Received: 12 September 2024 | Accepted: 22 May 2025

DOI: 10.1002/its2.70097

International Turfgrass Society Research Journal

SHORT COMMUNICATION

Turfgrass Establishment and Maintenance

Evaluation of equestrian eventing cross-country ground safety using field parameters: The case of Santiago 2023 Pan-American Games

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Assigned to Associate Editor Christian Spring.

Abstract

Cross country is one of the three equestrian disciplines, including eventing, and it has a high injury and fall risk for the horse and rider. Testing cross-country ground in terms of soil compaction and penetration gives valuable information regarding the ground condition for competition. The objective of this study was to evaluate the quality of a Chilean cross-country ground for equestrian eventing after the Santiago 2023 Pan-American Games using field parameters and complementary soil analysis. Turf on the cross-country area mainly comprised kikuyugrass (*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone), a natural turfgrass species found at the location. The total route distance of the cross-country was 3700 m, and data were taken at each 250 m of the route completing a total of 27 points, considering at least two replications on obstacle points. One data point was not considered in the analysis. Parameters measured were soil temperature, volumetric water content, soil salinity (dS/cm) measured as electrical conductivity using a TDR 350; soil compaction using 2.25 kg Clegg impact hammer (CIH); soil penetration using a Longchamp penetrometer (LP); turfgrass height, thatch depth and turfgrass vigor using FieldScout TCM 500 NDVI turf color meter. Data sets were taken in January (summer) and July (winter) during 2024. Differences between seasons were detected for CIH and Delta LP values. Despite seasonal variations, volumetric water content (VWC) and soil texture significantly influenced surface condition, with this study showing that this was true especially the case where obstacles were at high elevation and had low turfgrass density. Agronomic management strategies that account for environmental variations, such as implementing a consistent irrigation program, aeration, topdressing, and maintaining sufficient turfgrass cover, should be carefully addressed prior to any event. Future research considering evaluations in different seasons and points are needed to improve safety for horses and riders in Chile.

Abbreviations: CIH, Clegg impact hammer; CIV, Clegg impact value; LP, Longchamp penetrometer; NDVI, normalized difference vegetation index; OBST, Orono Biomechanical Surface Tester; VWC, volumetric water content.

1 | INTRODUCTION

The surface a horse works on has been documented as a risk factor for injury among other variables such as horse conformation and type of training (Holt, 2013). Eventing is an equestrian discipline in which horses and riders complete three stages of competition designed to test training, endurance, and versatility (Cochran, 2024).

The cross-country phase has been identified as the discipline that carries the greatest risk of injury to both horse and rider (Bennet et al., 2022) due to the risk of rider falls and significant horse injuries. According to Graidon et al. (2023), ground has long been cited as a key contributing factor for injury risk in the cross-country phase of eventing. However, no formal measurements and published recordings have been taken on Chilean cross-country ground, mainly because the focus is on the competition, and no local mandatory requirements have been taken into account. Considering that since the year 2000 there have been at least 50 reported human deaths and 109 reported horse deaths from injuries sustained during the cross-country phase of eventing at both the national and international levels (Bennet et al., 2022), it is important to have a local protocol of grounds measurements to ensure horse and rider safety. The objective of this study was to evaluate the quality of a Chilean cross-country ground for equestrian eventing after the Santiago 2023 Pan-American Games using field parameters and complementary soil analysis. This study focuses on data taken after the event, so it can inform surface understanding of future cross-country events. Considering no local protocols have been implemented to ensure surface safety for horse and rider in Chile, this study gives guidelines and comparisons for future measurements.

Core Ideas

- Cross-country in situ ground evaluation requires record field parameters to ensure horse and rider safety.
- Soil volumetric water content is a good predictor of ground eventing safety conditions.

2 | MATERIALS AND METHODS

The 2023 Pan-American Games equestrian venue was at the Escuela de Equitación Regimiento Granaderos in Quillota, a traditional army compound in the Valparaiso region that lies in the foothills of Chile coastal mountain range. Quillota is located 126 km from Santiago city (32°52′48″S 71°14′51″W) and has a Mediterranean climate with rainfall concentrated mainly in winter (Figure 1). The cross-country area had a grass sward that was composed primarily of kikuyugrass (*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone), a natural turfgrass species found at the location in its fertile form, due to the significant production of stamens during the flowering season.

The total course length of the Cross Country was 3700 m (Figure 2). Data were taken at ~250-m intervals (Graydon et al., 2023) along the course, resulting in a total of 26 points. These points considered two replications at points 8A, 8B, 9A, and 9B (obstacle points) at rejection (R) and fall (C). Three distinct areas within the course display heterogeneity in both altitude, typical on cross country ground, and turfgrass density (Figure 2) due to differences in irrigation overlap and soil type. The course operates under two seasonal irrigation regimes: no irrigation is required during winter, while in summer, supplementary irrigation is applied according to the random criteria of military management (irrigation water availability).

Parameters measured were soil temperature (°C), soil volumetric water content (%), and soil salinity measured as electrical conductivity (dS/m) using a TDR 350 soil sensor (Spectrum Technologies Inc.); soil compaction using 2.25 kg Clegg impact hammer (CIH) (Lafayette Instrument Company); soil penetration using a Longchamp penetrometer (LP); turfgrass height, thatch height, and turfgrass vigor using FieldScout TCM 500 NDVI turf color meter (Spectrum Technologies Inc.). Two sets of data were collected during the duration of the evaluation: January 2024, corresponding to summer evaluation, and July 2024 corresponding to winter evaluation.

The CIH was dropped five times in every site, and Clegg impact value (CIV) was calculated following ASTM D5874-16 (2016). Readings were taken with the Longchamp penetrometer by dropping the 1 kg mass using the scale on the device and recording the value after the impact. The Delta LP was calculated as described by Schmitt et al. (2024).

The measurements for this study were taken manually following the route of the whole course (Figure 2). The location of each point was recorded using inbuilt GPS of the TDR 350. The TDR 350 was used to measure volumetric water content, temperature, and salinity (as electrical conductivity) of the soil and were measured nine times in accordance with ASTM D6780 (ASTM, 2019); mean value was calculated at each point.

In addition, three composite random soil samples were taken from each one of the three heterogeneity areas within the course (Figure 2) and were sent to a local soil analysis lab. Methodologies for the parameters reported are given in Table 1. Rainfall and temperatures records were collected at a local station (La Cruz, Quillota, Figure 1).

Data were analyzed using the Package R IDE RStudio version 1.4.1717, after testing for normality using the Shapiro–Wilk test, multiple comparisons were performed

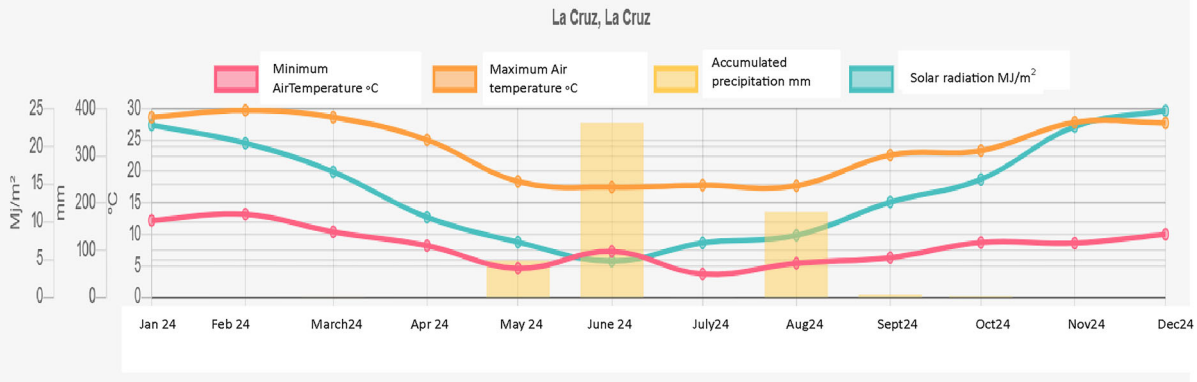

FIGURE 1 Weather data for the location of measurements: La Cruz (Quillota) Región de Valparaiso, Chile, data collected from January 2024 to December 2024. *Source*: INIA, 2025.

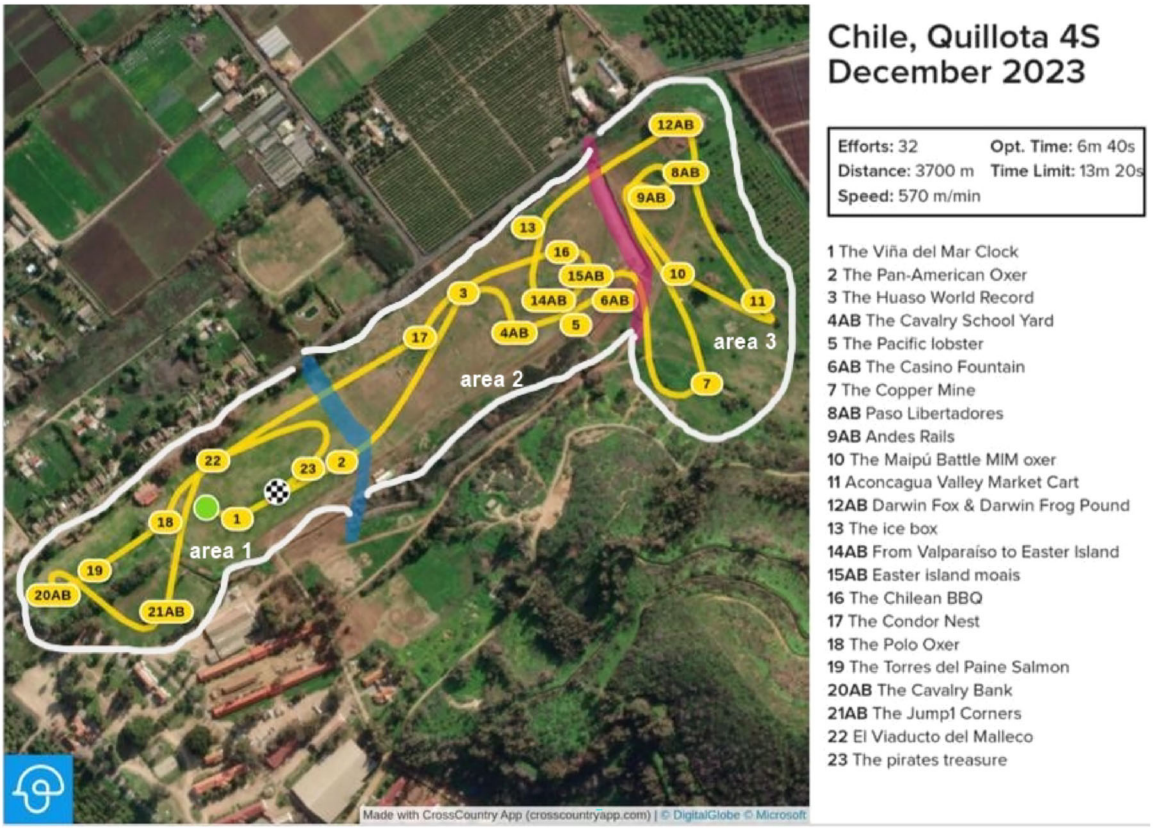

FIGURE 2 Map showing approximate location of measured points (only points 8A, 8B, 9A, and 9B were measured before(R) and after(C) the obstacle). Cross-country ground Pan-American event at Quillota, Chile. Area 1: highland, area 2: midland and area 3: lowland. *Note*: Points shown on the map were measured correlatively from 1 to 18 R and 18 C, points 17, 19, 20AB, 21AB, 22, and 23 were not included.

TABLE 1 Soil parameters obtained from three different composite soil samples collected from three areas across the cross-country ground.

Soil sample	pH	Electric conductivity (dS/cm)	Organic matter (%)	P (mg/kg)	K (mg/kg)	Sand (%)	Clay (%)	Silt (%)
Soil 1 (area 1)	7.19	2.14	9.37	23	682	36	20	44
Soil 2 (area 2)	6.97	1.34	4.55	42	461	42	18	40
Soil 3 (area 3)	6.61	3.09	8.9	54	663	31	24	45

Note: Methodologies used: pH: in water ratio 1:2.5. Electrical conductivity: saturated paste extract. Organic matter: Walkley and Black. P: Olsen. K: ammonium acetate 1 mol/L at pH 7,0; Soil Texture: Bouyoucos method.

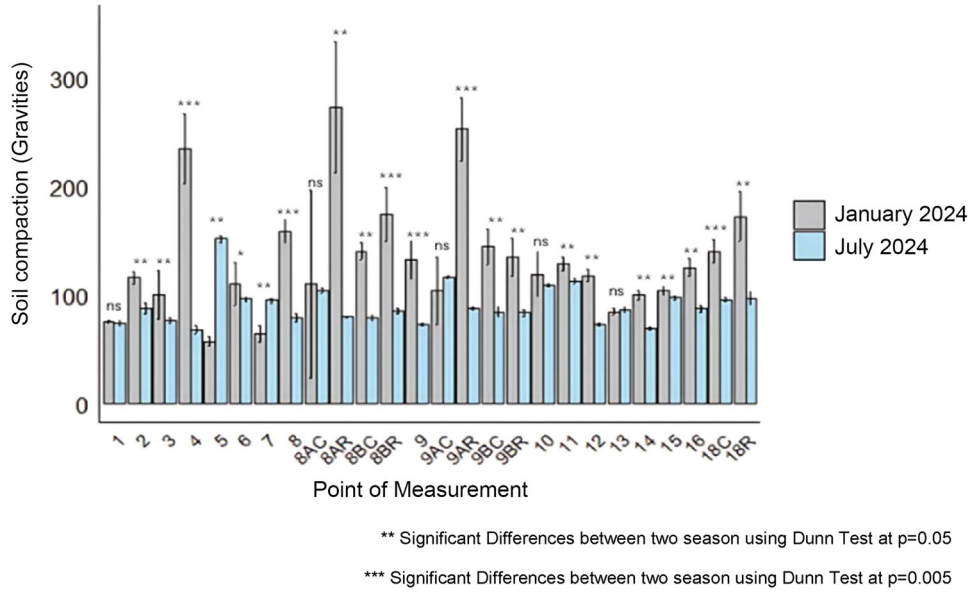

FIGURE 3 Mean soil compaction values measured using Clegg (CIH) (gravities) and comparisons for two dates of measurement (January 2024 and July 2024) at cross-country ground located at Quillota, Chile. **Significant differences between two season using Dunn test at $p = 0.05$. ***Significant differences between two season using Dunn Test at $p = 0.005$.

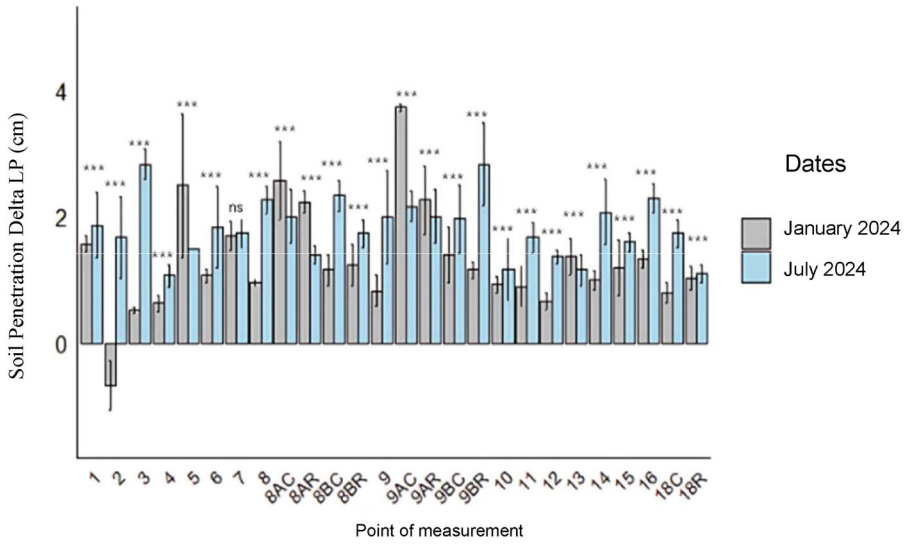

FIGURE 4 Mean Longchamp penetrometer values (Delt LP = is calculated as the difference between the final penetration depth after the drop and the initial zero position) and comparisons for two dates of measurement at cross-country ground located in Quillota, Chile. ***$p < 0.001$.

using Dunn test for soil compaction (CIH) and penetration Delta (LP) values (Figures 3 and 4). Pearson correlations between measured variables were also performed at each season of measurement.

3 | RESULTS AND DISCUSSION

Weather data for the location indicate rainfall was concentrated in winter, and mean higher temperatures were over 25˚C in summer (January and February were the hottest months). During winter, no freezing temperatures were observed (Figure 1).

Soil data (Table 1) indicate high levels of organic matter and potassium, and a loam soil was found at each of the point of sampling.

As can be seen on Table 2, higher soil compaction ClH values over 100 Gravities and low Delta LP values were measured from points with obstacles (8A, 9A, 8B, 9B) including the values taken at the rejection jump area (marked as R) and fall (marked as C). In these areas, low volumetric water content and NDVI values were measured, mainly due

TABLE 2 Mean values at each point of measurement for seven variables taken during summer (January 2024) and winter (July 2024) at the cross-country ground Pan-American event at Quillota, Chile.

January 2024 (Summer)								July 2024 (Winter)							
Point	CIH (gravities)	Delta LP (cm)	TH (cm)	NDVI	EC (dS/cm)	TEMP (˚C)	VWC (%)	Point	CIH (gravities)	Delta LP (cm)	TH (cm)	NDVI	EC (dS/cm)	TEMP (˚C)	VWC (%)
8AR	274	2.2	ND[a]	NA	0.00	40	8	5	152	1.5	9	0.36	0.06	24	22
9AR	254	2.3	ND[a]	NA	0.00	39	10	9AC	117	2.2	24	0.66	0.02	19	11
4	236	0.6	8	0.20	0.02	39	15	11	113	1.7	8	0.48	0.08	22	25
8BR	175	1.2	3	0.29	0.05	40	13	10	109	1.2	7	0.31	0.06	26	27
18R	173	1.0	10	0.53	0.25	42	23	8AC	104	2.0	14	0.71	0.03	23	16
8	159	1.0	7	0.57	0.00	37	21	15	98	1.6	11	0.34	0.07	24	28
9BC	145	1.4	7	0.28	0.00	41	17	18R	97	1.1	7	0.26	0.10	22	24
18C	141	0.8	11	0.64	0.23	43	28	6	97	1.8	9	0.24	0.12	23	27
8BC	141	1.2	4	0.42	0.01	41	16	18C	96	1.7	3	0.27	0.08	18	20
9BR	136	1.2	7	0.34	0.02	43	19	7	95	1.7	9	0.26	0.14	27	27
9	133	0.8	6	0.64	0.13	40	30	9AR	88	2.0	17	0.64	0.00	19	6
11	129	0.9	14	0.49	0.30	39	29	16	88	2.3	6	0.22	0.09	25	28
16	126	1.3	5	0.39	0.21	41	32	2	88	1.7	7	0.26	0.02	25	19
10	119	0.9	7	0.54	0.09	37	27	13	87	1.2	5	0.56	0.09	25	18
12	118	0.7	5	0.28	0.14	41	23	8BR	86	1.7	2	0.37	0.10	23	27
2	116	−0.7	13	0.58	0.04	38	30	9BC	85	2.0	3	0.51	0.14	26	28
6	111	1.1	25	0.73	0.29	36	48	9BR	84	2.8	4	0.41	0.13	18	23
8AC	110	2.6	ND[a]	NA	0.00	40	6	8AR	81	1.4	21	0.69	0.02	19	15
15	105	1.2	5	0.38	0.04	42	24	8	80	2.3	12	0.31	0.10	20	23
9AC	104	3.7	9	0.61	0.00	40	19	8BC	80	2.3	4	0.33	0.00	21	16
3	101	0.5	10	0.61	0.08	38	29	3	77	2.8	9	0.24	0.04	20	15
14	100	1.0	6	0.65	0.22	40	34	1	75	1.9	6	0.38	0.03	20	18
13	85	1.4	8	0.69	0.11	40	29	12	73	1.4	9	0.31	0.09	25	28
1	76	1.6	7	0.62	0.67	36	46	9	73	2.0	3	0.20	0.31	28	39
7	65	1.7	12	0.67	0.49	35	56	14	70	2.1	9	0.41	0.04	25	21
5	58	2.5	11	0.67	0.76	35	53	4	69	1.1	20	0.39	0.02	21	21

Abbreviations: CIH, 2.25 kg Clegg Hammer, Delta LP, Longchamp penetrometer; EC, electrical conductivity; NDVI, normalized difference vegetation index; TEMP, temperature; TH, turfgrass height; VWC, volumetric water content.

[a]ND: Not determined due to no turfgrass coverage.

to the lack of turfgrass cover. These points were located at higher altitudes, and irrigation was applied randomly or not at all, which may explain the low volumetric water content (VWC). The relationship between low VWC and high soil compaction has been reported by Schmitt et al. (2024) and Holt (2013).

Higher NDVI values were detected in summer compared with winter due mainly to kikuyu dormancy. Significant variability in turfgrass height (Table 2) was observed across the ground, primarily due to difficulties in achieving uniform growth around certain obstacles (points 8A, 9A, 8B, 9B). A positive correlation between turfgrass height and NDVI was detected in January 2024 ($r = 0.52$, $p < 0.05$) and July 2024 ($r = 0.57$, $p < 0.05$; data not shown).

Regarding soil compaction, CIH values were higher in summer (January 2024) than in winter (July 2024) (Figure 3), due to intensive use, climatic conditions (high temperature), and low irrigation regime in some high areas. Significant differences between sample points were detected during summer; those with obstacles and at low elevation (area 3) had higher soil compaction values than points without obstacles and at moderate elevation (area 2). This fact suggested that the effects of jump rejection and falls are related to altitude and ground cover.

Differences among soil compaction (CIH) and VWC values were more consistent among areas of the course (Table 2) due to the natural rainfall of the season. Soil VWC values were greater in January 2024, mainly due to irrigation applications and the effect of water movement, in low areas: points 1, 7, and 5 (Table 2). There was a negative correlation between CIH values and VWC values in summer ($r = -0.74$, $p < 0.05$; data not shown), indicating a relationship between soil compaction and VWC. Thus, VWC was a simple measurement that appeared to explain ground conditions from the cross-country course in Chile.

The Orono Biomechanical Surface Tester (OBST) is the gold standard in the equine industry for testing the safety and compliance of equestrian surfaces (Schmitt et al., 2024). It uses high dynamic loads to simulate the horseshoe in motion. Findings from Graydon et al. (2023), based on over 90 courses in the United Kingdom, determined that lower soil water content values correlate with higher OBST cushioning, which indicates that the surface can resist more loading. Cushioning refers to how much the surface absorbs and reduces peak force (Hobbs et al., 2010). CIH, being a very lightweight tool, does not represent the loading rates of a horse during a gallop, but when used alongside VWC, it can help detect compaction and identify hard surfaces for horses and assisting turf managers to improve eventing surfaces with agronomic practices.

4 | CONCLUSIONS

This study represents the first cross-country ground assessment conducted in Chile and establishes both the methodology and general trends for future comparisons in international events. This area of research is of potential interest to expand to other equine sports and relate ground data with horse and rider injury casualties. Current standards are based on big and expensive devices, and this study shows soil VWC is a good predictor of ground eventing safety conditions. Significant seasonal differences were detected in Clegg-hammer and Longchamp values, highlighting potentially risky conditions for horse performance in summer 2024, particularly in areas of high elevation with obstacles and suggesting in this particular case an event in summer will not be recommended for horse and rider safety. Agronomic measures, such as more consistent irrigation events, topdressing, aeration, and improved turfgrass cover, should be addressed prior to events to mitigate risks. Future research, including evaluations across different seasons and specific points and including rider and horse injury events, is essential to enhance safety for equestrian eventing cross-country ground in Chile.

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How to cite this article: Acuña, A., Blanco, M. A., Carter, C., Arias, R., Del Campo, T., & Danneberger, K. (2025). Evaluation of equestrian eventing cross-country ground safety using field parameters: the case of Santiago 2023 Pan-American Games. *International Turfgrass Society Research Journal*, 1–7. https://doi.org/10.1002/its2.70097