. This is probably because playing fields are purposely constructed in such a way that water drains quickly through the synthetic surface. The watered area soon dries out on the surface and temperatures quickly increase as the sun heats the dry surface, [13].

In WAT 2x treatment (Figure 3d), where water was applied in a 2-cycle short duration (10 min) at 14:50 and 16:50, the surface temperature dropped in the same manner and level as in 1x treatments and returned to control before the second cycle start. Irrigation effects produced by the second irrigation cycle (16:50) lasted for a longer period compared to the initial one. This was probably due to the radiation being reduced at these hours of the day.

The best cooling effect occurred when water was applied in a 3-cycle short duration (5 min) each hour from 15:00 until 17:00 (Figure 3e). The Irrigated surface's temperature remained below of control temperature throughout the time, after the first water application and even required less water.

While it is well documented that artificial turf can have elevated surface temperatures during periods of high solar intensity, limited peer-reviewed works have focused on irrigating the synthetic turf surface to lower these surface temperatures.

After 30 min of irrigation on an infilled synthetic turf, the surface temperature was lowered to 29ºC. However, the surface temperature rose very quickly, and within 5 min of ending irrigation, the surface temperature measured 49ºC, [10].

A similar response with 20 mm of irrigation lowered the surface temperature by 30°C for only 20 min for both infilled and non-infilled synthetic turf. Although temperatures increased after 20 min, irrigation kept synthetic surfaces 10ºC cooler than non-irrigated synthetic turf for 3 h, [5], [15].

In Penn State's Center for Sports Surface Research study, on the effects of various irrigation regimes on the surface temperature of AT, temperatures did not rebound as quickly when a higher amount of water was applied compared to a lighter amount, and double, heavy (20 mm) irrigation revealed as the most effective regime for irrigating synthetic turf for surface temperature reduction, [14].

In an experiment conducted at New Mexico State University to evaluate the amount of water required to maintain surface temperatures, 20 minutes of irrigation did decrease surface temperatures dramatically for a short period (from 20 to 70 min, depending on solar radiation intensity). After that, the temperatures rebounded somewhat but the surface remained cooler than nonirrigated surfaces for about 3 hours, [21].

Where artificial turf sports fields are installed, managers need to consider the effect of the elevated surface temperatures and apply management strategies to address this critical health issue in their heat policies. Such strategies could include changing the time of day play is scheduled, additional mandatory hydration and cooling breaks, and more frequent player interchanges or substitutions, [12]. To avoid undue heat stress, artificial turf use can only be recommended for certain site weather and user-activity scenarios, [22].

4 Conclusion

The findings indicate that artificial turf surfaces exhibit significantly higher surface temperatures compared to natural grass surfaces and that the intensity of solar radiation is the primary determinant of surface temperatures experienced.

Artificial turf was also found to produce a substantially higher surface temperature than running track, asphalt, and bare soil.

The temperature problem on artificial turf fields is manageable with irrigation. The experimental results, however, indicated brief cooling, referring to long-duration irrigation that was applied once.

Under the conditions of this trial, short-duration, cycling water application, seems the most effective regime for irrigating artificial turf for surface temperature reduction.

These preliminary results prompted a more comprehensive examination of the irrigation protocols employed to cool the artificial turf. In future works, technological solutions can be employed for more accurate data collection, and it would be valuable to include studies on the heating effect under a range of seasonal environmental conditions and the assessment of material aging and compaction impact on the surface temperature of artificial turf fields.

References:

[1] Cheng, H., Y. Hu, M. Reinhard, Environmental and Health Impacts of Artificial Turf: A Review, *Environ. Sci. Technol*., 48, 2014, pp. 2114-2129,

[2] Serensits, T.J., A.S. McNitt, J.C. Sorochan, Synthetic turf, In: J.C. Stier, B.P. Horgan, S.A. Bonos, editors, *Turfgrass: Biology, Use, and Management*, American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America. Madison, WI, 2013.

[3] Jim, C. Y., Intense Summer Hat Fluxes in Artificial Turf Harm People and Environment, *Landscape and Urban Planning*, 157, 2017, pp. 561-576, https://doi.org/10.1016/j.landurbplan.2016.09.012.

[4] Howe, A.S., B.P. Boden, Heat-Related Illness in Athletes, *The American Journal of Sports Medicine,* 35(8), 2007, pp. 1384-1395, https://doi.org/10.1177/0363546507305013.

[5] McNitt, A.S., D.M. Petrunak, T.J. Serensits, Temperature Amelioration of Synthetic Turf Surfaces through Irrigation, *Acta Hortic*. (ISHS), 783, 2008, pp. 573-582, https://doi.org/10.17660/ActaHortic.2008.783.59.

[6] Devitt, D.A., M.H. Young, M. Baghzouz, B.M Bird, Surface Temperature, Heat Loading and Spectral Reflectance of Artificial Turfgrass, *Journal of Turfgrass and Sports Surface Science*, 83, 2007, pp. 68-82.

[7] Thoms, A.W., J.T. Brosnan, J.M. Zidek, J.C. Sorochan, Models for Predicting Surface Temperatures on Synthetic Turf Playing Surfaces, *Procedia Engineering*, Vol.72, 2014, pp. 895-900, https://doi.org/10.1016/j.proeng.2014.06.153 .

[8] Jim, C.Y., Solar–terrestrial Radiant-energy Regimes and Temperature Anomalies of Natural and Artificial Turfs, *Applied energy*, 173, 2016, pp. 520–534, https://doi.org/10.1016/j.apenergy.2016.04.072.

[9] Villacañas, V., J. Sánchez-Sánchez, J. García-Unanue, J. López, L. Gallardo. The influence of various types of artificial turfs on football fields and their effects on the thermal profile of surfaces. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology,* 231(1), 2017, pp. 21-32, https://doi.org/10.1177/1754337115624819.

[10] Williams, C.F., G.E. Pulley, Synthetic Surface Heat Studies, 2002, available at https://plantscience.psu.edu/research/centers/ssrc/research/synthetic-turf-surface-temperature (accessed Jan. 2021).

[11] Guyer, H., M. Georgescu, D.M. Hondula, F. Wardenaar, J. Vanos, Identifying the Need for Locally-observed Wet Bulb Globe Temperature Across Outdoor Athletic Venues for Current and Future Climates in a Desert Environment, *Environ. Res. Lett*. 16, 2021, 124042, https://doi.org/10.1088/1748-9326/ac32fb.

[12] Liu, Z., C.Y. Jim, Playing on Natural or Artificial Turf Sports Field? Assessing Heat Stress of Children, Young Athletes, and Adults in Hong Kong, *Sustainable Cities and Society*, Vol. 75, 2021, 103271, https://doi.org/10.1016/j.scs.2021.103271.

[13] Minner, D., If You Can't Take the Heat, *SportsTurf Magazine*, Vol.20, No.11, 2004, p. 42.

[14] Penn State's Center for Sports Surface Research, The Effect of Irrigation on Synthetic Turf Characteristics: Surface Temperature, Soccer Ball Roll, and Traction, *Progress Report*, 2015, available at https://plantscience.psu.edu/research/centers/ssrc/research/synthetic-turf-surface-temperature (accessed Jan. 2021).

[15] Serensits, T.J., A.S. McNitt, D.M. Petrunak, Human Health Issues on Synthetic Turf in the USA, Proceedings of the Institution of Mechanical Engineers, Part P, *Journal of Sports Engineering and Technology,* 225(3), 2011, pp. 139-146, https://doi.org/10.1177/1754337111398407.

[16] Twomey, D., L. Petrass, J. Harvey, L. Otago, P. LeRossignol, Heat Experienced on Synthetic Turf Surfaces: An Inevitable or Preventable risk? *Journal of Science and Medicine in Sport*, Vol. 18, Supplement 1, 2014, pp. e119-e120, https://doi.org/10.1016/j.jsams.2014.11.086.

[17] Petrass, L.A., D.M. Twomey, J.T. Harvey, L. Otago, P. LeRossignol, Comparison of Surface Temperatures of Different Synthetic Turf Systems and Natural Grass: Have Advances in Synthetic Turf Technology Made a Difference, *Journal of Sports Engineering*

and Technology, 229, 2014, 1–7, https://doi.org/10.1177/1754337114553692.

[18] Aoki, T., Solar Illuminance and Albedo on Surface Temperature of Outdoor Sport Surfaces, *Nature and its Environment*, 11, 2009, pp. 40-48.

[19] Adamson, C., B. Fresenburg, *Synthetic Turf Playing Fields Present Unique Dangers*, College of Agriculture, Food and Natural Resources (CAFNR), 2005, University of Missouri.

[20] Petrass, L.A., D.M. Twomey, J.T. Harvey, Understanding how the Components of a Synthetic Turf System Contribute to Increased Surface Temperature, *Procedia Engineering*, 72, 2014, pp. 943–948, https://doi.org/10.1016/j.proeng.2014.06.159.

[21] Kanaan, A., E. Sevostianova, B. Leinauer, I. Sevostianov, Water Requirements for Cooling Artificial Turf, *J. Irrig. Drain Eng.*, 2020, 146(10):05020004, https://doi.org/10.1061/(ASCE)IR.1943-4774.0001506.

[22] Shi, Y., C.Y. Jim, Developing a Thermal Suitability Index to Assess Artificial Turf Applications for Various Site-weather and User-activity Scenarios, *Landscape and Urban Planning*, Volume 217, 2022, 104276, https://doi.org/10.1016/j.landurbplan.2021.104276.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflict of interest to declare.