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Exploring the coverage of environmental-dimension indicators in existing campus sustainability appraisal tools

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ABSTRACT

Despite the plethora of comprehensive review of campus sustainability assessment tools, reporting, and indicators in the extant literature, studies are absent specifically on campus-wide and spatial-based indicators in existing tools. Although, several academic campuses across the globe are located on a vast area of land with multiple activities and operations associated with serious ecological consequences. This paper explores the environmental-dimension indicators with spatial and campus-wide attributes in 13 existing campus sustainability appraisal tools via coverage evaluation and the SMART approach. The findings reveal a severe absence of comprehensive coverage of spatial-based indicators and the lack of the integration of a GIS and or related spatial software in their appraisal process. The article demonstrates how integrating GIS and or other related spatial techniques and software into environmental dimension indicators with campus-wide and spatial attributes could be carried out to remedy the challenges of absence, inadequate of or restrained access to basic information for campus sustainability appraisal project in developing world.

1. Introduction

The knowledge base around the world is expanding at an incredible pace. One such sector that has undergone a rapid transformation during the last few decades is the development of information-based systems that have made it easier for professionals in the built environment to successfully and efficiently complete humongous urban and campus planning tasks within a short duration. The information systems that derive their roots from the field of geography have certainly made more infiltration due to the increased awareness among policy and decision-makers to rely on these systems for public policy formulation. One such system is the geographic information system (GIS).

GIS allows incorporating, manipulating, and displaying huge datasets, which makes it more adaptable than any other spatial application to guide decision-making. GIS, a computer-based system, can process data from a variety of sources and integrate them with geographical location while providing the user with the information necessary for making informed decisions (Han and Kim, 1989). The compilation, stockpiling, dissection, and presentation of the combination of topographical, ecological, and non-ecological data for specialized activities could be carried out on the GIS platform (de Winnaar et al., 2007). Given that framework development is an important component of urban and campus development, GIS and other related spatial tools could be utilized in the establishment of campus sustainability appraisal (CSA) embedded with spatial-based indicators, after which the data needed as input during and after the appraisal process could be generated. Using GIS as a tool for the CSA project can assist in determining a set of scenarios that ultimately reflect the situation of the overall campus-wide sustainability situation. Where data about spatial components of campus development and appraisal project are missing, a GIS-based integrated framework could help in determining the value of the missing data by extracting the values from satellite images and maps that can be freely obtained online and geo-referenced on the GIS map.

In urban and campus planning, GIS provides a comprehensive digital database for project boundary areas that would improve coordination of socioeconomic, environmental, and developmental information. A GIS-based CSA project could also assist in analyzing existing data to generate more information about a selected university campus. For instance, in a GIS-based urban planning project, GIS can allow easier priority setting for conserving natural land features when they are linked

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with their unique locational attributes (Geneletti, 2004). GIS also helps in measuring and calculating the percentage of the urban roads with bus lanes, walkways, and bicycle lanes. Also, accessibility and compactness of urban center facilities can be analyzed using GIS techniques (such as buffering or network analyses) and the result can be input into the overall assessment of the urban center. During the implementation of a GIS-based urban planning project, GIS also allows the production of a chart of a geographic area, required for progress monitoring, unnecessary spending, and review process in campus planning and development project.

However, various sets of tools have been devised by different organizations to appraise the sustainability of academic campuses. These assessment tools range from the rating system to a ranking system and differ in the scope of assessment (Sonetti et al., 2016). Multiple systems for CSA are in operation across the globe. Sustainability appraisal is a complex evaluation method that does not only encompasses the socio-economic and environmental aspects of sustainability, rather it extends to the cultural elements of the community the appraisal is being conducted (Sala et al., 2015). Devuyst (2001, p.9) defines a system of sustainability appraisal as a tool that assists "decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable". However, within the university campus situation, the purpose of CSA systems varies from (i) providing an overall picture of the status of sustainability within a university campus, (ii) encouraging the reporting, benchmarking, measuring and comparison of sustainability achievements and efforts of various universities (iii) providing a clear understanding of the progress that is being made by university stakeholders towards sustainability (iv) creating a mechanism for exchange of experiences and motivations between universities and (v) identifying the university campuses strength and weaknesses and the introduction of activities of education for sustainable development (Alghamdi et al., 2017). Others include but not limited to assisting in the implementation of university sustainability plans and greening of university campuses.

Also, there are various scope, focus, weighting methods, functions, flexibility, state of development, and access to information for different CSA framework (Kamal and Asmuss, 2013; Shriberg, 2002). These variation, complexity, and comprehensiveness also increase based on several assessment criteria and indicators in addition to the huge amount of data set for both collection and analysis. In the past few decades, CSA has become one of the most significant undertakings engaged by most higher educational institutions (HEI), educational stakeholders, private and government organizations across the globe. Besides, several CSA has been established across the globe to assess, track, measure, and evaluate the level of sustainability in university campuses (Alghamdi et al., 2017; Alonso-Almeida et al., 2015; Alshuwaikhat and Abubakar, 2008).

The continuous increase in the utilization of different CSA by several HEI across the globe to track sustainability performance within their campuses meant that their indicators for appraisal purposes in the field of campus sustainability are significant to academic administrators, researchers, practitioners, stakeholders, and policymakers. A list of selected indicators with some guidelines are the major component of the various existing CSA framework to ensure an objective presentation of the sustainability status of the appraised campuses. But a comprehensive review of the literature reveals the absence of studies specifically for the exploration of spatial, campus-wide, and environmental-dimension indicators of HEI campuses in existing CSA tools despite the massive geographical area with several infrastructure and functions of most HEI campuses. HEI campuses are also home to complex operations and multiple activities with serious impacts on the environment. Several studies have also been conducted stating the need for the incorporation of the spatial dimension of sustainability into sustainability appraisal (Alshuwaikhat and Aina, 2006; Stylianidis, 2012).

Surely, the dimension of spatial-based indicators is paramount for an efficient appraisal of the environmental aspect of sustainable development. There is an urgency to incorporate the sustainability indicators with spatial dimension and their analysis based on GIS techniques to conduct sustainability appraisal in a diverse community like HEI campuses. For instance, a spatial decision support system (SDSS) has been reported to have the ability to modifies spatial-based data into its system to improve the accuracy of decision-makers on spatially referenced information indicating the importance of SDSS, and computer-based framework (V. Maniezzo, I. Mendes, 1998). While the reasons for the variation in the list of indicators in existing CSA have not extensively studied, the examination of the campus-wide, environmental and spatial-based indicators coverage practices in existing CSA is lagging in extant literature. This article aims at the exploration of the inclusion and utilization of campus-wide, environmental and spatial-based indicators in 13 existing CSA tools and their capacity to appraise diverse aspects of sustainable campus via the utilization of a structure coverage evaluation approach. Also, the SMART approach was utilized to analyze the extracted spatial-based indicators from the tools to identify indicators that can be adopted for GIS and or related software CSA framework.

2. Campus sustainability indicators, categories and appraisal tools

This article is focused on the exploration of the variation that exists in the use of environmental-based indicators (with campus-wide and spatial-dimension) and their categorization. This section discusses the composition and the arrangement of CSA tools and their capacity in appraising sustainable indicators and sub-indicators relating to HEI.

2.1. Appraising sustainability in HEIs campus: categories, indicators, and sub-indicators

A review of the literature indicated that the dominant tools for CSA, in which their spatial-based indicators are the focus of this study, are the Global Reporting Initiative (GRI) and Sustainability Tracking, Assessment, and Rating Systems (STARS). The GRI is a voluntary standard-setting tool used for sustainability appraisal and reporting mainly in the corporate world (Hahn and Kühnen, 2013; Kolk, 2010), while some universities also utilize it in assessing their campus sustainability. It is a global triple bottom line and multi-stakeholder framework. On the other hand, STARS provides sustainability appraisal guidelines and framework to assist HEI to assess and measure their progress in sustainable campus performance. Indeed, the efficacy of any approach to appraising campus sustainability performance progress can only be determined if we have some yardstick or a set of criteria. In the absence of such criterion, the success of the report in attaining campus sustainability is subject to different interpretations.

However, numerous sets of CSA indicators have been developed, to the extent that selecting the suitable ones is a huge but important task. That is why some frameworks of indicators selected to suit particular objectives, settings, and availability of resources are developed for CSA. The frameworks are also intended to minimize some challenges of CSA like data limitations, and the capacity of the selected indicators to collect adequate and relevant information about the HEI. For this purpose, the next sub-section analyzes the concept of campus sustainability indicators and sub-indicators as well as their categorization. This is because all the existing CSA tools are comprised of sub-indicators and indicators grouped under categories/criteria in the form of hierarchies.

2.1.1. Campus sustainability appraisal indicators and sub-indicators

Three major ways of appraising sustainability are found in extant literature (Dalal-Clayton and Bass, 2002). The first is an "account of sustainability status", followed by "narrative assessment" and lastly an "indicator-based assessment" which is the focus of this article. Indicator-based sustainability appraisal is centered on the utilization of indicators or lower subset known as sub-indicators that are systematically selected to address the challenges of urban or campus sustainability. These selected sets of indicators and or sub-indicators were mostly utilized within a specified period in which the current appraisal will be compared with the one conducted previously. As such ensuring that consistency is incorporated in the appraisal process. The sustainability appraisal approach based on a set of sustainability indicators mostly involves a comprehensive process of prioritization and systematic organization of indicators and or sub-indicators. Compared with narrative assessment or an account of sustainability status, the utilization of this approach ensures better strategy advancement, performance follows up and genuine decision-making and most importantly describes HEI strengths and weaknesses. Also, their transparency and objectivity (Kumar et al., 2009) provide easy measurement with greater performance than the other sustainability appraisal techniques.

2.1.2. Campus sustainability appraisal categories

A principal definition of a sustainable university by Velazquez et al. (2006) states that a university is sustainable when the whole or part of the campus addresses, involves in or promotes locally or globally "*the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles*" (p. 812). To ascertain the rate at which a university campus as a whole or in part is addressing the minimization of its negative environmental impacts based on its functions and operations, several CSA tools have been established in performing this task. Though, the literature review of extant articles shows that these tools and practices in appraising campus sustainability typically organize sustainability indicators under a classification system known as criteria (Alghamdi et al., 2017), dimension, or categories. The list of indicators and or sub-indicators are represented within the categories theme. Therefore, every dimension or category contains a wide range but a distinct aspect of CSA and sustainable quality lifestyles.

For example, New York University carried out their campus sustainability assessment using STARS along with the guidelines of eight categories. Similarly, the University of Calgary (UOC) developed an institutional sustainability plan utilizing the STARS assessment system categorization as a baseline. The primary rationale for this selection is the reliance of North American academic institutes to measure their sustainability. However, UOC and several other North American universities have made necessary modifications to STARS categorization to encompass the indigenous needs for its sustainability plans and appraisal framework.

2.2. Categories, indicators, and sub-indicators selection

A review of extant literature shows that there exist a myriad of appraisal tools consisting of several single-attribute appraisal tools as well as diverse multi-criteria appraisal tools. Although, the focus of this article is on tools with multi-criteria yet the majority of them have the conventional three fundamental components which are (i) the local/regional/national context (ii) the weighting scheme and (iii) criteria or domain. Although, these components of the multi-criteria assessment tools vary from moderately to greatly from one tool to another. The variation in the major components of various assessment systems are explained as follows:

The first (i.e. local/regional/national context), contains attributes, features, and characteristics of every country's HEI in terms of socio-economic and environmental elements that are different across the globe. As such, these differences play a huge factor in determining the indicator components of the individual assessment system in different countries across the world. According to Banani et al. (2013), examples of these local attributes that vary from one region to another include but not limited to (i) climatic conditions (ii) geographical composition (iii) government laws and policies (iv) natural resources utilization (v) knowledge of the building compositions (vi) knowledge of the relevant historical elements and (vii) public awareness and cultural value. This has led to the challenges of utilizing a CSA system that works in one country for another country (Alyami and Rezgui, 2012). Besides, this has also led to the establishment of different assessment criteria for different assessment rating and appraisal system.

The second (Weighting Scheme), entails the allocation of importance or preferences in a quantifiable way between a set of indicators (Tanguay et al., 2010). This method of value allocation has been critiqued by many scholars because of the inconsistency associated with the process as well as the absence of the objectivity of the allotted weight to the individual indicators (Tanguay et al., 2010). Although, some scholars opined that indicators assessment utilizing this approach takes into consideration the involvement of citizens and relevant stakeholders. The last is an assessment criterion. However, for a campus sustainability assessment framework to achieve a comprehensive appraisal of a university campus, it is agreed upon by several experts that it must combine both qualitative and quantitative criteria. Despite the above justification for the variation in the inclusion, selection, and adoption of indicators amongst the existing CSA tools, another major explanation is the absence of "systemic standard procedure" that accompany the identification of indicators that reflect the objectives of a specific study or match the nature of the case study (Diener, 1995). The inclusion of the absence of GIS should also be included. The next section discusses the methodology of this study.

3. Methodology

The main objective of this article is the comprehensive exploration of some selected existing appraisal tools for sustainability in HEIs campuses. This was undertaken to spot variations in the utilization of environmental-dimension (that encompasses the campus-wide and spatial-based) indicators, sub-indicators, and their broad theme categorization. In actualizing this objective, a comprehensive list that focuses only on campus-wide, environmental and spatial-based indicators were derived from 13 current CSA tools. The comprehensive list named 'ECS (Environmental, Campus-wide and Spatial-based indicators) Broad List' (see Table 2) was extracted to create a template for relative analysis across the practices of sustainability appraisal in HEI. As such, the ECS Broad List serves as the study's foundation for the exploration of the spatial-based indicators in every selected CSA tool. The benchmarking of the indicators to the ECS Broad List will allow for a detailed analysis of the hierarchical categorization of indicators in each tool.

Knowing that CSA tools are deemed as strategies for operationalizing sustainability within the campuses of HEI, it is, therefore, paramount to adopt an appropriate approach for exploring and analyzing the sustainable indicators affecting them. This is due to the presence of several sustainability indicators, rendering the selection process for CSA a serious challenge. The SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) approach (Alshuwaikhat et al., 2017; Shahin and Mahbod, 2007), depicted in Fig. 1, guarantees an efficient and productive spatial-based attributes were used to analyze the ECS Broad List. The SMART approach also ensures that all considerations that are required before selecting spatial-based indicators for the CSA model incorporating GIS or any other related spatial techniques or tools are met.

3.1. Existing campus sustainability appraisal tools

In this study, 13 CSA tools were chosen for structured coverage analysis. The 13 existing CSA was selected because of the following reasons: Firstly, they are all available in the English language and not in other languages like German and French. During this study, a tool written in German was excluded from the selected tools. Secondly, they are indicator-based appraisal tools. CSA tools that are either narrative-based (such as the tools developed by the World Bank, UN-Habitat, or World Health Organization) or those in the form of an account of sustainability status were all excluded. Thirdly, they are developed to be specifically used for appraisal of campuses within HEIs. Tools such as GRI which is a voluntary standard-setting tool utilized for sustainability appraisal and reporting mainly in the corporate world was excluded. Lastly, all have

Table 1
Overview of the 13 CSA tools.

Campus Sustainability Appraisal Framework	Version Reviewed	Categories	Indicators	Sub-indicators
Sustainability Assessment Questionnaire (SAQ) ULSF (2009)	2001	7	–	–
Graphical Assessment of Sustainability in University (GASU) Lozano (2006)	2006	4	8	59
Sustainable University Model (SUM) Velazquez et al. (2006)	2006	4	23	–
University Environmental Management System (UEMS) Alshuwaikhat & Abubakar (2008)	2008	3	8	23
Assessment Instrument for Sustainability in Higher Education (AISHE) AISHE 2.0 Manual (2009)	2009	5	30	–
Unit-based Sustainability Assessment Tool (USAT) Togo & Lotz-Sisitka (2009)	2009	–	9	–
Three dimension University Ranking (TUR) Lukman et al. (2010)	2009	3	15	–
DPSEEA-Sustainability index Model (DPSEEA) Waheed et al. (2011)	2011	5	20	56
Graz Model for Integrative Development (Graz) Mader (2013)	2012	5	15	–
Sustainable Campus Assessment System (SCAS) Hokkaido University (2013)	2013	4	25	34
Adaptable Model for Assessing Sustainability in Higher Education (AMAS) Gomez et al. (2015)	2014	3	9	25
UI's GreenMetric University Sustainability Ranking (Green Metric) Universitas Indonesia (2019)	2019	6	39	–
Sustainability Tracking, Assessment and Rating System (STARS) STARS Technical Manual (2019)	2019	6	19	69
Total		**55**	**220**	**266**

either a technical manual, report, or publication for easy accessibility and reference. Tools such as Benchmarking Indicators Questions – Alternative University Appraisal, Unit-based Sustainability Assessment Tool, and The Green Plan were excluded from the selected tools based on this.

3.2. ECS Broad List selection process

The ECS Broad List is an extensive list of environmental-dimension (that encompasses the campus-wide and spatial-based indicators, sub-indicators, and their broad theme categorization) extracted from the selected existing CSA tools. The arrival of the ECS Broad List follows through two stages. First, all categories of indicators from the 13 tools were extracted to arrive at 55 categories, 220 indicators, and 266 sub-indicators as shown in Table 1 below. The second stage involves the exclusion of all categories, indicators, and sub-indicators that are not within the scope of this research. Thus, reducing the numbers extracted during the first stage to 13 categories, 50 indicators, and 65 sub-

Table 2
ECS (Environmental, Campus-wide and Spatial-based indicators) Broad List.

Tools	Categories	Indicators	Sub-indicators
SAQ	(1) Operations		
GASU	(2) Environmental	1. Environmental	(1) Materials (2) Energy (3) Water (4) Biodiversity (5) Emissions, effluents, and waste (6) Transport
SUM	(3) Sustainability on campus	(2) Energy Efficiency (3) Global Climate (4) Water efficiency (5) Composting (6) Transportation and commuting (7) Hazardous Waste Management (8) Non-Hazardous Waste Management (9) Environmental Procurement (10) Natural Heritage (11) Access for Handicapped People	
UEMS	(4) University EMS	(12) Environmental Management and Improvement	(7) Minimize negative impacts of operations (8) pollution prevention (9) Energy efficiency (10) Resources conservation (11) Environmental improvement (12) Waste reduction (13) Recycling
		(13) Green Campus	(14) Green buildings (15) Green transportation (16) Campus preservation
AISHE	(5) Operation	(14) Ecology (15) Physical structure	
USAT		(16) Operations and Management	
TUR	(6) Environmental		
DPSEEA		(17) Environment	(17) Annual energy consumption rate
		(18) Environment	(18) Production of greenhouse gases (19) Production and consumption of ozone-depleting substances (20) Production of emission, effluents, and waste (21) Amount of energy used (22) Amount of water supplied and distributed/collected for purification (23) Increasing transport density
		(19) Environment	(24) Concentration of greenhouse gases (25) Concentration of emissions, effluents, and waste (26) Rate of depletion of energy resources (27) Rate of water consumption and quality (28) Percentage daily commute by motor vehicle and transport conflicts (29) Exceedance of noise level
		(20) Environment	

(*continued on next page*)

Table 2 (*continued*)

Tools	Categories	Indicators	Sub-indicators
			(30) Changes in environmental conditions (31) Proportion of people exposed to poor air conditions (32) Proportion of people exposed to poor water quality (33) Proportion of people exposed to various hazards (34) Proportion of people exposed to high noise levels (35) Impact on energy resources
		(21) Environment	(36) Effects on human health (37) Effects on environment (38) Effects on biodiversity
Graz SCAS	(7) Environment	(22) Ecosystem	
		(23) Land	(39) Green space and forest land (40) Other open space
		(24) Public Space	
		(25) Landscape	
		(26) Waste	
		(27) Energy and resources	(41) Energy management (42) Greenhouse gases (43) Renewable energy
		(28) Basic Equipment	
		(29) Facilities	(44) Environmental performance (45) Indoor environment
		(30) Transportation	(46) Flow planning (47) Pedestrians and cycling (48) Connecting with the local community
		(31) Use of historical assets on campus	
		(32) Disaster prevention locations	
AMAS		(33) Resource consumption	(49) Energy consumption (50) Energy efficiency measures (51) Water consumption (52) Water efficiency measures (53) Hazardous waste management
Green Metric	(8) Setting and infrastructure	(34) The ratio of open space area to the total area (35) Total area on campus covered in forest vegetation (36) Total area on campus covered in planted vegetation (37) Total area on campus for water absorption besides the forest and planted vegetation	
	(9) Energy and climate change	(38) Number of renewable energy sources in campus	
	(10) Waste	(39) Organic waste treatment (40) Inorganic waste treatment (41) Toxic waste treatment (42) Sewage disposal	
	(11) Water	(43) Treated water consumed	
		(44) Shuttle services	
	(12) Transportation		
STARS	(13) Operations	(44) Air & Climate	(54) Greenhouse Gas Emissions
		(46) Buildings	(55) Building Design and Construction (56) Building Operations and Maintenance
		(47) Energy	(57) Building Energy Efficiency (58) Clean and Renewable Energy
		(48) Transportation	(59) Campus Fleet (60) Commute Modal Split
		(49) Waste	(61) Waste Minimization and Diversion (62) Construction and Demolition Waste Diversion (63) Hazardous Waste Management
		(50) Water	(64) Water Use (65) Rainwater Management
Total	**13**	**50**	**65**

indicators at the end of the second stage as shown in Table 2.

This reduction of the indicators from the first stage to only spatial-based indicators that fall under the environmental pillar of sustainability, operations, and with campus-wide planning and development of HEI campuses ensures spatially referenced and definite data set for evidence base sustainability appraisal for both current and generation unborn are achieved. This will eliminate the challenges of appraising sustainability in HEI in the global south, which include the absence, inadequate of or restrained access to basic information for campus sustainability appraisal project, selecting a set of indicators, as well as difficulties in indicators measurement. With the integration of spatial-based indicators into the framework of GIS and other related spatial tools, a comprehensive system that will help university environmental managers in carrying out campus sustainability assessment on a unified platform could be achieved. The integration of GIS into indicator framework in sustainability assessment will result in better integration of space to sustainability indicators, thus allowing visualization of the assessment outcome. Also, the integration of GIS with the spatial-based indicator framework can allow comparison of assessment results over the years as previous data is stored into the GIS database.

3.3. Structured coverage evaluation and SMART approach

The ECS Broad List established in this study is utilized as a base case for carrying out a structured coverage evaluation that entails the cross-examination and exploration of the spatial-based categories, indicators, and sub-indicators in the 13 tools. This was carried out to ascertain the coverage of the indicators (directly or using the same operational definition) across the individual tool.

Thereafter, the SMART approach was applied to ensure that the ECS Broad List is further analyzed to reduce the list to only the set of spatial-based indicators that can be effectively incorporated into the framework of a GIS and or related software. The SMART approach ensures that the selected indicators are 'Specific' to dismiss lack of clarity during the process of CSA; '**M**easureable' to aid numerical quantification and statistical analysis; '**A**chievable' to arrive at the aim and objectives of an appraisal process; '**R**elevant' to the aim and objectives of an appraisal process, and lastly '**T**ime-bound' to give room for adaptive change and repetition of an appraisal.

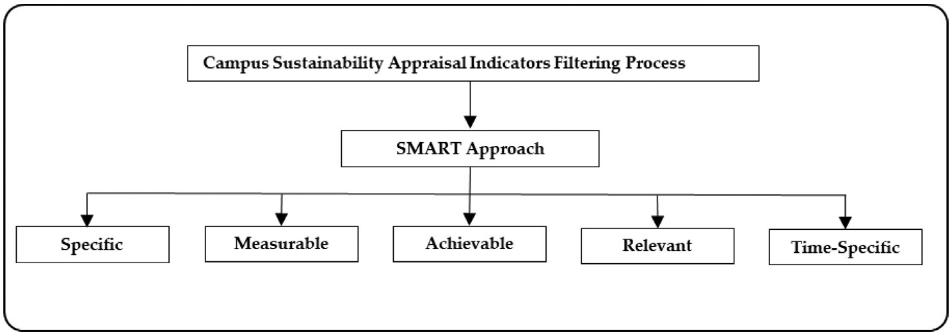

Fig. 1. Smart approach.

4. Results and analysis

4.1. Description of the analyzed CSA tools

The versions of the CSA tools for structured coverage evaluation and SMART approach analysis are between 2001 and 2019 has displayed in Table 1. While most of the tools are developed to be utilized in every part of the world, some are designed for HEIs in regions such as North American and others are country-specific. The indicators that fall under campus sustainability such as curriculum, research & scholarship, economic, social, outreach & partnership, institutional commitment, etc. were not considered for analysis in this study. Indicators or sub-indicators that are included under broad categories such as operations and environmental-dimension without campus-wide or spatial-based operational definitions are also excluded from the final selection. The analysis only concentrates on indicators with spatial coverage of HEI campuses.

The review of the technical manuals, reports, and articles of the 13 CSA tools show that none of the selected appraisal tools used social media data, main social theories nor GIS or spatial-based techniques for appraisal of a set of environmental indicators for CSA with a spatial dimension (i.e., they can be linked to a spatial or geographical region). Assessment of the existing tools based on a tested conceptual model shows that majority of the tools are driven by the availability of indicator-based sustainability data as well as planning and developmental policies but not driven by a sound theoretical framework. Social theories such as symbolic interactionism, structural functionalism, and Anthropocene were missing in the tools. Some of the challenges of not utilizing or incorporating a tested theoretical basis are the difficulties of knowledge accumulation and inappropriate methodology usage. With the advent of different social media platforms since early 2000, one will expect the CSA tools would utilize the availability of huge campus sustainability data on these media platforms to drive the design and selection of their indicators.

In the technical manual of STARS, GIS was referred to as university coursework and not a tool for appraisal of spatial indicators although there exist the presence of spatial dimension indicators in its framework as can be observed in Table 2. It states: "*although specific tools or practices such as GIS (Geographical Information Systems) or engineering can be applied towards sustainability, such courses would not count unless they incorporated a unit on sustainability or a sustainability challenge, included a sustainability-focused activity, or incorporated sustainability issues throughout the course*" p.6 (STARS Technical Manual, 2019). However, it is very important to provide guidelines about GIS because the study by Urbanski & Filho (2015) suggested that the level of adoption of issues that are explicitly stated in the guidelines is higher than the implicit issues. The absence of GIS and spatial software utilization in appraising indicators with spatial-dimension in all the tools shows the need for this study.

5. Findings and discussion

The individual CSA tool reviewed has different sets of spatial-based sustainability indicators and sub-indicators under various categories as well as diverse methodologies (such as analytic hierarchy process) in adopting the arriving at the selected indicators. The presence of these variations in these tools is associated with some of their pros and cons. In this discussion section, the authors' findings and results for these variations are presented.

5.1. Structured coverage evaluation

The structured coverage evaluation was performed on the 13 CSA tools to explore the degree of coverage with the ECS Broad List. This was carried out to ascertain the coverage of the indicators (directly or using the same operational definition) across the individual tool. In this study, CSA tools with indicators or sub-indicators of 5 and above were referred to as 'deep coverage'. The depth of coverage evaluation reveals that five tools (SUM, DPSEEA, SCAS, GreenMetric, and STARS) meet the attribute of deep coverage at the indicators hierarchy. On the other hand, 6 tools (GASU, UEMS, DPSEEA, SCAS, AMAS, and STARS) met the characteristics of deep coverage at the sub-indicators hierarchy. It is only DPSEEA, SCAS, and STARS that extensively included spatial-based indicators at both indicators and sub-indicators levels. The findings of other coverage evaluation are discussed in the next two sub-sections.

5.1.1. Number of categories, indicators, and sub-indicators in a tool

The findings reveal the presence of some variations in spatial-based campus sustainability indicators coverage practices in appraising the level of sustainability in HEIs. The number of categories varies from zero to five as tools such as USAT, Graz, and AMAS are without spatial-based sustainability categories as shown in Fig. 2. Despite the presence of 13 unique categories of spatial-based indicators and sub-indicators, only two categories (i.e. Operation × and Environment*) are used in more than one CSA tool. One of the outcomes that deserve attention is the average number of spatial-based categories (i.e. one) used in most of the tools. This shows that the existing tools did not put serious considerations on the inclusion of spatial-based sustainability categories when designing their CSA tools. Five out of the six CSA categories in UI GreenMetric World University Ranking (managed by Universitas Indonesia) are campus-wide in dimension indicating the interest of this tool in addressing the focus of the study. However, the incorporation of a GIS or spatial-based techniques into its framework in appraising these dimensions is missing.

Concerning the indicators and sub-indicators, the total number of unique indicators and sub-indicators is 50 and 65 respectively. The findings that worth paying attention to are as follows. First, the wide variations in the number of indicators and sub-indicators from 0 to 11 and 0–22 respectively reveal some difficulties in the selection of

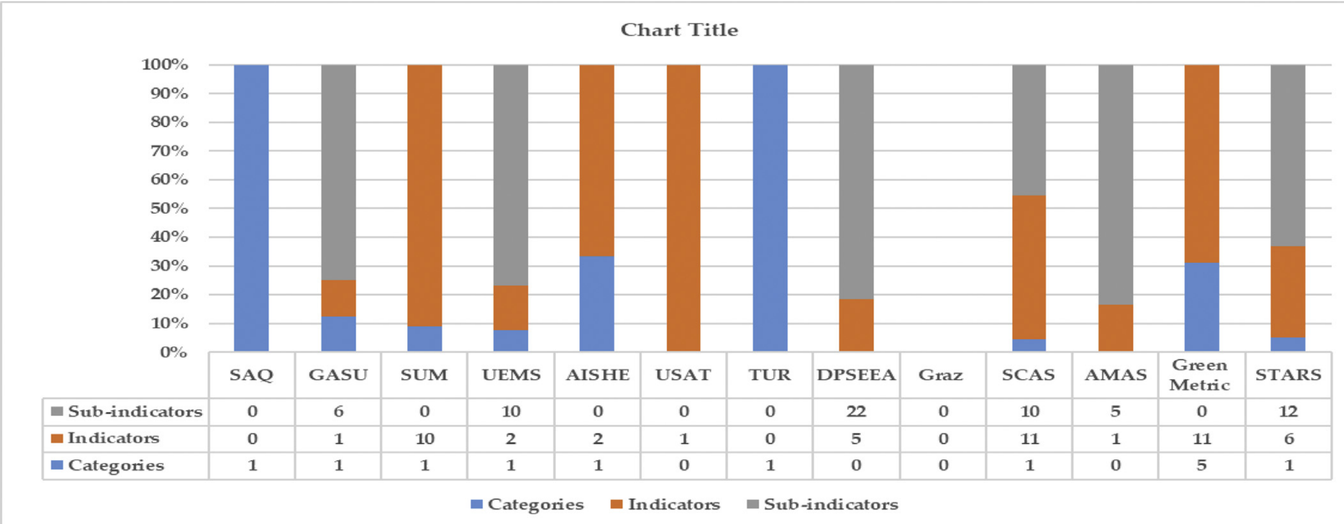

Fig. 2. Number of Spatial-based attributes from the 13 CSA Tools.

appropriate/average numbers while establishing these tools. The absence of campus-wide, environmental and spatial-based sustainability indicators and sub-indicators in some of the tools raises suspicious and the inclusion of a limited number shows the absence of considerations for these indicators over the years. Even though HEIs campuses across the globe are located in a vast area of land with multiple activities and operations associated with serious ecological consequences. The low indicators and sub-indicators show that a greater number of the tools are not multi-criteria in nature, due to their inability to include diverse environmental-dimension of CSA. This is in contrast to the findings from extant literature that placed high importance on multi-criteria assessment tools in appraising institutions with diverse land area and complex activities such as HEI.

5.1.2. Frequency of categories, indicators, and sub-indicators usage

Although the ECS Broad List contains 13, 50, and 65 unique categories, indicators and sub-indicators respectively, the number of times these unique attributes appear or utilized in more than one tool vary greatly. The utilization of an attribute in only one tool or more than one tool shows its level of importance and preference in appraising campus-wide dimensions of HEI. The outcomes of the study's coverage evaluation reveal an absence of concurrence regarding the process of categories, indicators, and sub-indicators selection.

For instance, regarding the frequency of usage under the CSA tools categories hierarchy, (Operation × and Environment*) both appear in three different categories. For the indicators frequency of usage, (Environment*) appears six more times as indicators but only across two tools as it appears five times in one of the tools (i.e. DPSEEA-Sustainability index Model). The two indicators (Energy and Energy and Resources) having the same operational definitions. As for the sub-indicators, the two indicators (Energy efficiency and Energy efficiency measures) have a similar technical meaning. Three sub-indicators (Amount of energy used; Rate of depletion of energy resources; and Energy consumption) have the same technical meaning. Another two sub-indicators (Water consumption and Water Use) both have the same technical meaning. Also, the sub-indicator (Emissions, effluents, and waste; Production of emission, effluents, and waste) have a similar operational definition.

However, there is also the usage of several other attributes utilized literally or having similar operational definitions across the hierarchies (categories, indicators, and sub-indicators) of the selected tools. For instance, (Hazardous waste management) was utilized twice as sub-indicators and once as an indicator. (Environmental improvement) was utilized in one of the tools as a sub-indicator and (Environmental Management Improvement) was used as an indicator in another tool with both having the same operational definition. The results of the frequency of usage is an interesting one and the authors perceived the lack of sound theoretical framework and use of huge social media data across the globe in arriving at the selected attributes.

5.2. SMART approach

Although, the deep coverage evaluation that reveals the extensive coverage of the indicators and sub-indicators in each of the tools is important in obtaining a better representation of the individual attributes. It should be noted that deep coverage can be embedded with the repetition of indicators usage and appraisal or communication challenges due to large or complex data. Also, it can lead to an underrepresentation of other important indicators. Therefore, there is a need for the elimination of repeated attributes and striking of balance to ensure the inclusion of all important attributes in the CSA framework. Therefore, in ensuring that the ECS Broad List contains attributes that strike balance between breadth of coverage and the inclusion of campus-wide indicators that could be adopted in GIS and or related software, SMART applied was utilized.

Before the utilization of each characteristic of the SMART approach, the repeated attributes were merged as follows. Operation × and Environment × both appear in three of the different categories of the existing 13 tools and were, therefore, merge to make them both appear once under the theme of categories. However, Environment × appears six more times as indicators but only across two tools as it appears five times in one of the tools. The six Environment × indicators were removed as it has already appeared in the category theme. Environmental improvement that appears a sub-indicator was removed because it has the same operational definition as the indicator (Environmental Management Improvement). The two indicators (Energy and Energy and Resources) having the same operational definitions were both removed due to the appearance of Energy and climate as a broad category. Energy also appears as a sub-indicator and was deleted. The (Energy efficiency and Energy efficiency measures) with similar technical meaning that appeared both as a sub-indicator were merged with the one that already exists as an indicator. The three sub-indicators (Amount of energy used, Rate of depletion of energy resources, and Energy consumption) seem to have the same technical meaning and as such were merge to Energy consumption.

The two sub-indicator (Renewable energy, and Clean and Renewable Energy) were both merged with the indicator (Number of renewable energy sources in campus). Water appeared three times as category, indicator, and sub-indicator and was merged into one under the category theme. The sub-indicator (Water efficiency measures) merged with the indicator (Water efficiency) as they both have the same operational meaning. The two sub-indicators (Water consumption and Water Use) were both merged as Water consumption as both have the same technical meaning. The sub-indicator (Emissions, effluents, and waste) is merged with (Production of emission, effluents, and waste). Transport × appeared four times. Three indicators and one sub-indicator (Transport*) were all merged with (Transport*) underneath the category theme. Hazardous waste management was mentioned 3 times. The two sub-indicators (Hazardous waste management) were merged with that underneath the indicator. Waste appeared three times and merged with the Waste underneath the category. The two sub-indicators (Waste Minimization and Diversion and Waste reduction) were merged as Waste reduction. Three sub-indicators (Production of greenhouse gases, Greenhouse gases, and Greenhouse Gas Emissions) were merged as Greenhouse Gas Emissions. This process leads to the reduction of the attributes to 9 categories, 36 indicators, and 47 sub-indicators. The process of the SMART approach is discussed in the sub-sections that follow.

5.2.1. *Specific process*

At the end of the filtering process based on how specific nature of the indicators, five indicators (Ecology, Ecosystem, Basic Equipment, Facilities, and Resource consumption) and 19 sub-indicators (Materials, Biodiversity, Resources conservation, Recycling, Campus preservation, Exceedance of noise level, Changes in environmental conditions, Proportion of people exposed to poor air conditions, Proportion of people exposed to poor water quality, Proportion of people exposed to various hazards, Proportion of people exposed to high noise levels, Impact on energy resources, Effects on human health, Effects on environment, Effects on biodiversity, Other open space, Environmental performance, and Commute Modal Split) were removed from the list due to lack of specificity on the aspect of HEI campuses. For instance, "impact on energy resources" is too generic without information about what is causing the impact. This approach reduced the attributes to 9, 31, and 29 categories, indicators and sub-indicators respectively.

5.2.2. *Measurable process*

Under the category theme, the three categories (i.e. Sustainability on campus, Operations, and University EMS) were removed from the comprehensive list as they do not process specific numeric values or units. On the other hand, 11 indicators (Hazardous Waste Management, Non-Hazardous Waste Management, Environmental Procurement, Environmental Management, and Improvement, Green Campus, Operations and Management, Use of historical assets on campus, Organic waste treatment, Inorganic waste treatment, Toxic waste treatment, and Shuttle services) and 11 sub-indicators (Minimize negative impacts of operations, pollution prevention, Production and consumption of ozone-depleting substances, Increasing transport density, Percentage daily commute by motor vehicle and transport conflicts, Energy management, Indoor environment, Connecting with the local community, Building Design and Construction, Building Operations and Maintenance, Rainwater Management) were excluded from the list. This approach reduced the attributes to 6, 20, and 18 categories, indicators and sub-indicators respectively.

5.2.3. *Achievable process*

Achievability is one of the paramount characteristics of good sustainability indicators. An indicator that could not achieve will make the conclusions and findings of an appraisal process impossible. As such it could be regarded as a hypothetical indicator. An achievable indicator should also be linkable to the exact and overall sustainability mission of HEI without neglecting the participation of its stakeholders. At this stage, all the indicators qualified the achievable process and no reduction was done.

5.2.4. *Relevant process*

During this phase, only three indicators (Global Climate, Composting, and Disaster prevention locations) were identified as not being in line with the objective of spatial-based, environmental, and campus-wide planning and development principles of sustainable campus appraisal in Nigeria. This is because the authors aim to develop a local CSA appraisal model that will have the capacity to appraise spatial indicators that reflect and match the nature of HEIs in Nigeria. This is also in line with the World Green Building Council that encourages its representatives in each country to implement the sustainability concept that relates to green building or green campus according to the unique local conditions of their region (World Green Building Council, n. d.). On the other hand, campuses of HEI with the tenets of sustainability is a neighborhood that "*acts upon its local and global responsibilities to protect and enhance the health and well-being of humans and ecosystems*" (Cole, 2003 p.30).

5.2.5. *Time-specific process*

Finally, similar to the ability of effective indicators to be measurable to quantify the campus development and sustainability level numerically with specific numeric value and unit. A noticeable difference within a specified period is also an important characteristic of indicators for CSA. An effective indicator should have the ability to be adaptive to change and allow for the process of review or repeated within the short, medium, and long term. Also, at the end of this process, all the indicators qualified and no reduction was done.

Table 3 illustrates the results of the SMART Approach indicating the extent to which the indicators meet all the SMART criteria. All the attributes in the various categories meet the "Specific" criteria while 66.67% meet the remaining four criteria. As presented in Table 3, none of the indicators and sub-indicators across the tools meet 100% of the SMART criteria.

At the end of the SMART approach stage, the hierarchy in the ECS Broad List was restructured to two (i.e. categories and indicators) as shown in Table 4 below. While the number of categories remains at 6, the sub-indicators were all move to indicator themes making it a total of 35. This was carried out to eliminate some identified challenges of large data requirement, complex appraisal process, and comprehension difficulties in the selected tools (Alghamdi et al., 2017).

6. Integrating GIS and or other spatial software into CSA spatial-based model

From the previous sections, highlighted was the need for a set of environmental indicators for CSA that have campus-wide and spatial dimensions (i.e., they can be linked to a spatial or geographical region). In this section, discussion on how sustainability appraisal for HEI campuses that are integrated with GIS and related spatial techniques and demonstrating its uniqueness as compared to other CSA tools, frameworks, and approaches would be discussed.

For the said purpose, it is recommended that GIS and or other spatial software should be utilized to developing a CSA model within its sphere of operations mostly in developing countries. The endorsement of GIS and or other spatial software is primarily due to their application and ability to incorporate huge datasets within their program. Secondly, they have made more infiltration due to the increased awareness among policy and decision-makers to rely on these systems for public policy

Table 3
Percentage of Indicators Coverage based on SMART Approach.

	Category	Indicator	Sub-indicator
Specific	100%	86.1%	61.7%
Measurable	66.67%	55.56%	38.3%
Achievable	66.67%	55.56%	38.3%
Relevant	66.67%	47.22%	38.3%
Time-bound	66.67%	47.22%	38.3%

Table 4
Spatial-based campus sustainability indicators.

Categories	Indicators	The function of GIS and other related spatial software in spatial-based indicator appraisal
1. Environment	(1) Land (2) Public Space (3) Landscape (4) Greenspace and forest land (5) The ratio of open space area to the total area (6) Total area on campus covered in forest vegetation (7) Total area on campus covered in planted vegetation (8) Total area on campus for water absorption besides the forest and planted vegetation	- The acreage/area of green area, land, public space, and public space in m^2 - Area of heat islands in m^2
2. Setting and infrastructure	(9) Physical structure (10) Natural Heritage (11) Buildings (12) Green buildings	- Area of buildings, green building with Certified LEED, natural heritage and physical structure in m^2 - Location of green buildings/ buildings, natural heritage, and physical structure
3. Energy and climate change	(13) Number of renewable energy sources in campus (14) Energy Efficiency (15) Greenhouse Gas Emissions (16) Building Energy Efficiency (17) Energy consumption (18) Air & Climate (19) Annual energy consumption rate (20) Concentration of greenhouse gases (21) Production of emission, effluents, and waste (22) Concentration of emissions, effluents, and waste	- Location of renewable sources, greenhouse gas concentration, emissions, effluents, and waste concentration - Energy consumption in kWh - Quantity of electricity per area of solar - Area and percent of buildings that generate greenhouse gases - Greenhouse gases in CO_2 equivalent
4. Waste	(23) Sewage disposal (24) Waste reduction (25) Construction and Demolition Waste Diversion	- Amount of waste disposal and reduction in m^3 and metric tons - Location of sewage disposal - Area of waste collection in m^2
5. Water	(26) Treated water consumed (27) Water efficiency (28) Water consumption (29) Rate of water consumption and quality (30) Amount of water supplied and distributed/ collected for purification	- Amount of water in m^3/ litres/$ft.^3$/gallons - locations of water supply - Area of water supply
6. Transportation	(31) Access for Handicapped People (32) Campus Fleet (33) Flow planning (34) Pedestrians and cycling (35) Green transportation	The dimension (1D, 2D, 3D) of cycling, pedestrian, ramp and campus route in m/km/ km^2

formulation. For instance, GIS and CityEngine, both computer-based system, can process the data from a variety of sources and integrating it with the geographical location while providing the user or the decision-maker with the information necessary for making informed decisions. The compilation, stockpiling, dissection, and presentation of the combination of topographical, ecological, and non-ecological data for specialized activities could be carried out on these spatial platforms. It must be kept in mind that these spatial tools are automated tool and work on human commands. To use these spatial techniques as tools for campus-wide sustainability appraisal of HEI campuses, it is imperative to develop a logical and scientific model based on empirical evidence. The model as a whole shall be established on the indicators contained in Table 4 that will ultimately reflect the overall sustainability assessment of academic institutions. The campus-wide indicator development and model building in spatial-based technique is an important step for generalizing sustainability assessment of academic campuses as results can be presented to ultimate decision-makers in a most logical, comprehensive, and efficient manner (Geneletti, 2004).

The integration of these software with CSA can be useful in two ways. Firstly, it can help in generating the data needed as input into the assessment framework. For example, the percentage of campus routes with campus fleet, flow planning, pedestrians, and cycling. Some scholars have designed a GIS-based tool for evaluating the walkability of a street network (Ble et al., 2014; Blečić et al., 2015). CityEngine was utilized as a 3-dimension GIS visualization technology to appraise urban sustainability and future sustainability scenarios in a city in Germany. Such a tool could be useful for adoption, incorporation, and modification for CSA. Likewise, GIS and other related techniques can help in the analysis of provided data to generate more information. For example, accessibility of facilities can be analyzed using GIS and the result input into the appraisal framework. Besides, this software infrastructure could be utilized in the establishment of spatial-based sustainability indicators in the production of thematic maps to aid the visualization of the state of sustainability within a geographical location (Stylianidis, 2012). Table 4 shows the proposed indicators that relate to operations and management of campus functions and space, thus have a spatial dimension. It indicates how GIS and or other related spatial techniques could assist in measuring the spatially-related indicators based on the structured coverage evaluation and SMART approach applied to the selected 13 existing CSA tools.

When the selected campus-wide and spatial-based sustainability indicators are integrated into the spatial data infrastructure system will generate a set of appraisal reports associated with a unique campus location. In line with the principles of national spatial strategy, location and its surroundings are important factors in the CSA model. This model cannot be executed in isolation without due regard to location. It will provide the relevant connection within site, spots, area as well as sustainability components of structures and other facilities within the geographical boundary of HEI campuses. This connection will help in focusing on the energy and resources needed to attain maximum campus sustainability standards. Also, unlike the 13 CSA tools reviewed in this study, the proposed model will provide a comprehensive spatial and non-spatial database for HEIs. This digital database will be beneficial as values or quantities of specific indicators could be altered to appraise on a routine basis performance of sustainability in HEI. It will also reduce economic cost and the assistance of the evaluation and review process.

Similarly, the proposed model can provide the HEI administrators and management with ample room to evaluate a different sequence of events and master plan implementation. Spatial software empowers the operators the capacity to observe different scenarios encouraged by using various specifications. Environmental-dimension indicators with campus-wide and spatial attributes could be worked upon to view the various results of any strategies. These measures and strategies can be appraised before implementation to save valuable cost and time. The difference between the reviewed CSA tools and this study's proposed model is demonstrated in Fig. 3.

In the existing CSA tools, despite the existence of environmental-dimension indicators with spatial and campus-wide attributes the appraisal process mostly involves the sustainability performance evaluation of selected indicators with the outcome in the form of reports, ranking, rating, awards, etc. However, with the incorporation of the proposed spatial-data infrastructure system based on spatial software, the appraisal process will entail spatial visualization technologies to reveal the current and future scenarios of campus-wide sustainability performance, citizen involvement in the appraisal, planning, and decision-making process.

The coverage evaluation of the 13 existing tools reveals that the data sources for indicator selection are mostly from existing tools and models, literature review, surveys, workshops, internet sources, development process, and HEI with sustainability initiatives. Also, the opinions of selected professionals were used in arriving at their preferences. Although three existing tools (i.e. TUR, Graz, and STARS) utilized social media platforms (i.e. Wikipedia, Facebook, Twitter, and Interactive blog)

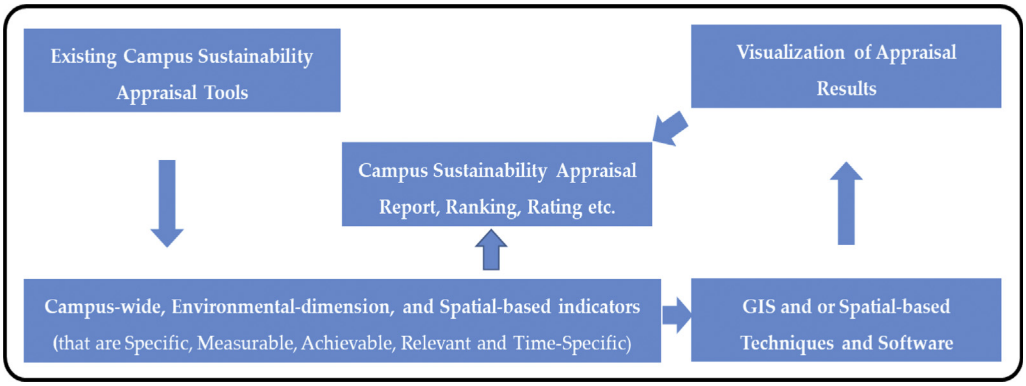

Fig. 3. Proposed model integration into the existing tools.

in data sources for indicators selection, there is the need for more utilization of citizen/stakeholders participation via social media to improve the process of developing and selecting indicators for CSA.

This study recommends the utilization of a novel method involving the use of data from social media to arrive at the preferences of HEI stakeholders on environmental-dimension indicators with spatial and campus-wide attributes. The data could be extracted and analyzed using scrapping tools and programming language to mine from social media application program interfaces or libraries. Twitter which is one of the current various available social media platforms has been effective in the discussion of sustainability in academic campuses and several related topics. Currently, data on Twitter contain relevant and pragmatic information for the planning and implementation of campus sustainability strategies based on the preferences of the major stakeholders. As such, it can be deduced that with the ubiquitous of electronic gadgets with an internet connection, several million active Twitter users across the globe, preferences of stakeholders on campus sustainability indicators should be carried out based on social media data with a strong theoretical basis.

Lastly, citizen participation options are available in ESRI's spatial technique platforms allowing for a participatory appraisal mechanism. The public participation platform options have not yet been utilized in CSA despite their potential in advancing the process of developing and selecting indicators.

Conclusion

The article utilized coverage evaluation and a SMART approach to explore the coverage practices of campus-wide, environmental-dimensions, and spatial-based indicators in appraising campus sustainability from 13 existing CSA tools. The outcomes reveal an absence of these nature of indicators and variations in their usage and selection. These variations can lead to the difficulties of arriving at uniform appraisal ratings of several campuses. However, with this study's proposed model, different campuses could be appraised across the world with the limitation of the indicators to the relevance of each campus. The adaption of selected spatial-based indicators to specific campus do not need a complex and difficult to comprehend process, rather the filtering of the ECS Broad List using the SMART approach. This finding illustrates a humongous improvement can be adopted, utilized, or modified to fill the research gap identifies in the literature in terms of lack of or restricted access to data, choosing a set of indicators, as well as difficulties in indicators appraisal. With the integration of the GIS and or other Spatial Software into the CSA spatial-based Model, these challenges could be minimized. This study presents the initial attempt toward the development of a CSA model for HEI in sub-Saharan African countries. The 2009 Abuja Declaration recommends the appraisal of the sustainability performance of HEI in Africa. Future research is required in test-running and validating the proposed model within the context of HEI in sub-Saharan African nations.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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