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Sustainability in Universities: The Triad of Ecological Footprint, Happiness, and Academic Performance Among Brazilian and International Students

Biagio F. Giannetti [1,*], Marcos José Alves-Pinto Junior [2], Maritza Chirinos-Marroquín [3], Luis Velazquez [4], Nora Munguia [4], Feni Agostinho [1], Cecília M. V. B. Almeida [1], Ginevra Lombardi [5] and Gengyuan Liu [6]

1 Graduate Program in Production Engineering, Paulista University (UNIP), São Paulo 04026-002, Brazil; feni@unip.br (F.A.); cmvbag@unip.br (C.M.V.B.A.)
2 School of Applied Sciences, State University of Campinas (UNICAMP), Limeira 13484-350, Brazil; mjapj@unicamp.br
3 Departamento de Ingenierías de la Industria y el Ambiente, Universidad Católica San Pablo (UCSP), Arequipa 04001, Peru; mchirinos@ucsp.edu.pe
4 Industrial Engineering, University of Sonora (UNISON), Hermosillo 83000, Mexico; luis.velazquez@unison.mx (L.V.); nora.munguia@unison.mx (N.M.)
5 Department of Economics and Management, University of Florence (UNIFI), 50127 Florence, Italy; ginevravirginia.lombardi@unifi.it
6 School of Environment, Beijing Normal University (BNU), Beijing 100875, China; liugengyuan@bnu.edu.cn
* Correspondence: biafgian@unip.br

Abstract: Universities, as hubs for educating future leaders and decision-makers, hold a crucial role in advancing sustainable development. However, the challenge of effectively integrating sustainability into university practices and student behavior remains significant. The Ecological Footprint, subjective well-being, and academic performance are three critical dimensions that, when evaluated together, offer a comprehensive view of sustainability in the educational context. This study aims to apply a university sustainability assessment model called 'Sunshine' to university students in a diverse sample of five different countries. Additionally, the study provides a critical analysis of the relationships among the indicators of Ecological Footprint, Happiness, and Academic Performance. This application seeks to test the robustness of the model and explore lifestyle differences among students, providing valuable insights for decision-making in the context of university sustainability. Data were collected through specific questionnaires administered to a representative sample of students, and analyses were conducted using descriptive and inferential statistical techniques. The results show that Brazilian, American, and Peruvian students exhibit an unsustainable lifestyle, requiring more than one planet to support their consumption habits. However, they are considered happy and perform well academically. These students were classified as environmentally distracted, highlighting a disconnect between their environmental awareness and practices. Chinese students showed a high ecological footprint, contrasting with the Italian group, which had an ecological footprint below one planet. However, both groups presented similar results, with low happiness indices and high academic performance. On the other hand, the group of Mexican students was the most sustainable, achieving acceptable levels in all three sustainability indicators. The analyses revealed that academic performance is related to happiness in some groups but not happiness in Ecological Footprint. This study significantly contributes by testing and validating the model in a multicultural and diverse sample, offering insights that can guide institutional policies to promote sustainability in the university environment.

Keywords: university sustainability; ecological footprint; happiness; academic performance; university students

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1. Introduction

Higher education institutions hold a pivotal position in advancing sustainable development, as they are tasked with preparing future leaders, entrepreneurs, and policymakers [1,2]. The concept of a Sustainable University, which aims to minimize negative impacts on the environment, economy, society, and health, has been widely discussed in the literature. Ref. [3] defines a Sustainable University as one that promotes the efficient use of resources in its teaching, research, outreach, and management functions, helping society transition to more sustainable lifestyles. In this context, despite often being compared to small communities, universities have a significant environmental impact, particularly in energy and resource consumption, comparable to large commercial areas or small cities [4–6].

However, universities face significant sustainability challenges despite their potential to influence society positively. One of the primary challenges is the engagement of university stakeholders, including students, faculty, and staff, whose involvement in sustainability initiatives has diminished over time [7–9]. For universities to become genuinely sustainable, it is essential to expand the dialogue on sustainability and ensure the active participation of all involved in institutional governance [10,11].

Traditionally, university sustainability has been evaluated using three main approaches: institutional infrastructure, the didactic–pedagogical system, and the students themselves [9,12–15]. While these approaches are essential, most studies have focused only on environmental indicators in isolation, neglecting a more holistic assessment that includes students' well-being and academic performance simultaneously. This narrow focus may result in an incomplete view of university sustainability, as a university's main objective is precisely its students' education [16–18]. The authors [9,19] emphasize that universities bear a crucial responsibility in promoting sustainability through their students, who are central to society and the very purpose of academic institutions.

An essential advancement in university sustainability studies is the model proposed by [14], presented conceptually and applied to a sample of Peruvian students by [20]. In this model, although sustainability is attributed to the university, students are the central focus, assessed integrally through Ecological Footprint, Happiness, and Academic Performance indicators. The Ecological Footprint, a widely used concept to measure individual environmental impact, represents the land and water required to sustain a person's lifestyle, considering resource consumption and waste production [21,22]. Student happiness is a crucial aspect that directly influences engagement and learning capacity, making it essential to assess institutional sustainability [23,24]. Moreover, self-assessed happiness has been a crucial element in sustainability research conducted at the community and urban levels [25]. The theoretical underpinning of this study aligns with Maslow's hierarchy of needs [26], which provides a framework for understanding how subjective well-being influences individual motivations and behaviors. In this context, students who have their basic and psychological needs fulfilled are more likely to engage in sustainable practices, as they are equipped to address higher-order goals, including environmental and social sustainability. Academic performance, traditionally assessed through average grades, is essential for the effectiveness of teaching and learning processes [27].

Research on sustainability in universities and students' perceptions of related topics has shown that the university context significantly influences students' understanding of sustainability and corporate social responsibility (CSR). For instance, ref. [28] investigated the perceptions of CSR among management students from Colombia, Ecuador, and Peru, highlighting the importance of national university contexts as explanatory variables. This study emphasized that students' perceptions vary not only across countries but are also influenced by the specific academic and cultural settings of each university. Similar to our research, these findings underline the relevance of addressing cross-country and institutional variations to better understand how sustainability concepts are internalized by students. The present study contributes to this discourse by integrating a broader framework of sustainability assessment, focusing on the triad of ecological footprint, happiness, and academic performance and comparing results across a more diverse set of countries.

This study aims to apply the integrated student sustainability assessment model proposed by [20] to a broad and diverse sample. Unlike the previous study, which used a more limited sample focused on a single country, this work seeks to apply the model to students from five countries: Brazil, China, the United States of America (USA), Italy, Mexico, and Peru. Additionally, the study explores the relationships between the proposed indicators, such as the influence of happiness on academic performance and the connection between environmental burden and student well-being, which is considered a differential approach from the authors' initial proposal of the model.

Through this application, the study aims to test the robustness of the model and explore the cultural and economic differences present in different lifestyles, thus providing valuable insights for decision-making in the context of university sustainability. This work contributes to filling the existing gap in the literature on Sustainable Universities, placing the student at the center of institutional sustainability assessment.

2. Literature Review

2.1. Approaches to Sustainability in Universities: Infrastructure, Didactic–Pedagogical System, and Focus on the Student

Sustainability in universities has become a topic of growing interest in the academic literature, reflecting the need to integrate sustainable practices into educational environments, not only in operations but also in teaching and student development [9,29]. The Sustainable University concept encompasses several dimensions: infrastructure, the didactic–pedagogical system, and the students themselves [30]. Each of these dimensions contributes uniquely to promoting sustainability in the university context. Still, they are all interdependent and essential for creating a genuinely committed university to sustainable development [9].

University infrastructure is often the initial focus when discussing sustainability in higher education institutions. This issue is because universities, in physical terms, function like small cities with significant demands for energy, water, building materials, and other resources [12,13]. Research in this field has developed conceptual and systematic frameworks to guide the sustainable management of university infrastructure. Models like Plan-Do-Check-Act (PDCA) and approaches that consider energy conservation, waste management, and the rational use of resources are examples of how sustainability can be operationalized within the university environment [3,31]. Efficient management of these resources reduces environmental impact and serves as an educational model for students, demonstrating how organizations can adopt more sustainable practices.

In addition to infrastructure, the didactic pedagogical system is crucial in promoting sustainability within universities. The curriculum and teaching practices need to incorporate sustainability principles to prepare students for the future's environmental, social, and economic challenges [29,32,33]. Including sustainability-related topics in the university curriculum is a matter of content and methodology [33]. Pedagogical approaches that promote transdisciplinarity, critical thinking, and collaborative learning are essential to empower students to tackle the complex and interconnected issues that characterize sustainability problems [34,35]. Furthermore, education for sustainability must go beyond classroom teaching, engaging students in practical projects and campus experiences that reinforce sustainability values [36,37].

As a central agent of the university, the student is also an important focus of discussions on sustainability. Unlike approaches that focus only on the physical or administrative aspects of universities, some studies have turned their attention to assessing the students' sustainability, considering their lifestyles, consumption choices, and environmental impact [38,39]. The Ecological Footprint is a widely recognized metric to assess the environmental impact of students, taking into account their consumption of resources such as energy, food, and transportation [21,22]. In addition, students' subjective well-being, or happiness, has been recognized as an essential factor, as happy students are more inclined to adopt sustainable behaviors and perform better academically [23,24]. Therefore, student sustainability should be viewed as integrating environmental health, social well-being, and academic success, reflecting the complexity of interactions between the individual and their environment [24].

The literature indicates that sustainability in universities cannot be effectively achieved without an integrated approach that considers infrastructure, the didactic–pedagogical system, and the role of students. Each of these elements offers a unique contribution. Still, it is in their intersection that the true potential lies in transforming universities into environments that not only teach sustainability but also practice it holistically and exemplarily.

The literature on university sustainability highlights diverse approaches and dimensions, ranging from infrastructure improvements to pedagogical innovations and student-centered initiatives. To provide a concise overview of these contributions, Table 1 summarizes the key findings of studies that have informed the conceptual and practical foundations of sustainable universities. The reviewed studies collectively illustrate the complex interplay between institutional frameworks, educational methodologies, and student engagement in advancing university sustainability. By addressing these three core dimensions—Infrastructure, Didactic–Pedagogical Systems, and Student-Centric Focus—universities can not only reduce their ecological footprint but also foster transformative educational experiences and empower students as agents of change. The findings emphasize that achieving a truly sustainable university requires an integrated approach, where governance mechanisms actively involve all stakeholders and align with long-term sustainability goals. This comprehensive understanding provides a robust foundation for the Sunshine Model, which seeks to harmonize ecological, academic, and human well-being in diverse university contexts.

Table 1. Summary of key contributions in university sustainability studies by dimension.

Ref.	Dimension of Sustainability	Key Contributions/Main Findings
[3]	Infrastructure	Proposed a strategic model for sustainable universities, identifying phases of implementation and institutional barriers.
[31]	Infrastructure	Highlighted water-saving programs at UFBA, showing a 50% reduction in per capita water use and challenges in institutionalization.
[12]	Infrastructure	Used emergy synthesis to evaluate sustainability in engineering programs and guide ecological campus management.
[13]	Infrastructure	Comparing the environmental costs of on-campus versus distance learning programs suggests trade-offs in sustainability.
[32]	Didactic–Pedagogical System	Applied scenario-based learning to build interdisciplinary and transdisciplinary competencies for sustainability.
[33]	Didactic–Pedagogical System	Found that environmental education activities enhance student engagement in green campuses.

Table 1. *Cont.*

Ref.	Dimension of Sustainability	Key Contributions/Main Findings
[34]	Didactic–Pedagogical System	Emphasized interdisciplinarity and holistic thinking as critical attributes for sustainable education in higher education.
[35]	Didactic–Pedagogical System	Explored transdisciplinary courses, highlighting university–city collaborations in urban sustainability challenges.
[37]	Didactic–Pedagogical System	Demonstrated the benefits of gamified flipped classrooms in fostering critical thinking and problem-solving.
[29]	Didactic–Pedagogical System	Integrated mathematical modeling with sustainability, enhancing student understanding of the SDGs through interdisciplinarity.
[33]	Didactic–Pedagogical System	Advocated active methodologies to develop sustainability and social responsibility competencies in teacher training.
[38]	Student-Centric Focus	Designed a scale to evaluate sustainability practices in universities from students' perspectives, identifying four dimensions.
[24]	Student-Centric Focus	Demonstrated a positive relationship between educational environment improvements and student well-being.
[23]	Student-Centric Focus	Developed the Gross Institutional Happiness Index (GIHI), evaluating student and staff happiness across nine domains.
[39]	Student-Centric Focus	Examined dietary choices as an indicator of sustainability and well-being, advocating for plant-based diets in education.

Source: Authors' creation.

2.2. The Sunshine Model and Its Sustainability Indicators: Ecological Footprint, Happiness, and Academic Performance in the University Context

The present study uses the "Sunshine Model" [20] to assess student sustainability in the university context. This model (Figure 1) integrates three leading indicators: Ecological Footprint, Happiness, and Academic Performance. The model's approach stands out by offering a multidimensional view of student sustainability, considering environmental impacts, subjective well-being, and academic performance, offering a broader perspective on the effects on both students and universities.

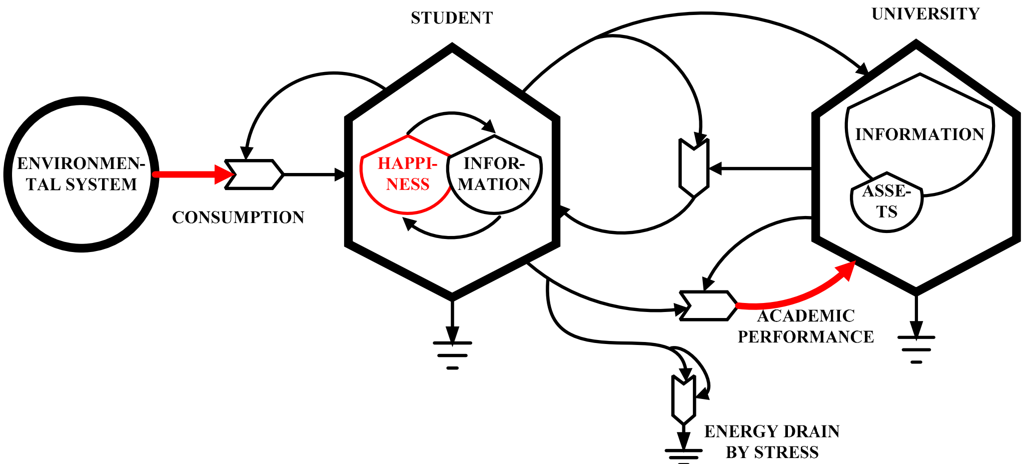

Figure 1. The Sunshine Model. Source: Authors' creation based on [20].

Figure 1 represents the "Sunshine Model" according to [40] symbolism, highlighting the flows of energy, matter, and information that interact in the university context. The model connects global and local sustainability scales, with the student at the center of the system. From left to right, the flow of natural resources (renewable and non-renewable) and natural capital feeds the environmental system, which directly influences student and university activities. The student, positioned at the model's center, interacts with the university environment through the teaching–learning process and the evaluation system, which impacts their happiness, stress, and academic performance. Happiness, in particular, is highlighted as a central element that can directly influence educational outcomes and overall sustainability. The evaluation system, connected to the university's resources and assets, generates a continuous flow of information that feeds into the process, allowing the institution to adjust to improve student sustainability. The model's visual representation facilitates understanding the interactions between the environment, social and economic resources, and the university's active role in creating a sustainable and inclusive environment.

The Ecological Footprint is a broadly recognized indicator for measuring individual environmental impact, representing the amount of biologically productive land and water required to support a person's resource consumption and assimilate the waste they generated [21,41]. In the university context, students' Ecological Footprint can provide essential insights into resource consumption and waste generation [20,22,42]. Studies in this area often focus on energy, food, transportation, and other goods consumption, highlighting the significant environmental impact of students' lifestyles [43]. In addition to providing a quantitative measure of environmental impact, the Ecological Footprint serves as an educational tool, raising awareness among students and encouraging changes in their consumption behaviors [44].

Another indicator used in the model is student Happiness, a measure of subjective well-being that has gained prominence as an essential component of sustainability [23,45]. Happiness is a complex variable influenced by multiple factors, including social, emotional, and economic aspects. Happy students are generally more engaged in the university environment, perform better academically, and adopt pro-environmental behaviors [46–48]. To assess happiness, the model uses a questionnaire based on established surveys, such as the Gallup World Poll [46], Santa Monica Well-being Survey [47], and the Happiness Alliance [48], enabling a broad and comparative evaluation of students' well-being. The inclusion of happiness as a sustainability indicator is innovative, as it expands the scope of assessment beyond environmental and economic impacts, integrating the social dimension of sustainability [20].

Academic performance is the third key indicator of the model and is traditionally measured by students' grade point averages. This indicator is essential for assessing the effectiveness of university teaching and learning processes [27,49]. Including academic performance in the sustainability model is crucial, as it directly links the quality of education provided to the future success of students, who are society's change agents. Strong academic performance demonstrates students' ability to absorb knowledge and apply it effectively in practical and sustainable contexts [24,50].

The interaction between the three indicators—Ecological Footprint, Happiness, and Academic Performance—is a central aspect of the 'Sunshine' Model. The feedback between these indicators reveals how different elements of university life are interconnected and can influence one another. For example, a student with a high Ecological Footprint may be unaware of the environmental implications of their actions. Still, if they are happy and perform well academically, they may be more receptive to educational interventions that promote sustainability [51]. Similarly, the model explores how students' happiness may affect their academic performance and how the Ecological Footprint can influence both factors.

The integrated use of these indicators in the model offers a comprehensive and multidimensional approach to assessing student sustainability in the university context. By considering both environmental impacts and students' well-being and academic success, the model provides a powerful tool for universities to self-assess and implement practices that promote complete and adequate sustainability.

The Sunshine Model distinguishes itself from existing frameworks by its unique integration of ecological, human, and academic dimensions into a cohesive sustainability assessment tool. While prior studies often focus on single dimensions—such as ecological footprint reduction [3] or the promotion of active pedagogical systems [32]—the Sunshine Model bridges these gaps by simultaneously addressing ecological sustainability, student well-being, and academic performance.

The theoretical foundation of the model lies in the recognition of universities as complex systems where environmental, social, and educational factors are deeply interwoven. For instance, the inclusion of the Ecological Footprint as a core metric aligns with the need to measure resource efficiency [12], while the emphasis on Happiness draws from studies showing its critical role in enhancing student engagement and resilience [23,24]. Academic Performance, as an equally critical dimension, ensures the model's relevance in evaluating institutional goals and student success.

This multidimensional approach provides not only a theoretical advancement but also practical utility, allowing universities to identify actionable strategies that align sustainability with human-centric outcomes. By connecting these dimensions, the Sunshine Model offers a novel perspective that fills critical gaps in the current literature and positions universities as active agents in promoting holistic sustainability. Furthermore, the model serves as a guide for institutions to align their practices with global sustainability goals while addressing the specific needs of their students and academic communities.

In summary, the Sunshine Model advances the state of the art by providing a comprehensive framework for understanding and improving sustainability in universities. Its emphasis on the interplay between Ecological Footprint, Happiness, and Academic Performance underscores the interconnectedness of environmental, social, and educational systems, offering a robust foundation for research and practical application in higher education.

3. Method

3.1. Data Acquisition

The data for this study were collected between 2018 and 2022 across five countries: Brazil, China, Italy, Mexico, and the United States. These countries were selected due to their diverse cultural, social, and economic contexts, which allow for a comprehensive comparison of sustainability perceptions and behaviors among students. Additionally, they represent significant differences in higher education systems and environmental policies, serving as critical variables in understanding sustainability outcomes. The inclusion of these countries was further facilitated by established academic partnerships and collaborations, which ensured access to representative student samples. This diversity enhances the generalizability of the findings, highlighting the influence of contextual factors on sustainability practices within universities.

Data collection was conducted in loco at all universities included in this study, both in Brazil and abroad. In practice, data were collected using four distinct methods, adapted according to resource availability and ease of access for respondents: (i) Plickers: an app that uses standardized cards where students indicate their answers by positioning the card with the correct answer facing up. Each card allows up to four response options; the results are exported in CSV format. (ii) ZipGrade: a mobile app that quickly reads paper answer sheets filled out by students. The responses are scanned via the mobile phone camera, stored online, and exportable in CSV format for analysis. (iii) GoogleForms: an online platform used to create and distribute questionnaires via a link. Responses are collected digitally; data can be exported in CSV format. (iv) Paper Questionnaire: used in locations where access to digital methods was limited, the questionnaire was printed on double-sided sheets and distributed manually. In addition to collecting demographic data from the students, the courses taken by the students were categorized following the framework of the International Standard Classification of Education (ISCED)—a classification of courses created by UNESCO to compile and present education statistics at national and international levels [52]. Data were collected from different classes and classified according to ISCED; however, the Services group was modified to the designation Society and Nature to include courses specified by ISCED and environmental courses, which ISCED does not clearly categorize.

The study gathered data from an overall total of 4088 students, distributed as follows: Brazil (n = 2204), China (n = 658), Peru (n = 603), Mexico (n = 355), Italy (n = 194), and the USA (n = 74). In total, data were collected from 117 universities across 6 countries, including 22 in Brazil, 90 in China, 2 in Italy, 1 in Mexico, 1 in Peru, and 1 in the United States. Data collection occurred through questionnaires assessing the students' Ecological Footprint, Happiness, and Academic Performance, which are available in Appendix A. The Ecological Footprint was measured using a questionnaire that covered the consumption of meat, fish, vegetables, fruits, milk and dairy products, paper, electricity, transportation, and built area. Students' happiness was assessed using a questionnaire adapted from established sources, such as the Gallup World Poll, Santa Monica Well-being Survey and the Happiness Alliance, presented and applied in the work by [20]. The questionnaire was structured to capture different dimensions of subjective well-being, such as life satisfaction, feelings of purpose, and perceptions of social support. Academic performance was measured through the students' perceived grade point average in their courses. This measure was chosen because it is widely used and reflects the effectiveness of teaching and learning processes [16].

The detailed methodology for quantifying the indicators, including the calculation of the Ecological Footprint, Happiness Index, and Academic Performance Assessment, is provided in the Supplementary Materials (see SM-S1).

3.2. Results Analysis Method

3.2.1. Independence Test Evaluation

Pearson's chi-square independence test (X^2) was used to assess the relationship between the variables of Ecological Footprint, Happiness, and Academic Performance of students. This test allows for determining whether there is a significant association between the categorical variables analyzed [53]. This test is fundamental as it identifies patterns and interdependencies between the indicators, providing valuable insights into how sustainable practices, subjective well-being, and academic performance relate. This approach enhances the understanding of the interplay among these factors within the university environment.

The Pearson chi-square test was applied to evaluate the independence between the assessment indicators: happiness as a function of Ecological Footprint and Academic Performance as a function of happiness. Equation (1) presents the calculation for X^2:

$$X^2 = \sum_{i=1}^{n} \frac{(o_i - e_i)^2}{e_i} \quad (1)$$

where

o_i: observed quantity for category i;

e_i: expected quantity for category i;

n: degree of freedom for the contingency table.

For the preparation of 2 × 2 contingency tables, categorical variables by the studied group were used. The student groups' variables included gender (male and female), age

(16 to 24 years and 25 to 61 years), occupation (working and not working), ISCED (course groups SSBL, EMC, SCI, and SN), student level (freshman, sophomore, and senior), and study period (daytime and nighttime). The number of students who meet or do not meet both assessment indicators was identified for each of these student groups.

The research hypotheses regarding happiness concerning the ecological footprint for each variable are

- H1: Happiness and ecological footprint variables are independent [14,18];
- H2: Happiness depends on the ecological footprint [14,18,24].

The research hypotheses regarding academic performance as a function of happiness are

- H3: Performance and happiness variables are independent [23,45];
- H4: Performance depends on happiness [23,25].

When the sample is small and a percentage greater than 25% of cells is observed with an expected count of less than five subjects, Fisher's Exact Test was used, as recommended by [54].

3.2.2. Odds Ratio Evaluation

The Odds Ratio (*OR*) was applied, also known as the odds or likelihood ratio, to assess the probability of an event occurring in two distinct groups. This indicator is important because it quantifies the strength of association between the indicators, highlighting differences in the probabilities of achieving a given sustainability scenario among the analyzed groups. For the identification of the *OR*, it is necessary to have categorical variables; therefore, the same categorical variables from the contingency tables used in the chi-square calculation were employed. The *OR* result represents the odds of finding the best scenario in the quadrant of the contingency table. Equation (2) below shows how *OR* was calculated:

$$Odds\ Ratio = \frac{a/c}{b/d} = \frac{a.d}{b.c} \tag{2}$$

where a, b, c, d are the student groups of the variables that meet or do not meet two analyzed indicators.

The OR is accompanied by a Confidence Interval (CI), which reflects the degree of uncertainty surrounding the effect measurement (precision of the estimate). In this study, where a sample from the general population was analyzed, the CI establishes upper and lower limits, indicating the range within which the true population effect is likely to fall. A 95% CI was applied, aligning with standard practice in most studies [55].

3.2.3. Student Classification into Clusters

The students' Ecological Footprint, Happiness, and Academic Performance results were used to group them into different clusters. Based on whether or not they meet the model's indicators, there are eight scenarios or clusters, as presented by [20]. These clusters are Unsustainable, Effective, Socially Distracted, Focused, Unfocused, Environmentally Distracted, Ineffective, and Sustainable. The classification was carried out to identify the most representative clusters, using Pareto's Principle [56], where the most frequent clusters, representing about 80% of the students, were selected for interventions and improvement actions. These interventions focus on the indicators that did not reach the desired sufficiency level to promote a more sustainable lifestyle and increase student well-being.

4. Results

For better understanding, the results are divided into two parts: (i) the sustainability assessment of Brazilian students, followed by (ii) the sustainability assessment of students from other countries. This division was considered due to the significantly larger size of the Brazilian sample, allowing for a more detailed and comprehensive analysis, as recommended in studies with large samples [57]. In this way, the results of the Brazilian students provide a robust reference point for subsequent comparison with the smaller samples from other countries.

4.1. Sustainability Assessment of Brazilian Students

The questionnaire applied to Brazilian students resulted in n = 2204 responses. It is a group of students where gender is evenly divided; the majority are young people between the ages of 16 and 24, and most of them work and study at night. In addition, two groups of courses are representative: Social Sciences, Business, and Law, as well as Engineering, Manufacturing, and Construction. An independence test was conducted for happiness as a function of the Ecological Footprint and another for performance as a function of happiness. Both independence tests evaluated the student group as a whole and analyzed subgroups based on studied variables (see Table S1—Supplementary Materials).

We do not reject the hypothesis that the variables are independent for the Brazilian student group. There was no evidence of a dependency association between happiness and Ecological Footprint. The calculated X^2 (0.780) is less than the critical X^2 (3.841), confirmed by the p-value. However, among all the variables studied, it was found that students in the Sciences group (SCI) showed a dependency on happiness in the Ecological Footprint. This same group of students had a higher likelihood of being happy with a lower environmental burden (4.44 times more likely). There is a 95% confidence that this parameter lies between 1.39 and 14.19.

Conversely, the independence test for academic performance based on happiness rejected the hypothesis that the variables are independent, meaning that performance depends on happiness. This issue was observed for the Brazilian student group and the studied variables, except for the science students (see Table S2—Supplementary Materials).

The overall sustainability indicators show that the environmental impact of this group of students reflects a lifestyle that, on average, requires 1.8 planets, a Happiness Index of 0.8, and academic performance with an average grade of 7. These students were grouped into clusters, considering the different sufficiency levels for the sustainability model indicators. Table 2 shows the frequency of each cluster within the group of students. Thus, Brazilian students can be classified as "environmentally distracted" (Table 2), meaning they consume more than the planet's biocapacity while generally being happy and performing academically. The ecological footprint was the only indicator among the three sustainability indicators not achieved satisfactorily in this assessment. Only a few students belong to the extreme clusters: 7% of students are classified as sustainable, achieving all three model indicators, while 8% are classified as unsustainable, failing to achieve sufficiency in any indicator.

Table 2. Frequency of Brazilian students in clusters.

Ecological Footprint	Happiness	Academic Performance	Cluster	Frequency (%)
● (green)	● (green)	● (green)	Sustainable	7
● (red)	● (green)	● (green)	Environmentally distracted	33
● (green)	● (green)	● (red)	Ineffective	1
● (green)	● (red)	● (green)	Unfocused	7
● (red)	● (green)	● (red)	Focused	2
● (red)	● (red)	● (green)	Effective	40
● (green)	● (red)	● (red)	Socially distracted	2
● (red)	● (red)	● (red)	Unsustainable	8

Source: Cluster classification based on [20]. The green color indicates that the threshold for the indicator has been exceeded, while the red color indicates the opposite.

Three were highlighted to identify how the cumulative frequency approaches 80% among the most expressive clusters: environmentally distracted, effective, and unsustainable. These three clusters represent 81% of the students, and all have at least one insufficient indicator. Next, the insufficient indicators for each cluster are analyzed in detail, which is essential for decision-makers to develop strategies to improve sustainability in the university environment.

4.1.1. Ecological Footprint Assessment of Environmentally Distracted, Effective, and Unsustainable Clusters

One thousand seven hundred ninety-four students were identified, representing the environmentally distracted, effective, and unsustainable clusters. The Ecological Footprint did not meet the sufficiency level for these three clusters. Table S3—Supplementary Materials shows the profile of this sample for all three clusters combined. Regarding gender, the sample is evenly divided between men and women. The majority are young (aged 16–24), work while studying at night, and are enrolled in courses within the Social Sciences, Business, and Law, as well as Engineering, Manufacturing, and Construction, and most are sophomores.

Figure 2 provides a more detailed representation of the Ecological Footprint by the area used, showing the deficit or reserve of area and consumption. Brazilian students consume more than their country can supply regarding productive grazing and fishing areas. Grazing use is significant, with high consumption of dairy products followed by meat. In fishing areas, fish consumption exceeds the biocapacity. These consumptions contribute to an Ecological Footprint exceeding one planet for this group of Brazilian students. To align the Ecological Footprint with the capacity of a single planet, a 44% reduction is required. Proposed actions for environmentally distracted, effective, and unsustainable clusters (see Table S4—Supplementary Materials). Each action to reduce consumption impacts the student group differently. To reduce the Ecological Footprint by 44%, meat, dairy, and derivative consumption must be reduced. Reducing fish consumption alone, despite its deficit, would not significantly impact the Ecological Footprint indicator. The analyst or manager can set their initial goals targeting direct impact on deficit, consumption, or the Ecological Footprint indicator.

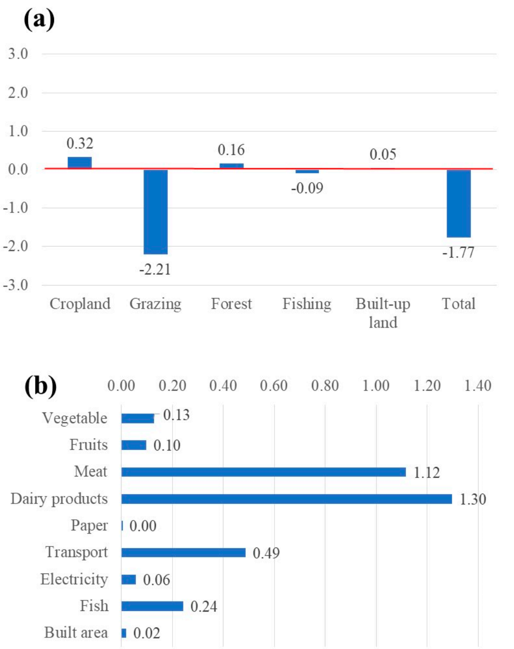

Figure 2. Area deficit or reserve (**a**) and consumption Ecological Footprint (**b**) of Brazilian students. Source: Authors' creation.

4.1.2. Happiness Evaluation of Effective and Unsustainable Clusters

Among the three identified representative clusters, the practical and unsustainable clusters did not reach sufficiency in the Happiness Index. Table S5—Supplementary Materials provides the sample profile of 1057 students representing these two clusters. The gender and study period of the students do not differ in the sample. Most are young (16 to 24 years old), work while studying, and are sophomores, and about half are enrolled in Engineering, Manufacturing, and Construction courses.

Figure 3 illustrates the breakdown of the Happiness Index by domains and indicators. Brazilian students did not reach sufficiency in any domain of happiness. The well-being, community, and perspective domains failed to meet the minimum index threshold of 0.8. The indicators associated with these domains help better understand which aspects may need improvement or focus within the university. Only the professional future indicator achieved sufficiency within the perspective domain, as students identified a positive outlook on their career prospects through their course. However, other indicators did not reach sufficiency. In particular, indicators for recreation, culture, and volunteer activities had very low scores, with students reporting that these activities were either unavailable or insufficiently provided by the university.

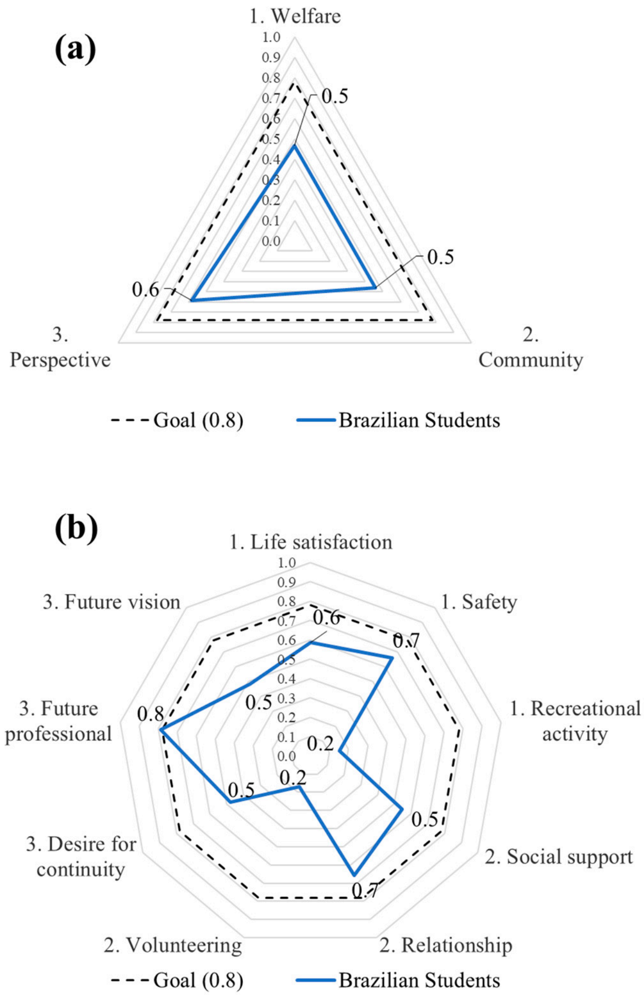

Figure 3. Happiness performance of Brazilian students, focusing on happiness domains (**a**) and indicators (**b**). Source: Authors' creation.

To achieve a minimum sufficiency level for the Happiness Index across the effective and unsustainable clusters, an increase of 14% is needed. If the goal is to improve the Happiness Index, focusing on the indicators of recreational and cultural activities or volunteer activities would be sufficient. However, improving the Happiness Index by addressing six other indicators collectively is also possible. The second approach may be more complex as the actions required to improve these indicators vary and may involve a more significant number of students (see Table S6—Supplementary Materials).

4.1.3. Academic Performance Evaluation of the Unsustainable Cluster

Among the three most representative clusters for the academic performance indicator, the unsustainable cluster was the only one that did not reach sufficiency. Table S7—Supplementary Materials presents the profile of this cluster's sample, consisting of 173 students. In the unsustainable cluster, the gender distribution shows a slight majority of male students between 16 and 24 years old, working, studying as sophomores, and predominantly enrolled in Engineering, Manufacturing, and Construction courses.

It was noted that no student in this cluster achieved an average score equal to or above 7, the minimum expected score for sufficiency. All students in this cluster had average scores of 6 or below, with the majority scoring between 5 and 6. Lower exceptions were observed in groups of students nearing the end of their courses, and there was a general trend of declining grades as students progressed through their studies. Except for the Society and Nature group, which had a mean score of 6, all other variables showed an average score of 5. This group also exhibited homogeneity in their grades, unlike students in different groups with more variability (see Table S8—Supplementary Materials).

4.2. Evaluation of Sustainability Among Students from Other Countries

To enhance the analysis of the sustainability assessment of Brazilian students, information was gathered from students in five other countries: China, the USA, Italy, Mexico, and Peru. The sample sizes varied by country, with 658 responses collected from Chinese students, 74 from USA students, 194 from Italian students, 355 from Mexican students, and 603 from Peruvian students. The profiles of the samples are relatively similar across the countries, with few differences in student characteristics. Except for Mexican and Peruvian students, where gender distribution lacked representativeness, most respondents in the other countries were female. Most were young people aged 16 to 24, unemployed, and primarily freshmen and sophomores studying during the daytime. The course group was the variable with the most significant differences among the students. Most students in the USA, Italy, and Peru were enrolled in Social Sciences, Business, and Law courses, while most Mexican students were enrolled in Engineering, Manufacturing, and Construction courses. Chinese students were predominantly from Engineering, Manufacturing, Construction, and Society and Nature course groups (see Table S9—Supplementary Materials).

Independence tests and *OR* were conducted to measure happiness in relation to the ecological footprint and academic performance in relation to happiness for the student groups from the five countries. The independence test showed no dependence between happiness and Ecological Footprint for the student groups from different countries (X^2 = China: 3.456, USA: 0.356, Italy: 1.096, Mexico: 0.989, Peru: 0.861). Only the working Peruvian students depended on happiness and Ecological Footprint (X^2 = 4.619) when analyzed by the variable.

The independence test for academic performance concerning happiness showed that only the Chinese students had dependence (X^2 = 9.553). For the other four groups of students, no dependence was found between performance and happiness (X^2 = USA and Mexico: no statistics computed due to the small number of cases, Italy: 0.493, Peru: 1.720). Not all student subgroups by variable showed the same dependence among Chinese students. Only the groups of students aged 16 to 24 from the Engineering, Manufacturing, and Construction groups, as well as freshmen and those studying during the day, showed dependence.

As previously mentioned, Peruvian students did not show a dependence between performance and happiness. However, within this same group, male students (X^2 = 4.234) and freshmen (X^2 = 5.571) showed dependence between these two variables.

Among the student groups from the five countries, students from the USA were more likely to find a happy student with a low environmental footprint (1.45 times more likely). Within the USA group, students from the Social Sciences, Business, and Law group (2.11 times) and the Sciences group (2.00 times) had slightly higher chances of finding happy students with a low environmental footprint.

Students from the USA also stood out for their chances of finding a happy student with good academic performance compared to other groups of students (3.28 times more likely). Within this group, Social Sciences, Business, and Law students had even higher chances (4.94 times more likely). In the same perspective, Peruvian students from the Sciences group had higher chances of being happy and performing well academically (3.50 times more likely) within their group.

Evaluating the sustainability of students (Figure 4), it was found that the Mexican students are sustainable, meaning they reached the sufficiency level for all three model indicators. Peruvian students and students from the USA were classified as environmentally distracted, requiring more than one planet to sustain their lifestyle. Italian students were classified as unfocused and did not achieve satisfactory results for the happiness indicator. Chinese students who did not achieve sufficiency in either the Ecological Footprint or happiness indicators were classified as effective, being only productive according to the model.

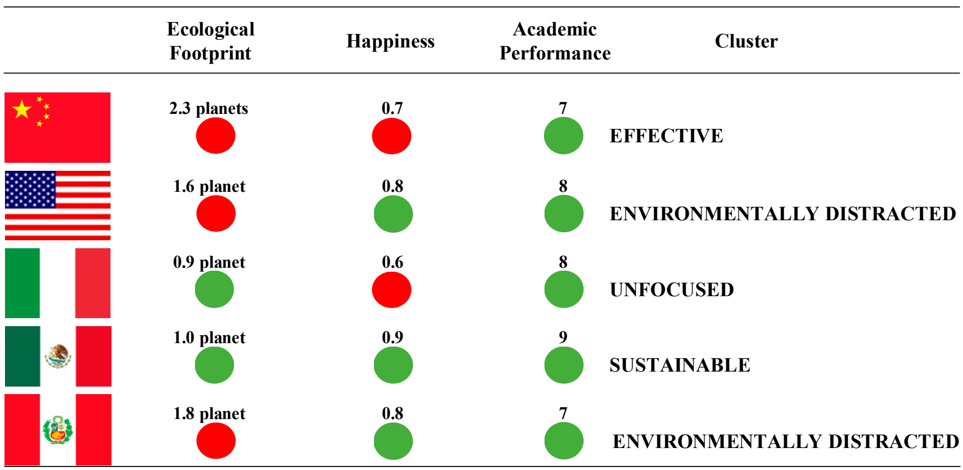

Figure 4. Results of sustainability assessment of students from different countries. Source: Authors' creation. The green color indicates that the threshold for the indicator has been exceeded, while the red color indicates the opposite.

The students from each country group were evaluated in clusters. Among the most representative clusters of each country—meaning those that, in cumulative frequency from highest to lowest, approach 80%—the environmentally distracted clusters (China, the USA, Mexico, and Peru) and effective clusters (China, the USA, Italy, and Peru) stand out, as they were identified in four countries. Among all nations, Peru has the most significant number of representative clusters, with four clusters: environmentally distracted, focused, effective, and unsustainable. The Mexican group has the highest proportion of sustainable students, while the Chinese group has the highest proportion of unsustainable students. Ineffective and socially distracted clusters had a low frequency in all countries.

5. Discussions

The results of this study reveal important insights into the sustainability of university students, integrating Ecological Footprint, Happiness, and Academic Performance. The analysis of these indicators provides a comprehensive understanding of students' sustainable behavior and highlights the complex interactions between subjective well-being, environmental impact, and academic success.

The high Ecological Footprint observed among Brazilian students is consistent with the findings of [21,22], which highlight how resource consumption, especially food and transportation, significantly contributes to individual environmental impact. This study confirmed that the main contributors to the Ecological Footprint of Brazilian students are meat consumption and transportation use, reflecting consumption patterns that require a high amount of natural resources. This issue aligns with the observations of [43], who emphasize the importance of considering these factors when assessing individual sustainability in educational contexts.

On the other hand, the analysis of happiness revealed that, despite the high environmental impact, Brazilian students consider themselves happy, reinforcing the findings of [46–48], where subjective well-being is often influenced more by social and emotional factors than by environmental concerns. This paradox between a high Ecological Footprint and high happiness levels may indicate a disconnection between environmental awareness and sustainable practices, suggesting that educational interventions are necessary to align subjective well-being with environmentally responsible behaviors [23].

Regarding Academic Performance concerning happiness, a level of dependence was identified for the entire group of Brazilian students (X^2 = 58.143). These results corroborate with [23,24], suggesting that happier students tend to perform better academically. These data highlight the importance of promoting student well-being as a strategy to improve academic outcomes while aiming to minimize the environmental impact of these students.

The comparison between countries revealed that students from countries like China and Italy have lower ecological footprints, reflecting cultural practices and public policies more aligned with sustainability [21]. These findings suggest that national policies and cultural norms are crucial in shaping students' sustainable behavior. On the other hand, students from the USA and Peru, as well as those from Brazil, presented high Ecological Footprints and high levels of happiness, reinforcing the need for educational strategies that address these discrepancies and foster increased environmental consciousness among students.

The combination of the three indicators enabled the classification of students into general performance clusters using the Sunshine Model. Students classified as "environmentally distracted", who exhibit a high Ecological Footprint and high levels of happiness, stand out as a group that could benefit from specific interventions promoting more sustainable practices without compromising their well-being or academic performance [51]. These findings suggest that universities play a crucial role in forming more conscious and sustainable students and that an integrated approach that considers Ecological Footprint, Happiness, and Academic Performance can effectively achieve this goal. Students classified as environmentally distracted, such as those from the USA and Peru, exhibit a moderate Ecological Footprint (1.6 and 1.8 planets, respectively) and high happiness levels but with potential environmental impact. For these countries, efforts should focus on reducing the Ecological Footprint, particularly in activities related to excessive resource consumption and transportation, promoting practices that encourage them to align happiness with sustainability, such as using public transport and conscious consumption.

For Chinese students classified as "effective", the Ecological Footprint is the highest (2.3 planets), while happiness levels are insufficient (0.7). Therefore, Chinese universities should focus on reducing the Ecological Footprint by raising awareness of more sustainable practices on campus, such as reducing the use of disposable materials, improving student satisfaction and well-being through support activities, and promoting quality of life.

In Italy, students were classified as "unfocused", with a sustainable Ecological Footprint (0.9 planets) but low happiness levels (0.6). In this case, interventions should focus on improving student happiness through activities that promote engagement, social support, and mental health while maintaining sustainable consumption habits.

In Mexico, where students were classified as "sustainable" with an Ecological Footprint within limits (1.0 planet) and high levels of happiness (0.9), the effort should be to maintain these practices and reinforce sustainability education as a model to follow. Mexican universities can implement educational actions and green campus policies to ensure the continuity of this sustainable balance.

The results of this study align with findings from other contexts, further illustrating the interplay between sustainability indicators such as ecological footprint, happiness, and academic performance. For instance, in Brazil, studies in low-income communities, such as the Felicidade community in São Paulo, revealed high levels of happiness despite significant ecological footprints, driven by strong social ties and access to basic services like health and education [58]. Similarly, the ecological efficiency observed in this study parallels findings from Mexico, where institutional efforts face cultural and structural barriers to enhancing student sustainability practices [18]. However, our results diverge from studies on distance education in Brazil, which highlight the environmental challenges associated with this modality due to increased energy demands [13].

Additionally, the application of a sustainability assessment in a Peruvian university demonstrated its utility in evaluating student sustainability through multidimensional indicators, corroborating the methodological robustness of this approach for understanding complex interactions between academic performance, happiness, and ecological impact [20]. These comparisons underscore the relevance of considering cultural and institutional contexts when analyzing student sustainability and highlight the contributions of this study to advancing knowledge in diverse educational environments. These actions, customized to the unique needs of each country, have the potential to foster more sustainable and integrated practices within universities, contributing to the formation of more conscious students prepared to face global environmental challenges. Although this study is framed within the context of higher education institutions in five countries, its findings provide insights that may extend to other educational settings. The integration of ecological footprint, happiness, and academic performance as key indicators offers a flexible framework that can be adapted to various educational levels, such as secondary education or technical training programs. For instance, younger students could benefit from tailored sustainability initiatives that address their specific developmental and educational needs. Additionally, the approach can be applied in non-formal educational contexts, such as community workshops or professional training programs, to promote sustainability awareness and behavioral change across diverse audiences. Future studies could explore these applications to evaluate the broader applicability and effectiveness of the framework beyond traditional university environments.

By focusing on localized strategies that address the unique environmental, social, and economic challenges faced by different nations, these efforts can foster a deeper institutional commitment to sustainability. Such approaches not only contribute to the formation of environmentally conscious students but also equip them with the skills and mindset necessary to navigate and address complex global environmental challenges. This highlights the pivotal role of universities in bridging local sustainability efforts with global environmental objectives.

The findings of this study align with those of [28], who demonstrated that students' perceptions of corporate social responsibility and sustainability are significantly influenced by the specific context of their universities and countries. While [28] focused on management students in Colombia, Ecuador, and Peru, highlighting the role of institutional and national contexts as explanatory variables, our results extend this understanding by incorporating a broader sustainability framework. By evaluating ecological footprint, happiness, and academic performance across five countries, we provide additional evidence that university settings and cultural environments are critical in shaping students' sustainability behaviors and outcomes. These similarities underscore the need for tailored approaches to sustainability education that reflect the unique challenges and opportunities of each context.

6. Conclusions

This study applied a previously proposed student sustainability assessment model (the Sunshine Model) in universities, integrating Ecological Footprint, Happiness, and Academic Performance as crucial indicators. Applying a broader and more diverse sample allowed for an improved analysis of the relationships between these indicators.

The results revealed that, although Brazilian students have a high Ecological Footprint, they also consider themselves happy and perform well academically, suggesting the need for educational interventions that can align subjective well-being with more sustainable practices. The international comparative analysis revealed that students from countries such as China and Italy have lower Ecological Footprints, which reflects the influence of public policies and cultural norms on students' sustainable behaviors. Conversely, students from countries like the USA, Peru, and Brazil encounter similar challenges in balancing happiness with environmental sustainability. The classification of students into different clusters demonstrated that a significant group of students could be considered environmentally distracted, highlighting the need for specific educational strategies to promote practices with lower environmental impact among these individuals.

In practical terms, the findings of this study suggest that universities play a crucial role in promoting sustainability among students, not only through initiatives aimed at reducing the environmental impact of campuses but also through educational programs that integrate subjective well-being and academic success with sustainable practices. Practical recommendations for universities include developing targeted sustainability education programs that encompass the ecological, social, and academic dimensions of student life. Universities should implement campus-wide initiatives to reduce students' ecological footprints, such as promoting sustainable transportation, reducing energy consumption, and enhancing waste management systems. Additionally, fostering environments that support student happiness and well-being through mental health programs and inclusive campus policies can further enhance sustainability efforts. Future studies could investigate the long-term impact of these initiatives on students' behaviors and perceptions, as well as assess the effectiveness of tailored interventions across diverse cultural and institutional contexts.

While this study provides valuable insights into the sustainability of university students across five countries, some limitations should be acknowledged. First, the data collection was conducted between 2018 and 2022, which may not fully capture the evolving sustainability practices influenced by recent global events, such as the COVID-19 pandemic. Second, the study relied on self-reported data, which could introduce bias due to subjective perceptions or social desirability. Third, the focus on five countries limits the ability to generalize findings to all regions, particularly those with significantly different educational and cultural contexts. Future research could address these limitations by incorporating longitudinal data to track changes over time, expanding the geographic scope to include more diverse regions, and integrating additional qualitative methods, such as interviews or focus groups, to complement the quantitative data.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17030950/s1, SM-S1: Procedure for Quantifying the Indicators; Table S1: Independence Test and Odds Ratio (OR) of Happiness Based on Ecological Footprint; Table S2: Independence Test and Odds Ratio (OR) of Academic Performance Based on Happiness; Table S3: Sample Profile of Environmentally Distracted, Effective, and Unsustainable Students; Table S4: Actions to Improve Ecological Footprint and Their Impacts; Table S5: Sample Profile of Effective and Unsustainable Students; Table S6: Actions to Improve Happiness and Their Impacts; Table S7: Sample Profile of Unsustainable Students; Table S8: Average, Median, and Standard Deviation of Student Grades by Variable; Table S9: Sample Profile by Country (in percentage).

Author Contributions: Conceptualization, M.J.A.-P.J. and B.F.G.; methodology, M.J.A.-P.J., B.F.G., F.A. and C.M.V.B.A.; validation, C.M.V.B.A. and F.A.; formal analysis, M.J.A.-P.J. and B.F.G.; investigation, M.J.A.-P.J.; data curation, M.J.A.-P.J., B.F.G., M.C.-M., L.V., N.M., G.L. (Ginevra Lombardi) and G.L. (Gengyuan Liu); writing—original draft preparation, M.J.A.-P.J., B.F.G., F.A. and C.M.V.B.A.; writing—review and editing, M.J.A.-P.J., M.C.-M., L.V., N.M., G.L. (Ginevra Lombardi) and G.L. (Gengyuan Liu); supervision, M.J.A.-P.J. and B.F.G.; project administration, B.F.G. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article and supplementary material. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Structured Questionnaire Survey Applied to Students to Obtain Data on Their Socio-Demographic, Ecological Footprint, Happiness and Academic Performance Profile

Part I: Socio-demographic profile
(1) University and campus:
(2) Bachelor degree/graduate program:
(3) On a scale of 0 (zero) to 10 (ten), what number represents your average grade in the general course?
(4) Year in the school: (a) Freshmen, (b) Sophomore, (c) Senior
(5) Gender: (a) Female, (b) Male, (c) I do not want to answer
(6) Age

Part II: Happiness
(7) How would you rate your happiness level now?
(a) Not Yet Happy, (b) Somewhat happy, (c) Happy, (d) Very Happy
(8) Inside the campus, do you feel safe?
(a) No, (b) A little, (c) Yes, (d) Much
(9) Does your school offer recreational and cultural activities?
(a) No, it doesn't, (b) Offers few options, (c) Offers is enough, (d) It offers a lot of options
(10) How often do you feel lonely in school?
(a) Always, (b) Most of the time, (c) Sometimes/Rarely, (d) Never
(11) How would you rate your relationship with colleagues and teachers?
(a) Unsatisfactory, (b) Regular, (c) Good, (d) Great
(12) Does your school offer volunteer activities?
(a) No, it doesn't, (b) Offers little, (c) Offers, (d) It offers a lot
(13) Do you intend to continue being a student of your bachelor degree?
(a) No, I don't, (b) I intend, but I would make many changes, (c) I intend to make few changes, (d) I intend without changes
(14) Do you think your academic training is preparing you for a professional carrier?
(a) No positive expectation, (b) Low expectation, (c) Normal expectation, (d) High expectation
(15) Has your bachelor's degree program prepared you to be a change agent for a more sustainable world?
(a) No, it doesn't, (b) Poorly, (c) Yes, it allows, (d) Yes, very much
Part III: Ecological Footprint
(16) How often do you eat meat during the week?
(a) I do not eat meat, (b) Rarely (one serving per week), (c) Occasionally (four or more servings per week), (d) Often (two or more servings per day)
(17) How often do you eat fish during the week?
(a) I do not eat fish, (b) Rarely (one serving per week), (c) Occasionally (four or more servings per week), (d) Often (two or more servings per day)
(18) How often do you eat vegetables during the week? (vegetables and greens)
(a) I do not eat vegetables, (b) Rarely (one serving per week), (c) Occasionally (four or more servings per week), (d) Often (two or more servings per day)
(19) How often do you eat fruit during the week?
(a) I do not eat fruit, (b) Rarely (one serving per week), (c) Occasionally (four or more servings per week), (d) Often (two or more servings per day)
(20) How often do you have dairy products during the week?
(a) Never, (b) Rarely (one serving per week), (c) Occasionally (four or more servings per week), (d) Often (two or more servings per day)
(21) Which means of transportation do you use the most on your way to school?
(a) Car, (b) Motorcycle, (c) Public transportation, (d) I do not use motorized means of transportation to come to school
(22) How far is your university from your place?
(a) Up to 30 km, (b) 30 to 90 km, (c) More than 90 km, (d) I live on campus
(23) What is your paper consumption during the week? Consider any type of paper you use for writing or printing.
(a) Up to 20 sheets of paper, (b) 21 to 50 sheets of paper, (c) 51 to 100 sheets of paper, (d) More than 100 sheets of paper
(24) What is the area of your home?
(a) Small—up to 100 m^2, (b) Average—101 to 200 m^2, (c) Large—201 to 400 m^2, (d) Very large—more than 401 m^2
(25) How many people live in your home—including you?
(a) 1 person, (b) 2 persons, (c) 3 persons, (d) More than 3 people
(26) How would you rate your electricity consumption?
(a) Low, (b) Medium, (c) Normal, (d) High

Source [1].

Appendix B. Coefficient Factors Considered in the Ecological Footprint Method

The consumptions P were collected using the Ecological Footprint questionnaire, where weekly consumption was asked, then converted into annual consumption (multiplied by 52 weeks) and from grams to tons. The coefficients representing the students' responses, used for students from all countries, are presented in Table A1.

The built area of the residence was divided by the number of people living there. The electricity consumption was calculated for each country in the study, trying to reflect the reality of the energy matrix of each country (Table A2).

Table A1. Coefficients used for the Ecological Footprint questionnaire alternatives.

Consumption	Coefficient per Alternative	Unit
Meat	(a) 0; (b) 200; (c) 1000; (d) 4200	g/week
Fish	(a) 0; (b) 200; (c) 1000; (d) 4200	g/week
Vegetables	(a) 0; (b) 500; (c) 9500; (d) 19,000	g/week
Fruits	(a) 0; (b) 500; (c) 9500; (d) 19,000	g/week
Dairy	(a) 0; (b) 750; (c) 3500; (d) 7000	g/week
Transportation	(a) 0.1916; (b) 0.1; (c) 0.0408; (d) 0	$kgCO_2$/person km
Distance	(a) 30; (b) 90; (c) 200; (d) 0	km/day
Paper	(a) 90; (b) 180; (c) 240; (d) 500	g/week
Built area	(a) 0.01; (b) 0.02; (c) 0.03; (d) 0.06	ha
People in residence	(a) 1; (b) 2; (c) 3; (d) 6	person

Authors' creation.

Table A2. Coefficients used for electricity consumption alternatives.

Country	kWh/Person·Year	tCO_2/kWh	tCO_2/Person·Year	a	b	c	d
Brazil	2600	0.0001	0.21	0.11	0.21	0.42	0.85
China	4900	0.0008	3.86	1.93	3.86	7.72	15.44
Italy	5200	0.0004	2.10	1.05	2.10	4.20	8.39
Mexico	2300	0.0005	1.24	0.62	1.24	2.49	4.98
Peru	1500	0.0002	0.26	0.13	0.26	0.52	1.03
USA	12,800	0.0006	7.15	3.58	7.15	14.30	28.60

Authors' creation. Source: (https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC, accessed on 12 January 2021) for the year 2014.

The national average consumption yields were taken from the Food and Agriculture Organization (FAO) database, which has the most recent available data. The national totals of beef and poultry production were considered to calculate the national average yield for meat consumption. FAO's definitions and standards for beef include cow, buffalo, and general cattle. Poultry includes chicken, goose, turkey, and duck. The area for meat production was the permanent grassland and pasture areas. Table A3 presents the values used for the calculations for each country.

Table A3. National average yield for meat consumption.

Country	Meat (t)	Area (ha)	Y_N (t/ha Year)	Year
Brazil	2.38×10^7	1.73×10^8	0.14	2018
China	2.65×10^7	3.93×10^8	0.07	2018
USA	3.45×10^7	2.45×10^8	0.14	2018
Italy	2.09×10^6	3.25×10^6	0.64	2018
Mexico	5.36×10^6	8.03×10^7	0.07	2018
Peru	1.77×10^6	1.88×10^7	0.09	2018

Authors' creation. Source: (fao.org/faostat/en/#data, accessed on 12 January 2021) For meat: Food Balances (2014) > Countries > Production Quantity > Bovine Meat + Poultry Meat > Year. For area: Land Use > Countries > Area > Land under perm. Meadows and pastures > Years.

To calculate the national average yield for fish consumption, the total national production of freshwater, demersal, pelagic, and marine fish was considered. The area for fish production was supposed to be the Coastal Fishing Area for each country. Table A4 presents the values used for each country.

Table A4. National average yield for fish consumption.

Country	Fish (t)	Area (ha)	Y_N (t/ha Year)	Year
Brazil	1.15×10^6	3.57×10^7	0.03	2017
China	3.88×10^7	4.13×10^7	0.94	2017
USA	4.37×10^6	2.91×10^7	0.15	2017
Italy	1.92×10^5	7.20×10^6	0.03	2017
Mexico	1.34×10^6	3.13×10^7	0.04	2017
Peru	3.88×10^6	7.11×10^6	0.55	2017

Authors' creation. Source: (fao.org/faostat/en/#data) For fish: Food Balances (2014) > Countries > Production Quantity > Freshwater Fish + Demersal Fish + Pelagic Fish + Marine Fish > Year. For area: (https://www.seaaroundus.org/).

Fresh vegetable production was considered for calculating the national average yield for vegetable consumption. The same harvest area of national fresh vegetable production was considered, as shown in Table A5 for each country.

Table A5. National average yield for vegetable consumption.

Country	Vegetables (t)	Area (ha)	Y_N (t/ha Year)	Year
Brazil	3.21×10^6	2.47×10^5	13.01	2018
China	1.75×10^8	1.10×10^7	15.87	2018
USA	8.07×10^5	1.22×10^4	66.06	2018
Italy	1.99×10^6	1.34×10^5	14.88	2018
Mexico	9.02×10^5	1.06×10^5	8.52	2018
Peru	6.28×10^4	3.14×10^3	19.98	2018

Authors' creation. Source: (fao.org/faostat/en/#data) For vegetables: Crops and livestock products > Countries > Production Quantity > Vegetables, freshness > Year. For area: Crops and livestock products > Countries > Area harvested > Vegetables, freshness > Year.

Fresh tropical fruit production was considered for calculating the national average yield for fruit consumption. The same harvest area was considered for the production of fresh tropical fruits. Table A6 presents the values used for each country.

Table A6. National average yield for fruit consumption.

Country	Fruits (t)	Area (ha)	Y_N (t/ha Year)	Year
Brazil	6.03×10^5	4.27×10^4	14.10	2018
China	4.25×10^6	1.10×10^6	3.87	2018
USA	6.70×10^2	3.50×10^1	19.14	2018
Italy	5.85×10^4	1.36×10^4	4.29	2018
Mexico	4.79×10^5	4.81×10^4	9.97	2018
Peru	2.05×10^5	2.21×10^4	9.27	2018

Authors' creation. Source: (fao.org/faostat/en/#data) For fruits: Crops and livestock products > Countries > Production Quantity > Fruit, tropical freshness > Year. For area: Crops and livestock products > Countries > Area harvested > Fruit, tropical freshness > Year.

The total national production of fresh cow's milk was considered to calculate the national average yield for dairy consumption, as this is the primary product for dairy production. The same national production area for fresh cow's milk was used, as shown in Table A7 for each country.

Table A7. National average yield for dairy consumption.

Country	Milk (t)	Area (ha)	Y_N (t/ha Year)	Year
Brazil	3.38×10^7	1.73×10^8	0.20	2018
China	3.12×10^7	3.93×10^8	0.08	2018
USA	9.87×10^7	2.45×10^8	0.40	2018
Italy	1.19×10^7	3.25×10^6	3.68	2018
Mexico	1.20×10^7	8.03×10^7	0.15	2018
Peru	2.07×10^6	1.88×10^7	0.11	2018

Authors' creation. Source: (fao.org/faostat/en/#data) For milk: Crops and livestock products > Countries > Production Quantity > Milk, whole fresh cow > Year. For area: Crops and livestock products > Countries > Area harvested > Milk, whole fresh cow > Year.

The total national production of paper for printing and writing was considered to calculate the national average yield for paper consumption. The forest area for each country was used for calculation. Table A8 presents the values used for each country.

Table A8. National average yield for paper consumption.

Country	Paper (t)	Forest (ha)	Y_N (t/ha Year)	Year
Brazil	2.41×10^6	4.98×10^5	4.85	2019
China	2.51×10^7	2.18×10^5	115.07	2019
USA	1.08×10^7	3.10×10^5	34.84	2019
Italy	2.31×10^6	9.51×10^3	242.43	2019
Mexico	4.81×10^5	6.58×10^4	7.31	2019
Peru	1.47×10^4	7.25×10^4	0.20	2019

Authors' creation. Source: (fao.org/faostat/en/#data) For paper: Forestry Production and Trade > Countries > Production Quantity > Printing and writing papers > Year. For area: Land Use > Countries > Area > Forest land > Year.

The YF, EQF, $and\ BC$ were extracted from the National Footprint Accounts (NFA) 2018 Edition for the year 2014 (GFN, 2014), available online in a public data package in Microsoft Excel format and on an open data website (data.footprintnetwork.org, accessed on 12 January 2021), presented in Table A9.

Table A9. Yield factors, equivalence factors, and biocapacity.

Ecological Footprint Area	YF (Dimensionless)	EQF (gha/ha)	Biocapacity (gha/Person)
Cropland	0.71	2.52	0.6
Grazing	1.81	0.46	0.2
Forest	0.88	1.29	0.7
Built area	0.71	2.52	0.1
Fishing	2.04	0.37	0.2
Carbon		1.29	

Authors' creation.

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