sustainability

MDPI

Article

Analyzing Green Behavior and the Rational Use of Water in Portuguese Higher Education Campi

Ana M. Barreiros [1,*], Anabela Durão [2,3], Ana Galvão [4], Cristina Matos [5,6], Dina Mateus [7,*], Ivo Araújo [8], Luís Neves [9,10], Mário Matos [11] and Sandra Mourato [9,12]

1 Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Rua Conselheiro Emídio Navarro 1, 1959-007 Lisboa, Portugal
2 Polytechnic Institute of Beja, Campus do IPBeja, Rua Pedro Soares, 7800-295 Beja, Portugal
3 Associate Laboratory, MARE—Marine and Environmental Sciences Centre, ARNET—Aquatic Research Network, 4710-057 Braga, Portugal
4 CERIS—Civil Engineering Research and Innovation for Sustainability, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
5 Escola de Ciências e Tecnologia, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, 5000-801 Vila Real, Portugal
6 CIIMAR—Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Terminal de Cruzeiros do Porto de Leixões Avenida General Norton de Matos, S/N, 4450-208 Matosinhos, Portugal
7 Techn&Art—Centre for Technology, Restoration and Art Enhancement, Instituto Politécnico de Tomar, Estrada da Serra, 2300-313 Tomar, Portugal
8 proMetheus, Unidade de Investigação em Materiais, Energia e Ambiente para a Sustentabilidade, Instituto Politécnico de Viana do Castelo, Rua da Escola Industrial e Comercial de Nun'Alvares, 4900-347 Viana do Castelo, Portugal
9 School of Technology and Management, Polytechnic Institute of Leiria, 2411-901 Leiria, Portugal
10 INESC Coimbra—Institute for Systems Engineering and Computers at Coimbra, 3030-790 Coimbra, Portugal
11 Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
12 MED—Mediterranean Institute for Agriculture, Environment and Development, Universidade de Évora, Polo da Mitra, 7006-554 Évora, Portugal
* Correspondence: ana.barreiros@isel.pt (A.M.B.); dinamateus@ipt.pt (D.M.)

Abstract: In the forthcoming years Portugal expects to be an increasingly hot and dry country dealing with the risk of water scarcity. According to the Portuguese Institute for Sea and Atmosphere data, annual precipitation values have decreased 20 mm/decade. On the other hand, it is also verified that the periods of rain occur in a shorter interval, although more intensively. Water scarcity is one of the major challenges reflected in the UN 6th Sustainable Development Goal. Higher Education Institutions (HEIs), as places of responsibility in preparing future leaders, must have strong sustainability policies, namely through the implementation of water efficiency measures on their campi. The main aim of this work was to evaluate water consumption and the good practices that the different HEIs have implemented on their campi to improve and promote green and sustainable behaviors, and to calculate water efficiency indicators associated with each HEI. The data were collected through a survey completed by eight HEIs distributed throughout the country. The results show that some institutions have already been implementing measures for water efficiency and have developed some activities with the academic and surrounding community. The range of values calculated for the indicators is large and there is not a strong correlation between them. Per capita consumption values vary between 1.8 and 23.5 L/(person·day), the differences being explained mostly by campus characteristics, namely: green areas; water sources for irrigation; age of buildings; and the existence of facilities on campus such as residences and sports facilities. Nevertheless, the consumption per capita values are generally lower than those found in the literature for equivalent institutions. Given the growing concern with water scarcity, sharing this kind of information among institutions may contribute to improving water efficiency.

Keywords: higher education institutions; SDG; sustainability; water efficiency; water use

check for updates

Citation: Barreiros, A.M.; Durão, A.; Galvão, A.; Matos, C.; Mateus, D.; Araújo, I.; Neves, L.; Matos, M.; Mourato, S. Analyzing Green Behavior and the Rational Use of Water in Portuguese Higher Education Campi. *Sustainability* **2023**, *15*, 3035. https://doi.org/10.3390/su15043035

Academic Editor: Agostina Chiavola

Received: 29 December 2022
Revised: 3 February 2023
Accepted: 4 February 2023
Published: 7 February 2023

1. Introduction

Water scarcity is one of the great challenges of the current century, a concern reflected in the United Nations' 6th Sustainable Development Goal (SDG 6.4) "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of fresh water to address water scarcity and substantially reduce the number of people suffering from water scarcity", as water is fundamental to almost all aspects of sustainable development and water is under threat [1]. Demand for water is increasing, following the global population growth, urbanization, and pressure from agriculture, industry, and the energy sector, and for a long time, misuse, bad management, over-extraction and contamination of supplies increased water stress and deteriorated water-related ecosystems. Climatic change with an intensification of severe weather conditions, such as droughts and heatwaves, has also put a significant strain on fresh water supplies. Water scarcity can be mitigated through various strategies and technologies, including more eco-efficient industrial production approaches aimed at reducing water consumption and loss, as well as water supply systems and irrigation of crops or green spaces. The production of reclaimed water is another approach that is becoming more relevant, particularly at European level [2–4]. SDG 6 requires a significant investment in water and sanitation [5,6], but also an increased education and raised awareness of the society as a whole [7,8].

The concern on water scarcity is relevant in Portugal, once it has suffered an increasing frequency and intensity of drought periods, especially in the last four decades [9]. In fact, 21 of the 30 hottest years on record occurred since 1990, and 13 since 2000. The increasing temperatures and reduction in rain have led to lower amounts of stored water in impoundments and subterraneous reservoirs, difficulties in achieving a good status of the water masses, and an increased consumption due to higher temperatures [9]. According to the Portuguese Institute for the Sea and Atmosphere (IPMA), the annual precipitation rates have decreased at a rate of 20 mm/decade, and a recent study forecasts reductions in precipitation between 10 and 25% until the end of the century, relative to the last two decades [9,10].

The changes in consumption and society's standard of living makes water a priority in International, European, and National policies designed to increase water efficiency. It is undeniable that water efficiency leads to economic benefits for management entities and for consumers. The Higher Education Institutions (HEI) are privileged spaces where actions are developed that enhance observation, diagnosis, experiments, questioning, and innovation, so water efficiency should be an important topic to be analyzed by students, technicians and teachers [11,12].

According to Thomashow [13], the campus may be considered as an ecological place, inserted in the Environment where the activities and the history must be interesting and transparent, framed in the campus and in the Environment, where it is inserted, rooted in history, and projected for the future. Thus, Education has the great capacity to keep the history alive, and consequently, enhancing knowledge, understanding and respect for humanity's past can help society to transform itself by moving towards a harmonious development [14]. HEIs should advance values such as cultural, research innovation, etc., in order to become the school's places where students learn to live sustainably, and bring these messages to their home and communities [14,15].

A sustainable campus is a balance between protocols, habits and routines required with creativity, deliberation and reflection [13].

Sustainability considers a holistic integration of economic (it is imperative to keep costs within a reasonable range), environmental and social perspectives (green buildings significantly benefit social sustainability, as it improves life quality, health, and comfort) [16,17].

Promoting environmental education, adopting practices targeted at sustainability and reducing the impact that our activities may have on the ecosystem and resources are essential.

The activities carried out on the Sustainable Campus can be classified in three aspects or dimensions: (1) behavior; (2) learning and educational tools; and (3) physical facilities. Consequently, each dimension contains strategies that are used by several HEIs to create a Sustainable Campus [18]. Concerning behavior dimension two strategies are used: strengthening leadership commitment and building green engagement. Regarding the learning and educational tools dimension, three strategies can be used: developing and implementing a sustainable curriculum; adopting environmentally friendly technology in learning; and developing a paperless office. Regarding the physical facility dimension, several strategies have been developed, namely: evaluating and revitalizing the environment-based campus master plan; improving water quality and use efficiency; improving electricity and energy use; promote integrated waste management; and developing environmentally friendly campus transportation.

Recently, the evaluation criteria for the green campus are based on the premise of the whole life cycle of the building, aiming to improve the whole process from the overall planning and design of the building and environment, construction, and operation management [19]. Consequently, it includes sustainable site planning, water efficiency, natural environment and energy, materials and resources, indoor environmental quality, design innovation and area preference, integrated design, selection, and transportation.

Water management (water distribution efficiency and irrigation methods) from operational processes inside the buildings is an efficient method for water conservation [20].

According to Priyadarshini et al. [21], HEIs are considered critical in promoting and implementing the targets of the United Nations' Sustainable Development Goals. However, some critical aspects are still under debate, such as frameworks, curricula, pedagogies, and governance policies better suited for promoting sustainability through HEIs. Authors emphasized on imagining HEIs as Complex Adaptive Systems as an alternative to rigid units that are capable of adaptation and evolution based on the 'feedbacks and demands' of the society to which they supply [21].

HEIs have been progressively developing towards the integration of sustainable practices in their campi, recognizing their responsibility and incorporating sustainability into their operations and practices, following an all-inclusive approach [12]. Bautista-Puig and Sanz-Casado [12] analyzed how Spanish Public and Private Universities are integrating sustainability into their institutions, considering the vectors: research, internationalization, university governance, assessment and reporting, and campus operations. The findings revealed that some institutions present a higher production of scientific activity on the topic, while others with less production are more specialized; it revealed high association between some of the variables, per example sustainability plan, and the existence of a green office. This study clearly reveals that although Sustainable Development is recognized as being very central to HEIs and society, it is not so far rooted in the whole system's strategies, activities, and policies.

Ribeiro et al. [11] described how the implementation of Green Campus Initiatives at four Brazilian universities may promote student engagement in finding ways to incorporate sustainability in the way the university operates. The results showed that sustainable development diffusion strategies in HEIs explain around 18% of the students' level of proactivity and 27.7% of their knowledge and awareness regarding sustainable development.

Al-Hazaima et al. [22] presented the results of survey (702) data about the integration of sustainability education into the accounting curricula of tertiary education institutions, to understand the perceptions of relevant stakeholders in Jordan. The study developed a questionnaire survey based on a literature review for gathering data regarding the potential role of sustainability accounting education (SAE), the potential SAE usefulness, the suitability of SAE in tackling the objectives of the HEI in Jordan, the most applicable methods of SAE integration, and the most suitable SAE topics to be integrated into the curricula. According to these authors, the collected data were found useful to gain evidence regarding the SAE importance in the context of emerging economies like Jordan having significant implications to policymakers, accounting educators, government representatives, accountants working in the industry, and professional accountants in Jordan in their quest to develop education solutions through the SAE incorporation for a higher value, and eventually, advancements in the industry and the economy [22].

Many HEIs around the world are involved in a variety of sustainability initiatives; however, there is a lack of systematic international efforts in how best to map them. Filho et al. [23] described the results of an empirical study aimed at analyzing the current status of sustainability initiatives among Latin American HEIs. This study aimed to identify the main descriptors of sustainability initiatives among Latin American HEIs, and likewise the major drivers and challenges. The results show that sustainability is being incorporated in more than 80% of the sampled universities, and that a special weight is being given to campus operations. The study allows the mapping of how sustainable development initiatives are being practiced in 157 universities in 13 countries, and it also summarizes some of the main challenges that universities in the region face.

Klein et al. [24] reported a significant and positive relationship between the second-order construct, called HEI Lean practices, and the environmental, economic and social practices. In this study a questionnaire was performed that covered a sample of 966 valid responses among the academic staff of HEIs in Brazil and Portugal. A diminishing effect was also found as significant between the relation of Lean and social practices. According to these authors, the findings demonstrated the relevance of aspects such as leadership and systemic vision to support staff activities, continuous improvement, and waste elimination as a daily practice, long-term thinking, and the focus on the students as building blocks of the HEI success in promoting sustainability practices and thinking.

According to Bonnet et al. [25], as demonstrated by the Ecocampus European Collaboration in large university campi, electricity and water uses are similar to those of medium-sized cities. In fact, in these cases there is a diversity of activities where energy and water end-uses can be considered as significant, as in a city where residential, commercial, and industrial uses are present. Bonnet et al. [25] studied electricity and water uses on the campus of the University of Bordeaux, and the applied method showed the relative share of major uses and allowed the estimation of water conservation potential at the campus scale [25].

Marinho et al. [26] studied a water-saving program case study led by a research group at a university in the northeast of Brazil, and this group defended that the rational use of water could be a powerful tool to promote sustainability on university campuses, once in addition to resource and financial savings it also supports technological and conduct revolution towards a more well-adjusted connection between human activities and nature. The implemented program involved engineers, social workers and undergraduate students from different courses [26].

Despite the large number of studies involving water management and sustainability in HEIs, reporting of water consumption in university campi is scarce and not uniform. The indicators include mostly two types: water consumption per capita and water consumption per unit area. In water consumption per capita different types of users are considered, including: the total number of students [25,27]; the total number of faculty staff and students [26,28,29]; and full-time and part-time students [30]. Additionally, regarding water consumption per unit area, different areas are considered too: some studies consider the total campus area [27]; and/or total built area (including all floors) [25,27,29]. The analysis per type of building (considering different activities) is also a subject of study [25,29].

The Portuguese Sustainable Campus Network—Rede Campus Sustentável—Portugal, (RCS-Portugal) (http://www.redecampussustentavel.pt/, accessed on 21 November 2022) was created in 2018 as a platform of cooperation for members of academia, aiming to contribute to the active involvement of HEIs, with the following objectives: (a) mobilization of the academic community to the challenges of sustainable development; (b) creation of strategies and support structures for sustainable practices in all HEIs; (c) active cooperation among all the individual members of the network, regardless of their institutional affiliation; and (d) active cooperation among HEIs at institutional level, for initiatives and joint programs aiming to promote sustainability in higher education and in the society. Although being an informal network of people, one of its first achievements was the signature in 2019 of a letter of commitment to sustainability by most of the Portuguese HEIs (35 Universities/Polytechnic Institutions including five major faculties).

Apart from networking activities as meetings and conferences, a significant share of the activity of RCS-Portugal resulted from the creation in October 2019 of 10 thematic Working Groups (WG), which since then have been driving cooperation among members on the following themes: Sustainable Cities and Communities; Circular Economy; Energy Efficiency; Efficient Use of Water; Education and Curricula for Sustainability; Waste Management; Governance and Strategy for Sustainability; Gender Equality; Sustainable Mobility; and Sustainability of Food Production and Consumption.

In particular, the Working Group on Efficient Use of Water (WGEUW) aimed for the implementation of water efficiency measures on HEIs campi, as well as fostering the educative function by turning campi into demonstration hubs for good practices. As part of the WGEUW work, a first assessment of water consumption in campi, and of methodologies and procedures, including research, community projects and curricula related to the efficient use of water in different Portuguese HEIs, was considered essential to improve and promote green and sustainable behaviors.

The aim of this paper is to present the major conclusions drawn from these first efforts of characterization of the Portuguese HEIs regarding water use, through estimating water indicators and sharing good practices.

2. Methodology

2.1. Data Collection and Sample

Data regarding water use in Portuguese HEIs were collected through online surveys. A first questionnaire was sent by RCS-Portugal to all the 35 public institutions to obtain an overall diagnosis on the position of Portuguese HEIs regarding sustainability. This survey consisted of eleven (11) sections (Figure 1), of independent submission and completion, with a total of eighty-six (86) questions [31].

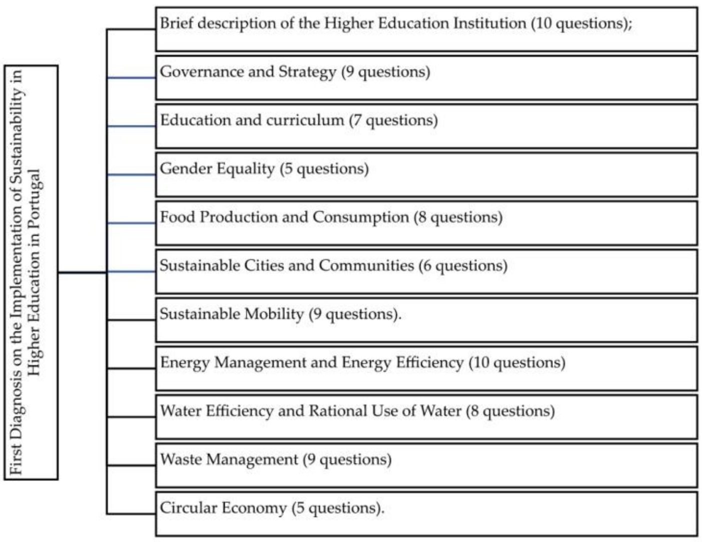

Figure 1. Portuguese Sustainable Campus Network survey sections.

The WGEUW then created a second questionnaire to explore in more detail the water efficiency among the campi and was answered by HEIs distributed throughout the country between January and May 2022. To ensure that the data collected reflected the normal functioning of the HEIs, the year 2019 was chosen as a reference to represent the situation before the COVID-19 pandemic crisis.

All data received were checked, and partially answered questionnaires were not included. From eleven (11) HEIs that responded, 3 were excluded in this study due to missing data. The results from the data obtained provided important guidelines that motivated the development of a more detailed WGEUW survey that is the object of the present work. A total of 8 HEIs with 15 campi participated voluntarily and agreed with the treatment and disclosure of survey data anonymously. All the institutions that responded to the survey are public institutions, two in Lisbon and the others spread across the country, located in large and small cities, inland and on the coast (Figure 2). These institutions have different numbers of students, campus areas, training areas, and include the two subsystems (Universities and Polytechnics) of Portuguese higher education. Table 1 presents some characteristics of the different Campi.

Figure 2. Spatial distribution of the HEIs across inland districts of Portugal that voluntarily responded to the survey.

Table 1. Characteristics of the different campus.

Campus	NUTS II [1]	Koppen Climate Classification [32,33]	Age	Other Water Sources	Comments
1	Centro	Csa [2]	30	G	Residence, canteen/bar, laboratories, sports facilities
2	Alentejo	Csa [2]	20	L, G	Canteen/bar, laboratory
3	Área Metropolitana de Lisboa	Csa [2]	30		Canteen/bar, laboratories
4	Área Metropolitana de Lisboa	Csa [2]	50		Canteen/bar, laboratories
5	Alentejo	BSk [3]	16	G	Canteen/bar, laboratories
6	Norte	Csb [4]	30	G, R	Canteen/bar, laboratories, sports facilities
7	Área Metropolitana de Lisboa	Csa [2]	48		Residence, canteen/bar, laboratories
8	Centro		28		Canteen/bar
9	Norte	Csb [2]	30	G, R	Residence, canteen/bar, laboratories, sports facilities, botanic garden
10	Norte	Csb [2]	30		Residence, canteen/bar, laboratories, sports facilities
11	Norte	Csb [2]	6		Canteen/bar
12	Norte	Csb [2]	40		
13	Norte	Csb [2]	13		Canteen/bar, sports facilities
14	Norte	Csb [2]	10		Canteen/bar, sports facilities
15	Norte	Csb [2]	50	G	Residence, canteen/bar, laboratories

[1] Regions according to Commission Delegate Regulation 2019/1755 of 8 August; [2] Csa—Mediterranean climate, temperate climate with warm summer and dry; [3] BSk—cold steppe climate of mid-latitude; [4] Csb—Mediterranean climate, temperate climate with dry and mild summer; G—groundwater; R—rainwater; L—lake.

The 15 campi from 8 HEIs that participated represent a total number of 48,881 persons, 2,444,976 m^2 of total campus area, 269,003 m^2 of total covered area, 582,330 m^2 of total built area, and 1,236,506 m^2 of green areas. All campi have irrigated green areas, some of which are irrigated with water from the water supply network and others using alternative water sources, as specified in Table 1. The total water consumption of the institutions was 225,647 m^3 in 2019. Consumption from groundwater and other alternative sources was not included.

2.2. Survey Design and Procedures

The results obtained in the first survey (not shown) indicated a scenario, although preliminary and with the need for further studies, which reveals that HEIs are generally aware of sustainability issues and are implementing several practices, although in an apparently fragmented way and without major investment [31].

The main questions of this survey include total consumption, whether regular monitoring is carried out and how it is done, whether water efficiency measures have been recently implemented, and how these investments were financed.

Data collected enabled the calculation of water efficiency indicators associated with each HEI, allowing the identification of areas of improvement, but also the gathering and exchanging of information about good practices in the efficient use of water and possible ways of financing the implementation of these measures.

The survey questions were organized with four distinct objectives: to characterize the different HEIs in terms of water consumption; to identify the type of infrastructure; to identify good practices; and to characterize curriculum and dissemination efforts. The different questions selected to assess each objective are presented in Table 2.

Table 2. Questions in the survey to detail water consumption and according to the four objectives.

Objectives			
Characterization	**Infrastructure**	**Good Practices**	**Curriculum and Dissemination**
Number of users (total of teacher, students, and staff)	Description of the water collection and storage infrastructure, if any, and what the collected water is used for.	Are periodic registers of water consumption made? If you answered yes to the previous question, how often? (Hourly; Daily; Weekly; Monthly)	Are there practices to promote water efficiency at the HEI? If you answered yes to the previous question, please describe the most important ones
Total area of Campus,	Average age of water supply infrastructure.	How to carry out the monitoring: Manual or Automatic Brief description of the monitoring system.	Is rational water management part of your institution's curricula?
The area of implantation (coverage) and built up area.	Has there been any recent rehabilitation of the infrastructure? If yes, please describe	Are there separate counters in campus buildings? (Yes or No).	How many courses include curricular units with this subject? If you answered yes to the previous question, indicate the courses. Which curricular units contain these contents?
Green space area		Is an analysis of invoicing carried out? (Yes or No). Indicate the entity/office responsible for invoice analysis.	Does the HEI promote good practices of water efficiency in the community? If you have answered yes to the previous question, describe the most important ones
Water consumption in 2019 (m^3/year)		Are water efficiency assessment indicators calculated? (Yes or No). If you answered yes to the previous one, which ones?	Actions of divulgation and dissemination to the outside of the HEI carried out in the last 5 years. Please describe the initiatives, if any.
What is the origin of the water consumed? (Public water supply: Own water abstraction; Rainfall; Gray water; Others).			Identify the main research projects in the area, carried out in the last 5 years. If there are protocols with companies or water management entities in the last 5 years, identify them.

2.3. Data Treatment and Statistical Analysis

To characterize the density of occupation in each campus, the following indicators were calculated:

- Campus area per person (m^2/person);
- Covered area per person (m^2/person);
- Total built area per person (m^2/person);
- Total green area per person (m^2/person).

With the data collected regarding water consumption, the following water efficiency indicators were calculated from the questions of the first survey objective:

- Consumption per capita (L/(person·day));
- Consumption per total area (L/(m^2·day));
- Consumption per green area (L/(m^2·day));
- Consumption per total covered area (m^3/(m^2·year));
- Consumption per ground floor area of buildings (m^3/(m^2·year)).

In these indicators total covered area includes only roofed areas; total built area is the sum of the area of all floors and total green area that includes gardens, parks, and other vegetated areas inside each campus.

For the remaining survey objectives, no indicators were defined given the qualitative nature of the questions. Regarding the infrastructure objective a critical analysis was performed, and for the other two objectives the results were aggregated by classes. Concerning the "Good Practices" objective, the answers were classified by: (i) flow reducing devices; (ii) water pressure reduction; (iii) irrigation management; (iv) awareness-raising campaigns; (v) water consumption monitoring; (vi) pipe maintenance.

Finally, for the "Good Practices" and "Curriculum and Dissemination" objective, the considered classes for the curriculum were the scientific areas of the courses where these issues are addressed: (i) Chemistry; (ii) Civil Engineering; (iii) Urban Planning; (iv) Mechanical Engineering; (v) Environmental Engineering; (vi) Architecture; (vii) Mineral Resources; and (viii) Forestry/agronomic Engineering.

To give robustness to the results provided by these classifications, a K-means cluster analysis was performed using SPSS. Cluster analyses are designed to group similar observations in a dataset, such that observations in the same group are as similar to each other as possible, and similarly, observations in different groups are as different to each other as possible. K-means groups observations by minimizing the Euclidean distances between them. The campi are assigned to a final cluster by the cluster centers that were significant to the univariate F test for each clustering variable. The final cluster number was achieved when all variables within the clusters had statistical significance.

3. Results and Discussion

3.1. Water Efficiency Indicators

The indicators relative to different types of area per person showed large variations between campi, with the campus area per person, covered area per person, total built area per person and total green area per person varying from 8 to 692, 2 to 29, 7 to 57, and 1 to 683 m^2/person, respectively (Figure 3). The highest value of 692 m^2 campus area/person and 683 m^2 total green area/person refers to campus 15, which includes a very large green area (99% of total area) with a football and rugby field and a forest area. A similar situation refers to Campus 14, with 98% of green areas, showing similar indicators than Campus 15. The remaining campi have total and green areas about an order of magnitude lower, but overall the built area indicators are similar between campi (Figure 3). Urban campi located in more densely populated areas (campus 3, 4, 5, 7 and 8) have a smaller area per person for all types of area per person indicators while campus located in more disperse peri-urban areas (1, 2, 6, 9, 10, 11, 12 and 13) have intermediate values.

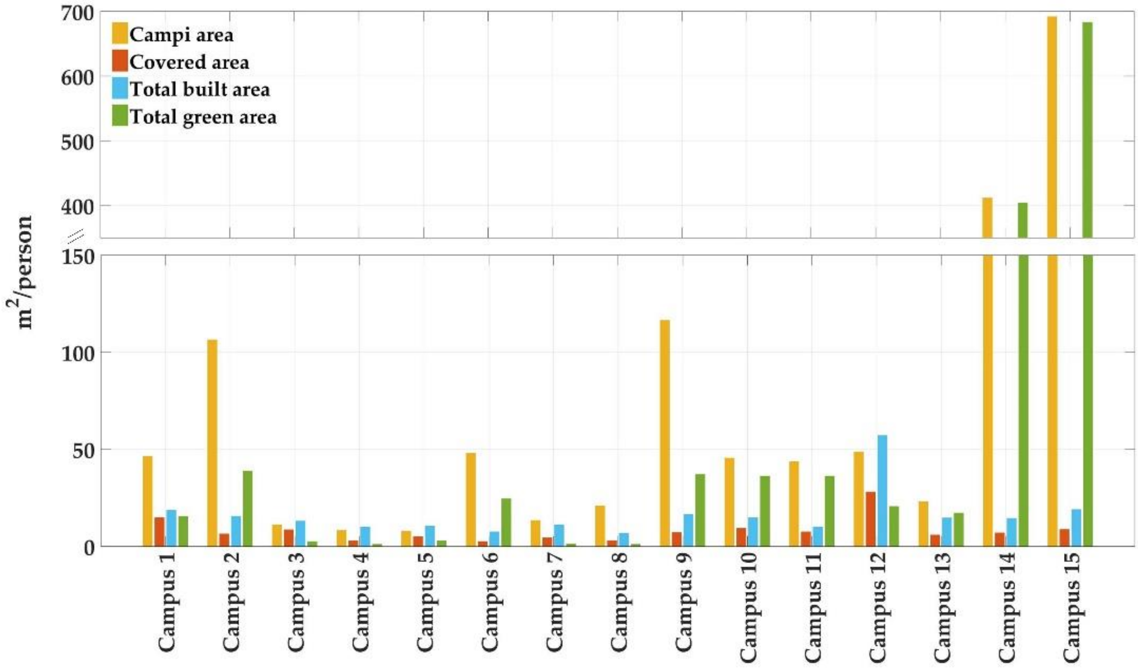

Figure 3. Campus area per person.

Regarding water consumption indicators, the water consumption per capita in the 15 campi varied between 1.8 and 23.5 L/(person·day), with an average value of 12.5 L/(person·day) and a standard deviation of 5.4 L/(person·day) (Figure 4).

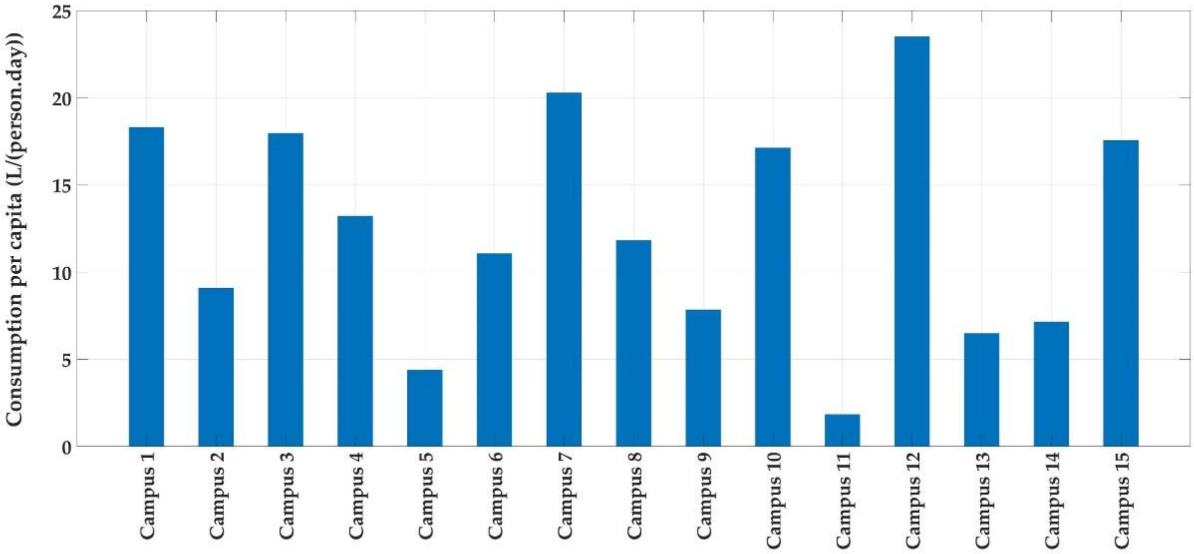

Figure 4. Water consumption per capita.

The larger differences among campi represented in Figure 4 can be explained in part by campus characteristics, namely: green areas; water sources for irrigation; age of buildings; and the existence of facilities on campus such as residences and sports facilities. Campi 5, 11, 13 and 14 are mostly composed of recent edifications (<10 years) with more efficient equipment, which do not include residences and have no green area or use their own groundwater sources for irrigation purposes. The higher consumption of campus 12 may be partly explained by the older age of its buildings (>30) and the lower number of persons in the campus. Campi 1, 7, 10 and 15 include student residences with buildings older than 25 years.

Table 3 presents water consumption per capita obtained from different studies carried out in different countries and continents, including the Koppen climate classification of each location [32] and the year of data collection. Comparing the water consumption indicators of the present study with other HEIs in Europe, Asia, and America, it was observed that Portuguese values are much lower than the ones found the literature. Overall, water consumption per capita reported in the literature is 2 to 20 times higher than the water consumption indicators of the present study [25–30,34,35].

Table 3. Per capita water consumption from different studies.

Study	Location/School	Climatic Koppen Classification [32]	Year	Per Capita Consumption (L/(Person·day)	Comments
Bonnet et al. [25]	France	Cfb [1]		38	Considers only students but also dorms with 4500 quartos (nearly 10% of the students)
Marinho et al. [26]	Brazil	Af [2]	1999/2000 2011	46.6 26.9	Implementation of water conservation program: monitoring, leak correction, update cadaster, communication. Nº users increased by 20%
Abdelalim et al. [28]	Canada	ET [3]		39	
Wichowski et al. [30]	Poland	Cfb [1]	2015/2016	28.1 23.9	Week consumption Weekend consumption
Zhou et al. [27]	China	Cfa [4]	2006 2010	247 211	Average values for 98 HEIs
Almeida et al. [29]	Brazil	Aw [5]		41	
WUR, [34]	Netherlands/Wageningen University	Cfb [1]	2019	26	10 % reduction in water consumption compared to 2018
Ferreira et al. [35]	Portugal/IST	Csa [6]	2010 2018	30 16	Monitoring and control from 2012 onwards; intervention in case of leakage; routine inspections. 2010 values considering number of students (30 L/(person·day)) considering total users)
Current study	Portugal (15 campi)		2019	12.5	Average from the 15 campi

[1] Cfb—Marine west coast climate; [2] Af—Wet equatorial climate; [3] ET—Tundra climate; [4] Cfa—Humid subtropical climate; [5] Aw—Tropical wet–dry climate; [6] Csa—Mediterranean climate.

Considering the different studies analyzed, consumption is not explained by a single variable. The most common variables used to explain consumption include the type of activity, surface area and occupation rate (full-time or part-time). According to Bonnet et al. [25], the variable with the largest influence on water consumption is the type of activity, where research and development uses have the highest share. Zhou et al. [27] studied a set of 98 colleges and universities in China where water consumption per capita also showed a large variation according to the type of school. In this study "Physical culture" and "Agricultural" colleges and universities showed the highest consumptions (>270 L/((student·day)) while "Financial and economics" and "Political science and law" ranked the lowest (<140 L/(student·day)).

Regarding consumption per area, the different campi have significant differences in terms of type of construction; namely, the number of building levels and non-built areas (parking and green areas), leading to large differences when comparing consumption per total area or consumption per ground floor area. The higher consumption values per covered area are a consequence of the larger built-up area and not of the lower efficiency associated with higher buildings.

It is also worth noting that campi 7, 9, 11, 14 and 15 have a very low consumption per total campus area given the large green areas within campus (Figure 5).

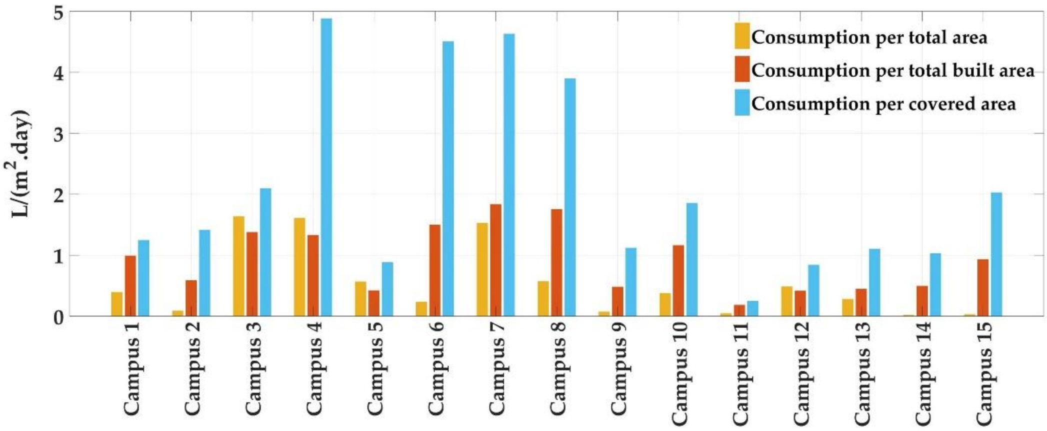

Figure 5. Consumption efficiency indicators per area.

No correlation between water consumption and green area irrigated was found that can be justified by some campi having alternative water sources for irrigation of green areas, such as groundwater sources or rainwater collection that were not accounted for the water consumption. Six campi have alternative water sources: six have groundwater sources (Campus 1, 2, 5, 6, 9 and 15) and three have both a groundwater source and rainwater collection (2, 6 and 9) (Table 1). Additionally, irrigation needs are different in distinct climatic areas of the country (Table 1).

Studies reporting water consumption per unit area are very scarce and usually report per unit of total built area. Nevertheless, results obtained in the present study fall within most of the ranges reported in the literature: Zhou et al. [27] reported values between 2.2 and 9.6 L/(m^2·day) in China; Bonnet et al. [25] reported values between 0.5 and 10.9 L/(m^2·day) in France; and Almeida et al. [29] reported values between 0.5 and 6.8 L/(m^2·day) in Brazil.

3.2. Good Practices, Curriculum and Dissemination

Regarding good practice, the most common water management action is the monitoring of water consumption, which was reported in all campi. In some institutions this is achieved using automatic software, while other campi monitor consumptions through water bills. The installation of flow-reduction devices and the implementation of awareness campaigns was also promoted in three institutions, and the less frequent actions (only one campus) included pipe maintenance, irrigation management and water pressure reduction (Figure 6).

Concerning the curriculum and disseminations actions, Water management topics are part of the study programs in Bachelor's and Master's degrees in eight different areas: Chemistry, Civil, Urban planning, Environment, Architecture, Mineral Resources, and Forestry and Agronomics.

The HEIs also reported actions to promote water management Academia, through workshops and seminars on the topic. The results were analyzed considering the number of degrees with water management topics per number of degrees in the campi. The involvement of students from different courses leads to the expectation of scientific work, and as a result, several publications were reported regarding water efficiency. The report and public discussion of the results found in works from students in different areas of study reveal operational activities, technical worries, unexpected results, and behavioral and administrative barriers, which are expected to be of great help in the definition of water management strategies. Marinho et al. [26] reported some similar results in their water conservation program AGUAPURA at the Federal University of Bahia.

The campi also reported taking actions to promote water management outside Academia, mostly through workshops and seminars on the topic.

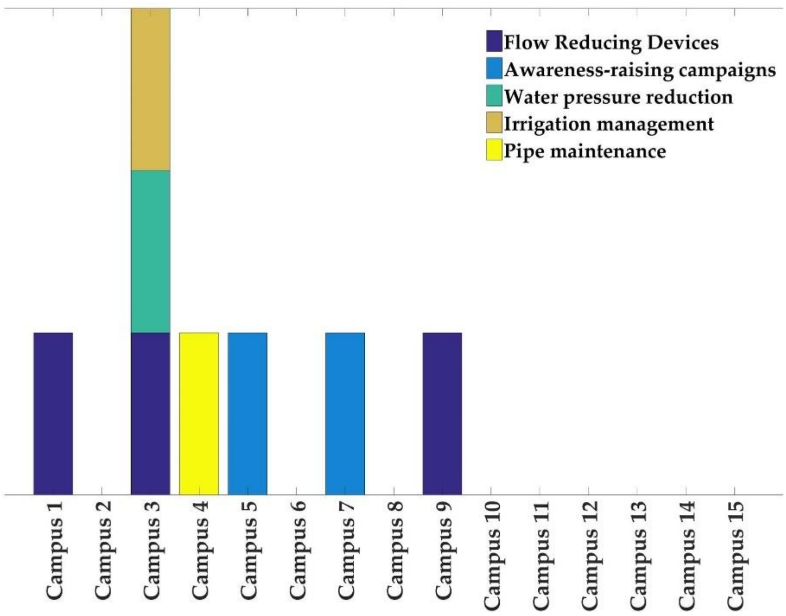

Figure 6. Water management actions taken by the surveyed campi.

Most campi in the present study reported water consumption monitoring, and this could help to explain the higher water efficiency when compared with data in literature. In fact, among the studies analyzed in Table 3, two reported a strong reduction in water consumption over time [26,35], because of investment in monitoring and leakage control to reduce water consumption. Water management strategies should always start with the knowledge of the present levels of water consumption and the definition of goals for the future.

The low per capita consumption values obtained in the present study (Figure 4), when compared with the literature, can be partly explained by the water efficiency culture already existing in the different HEIs, and the fact that the different HEIs promote the concept of efficiency either through some curricula, informally through dissemination actions, or research projects contributing to increasing environmental awareness and promoting good practice. Linked with this efficiency culture in HEIs, it is also worth mentioning the fact that the Portuguese climate is characterized by cyclical drought periods, which have been accentuated in the last decades [9]. For this reason there is an established culture of water saving, and since 2012 the country has a National Program for Efficient Water Use (PNUEA, 2012) [36] that proposes measures to protect water resources.

However, all the data collected and analyzed in this work are related to the year 2019 and do not allow correlation of all the factors that justify the different values of the indicators mentioned in Section 3.1.

3.3. Cluster Analysis

The k-means cluster analysis was performed to provide the class assignment for each campus according to the different survey objectives. The k-means cluster analysis for the “Infrastructure” and “Curricula and dissemination” objectives are not presented since they were not statistically significant.

For the objective “Consumption”, the variables used to aggregate the campi were the consumption per capita, the consumption per total area, the consumption per total built area, and the consumption per covered area, represented in Figures 4 and 5. For the objective “Good practices”, the variables used to aggregate the campi were the presence of actions of flow reducing devices, awareness-raising campaigns, water pressure reduction, irrigation management, and pipe maintenance, presented in Figure 6.

Table 4 shows the assignment of campus to clusters according to the objectives of “Consumption” (clusters A, B, C and D) and “Good practices” (E, F, G and H).

Table 4. Campi cluster assignment.

Campi	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Objective—Consumption	A	B	C	C	B	D	C	D	B	A	B	A	B	B	A
Objective—Good practices	E	E	G	H	F	E	F	E	E	E	E	E	E	E	E

The final cluster centers are computed as the mean for each normalized variable within each final cluster (Figures 7 and 8). These figures explain the dissimilarities among the campi that allowed for the cluster classification. The final cluster centers reflect the characteristics of the typical case for each cluster. Cluster analysis results are in line with the assessment made by the data analysis, highlighting the differences and/or similarities of the HEIs.

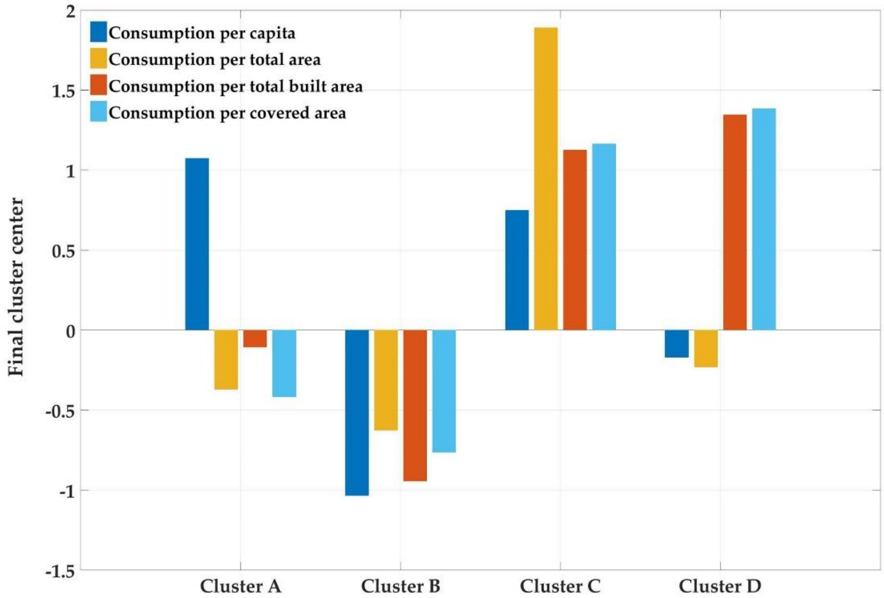

Figure 7. Final cluster center for variables in objective—consumption.

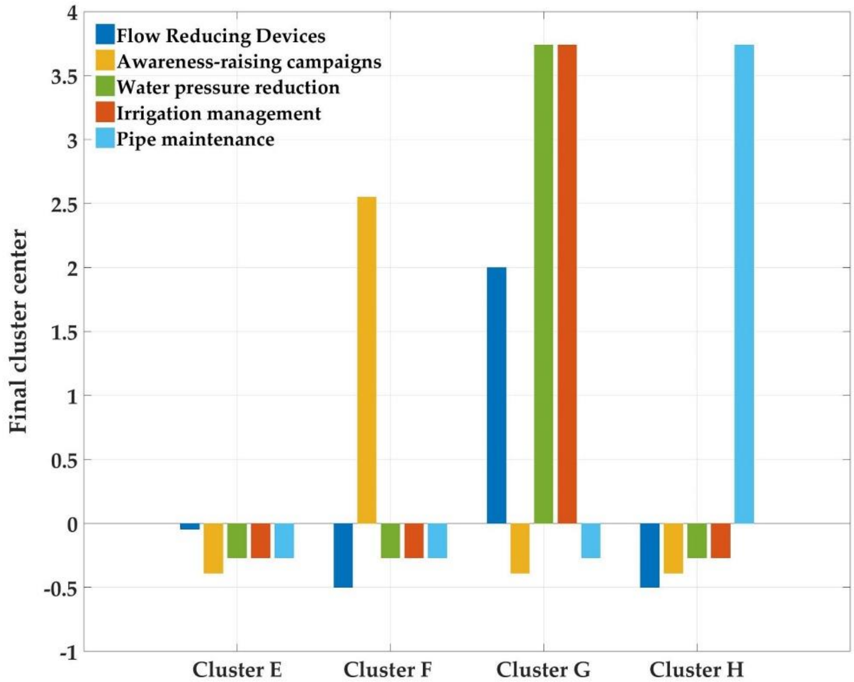

Figure 8. Final cluster center for variables in objective—good practices.

Regarding consumption, the campi were aggregated in four clusters with different consumption behavior (Figure 7): (i) cluster A—Higher consumption per capita and medium consumption per area; (ii) cluster B—Lower consumption per capita and per area; (iii) cluster C—Medium consumption per capita and higher consumption per area; (iv) cluster D—Medium–low consumption per capita and per total area, highest consumption per total-built area and per covered area.

Regarding good practices, the campi were aggregated in four clusters as follows (Figure 8): (i) cluster E—Lower number of monitoring measures with eventually flow reducing devices; (ii) cluster F—Campi with awareness-raising campaigns; (iii) cluster G—Larger number of monitoring measures; (iv) cluster H—Campi that have made pipe maintenance.

These results reinforce the difficulty in correlating the different indicators, since they have discrepant behaviors. However, a single cluster (C) was formed representing the campi with higher consumption (campi 3, 4 and 7, all urban campi, located in a densely populated areas area), which were also classified in the clusters with a higher number of good practices (cluster F, G and H). This may show the commitment of these institutions with improving their water management as a response to their higher consumption.

Additionally, grouping the different HEIs by cluster allows the identification of aspects that each HEI can still improve.

4. Conclusions

This study reports data of eight public Portuguese HEIs, with 15 campi spread across the country, in large and small cities, countryside and littoral: these include different numbers of students, campus areas, different training areas, and the two subsystems (universities and polytechnics) of Portuguese higher education. This study included HEIs with a total of 48,881 persons, 2,444,976 m^2 of total campus area, 269,003 m^2 of total covered area, 582,330 m^2 of total built area, and 1,236,506 m^2 of green areas. The total consumption of water in the campi of those institutions was 225,647 m^3 in 2019.

University campi are complex structures, consisting of several buildings with different typologies. Campi can be compared to small cities due to the area they occupy, the number of people they have, and the volume of water they consume in the various activities carried out.

This study provided some insights into water consumption in HEIs and their water management strategies. Results revealed that the cluster of institutions with higher consumption corresponds to urban campi located in more densely populated areas. These campi were also classified in the clusters with higher number of good practices, which might show the commitment of these institutions to improving their water management because of their higher consumption.

However, it represents only a snapshot of one year (2019), and because of that it is not possible to analyze trends or the long-term influence of courses and curricula. Overall, the values obtained for the indicators allow the identification of differentiated consumption depending on the geographical area, year of construction of the building, and number of users. As the adoption of measures that lead to the sustainable development of this type of structure is increasingly attracting the attention of those responsible for managing university campuses, the dissemination of this information is of outmost importance. The improvement in the monitoring of consumption, the application of more efficient devices, and the use of rainwater are the essential actions to proceed to sustainable development, but awareness-raising campaigns should also be carried out to increase education about water efficiency.

Author Contributions: Conceptualization, A.M.B., A.D., A.G., C.M., D.M., I.A., L.N., M.M. and S.M.; methodology, A.M.B., A.D., A.G., C.M., D.M., I.A., L.N. and S.M.; formal analysis, A.M.B., A.G., I.A. and S.M.; writing—original draft preparation, A.M.B., A.D., A.G., C.M., D.M., L.N. and S.M.; writing—review and editing, A.M.B., A.D., C.M., D.M., L.N. and S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used to support the finding of this study are available upon request.

Acknowledgments: The authors acknowledge the support from the Portuguese Sustainable Campus Network (RCS—Portugal), and from the Higher Education Institutions (HEIs) that collaborated in the study.

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

References

1. Guterres, A. Progress towards the Sustainable Development Goals: Report of the Secretary-General. *Econ. Soc. Counc. U. N.* **2022**, *2017*, 1–29.
2. Pinho, H.J.O.; Mateus, D.M.R. Sustainable production of reclaimed water by constructed wetlands for combined irrigation and microalgae cultivation applications. *Hydrology* **2021**, *8*, 30. [CrossRef]
3. Somoza-Tornos, A.; Rives-Jiménez, M.; Espuña, A.; Graells, M. A Circular Economy Approach to the Design of a Water Network Targeting the Use of Regenerated Water. *Comput. Aided Chem. Eng.* **2019**, *47*, 119–124. [CrossRef]
4. Rebelo, A.; Quadrado, M.; Franco, A.; Lacasta, N.; Machado, P. Water reuse in Portugal: New legislation trends to support the definition of water quality standards based on risk characterization. *Water Cycle* **2020**, *1*, 41–53. [CrossRef]
5. McDonald, D.A.; Marois, T.; Spronk, S. Public Banks + Public Water = SDG 6? *Water Altern.* **2021**, *14*, 117–134.
6. UN-Water. Financing Water and Sanitation Facts and Figures. Available online: https://www.unwater.org/water-facts/financing-water-and-sanitation (accessed on 21 November 2022).
7. Wiegleb, V.; Bruns, A. Hydro-social arrangements and paradigmatic change in water governance: An analysis of the sustainable development goals (SDGs). *Sustain. Sci.* **2018**, *13*, 1155–1166. [CrossRef]
8. Mateus, D.M.R.; Costa, M.C.O.; Gomes, M.M.M.S.; Pinho, H.J.O. Promoting Education for Sustainable Development: A Collaborative Project Between a Higher Education Institution and the Surrounding School Community. In *Handbook of Best Practices in Sustainable Development at University Level*; de Vasconcelos, C.R.P., Ed.; Springer: Cham, Switzerland, 2022; pp. 411–433.
9. APA. Avaliação das Disponibilidades Hídricas Atuais e Futuras e Aplicação do Índice de Escassez WEI+. 2021. [Online]. Available online: https://participa.pt/contents/consultationdocument/EstudoWEI_7122021.pdf (accessed on 21 November 2022).
10. IPMA. Seca e Desertificação em Portugal. 2020. Available online: https://www.ipma.pt/pt/media/noticias/news.detail.jsp?f=/pt/media/noticias/arquivo/2020/seca_desertificacao_portugal_062020 (accessed on 21 November 2022).
11. Ribeiro, J.M.P.; Hoeckesfeld, L.; Dal Magro, C.B.; Favretto, J.; Barichello, R.; Lenzi, F.C.; Secchi, L.; Lima, C.R.M.; Gerra, J.B.S.O.A. Green Campus Initiatives as sustainable development dissemination at higher education institutions: Students' perceptions. *J. Clean. Prod.* **2021**, *12*, 127671. [CrossRef]
12. Bautista-Puig, N.; Sanz-Casado, E. Sustainability practices in Spanish higher education institutions: An overview of status and implementation. *J. Clean. Prod.* **2021**, *295*, 126320. [CrossRef]
13. Thomashow, M. *The Nine Elements of a Sustainable*; The MIT Press: Cambridge, MA, USA, 2014.
14. Raposo, A.; Durão, A.; Piedade, A.; Almeida, G.; Xavier, M.; Rodeia, J. What Futures for Education? An Answer to the Challenge Launched by UNESCO. In Proceedings of the 11th International Conference The Future of Education, Florence, Italy, 1–2 July 2021; pp. 355–359. [CrossRef]
15. UNESCO (Ed.) *Reimagining Our Futures Together: A New Social Contract for Education*; UNESCO; Paris, France, 2021; Available online: http://www.unesco.org/open-access/terms-use-ccbysa-en (accessed on 21 November 2022).
16. Illankoon, I.M.C.S.; Tam, V.W.Y.; Le, K.N.; Shen, L. Key credit criteria among international green building rating tools. *J. Clean. Prod.* **2017**, *164*, 209–220. [CrossRef]
17. Silvius, G. Sustainability as a new school of thought in project management. *J. Clean. Prod.* **2017**, *166*, 1479–1493. [CrossRef]
18. Sugiarto, A.; Lee, C.W.; Huruta, A.D. A Systematic Review of the Sustainable Campus Concept. *Behav. Sci.* **2022**, *12*, 130. [CrossRef] [PubMed]
19. Zhao, H.; Xu, Y.; Hong, W.C.; Liang, Y.; Zou, D. Smart evaluation of green campus sustainability considering energy utilization. *Sustainability* **2021**, *13*, 7653. [CrossRef]
20. Amr, A.I.; Kamel, S.; El Gohary, G.; Hamhaber, J. Water as an Ecological Factor for a Sustainable Campus Landscape. *Procedia-Soc. Behav. Sci.* **2015**, *216*, 181–193. [CrossRef]
21. Priyadarshini, P.; Abhilash, P.C. Rethinking of higher education institutions as complex adaptive systems for enabling sustainability governance. *J. Clean. Prod.* **2022**, *359*, 132083. [CrossRef]
22. Al-Hazaima, H.; Al Shbail, M.O.; Alshurafat, H.; Ananzeh, H.; Al Shbeil, S.O. Dataset for integration of sustainability education into the accounting curricula of tertiary education institutions in Jordan. *Data Br.* **2022**, *42*, 108224. [CrossRef]

23. Filho, W.L.; Amaro, N.; Avila, L.V.; Brandli, L.; Damke, L.I.; Vasconcelos, C.R.O.; Hernandez-Dias, P.M.; Frankenberger, F.; Fritzen, B.; Valazquez, L.; et al. Mapping sustainability initiatives in higher education institutions in Latin America. *J. Clean. Prod.* **2021**, *315*, 128093. [CrossRef]
24. Klein, L.L.; Alves, A.C.; Abreu, M.F.; Feltrin, T.S. Lean management and sustainable practices in Higher Education Institutions of Brazil and Portugal: A cross country perspective. *J. Clean. Prod.* **2022**, *342*, 130868. [CrossRef]
25. Bonnet, J.F.; Devel, C.; Faucher, P.; Rotunier, J. Analysis of electricity and water end-uses in university campuses: Case-study of the University of Bordeaux in the framework of the Ecocampus European Collaboration. *J. Clean. Prod.* **2002**, *10*, 13–24. [CrossRef]
26. Marinho, M.; Gonçalves, M.D.S.; Kiperstok, A. Water conservation as a tool to support sustainable practices in a Brazilian public university. *J. Clean. Prod.* **2014**, *62*, 98–106. [CrossRef]
27. Zhou, X.; Yan, J.; Zhu, J.; Cai, P. Survey of energy consumption and energy conservation measures for colleges and universities in Guangdong province. *Energy Build.* **2013**, *66*, 112–118. [CrossRef]
28. Abdelalim, A.; O'Brien, W.; Shi, Z. Visualization of energy and water consumption and GHG emissions: A case study of a Canadian University Campus. *Energy Build.* **2015**, *109*, 334–352. [CrossRef]
29. Almeida, A.P.; Sousa, V.; Silva, C.M. Methodology for estimating energy and water consumption patterns in university buildings: Case study, Federal University of Roraima (UFRR). *Heliyon* **2021**, *7*, e08642. [CrossRef] [PubMed]
30. Wichowski, P.; Rutkowska, G.; Kamiński, N.; Trach, Y. Analysis of water consumption in the campus of Warsaw University of life sciences in years 2012-2016. *J. Ecol. Eng.* **2019**, *20*, 193–202. [CrossRef]
31. Rede Campus Sustentável. *Primeiro Diagnóstico Sobre Implementação da Sustentabilidade no Ensino Superior em Portugal-Análise dos Resultados de um Inquérito*; RCS: Coimbra, Portugal, 2022; ISBN 978-989-33-3247-4.
32. John, A.A. Köppen Climate Classification. Encyclopedia Britannica. 2022. Available online: https://www.britannica.com/science/Koppen-climate-classification (accessed on 21 November 2022).
33. IPMA. Climates Normals. n.d. Available online: https://www.ipma.pt/en/oclima/normais.clima/?print=true (accessed on 19 January 2023).
34. Wageningen University & Research. WUR Sustainability Report 2019. 2020. Available online: https://www.wur.nl/nl/show/2019-Sustainability-report.htm (accessed on 21 November 2022).
35. Ferreira, J.G.; Matos, M.; Silva, H.; Franca, H.; Duarte, P. Sustainable campus: The experience of the university of lisbon at ist. *Sustainability* **2021**, *13*, 8050. [CrossRef]
36. APA. Programa Nacional para o Uso Eficiente da Água-implementação 2012–2020 (PNUEA). 2012. Available online: https://apambiente.pt/sites/default/files/_SNIAMB_Agua/DRH/PlaneamentoOrdenamento/PlanosGestaoSecaEscassez/PNUEA/PNUEA_2020_Jun2012.pdf (accessed on 19 January 2023).