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Original Article

University sustainability in brazil and latin america: a comparative analysis of the ui greenmetric criteria using the entropy method

Sustentabilidade universitária no Brasil e América Latina: uma análise comparativa dos critérios do ui greenmetric pelo método de entropia

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ABSTRACT

Purpose – This study aims to identify which categories of UI GreenMetric indicators have the greatest weight in differentiating the performance of Brazilian and Latin American universities, and to analyze what these differences reveal about their sustainability policies and practices.
Design/methodology/approach – The entropy method was applied to data from 217 Latin American universities, including 38 Brazilian institutions. This technique allowed for the determination of objective weights for each criterion based on the variability of the information, minimizing subjective biases in the ranking evaluation.
Findings – The Water category (SDG 6) emerged as the most significant dimension in regional differentiation. While Brazilian universities show a balanced distribution across criteria, suggesting greater institutional maturity, other Latin American institutions exhibit a strong concentration in Water and Waste. This reveals specific infrastructure characteristics of the Global South that are frequently overlooked.
Originality/value – The study advances the literature by introducing a transparent quantitative weighting for sustainability rankings. The findings suggest that rankings should be used as diagnostic guides for strategic investments, positioning universities as key actors in the transition to a sustainable future and in the implementation of the 2030 Agenda.

Keywords: UI GreenMetric; Sustainability; Universities; SDGs.

RESUMO

Objetivo – Este estudo tem como objetivo identificar quais categorias de indicadores do UI GreenMetric têm maior peso na diferenciação do desempenho de universidades brasileiras e latino-americanas, e analisar o que essas diferenças revelam sobre suas políticas e práticas de sustentabilidade.
Desenho/Metodologia/abordagem – Aplicou-se o método de entropia aos dados de 217 universidades da América Latina, incluindo 38 brasileiras. Essa técnica permitiu determinar pesos objetivos para cada critério com base na variabilidade das informações, minimizando vieses subjetivos dos pesquisadores na avaliação do ranking.
Resultados – A categoria Água (ODS 6), emergiu como a dimensão mais significativa na diferenciação regional. Enquanto as universidades brasileiras apresentam uma distribuição equilibrada entre os critérios, sugerindo maior maturidade institucional, as demais instituições latino-americanas exibem forte concentração em Água e Resíduos, revelando especificidades de infraestrutura do Sul Global frequentemente negligenciadas.
Contribuições/Originalidade – O estudo avança ao introduzir uma ponderação quantitativa transparente para rankings de sustentabilidade. As contribuições sugerem que os rankings devem ser utilizados como guias de diagnóstico para investimentos estratégicos, posicionando as universidades como atores fundamentais na transição para um futuro sustentável e na implementação da Agenda 2030.

Palavras-chave: UI GreenMetric. Sustentabilidade. Universidades. ODS

1 INTRODUCTION

The Sustainable Development Goals (SDGs) were adopted by all United Nations (UN) member states in 2015 as a global call to action to eradicate poverty, protect the environment, and promote stability and prosperity for all by 2030 (Viera Trevisan et al., 2024).

This agenda provides a comprehensive framework to guide societies toward sustainable development (Prieto-Jimenez et al., 2021). In this context, universities emerge as strategic actors in SDG implementation, given their influence on campus operations, governance, third mission, research, and teaching (Vallez et al., 2022). As centers of knowledge production and social transformation, higher education institutions play a key role in shaping public policies and are therefore expected to assume leadership in advancing sustainability agendas (Domingos et al., 2024).

By incorporating sustainable practices, universities can generate broad and lasting impacts on society (Giesenbauer & Müller-Christ, 2020). At the same time, university rankings have gained prominence as influential instruments for assessing

and comparing institutional performance at national and international levels (Martins & Barreyro, 2023). These rankings typically evaluate institutions based on multiple dimensions, including research, teaching quality, academic productivity, reputation, employability, internationalization, and innovation (Ribeiro, 2023). Currently, approximately 20 global academic rankings coexist, each adopting distinct indicators and weighting schemes that reflect different conceptions of university quality (Márquez & López, 2023).

However, despite their widespread use, university rankings have been subject to significant criticism due to methodological limitations and inherent biases. Many rankings tend to place excessive emphasis on research outcomes and reputation indicators, often neglecting broader social contributions, contextual differences, and the diverse missions of higher education institutions (Hazelkorn, 2015; Dill & Soo, 2005). This narrow focus can disadvantage institutions focused on teaching, regional development, or social engagement, thereby reinforcing homogenized models of excellence.

In response to these limitations and growing global concerns about sustainable development, new ranking frameworks, and adaptations of existing ones, have increasingly incorporated sustainability-related criteria. This shift reflects the influence of global agendas such as the SDGs, encouraging universities to demonstrate their contributions to environmental management, social responsibility, and inclusive development (Lozano et al., 2015; Findler et al., 2019). Consequently, sustainability has emerged as a complementary dimension in rankings, aiming to provide a more holistic assessment of universities' performance and social impact. Among these, UI GreenMetric stands out as one of the few rankings explicitly dedicated to evaluating sustainability performance in higher education institutions (Silva, 2023).

Despite the growing volume of research on university sustainability, a significant theoretical gap persists in the Latin American context. Few studies systematically compare institutions in the region to identify which sustainability dimensions most strongly differentiate institutional performance. While Leal Filho et al. (2021)

document a wide range of initiatives, they highlight the scarcity of comparative and methodologically robust analyses. Similarly, Kayyali (2023) argues that global rankings often neglect regional specificities, thereby limiting their explanatory capacity. This study addresses both gaps by integrating UI GreenMetric indicators with the entropy method, enabling a more objective and context-sensitive assessment of sustainability performance in Latin American universities.

Furthermore, the applicability of global rankings such as UI GreenMetric in the Latin American context is often limited by structural, socio-economic, and institutional differences that standardized indicators do not adequately capture. Universities in Latin America often operate under conditions of limited funding, infrastructural constraints, and distinct governance models, which can significantly influence their ability to implement and report on sustainability practices (Arocena et al., 2018; Bernasconi, 2015).

As a result, performance metrics designed within, and for, institutions in the Global North may fail to reflect the actual efforts and impacts of Latin American higher education institutions, leading to potential misinterpretation or underestimation of their contributions. Disparities in data availability, reporting practices, and institutional priorities further challenge the comparability of results across regions (Salmi, 2016). These limitations reinforce the need for contextualized approaches that account for regional realities, justifying studies tailored specifically to Latin American higher education institutions to produce more accurate, meaningful, and policy-relevant insights.

Accordingly, this study aims to identify which UI GreenMetric categories carry the greatest weight in differentiating the sustainability performance of Brazilian and Latin American universities, and to analyze what these differences reveal about institutional sustainability policies and practices. To achieve this aim, we applied the entropy method to the scores of 217 Latin American universities, including 38 Brazilian institutions, across the six UI GreenMetric categories: Water, Waste, Energy and Climate

Change, Transportation, Education and Research, and Setting and Infrastructure. By relying on data variability, the entropy method allows objective determination of criterion weights, minimizing the influence of researchers' subjective judgments (Reimers, 2021; Karasan et al., 2023).

This study contributes to the literature in two main ways. Methodologically, it advances sustainability assessment research by introducing a transparent and quantitative weighting approach tailored to the Latin American context. Theoretically and practically, it reframes universities not merely as passive subjects of rankings, but as strategic actors capable of shaping governance structures, public policies, and sustainable development practices (Franco et al., 2019; Disterheft et al., 2015; Leal Filho et al., 2023). By foregrounding a Latin American perspective, this research contributes to diversifying sustainability debates in higher education, which remain largely dominated by Eurocentric approaches.

This paper is structured as follows. Sections 2 and 3 present an overview of university rankings and the UI GreenMetric framework. Section 4 outlines the methodological procedures. Sections 5 and 6 present the results, discussion, and conclusions.

2 UNIVERSITY RANKINGS

University rankings are a recent phenomenon, and their use as tools for evaluating and comparing institutional performance at national and international levels has become increasingly widespread (Martins & Barreyro, 2023). By definition, a ranking consists of an ordered classification based on predefined criteria that allow institutions to be compared in terms of performance or quality (Ribeiro, 2023).

Beyond their classificatory function, university rankings play a strategic role in higher education systems. They influence institutional positioning, guide decision-making processes, and support the definition of strategic priorities related to research, internationalization, and sustainability. As such, rankings often inform investment decisions and the formulation of institutional development plans (PDIs).

Since the early 2000s, global university rankings have expanded significantly,

adopting diverse methodological approaches and evaluation criteria. This expansion has shaped debates on quality, accountability, and international competitiveness in higher education. While most rankings prioritize research output and teaching performance, a smaller group has incorporated sustainability-related indicators, including environmental management, governance, and social impact.

Within this group, UI GreenMetric stands out as the first global ranking exclusively dedicated to assessing sustainability practices in higher education institutions. Created in 2010 by Universitas Indonesia, the ranking evaluates universities across multiple dimensions: setting and infrastructure, energy and climate change, water management, waste management, transportation, and education and research (Junges et al., 2023; UI GreenMetric, 2024). The following section presents the main characteristics of UI GreenMetric, highlighting its structure, indicators, and relevance for assessing university sustainability performance.

2.1 UI GreenMetric Ranking

UI GreenMetric is organized by Universitas Indonesia and is recognized as the first global initiative aimed at ranking universities based on sustainable practices (UI GreenMetric, 2024). Its primary objective is to evaluate policies and activities related to green campuses, thereby fostering a culture of sustainability in higher education institutions (HEIs) (Soeiro et al., 2023).

The ranking employs a set of criteria designed to be simple, transparent, and dependable. Currently, UI GreenMetric comprises 39 indicators grouped into six categories: Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation, and Education and Research (UI GreenMetric, 2024). These categories are intended to reflect the three core dimensions of sustainability: environmental, social, and economic, within the university context.

Since its establishment in 2010, UI GreenMetric has undergone periodic revisions

to its questionnaire and has expanded its scope by incorporating new indicators related to infrastructure development, climate action, community engagement, and alignment with the SDGs. These updates have accompanied a steady increase in the number of participating universities worldwide.

Participation in the ranking involves the submission of institutional data supported by documentary evidence. Each indicator is evaluated on a five-point scale, ranging from the lowest to the highest level of compliance. Assessment criteria may be quantitative, based on performance thresholds, or qualitative, distinguishing between early-stage initiatives and fully implemented, monitored, and institutionalized policies and programs (UI GreenMetric, 2024).

UI GreenMetric is designed to be applicable to universities in both developed and developing countries, which supports its characterization as a truly global ranking (Soeiro et al., 2023). Its relatively low entry barriers, reduced reliance on English-language scientific output, and recognition of locally grounded best practices contribute to its broad international adoption. For these reasons, it is widely regarded as the most prominent global ranking dedicated to university sustainability (UI GreenMetric, 2024).

Unlike comprehensive rankings such as QS, THE, or ARWU, where sustainability represents only one among multiple evaluation dimensions, UI GreenMetric focuses exclusively on environmental sustainability in campus management. Sustainability-oriented rankings play an essential role in directing managerial attention toward sustainable development actions and supporting the institutionalization of sustainability within universities (Junges et al., 2023; Mejía-Manzano et al., 2023).

Nevertheless, the literature highlights recurring critiques regarding the lack of methodological transparency and consistency in sustainability rankings. Concerns include unclear justifications for indicator selection, limited validation procedures, and insufficient transparency in decision-making processes (Soeiro et al., 2023; Mejía-Manzano et al., 2023). Despite the existence of alternative frameworks, such as STARS and the Green Report Card, UI GreenMetric remains the

most widely adopted global instrument focused specifically on campus sustainability, which justifies its selection for this study.

2.2 Sustainability in Latin American Higher Education Institutions

Sustainability in Latin American HEIs has gained increasing relevance in recent years, particularly as universities seek to align their missions with global agendas such as the SDGs. However, the incorporation of sustainability into teaching, research, governance, and extension activities remains uneven across the region. While some institutions have advanced in developing green campuses and sustainability-oriented curricula, many initiatives are still fragmented and lack institutional integration (Leal Filho et al., 2021; Lozano et al., 2015). This reflects a broader challenge: embedding sustainability as a strategic and systemic dimension rather than as isolated projects.

One of the main challenges faced by Latin American HEIs is the limitation of financial and material resources, which directly affects their ability to implement sustainability initiatives. Public universities, which represent a significant portion of the higher education system in the region, often depend on unstable government funding and face competing priorities such as access expansion and infrastructure maintenance (Arocena et al., 2018). These constraints hinder investments in sustainable technologies, research infrastructure, and long-term institutional planning, ultimately affecting performance in sustainability-related assessments.

In addition to resource constraints, governance and institutional diversity in Latin America pose important challenges to the standardization of sustainability practices. The region is characterized by heterogeneous higher education systems, including public, private, community-based, and religious institutions, each with distinct missions and organizational structures (Bernasconi, 2015). This diversity makes it difficult to apply uniform evaluation criteria, as sustainability strategies are often shaped by local social needs, regional development goals, and institutional identities. Consequently,

performance comparisons based on standardized global indicators may overlook context-specific contributions.

Another critical issue concerns data availability and reporting practices. Many Latin American universities face difficulties in systematically collecting, managing, and disclosing sustainability-related data, a prerequisite for participation in international rankings such as UI GreenMetric (Salmi, 2016). This limitation not only affects their visibility in global rankings but also reduces the reliability and comparability of results. Furthermore, language barriers and limited institutional capacity for international engagement may further restrict their participation and representation in global assessment frameworks.

Given these challenges, it becomes evident that the Latin American context requires a tailored analytical approach when assessing sustainability performance in HEIs. Global rankings, while useful for benchmarking, often reflect priorities and conditions typical of institutions in the Global North, potentially underrepresenting the efforts and achievements of Latin American universities (Kayyali, 2023). Therefore, context-sensitive methodologies that incorporate regional specificities, structural constraints, and diverse institutional missions are essential to produce more accurate and meaningful evaluations. Such approaches not only enhance the validity of performance assessments but also contribute to more equitable and relevant policy-making for sustainability in higher education.

The following section presents the methodological procedures adopted in this research, including the research design, data collection process, analytical methods, and the criteria applied to ensure robustness and reliability.

3 STUDY METHOD

Multi-Criteria Decision-Making (MCDM) techniques are designed to support decision processes that involve multiple, and often conflicting, criteria. These methods

enable decision-makers to evaluate and prioritize alternatives by systematically integrating diverse criteria, while addressing the complexity inherent in such decisions (Roszkowska & Wachowicz, 2024). Among MCDM approaches, the entropy method is particularly suitable when the objective is to assign criterion weights objectively, minimizing subjective judgment.

The quantitative application of the entropy method allows for a data-driven and measurable analysis, as recommended by Reimers (2021). Its main advantage lies in the fact that weights are derived exclusively from observed data, without reliance on expert opinions or predefined preferences. This characteristic reduces cognitive and institutional biases, which is especially relevant in studies involving a large number of indicators, secondary data sources, and international comparisons such as university rankings.

By converting information variability into weights, the entropy method emphasizes criteria that effectively differentiate institutions. Criteria exhibiting greater variability across universities receive higher weights, while those with limited variation, hence lower discriminatory power, are assigned less importance. Unlike subjective weighting approaches, the entropy method ensures transparency and replicability, as all calculations follow a clear and mathematically defined procedure based on UI GreenMetric data.

The adoption of entropy-based MCDM is consistent with objective approaches to criterion weighting, particularly in contexts where minimizing subjectivity is essential. Unlike subjective weighting techniques that rely on expert judgment, the entropy method determines weights based on the intrinsic variability of the data, assigning greater importance to criteria that exhibit greater informational diversity among alternatives (Shannon, 1948; Zeleny, 1982).

This characteristic makes entropy particularly suitable for comparative studies

involving a large number of indicators and institutions, such as higher education performance analyses and university rankings. In these contexts, the method enhances analytical rigor by reducing bias and allowing the data itself to reveal the relative importance of each criterion (Wang & Lee, 2009; Hwang & Yoon, 1981). Consequently, the use of entropy contributes to more robust, transparent, and replicable assessments, fundamental when evaluating complex, multidimensional phenomena such as sustainability in higher education.

The step-by-step application of the entropy method and the corresponding computational procedures are presented in the following section, detailing the mathematical formulation, normalization process, and weight calculation adopted in the analysis.

3.1 Data Analysis Technique

To analyze the data, we applied the entropy technique to measure the distribution and dispersion of information, assessing the uncertainty or disorder present in the system. In decision theory, entropy is often used to evaluate the uncertainty or information content of different alternatives, particularly in determining the weight of criteria in MCDM processes (Roszkowska & Wachowicz, 2024). These procedures were chosen for their ability to provide a precise and objective analysis of universities' sustainability indicators.

We quantified information using probabilities of occurrence of each event or state, calculated from historical data or estimates, allowing an accurate representation of the distribution. The Shannon equation was used to calculate entropy:

$$H(X) = -\sum p(x)\ log\ p(x) \quad (1)$$

where $p(x)$ represents the probability of an event x occurring.

The entropy of the system provided a quantitative measure of the disorder or uncertainty associated with the distribution of information. The results were ana-

lyzed to identify areas with high disorder or inefficiency. High entropy indicates large dispersion of information or resources, suggesting inefficiencies; low entropy indicates a more orderly and efficient system.

In the context of this study, we used the UI GreenMetric ranking, which evaluates Latin American universities (217 institutions in total) based on six criteria. Data were extracted directly from the UI GreenMetric website, guaranteeing accuracy and timeliness. Universities in Latin America that provided complete information on the six sustainability indicator categories were selected:

Water: conservation and efficient use programs;

Waste: recycling and waste treatment;

Transportation: vehicles and sustainable transport policies;

Energy and Climate Change: energy efficiency and renewable sources;

Education and Research: courses and research in sustainability;

Setting and Infrastructure: green areas and sustainable infrastructure.

Table 1 shows the University of São Paulo (USP) as an example.

Table 1– Information on the six categories of sustainability indicators from USP

University	**Configuration and Infrastructure**	**Energy and Climate Change**	**Waste**	**Water**	**Transport**	**Education and Research**
University of São Paulo USP	1400	1600	1725	950	1700	1675

Source: authors, 2026.

From there, normalization follows the entropy method. For the first criterion (Setting and Infrastructure), the sum of all scores for Latin American universities was 203,400. USP's score of 1,400 was divided by this sum, resulting in a normalized value of 0.006882989.

After normalizing the matrix data, the entropy of each criterion (not of universities) is calculated using equation (1). After normalization, the data are aggregated and applied

to the six criteria. The individual university scores help determine the weight W of each criterion.

The gross weight is then calculated, and final weights are determined. For the Setting and Infrastructure criterion, the entropy value obtained by applying formula (1) was 0.993634157. The gross weight is 1 minus the entropy value: 1 – 0.993634157 = 0.006365843.

Finally, the final weight Wj is obtained by dividing the gross weight of the analyzed criterion by the sum of the gross weights of all criteria. Thus, for Setting and Infrastructure, the weight Wj obtained (shown in the results section) is 7.96%.

The weights assigned by decision-makers to reflect the relative importance of criteria play a pivotal role in MCDM processes (Roszkowska & Wachowicz, 2024). In future research, this quantitative approach may be complemented by hybrid methods (e.g., AHP combined with entropy), allowing validation of entropy-based weights through expert judgment. The choice of the entropy weighting technique is supported by recent applications in sustainability and higher education studies (Roszkowska & Wachowicz, 2024; Leal Filho et al., 2024), reinforcing its suitability for objectively determining indicator relevance in ranking systems and for advancing transparent, data-driven assessment frameworks.

The following section presents and discusses the results obtained, highlighting their implications for sustainability assessment in higher education institutions.

4 RESULTS AND DISCUSSION

The application of the entropy method to UI GreenMetric data enabled assessment of the relative relevance of sustainability criteria among Brazilian and Latin American universities. As shown in Table 2, Brazilian universities exhibit a more balanced distribution of weights, ranging from 16.44% to 16.93%, suggesting a more homogeneous level of maturity in the institutional policies assessed by the ranking. This balance contrasts significantly with Latin America as a whole, where the Water and Waste categories together account for nearly half of the total weight (49.27%),

revealing regional disparities in university sustainability practices.

Table 2– Comparison of indicator weights (W) for Latin American and Brazilian universities

Indicator	***W* (%) Brazil**	***W*** (%) Latin America
Water	16,93%	30,79%
Waste	16,69%	18,48%
Energy and Climate Change	16,68%	17,14%
Education and Research	16,67%	13,24%
Transportation	16,59%	12,38%
Configuration and Infrastructure	16,44%	7,96%

Source: authors, 2026.

4.1 In-depth indicator analysis

This subsection presents the performance results for each individual indicator.

4.1.1 Water – SDG 6: The Critical Dimension of Infrastructural Vulnerabilities

The Water category emerges as the most significant in differentiating Latin American universities (30.79%), contrasting with its balanced distribution among Brazilian institutions (16.93%). This discrepancy reveals not only differences in the implementation stage of water policies but also deeply rooted infrastructural vulnerabilities in the Global South context. Water management in Latin American universities is intrinsically related to challenges that extend beyond the campus: regional water crises, deficient urban infrastructure, and climate change intensifying periods of scarcity (DeVincentis et al., 2021).

From a practical standpoint, the predominance of this indicator suggests that integrated strategies articulating three dimensions may be warranted: (1) investments in physical infrastructure, such as rainwater harvesting systems, graywater reuse, and real-time monitoring technologies; (2) long-term institutional policies establishing progressive consumption reduction targets; and (3) partnerships with local

governments and development agencies to access specific financing lines for sustainable water infrastructure.

In this context, the role of funding agencies becomes particularly relevant. National and international development institutions, such as the Inter-American Development Bank (IDB), the World Bank, and philanthropic foundations, could consider designing programs that acknowledge the specific characteristics of Latin American universities. Such initiatives could provide not only financial resources but also technical assistance and technology transfer mechanisms.

The Brazilian experience, characterized by greater homogeneity in this indicator, suggests an association between consistent public policies and the fostering of standardized sustainable practices across institutions. Measures such as mandatory monitoring of resource consumption in federal universities illustrate how regulatory frameworks, when combined with adequate investment, can accelerate the institutionalization of sustainability initiatives (Marinho et al., 2019).

4.1.2 Waste and Energy and Climate Change: Operational priorities with strategic gaps

The Waste category, with a weight of 18.48% in Latin America versus 16.69% in Brazil, and Energy and Climate Change, 17.14% versus 16.68%, represent dimensions where universities often initiate their sustainability journeys, as they are more tangible and measurable (Leal Filho et al., 2021). However, this apparent prioritization masks significant financial and institutional limitations.

In practice, Latin American universities face the challenge of implementing waste management and energy efficiency programs with restricted budgets and dependence on increasingly scarce public resources. The transition to renewable energy, for instance, requires substantial upfront investments in infrastructure, solar panels, solar heating systems, building retrofits, that compete with basic needs such as building maintenance and payroll. This reality creates a vicious cycle: without strategic

long-term investments, institutions remain trapped in emergency and short-term solutions that do not generate structural transformations.

These findings suggest that long-term strategic planning could benefit from integrating these dimensions into core institutional governance. The results indicate that incorporating environmental sustainability goals into institutional development plans (PDIs), establishing performance indicators, and exploring innovative financing models, such as public-private partnerships, energy performance contracts, and carbon credit markets, may represent viable pathways toward structural investments without compromising institutional autonomy.

Funding agencies may play a relevant role by offering dedicated credit lines with favorable conditions for energy efficiency and waste management projects. Such investments tend to generate medium- and long-term operational savings, which can partially or fully offset their own amortization costs.

4.1.3 Education and Research: The paradox of the neglected core mission

The Education and Research category presents a weight of only 13.24% in Latin America and 16.67% in Brazil, revealing a concerning paradox: precisely the dimension that constitutes the core mission of universities, knowledge production and dissemination, receives less attention in institutional sustainability practices than operational aspects such as water and waste.

This inversion of priorities reflects deep institutional limitations that go beyond financial issues. The integration of SDGs into curricular structures and research agendas requires cultural and pedagogical transformations that face consolidated resistances: curricula fragmented by departments, absence of incentives for interdisciplinarity, and an academic culture that still predominantly values disciplinary specialization (Franco et al., 2019).

From a practical standpoint, advancing in this dimension may involve

strategies operating at different institutional levels. At the macro level, the findings suggest that higher education evaluation frameworks, such as those coordinated by CAPES and CNPq in Brazil, could potentially benefit from incorporating sustainability and interdisciplinarity criteria into the assessment of graduate programs and research projects.

At the meso-institutional level, the results indicate that governance structures encouraging the transversality of sustainability, such as interdisciplinary committees, internal calls for SDG projects, faculty training programs, and institutional recognition mechanisms (career progression, awards, institutional prominence) for professors and researchers who integrate sustainability into their practices, may be associated with stronger institutional performance in this dimension.

Funding agencies may play an important role in channeling resources not only toward physical infrastructure but also toward what may be described as the intellectual infrastructure of sustainability. This includes investments in human resource training, development of innovative pedagogical approaches, creation of regional and international research networks, and production of applied knowledge tailored to the specific challenges of the Global South.

4.1.4 Transportation and Setting and Infrastructure: Structural barriers and urban-regional planning

Transportation and Setting and Infrastructure exhibit the lowest weights among all UI GreenMetric categories. Transportation accounts for 12.38% in Latin America (16.59% in Brazil), and Setting and Infrastructure for 7.96% (16.44% in Brazil). These findings suggest structural boundaries on institutional action, as performance in these dimensions may be strongly influenced by external conditions beyond direct university control, including urban planning, mobility systems, and public infrastructure investment. The present study cannot establish direct causal relationships given its

methodological design.

The low weight attributed to transportation may reflect, at least in part, the structural characteristics of many Latin American cities rather than institutional neglect per se. Limited public transportation coverage, strong dependence on individual motorized transport, and the peripheral location of many campuses may constrain the effectiveness of institutional initiatives (DeVincentis et al., 2021). Although universities may promote measures such as cycling incentives, shared mobility schemes, or public transport subsidies, their impact remains constrained by the absence of adequate urban infrastructure, integrated transport systems, safe cycling networks, accessibility, which fall outside institutional governance.

Similarly, the Setting and Infrastructure category is strongly influenced by historical campus development patterns and the availability of green spaces. These factors are difficult to alter in the short term and typically require large-scale investments in urban retrofitting and spatial requalification, which exceed the financial and regulatory capacity of individual institutions.

From a practical perspective, these results suggest that advancing sustainability in these dimensions may be supported by universities adopting broader advocacy and regional coordination strategies, for instance, engaging with municipal and state authorities to promote integrated policies on urban mobility and territorial planning that benefit both campuses and surrounding communities. Such engagement implies a redefinition of the university's role in regional governance: from relatively isolated academic spaces to active institutional actors capable of articulating policies, infrastructure, and community engagement in the transition toward sustainability (Disterheft et al., 2015).

In this context, funding agencies could complement direct institutional financing with support for inter-institutional arrangements, including university consortia, university-municipality partnerships, and pilot initiatives. These mechanisms could

facilitate the development of replicable models that integrate campus planning with broader sustainable urban strategies.

While these findings offer relevant insights into structural constraints on university sustainability performance, they must be interpreted considering the methodological limitations discussed below.

4.2 Methodological limitations and institutional contexts

The entropy method, by assigning greater weight to criteria with higher variability among universities, highlights significant inequalities in institutional maturity regarding the adoption of sustainable practices. However, these results must be interpreted with caution. Contextual factors, such as climate conditions, institutional culture, resource availability, governance structures, and national development priorities, strongly influence performance and may introduce biases in cross-country comparisons (Boiocchi et al., 2023; Kayyali, 2023).

Moreover, although widely adopted, the UI GreenMetric framework presents methodological limitations that deserve attention. Its emphasis on quantitative indicators may not adequately capture the quality, effectiveness, or long-term impact of sustainability policies, particularly in institutions where initiatives are still at an early stage or lack systematic monitoring (UI GreenMetric, 2024). As a result, key qualitative dimensions of institutional transformation, such as participatory governance, community engagement, and pedagogical innovation, remain insufficiently represented (Kayyali, 2023).

4.3 Strategic Implications and Future Pathways

The results of this study address the theoretical gap identified in the introduction by demonstrating how entropy-based analysis reveals regional disparities in university sustainability that are often obscured by traditional rankings. This alignment ensures

coherence between the research problem, the methodological approach, and the study's theoretical and practical contributions.

From a managerial and policy perspective, the findings indicate that rankings can be used not only for benchmarking but also as diagnostic tools capable of identifying critical areas with higher levels of "disorder" (in the entropic sense) and supporting the prioritization of strategic investments. In the Brazilian context, where federal universities are legally required to monitor resource consumption (Marinho et al., 2019), the results point to three priority actions: (i) establishing stable funding mechanisms for sustainability initiatives; (ii) expanding training for technical and administrative teams; and (iii) mitigating internal cultural barriers, such as resistance to long-term environmental management practices (Justi et al., 2021).

In developing countries, the advancement of sustainable universities is constrained by limited technical expertise, financial restrictions, insufficient formal documentation, and the absence of comprehensive institutional frameworks for environmental management (Falcone, 2023; Karasan et al., 2023). Political factors further shape these limitations, as sustainability policies are often subordinated to national priorities related to economic growth, poverty reduction, and improvements in quality of life (Utomo et al., 2024).

Empirical examples illustrate the importance of integrated and long-term sustainability strategies. The University of São Paulo (USP), ranked 5th and competing primarily with European and North American institutions, demonstrates how sustained investments in water efficiency, solid waste management, and renewable energy can result in high performance. Initiatives such as integrated monitoring systems, rainwater reuse, and comprehensive environmental programs highlight the role of robust governance structures and adequate infrastructure in achieving sustainability outcomes.

In contrast, institutions such as the Federal University of São Paulo (Unifesp), ranked 1,018th, face significant structural constraints, particularly limited financial resources and reduced technical capacity for environmental management. These limitations negatively

affect performance in key categories such as water, waste, and energy efficiency.

In the broader Latin American context, the Technological University of Pereira (UTP) in Colombia, ranked 86th, illustrates the growing adoption of carbon footprint assessments and advances in climate governance aligned with SDG 13. Similarly, the National Autonomous University of Mexico (UNAM), ranked 79th, despite managing one of the largest ecological reserves in the region, continues to face challenges in integrating sustainability practices consistently across its multiple campuses. These cases underscore the heterogeneity of sustainability maturity among Latin American universities.

Beyond environmental performance, the findings indicate that sustainability in Latin American universities is shaped by distinct patterns of governance and institutional culture. Centralized administrative structures, limited financial autonomy, and strong dependence on public funding tend to foster reactive rather than strategic approaches to sustainability.

This context highlights the need to strengthen internal governance mechanisms, expand participatory decision-making, and promote cultural change oriented toward innovation. In this sense, the contribution of this study extends beyond quantitative assessment by offering insights into the socio-institutional dynamics that condition sustainability practices in higher education.

Overall, the results reinforce the argument that university sustainability cannot be reduced to compliance with ranking indicators alone. Effective progress requires integrated governance arrangements and the active engagement of the academic community (Franco et al., 2019; Disterheft et al., 2015). From a practical standpoint, the entropy-based approach enhances the diagnostic value of rankings, enabling institutions and policymakers to identify priority areas and allocate resources more strategically.

From a critical perspective, it must be acknowledged that although the UI GreenMetric ranking is widely adopted and contributes to institutional progress (Fatriansyah et al., 2021), it has methodological limitations.

These limitations support the use of complementary qualitative or hybrid multicriteria methods, such as AHP or fuzzy logic, to incorporate the perceptions of experts, managers, and other stakeholders into the evaluation process (Boiocchi et al., 2023; Kayyali, 2023). Such integration can strengthen the ranking's usefulness as a decision-support and public policy instrument.

In conclusion, the findings highlight the need for a strategic approach that integrates institutional planning, pedagogical innovation, and partnerships with governments and civil society. By adopting such an approach, universities can consolidate their role as agents of social and environmental transformation and reinforce their contribution to regional and global sustainability agendas (Gratzer et al., 2019; Leal Filho et al., 2023).

From a practical standpoint, the entropy-based approach developed in this study offers university managers a diagnostic instrument for prioritizing sustainability investments at the institutional level.

By identifying the categories with the greatest variability, and therefore the greatest informational weight, across Latin American and Brazilian institutions, the results can inform resource allocation toward critical dimensions such as water management and waste reduction.

More specifically, the findings can support university managers in: (i) defining priority areas for inclusion in Institutional Development Plans (PDIs); (ii) establishing performance benchmarks aligned with regional peers; (iii) identifying structural gaps that may require advocacy-based or inter-institutional responses; and (iv) guiding medium- and long-term sustainability strategies beyond short-term compliance with ranking indicators.

These contributions position the entropy method not merely as an analytical technique but as a practical tool for evidence-based institutional governance in the domain of higher education sustainability.

5 CONCLUSION

This study analyzed which categories of UI GreenMetric indicators have the greatest influence on the performance differentiation of Brazilian and Latin American universities, as well as what these differences reveal about their sustainability policies and practices. The results indicate that water management is one of the main environmental challenges in the region, confirming evidence from the literature that points to its strategic relevance for institutional sustainability (DeVincentis et al., 2021).

Brazilian universities showed a more balanced distribution among the categories analyzed. In contrast, Latin American institutions showed greater concentration in the Water and Waste indicators, which together represent 49% of total relevance. This result reinforces the need for sustainability strategies that are sensitive to regional contexts, considering cultural, economic, institutional, and climatic factors (Martins & Barreyro, 2023).

Although there are criticisms regarding the transparency and rigidity of some ranking indicators (Kayyali, 2023), UI GreenMetric contributes to institutional advancement by guiding more sustainable policies and practices in higher education (Fatriansyah et al., 2021). Nevertheless, such indicators must be interpreted considering the institutional context to avoid reducing sustainability to isolated and decontextualized metrics (Boiocchi et al., 2023).

The results show that the effectiveness of sustainable actions in universities depends on integrated governance models capable of articulating institutional policies, curricula, infrastructure, and the engagement of the academic and external communities (Franco et al., 2019; Disterheft et al., 2015). In this sense, higher education institutions play a strategic role in implementing the SDGs, contributing to organizational transformation processes and the consolidation of an institutional culture of sustainability (Oyama et al., 2018).

In developing countries, however, structural and financial barriers persist that limit the adoption of these practices, reinforcing the importance of partnerships with local governments

and communities (Leal Filho et al., 2021; Leal Filho et al., 2023; Gaitán-Angulo et al., 2022).

From a practical standpoint, rankings can be used not only for institutional comparison but also as diagnostic and planning tools. In the case of Brazilian universities, where there is a legal requirement to monitor resource consumption (Marinho et al., 2019), the analysis allows identification of weaknesses, such as the low integration of sustainability in curricula and transportation systems.

From a managerial perspective, the entropy-based weights obtained in this study can be operationalized as a decision-support tool to prioritize sustainability investments and actions within universities. Specifically, higher-weighted categories (e.g., Water and Waste in the Latin American context) should be treated as critical leverage points in Institutional Development Plans (IDPs), guiding resource allocation, infrastructure investments, and performance monitoring systems. University managers can use these weights to establish priority matrices, linking sustainability indicators to budget planning, campus operations, and strategic objectives. For example, institutions may allocate greater financial and managerial efforts to water efficiency technologies, monitoring systems, and circular waste practices, while progressively strengthening lower-weighted dimensions to achieve balanced sustainability performance. In addition, the results enable benchmarking across institutions, supporting the identification of performance gaps and the design of targeted policies aligned with regional constraints. This approach shifts rankings from passive evaluation tools to active instruments for strategic planning and evidence-based decision-making in higher education.

These findings can guide strategic investments in digital monitoring, smart meters, and educational campaigns focused on efficient water use (Yáñez et al., 2018). For public policymakers, the results provide input for adjusting programs and incentives to national realities, considering the structural inequalities in Latin America.

This study has limitations. The exclusive use of the entropy method, although adequate for assigning objective weights based on data variability, does not incorporate the perceptions of experts and other stakeholders involved in university sustainability strategies.

In addition, the research was based on secondary data from UI GreenMetric, which depends on self-reporting by institutions, potentially leading to heterogeneity in information quality. Finally, the analysis focused on a specific period, which did not allow assessment of the evolution of sustainability practices over time.

Therefore, future studies should adopt hybrid multi-criteria approaches combining quantitative and qualitative methods, such as integrating entropy with AHP, TOPSIS, or other participatory methods, to incorporate the perspectives of managers, experts, and other stakeholders. Qualitative research and comparative case studies can deepen understanding of institutional factors, especially regarding water resource management. In addition, longitudinal analyses are recommended to assess the impact of public policies, financial incentives, and regulatory instruments on university performance over time.

In summary, the results contribute to the debate on sustainability in higher education and offer practical support for university managers and public policymakers. We recommend promoting financing programs for green infrastructure, defining performance indicators integrated with Institutional Development Plans (PDIs), and strengthening partnerships between higher education institutions, governments, and civil society.

Latin American universities can act as spaces for social and environmental innovation, integrating the SDGs into strategic planning and community engagement, thereby consolidating themselves as central agents in the transition to more sustainable and equitable development.

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2. Data curation	√	√	√	√	
3. Formal analysis	√	√	√	√	
4. Funding acquisition					√
5. Investigation	√	√	√	√	
6. Methodology				√	√
7. Project administration					√
8. Resources					√
9. Software	√	√	√	√	
10. Supervision					√
11. Validation	√	√	√	√	
12. Visualization	√	√	√	√	
13. Writing – original draft	√	√	√	√	
14. Writing – review & editing					√

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Data availability statement

Data will be available upon request