

Neighborhood sustainability assessment tools: Research trends and forecast for the built environment

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ABSTRACT

Rapid urbanization, environmental concerns and demand for sustainable cities contributed to the development of Neighbourhood Sustainability Assessment Tools (NSATs) such as LEED-ND and BREEAM-Communities. Whilst their success in increasing sustainability outcomes within the built environment is evident, there are unnoticed gaps in NSAT frameworks that might hinder their future suitability for sustainable urban planning and design. Therefore, to remain pertinent, NSATs must address the constantly evolving sustainability issues. To determine the gaps in NSATs frameworks and identify trends in sustainable communities, this study utilised a bibliometric exploration of NSAT-related publications. A total of 117 research articles over the last decade were reviewed to inform and provide insights on the research and development needs as well as areas of enhancing NSATs efficacy. The results revealed that research methods used to evaluate NSATs in journal articles are predominantly qualitative. This significantly limits the precision of research outcomes and highlights the need to increase quantitative (experiential and experimental) performance-based investigations which provide context and practically relevant outcomes. Furthermore, an upsurge in research themes related to big data and climate change, focused on smartness and resilience, was revealed. This indicates the suitability of NSATs for addressing existing societal concerns. To build on this achievement, tools may need to incorporate more health-based dynamics while considering issues of climate justice in order to remain effective and relevant. Another observation is the low research contribution from developing regions and lack of research from African regions. The observations and recommendations given in this study are pertinent to various stakeholders, including developers, and industry experts and consider the role of researchers in enhancing the performance of NSATs.

1. Introduction

Addressing how cities utilize their resources is paramount to urban sustainability research, especially for the development of strategies aimed at effective implementation and improvement of sustainability measures within any given locality. This has led to the development of a myriad of urban-based principles that seek to improve urban sustainability through the development of various 'sustainable' urban based frameworks. These frameworks are informed by sustainability initiatives such as the Brundtland Report, the principles of sustainable development and models regulating what is considered sustainable. These sustainable frameworks are further guided by parity between the pillars of sustainability [30]. More recently, blueprints such as sustainable development goals (SDGs), the New Urban Agenda, as well as ideologies of weak and strong concepts of sustainability have become pivotal to

addressing issues related to cities urban sustainability. These issues include poverty, disasters, unemployment, destruction of aquatic and land habitat, waste management, transportation etc. [5,9,28].

In terms of the scale of investigation and infrastructure, the aforementioned principles of sustainability have gradually shifted from macro scale to meso (neighborhood scale) and micro scale (building scale). All these principles have led to the use and development of criteria, indicators and indices that guide and assess how buildings, neighborhoods, and cities perform regarding the mitigation of localized social, economic and environmental issues [31,33]. An emerging research area with apparent importance is concentrated on neighborhood sustainability. This is because previous focus on micro-scale developments restricted the principles of sustainability to environmental issues and ignored the synergies, interactions and effects of clustered buildings within a city. Therefore, the analysis and development of

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sustainability initiatives that addresses the challenges of individual buildings do not consider the impact of buildings on the wider environment (Ayyoob [43]). Furthermore, the more intricate dimensions of sustainability such as economic and socioeconomic considerations are insubstantial from a micro perspective due to the limited interaction with the wider environment i.e. no consideration for aspects such as connectivity and accessibility, mixed use developments and urban energy and water strategies. Conversely, research addressing sustainability from a city-wide perspective neglects the context-specific nuances that exist within communities, neighborhoods and districts within cities by taking a one-size-fits-all approach to sustainable development (Ayyoob [43]). As argued by Choguill ([11], p.1) there is “no single city that can contribute to overall sustainability if its own component parts are found not to be sustainable”.

Consequently, the need to focus on neighborhoods led to the subsequent emergence of the Neighborhood Sustainability Assessment Tools (NSATs) in late 2000's as an effort made by governmental and non-governmental authorities to address the alarming rise in environmental degradation linked to buildings. Afterwards, these NSATs evolved into addressing socioeconomic inadequacies within the built environment through the use of criteria, indicators and a credit allocation system for providing guidance to users in order to plan and develop areas that could be certified as sustainable. Thus, emerged a pseudo-scientific tool that aids researchers, planners, developers, and clients in creating a society that can be certified as sustainable. Despite these benefits, there are some drawbacks associated with NSATs that have been well documented in literature (Ayotunde [17,37]; Ayyoob [43, 50]).

Until now, most studies often focused on the limitations and mitigation strategies of improving NSATs. Prior NSAT research involved the analysis of singular tools and provided context specific remedies such as articles under Leadership in Energy Efficiency Design for Neighborhood Development (LEED-ND) tool, which covers topics such as ‘Lessons for LEED for Neighborhood Development, Social Equity, and Affordable Housing’, ‘LEED for neighborhood development: Does it capture livability?’, ‘LEED-ND as an urban metric’, ‘Planning for urban sustainability: the geography of LEED-ND projects in the United States’ etc. These publications focus on the context-specific gaps and remedies of the tools under investigation. For example, the study on social equity and affordable housing for LEED argues that due to the optional, low credit/score of the ‘affordable homes’ category and cost of implementing LEED certification attributed, certain socioeconomic discriminatory issues arise, such as unaffordable sustainable homes, thus going against the inclusive premise of sustainability and raising the issue of environmental injustice [44]. Alternatively, research articles have also investigated multiple number of tools through case study investigations such as (Ayyoob [44])’s cross-evaluation of three assessment systems and their cases from the US, the UK or the analysis of Wang et al. [54] and Dawodu et al. (2018, 2019) of multiple NSATs leading to recommendation such as the need to move to more performance-based indicators, include considerations of the multiple dimension of sustainability into various NSAT categories, and/or the unsustainability of the top-down approach (lack of participatory method) used for NSAT development (Ayotunde [21]; Ayyoob [39]). In addition, the recipient or target audience of these limitations and recommended improvements are tool developers and in some cases government organization (both considered the implementers). With similar observations undoubtedly drawn out in our investigation, this study utilizes a more holistic approach by reviewing over 150 articles focused on NSATs with an intended audience researchers and investigators who are vital to the enhancements on NSATs.

The study will appraise published articles from the first emergence of NSATs till date. The aim of this appraisal is not to highlight the more notable gaps that have already been addressed in literature but to uncover trends through the identification of research directions that benefits both ‘implementers’ and researchers. Hence, this study investigates sustainability research from the neighborhood perspective through the

viewpoint of assessment tools.

Hence, the primary aim of this study is to examine the trends in research focus and direction of NSATs studies since the emergence in literature. Further objectives include recommendations on potential improvements to NSAT’s research direction. An additional objective is to identify trends for forecasting the future direction of sustainable research and development of assessment tools. This would be imperative to maintain the relevance of assessment tools in this erratic world filled with new challenges that constantly change the scope and understanding of sustainability. It should also be noted that currently there are no NSAT studies that investigate the trends and potential research direction and gaps that NSATs need to fulfill to improve their implementations and development. More popular investigations address gaps and challenges of assessment tools from the operation (indicators, criteria, credit, and category analysis) perspective. However, this study highlights the research trends of NSATs through bibliometric study of literature, thereby providing information on research trajectory and direction, as well as potential opportunities to improve NSATs research and implementation.

2. Literature review

Emergence of neighborhood sustainable assessment tools

NSAT tools are perceived as the latest generation of impact assessment tools that evolved from environmental building assessment tools [43]. These tools emerged based on the Brundtland report’s call to address the issues surrounding global environmental challenges and the need to pursue sustainable development and attain sustainability. The first generation of tools created to respond to this challenge was developed by the organization called Building Research Establishment (BRE) in 1990. This tool was called BREEAM New construction and largely focused on buildings. This was shortly followed by the tool developed by the U.S. Green Building Council (USGBC) called LEED New construction. These tools provided a step by step process required for buildings to reduce their carbon footprint and environmental impact, while sub-optimally addressing social issues (related to thermal comfort, ease, and convenience) in buildings [22]. By adhering to specific standards instructed by a set of criteria and indicators, a building is assigned sustainability credits. The subsequent accumulation of these credits under specific categories ultimately determines the degree of how sustainable a building or neighborhood is and/or its sustainability rating.

Over the last decade, developing sustainable or green neighborhoods has gained traction in science and policy circles. Emphasis on sustainable communities in the UN sustainable development goals such as SDG 11 (sustainable communities and cities) has further contributed to this trend and resulted in an increased volume of literature concentrated on neighborhood sustainability (Ayotunde [19]). It was determined that city-wide green initiatives were incapable of addressing all components of specific neighborhoods due to the diverse attributes of neighborhood from different regions within a city [8,11]. Moreover, the focus on micro-scale development revealed that certified buildings were inclined towards the environmental aspects of sustainability which is at odds with principles set out in the Brundtland Report (A. [17]; Ayyoob [43], 2014). This spurred the development of an advanced certification system that assesses neighborhoods. The pitfalls encountered in the micro-scale assessments eventually led to development of the NSATs which were first designed in Europe and North America and then proliferated throughout the world in various forms [3,50].

Currently, there are over 20 third party assessment tools in various regions of the world [50]. In terms of timeline, CASBEE-UD emerged first in 2006 along with EnviroDevelopment which is an Australian based tool. Also, another Australian based tool called Green Star Communities was developed in 2012 and is growing in popularity. Subsequently, LEED-ND, BREEAM-Communities and DGNB followed in 2007, 2009 and 2012 respectively. Nonetheless, BREEAM and LEED are

pioneering building and third party certification assessment tools in terms of neighborhood assessment [50,56]. Over the last 5 to 10 years, some tools have emerged for use in Asian countries such as BEAM Plus Neighbourhood (Hong Kong), BERDE Clustered Development (Philippines), Green Building Index Township (Malaysia), Green Mark for Districts (Singapore), and IGBC Green Township (India) [10]. Similarly, other developed tools originating from the Middle East include The Pearl Community (UAE), and GSAS District (Qatar) [10]. The timeline of the emergence of these tools is indicative of a gradual increase in their development and popularity particularly in Asia [10,57]. Interestingly, China is yet to create a localized third party NSAT even with the increase in assessment tools uptake within the Asian region. For instance, the Hong Kong's Building Environmental Assessment Method, (BEAM) Plus Neighborhood was developed in 2016 and the Philippines has its Building for Ecological Responsive Design Excellence (BERDE) Clustered Development tool developed 2013.

LEED-ND is still considered the most popular tool particularly due to the size of the US, the integration and support provided to LEED-ND by the policy and regulation has made them a globally recognized standards, thus allowing its usage on projects beyond the jurisdiction of their origin tool [10,50]. As a result, while BREEAM-Communities is also a pioneering tool, it has a lower quantity of executed projects in comparison to LEED-ND on a neighborhood level. Still, BREEAM-Communities is closely matched with LEED-ND when considering building scale assessment. Additionally, Envirodevelopment and

Star communities are next to LEED-ND when ranking these tools based on the project execution. However, evidence does not indicate these tools are used in different parts of the world (Sharifi et al., 2020). Hence, the more recent tools are more localized and context-specific with focus on their country of origin [50].

3. Materials and Methods

The Bibliometric methodology used for data collection and analysis is summarized in Fig. 1. The literature search and selection method is more accurately known as the protocol of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses, providing transparency and clearness for the whole process, which makes it easy to reproduce (Moher et al., 2009).

An initial search was performed to identify and explore potential keywords for developing a useful review strategy, indicating that the keywords All data used in this publication were obtained from peer reviewed journals included in the Web of science and Scopus that are two major databases. The aforementioned databases were chosen due to their large repository on the coverage of NSAT related articles. The initial literature search was done in June 2019, using a broad-based search string that includes different variants of terms related to NSATs that have been frequently used in the literature. Examples of a few of these terms are Building Research Establishment Environmental

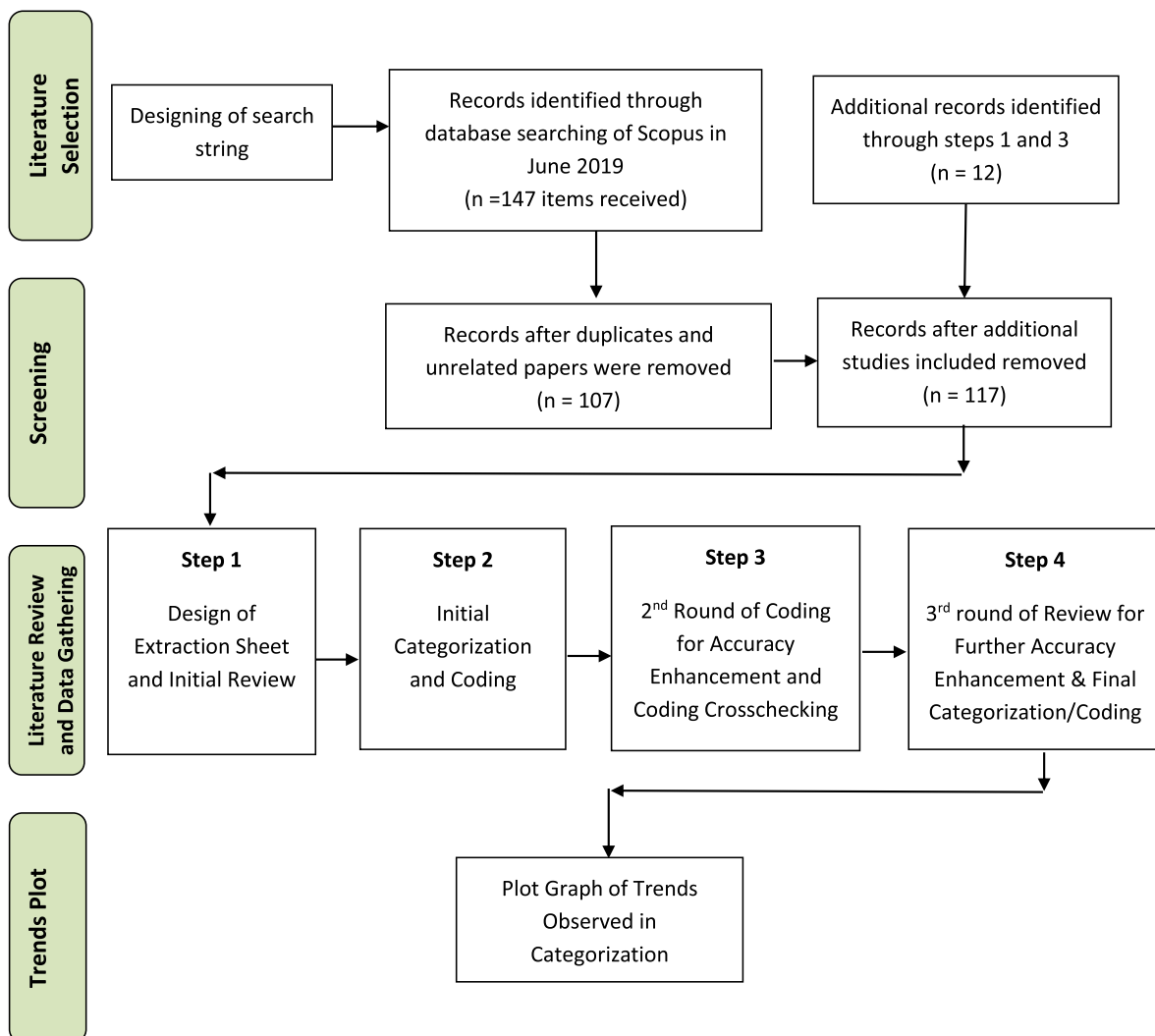


Fig. 1. Procedures for literature selection and data extraction.

Assessment Method for Communities (BREEAM-Communities), Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND), and Comprehensive Assessment System for Building Environmental Efficiency for Urban Development (CASBEE-UD). The complete search string is available in the Supplementary Appendix 1. Overall, about 40 NSATs were reviewed over the course of this investigation, but only 14 were mentioned directly in this study and is shown in Table 1. The remaining tools are represented as 'others' in analysis unless otherwise stated, these can be seen in Appendix 2. The categorization of 'others' is due to lower frequency of occurrence of these tools as compared to the 14 tools in Table 1.

By searching for publications with the NSAT related search string within titles, abstracts, and keywords of articles indexed in Scopus, 147 articles were obtained. Thereafter, the titles and abstracts of the 147 obtained articles were manually verified to exclude unrelated papers. This led to a reduction from 147 articles to 105 relevant articles. Afterwards, the comprehensive review of the contents of the 105 articles was executed. Furthermore, the references cited in these relevant journal papers were also searched for other relevant papers cited within the journal papers and a search alert function of Scopus was activated to receive alerts on newly published research. All articles obtained from these two routes were also added to the review database. As a result, twelve more articles were added to the database via these processes. Therefore, a total of 117 articles were analyzed for this investigation (A. [39]; Ayyoob [39]).

To extract required data, an excel sheet was designed with selected articles on the rows, and columns for collecting data on a wide range of items and issues, including titles of the NSA tools, successes, and

Table 1
List of NSATs investigated.

Tool	Main developer (s)	Origin	Year
LEED-ND	US Green Building Council (USGBC)	US	2009
BREEAM-Communities	Building Research Establishment (BRE Global)	UK	2009
CASBEE-UD	The Institute for Building Environment and Energy Conservation (IBEC)	Japan	2007
Green Star Communities	Green Building Council Australia (GBCA)	Australia	2012
HQE2R	Scientific and Technical Center for Building (CSTB)	France	2001
Pearl Community Rating System	Abu Dhabi Urban Planning Council	UAE	2010
IGBC Green Townships	Indian Green Building Council	India	2008
Global Sustainability Assessment System (GSAS)	Gulf Organization for Research and Development	Qatar	2007
DGNB for Districts	German Sustainable Building Council	Germany	2012
GBI Township	Green Building Index Sdn Bhd (GSB)	Malaysia	2011
BCA Green Mark for districts	Building and Construction Authority (BCA)	Singapore	2009
Building for Ecologically Responsive Design Excellence – Clustered Residential Development (BERDE)	Philippine Green Building Council (PHILGBC)	Philippines	2013
Sustainable Building Tool (SBTool)	International Initiative for a Sustainable Built Environment (iISBE)	Canada	2007
Building Environmental Assessment Method (BEAM) Plus Neighbourhood Assessment Tool	Hong Kong Green Building Council	Hong Kong (China)	2016

recommended solutions for building on success stories. The selected articles were analyzed in four steps by the lead author and co-authors. These steps are discussed below and in Fig. 1.

Step 1 – All papers were reviewed to extract the necessary data.

Step 2 - Upon completion of the reviews, the collected data were categorized and coded based on their commonalities.

Step 3 - The coded data extraction sheet underwent a second round of review to ensure accuracy, and for incorporating modifications (new categories) if deemed necessary.

Step 4 - The collected data went through a final review stage for reviewing all articles in the database and refining the categories based on the feedback received from Step 3. The categories were developed based on the identification of recurring issues and information that fit the scope of the research aim. Essentially, the focus was on NSAT issues linked to research directions and outcomes

Step 5 - After the completion of Step 1 – 4, frequency-based charts were drawn to illustrate the trends observed from the 117 articles. Since the key aim of this study is to inform not just the 'implementers' but also the researchers, information that was sought after included countries of research articles, the subject matter of journal papers, timeline of publications, methodological approaches used by researchers, and thematic coverage of tools. The thematic coverage was obtained by taking note of recurring themes relevant to NSATs in recent years, these included smart neighborhoods (mobility and ICT related), SDG-based discussions, resilience-based discussions, climate change adaptation and mitigation-based discussions, sustainability incentives.

The results and implications of these trends are discussed in the next section with recommendations on how to enhance research in and development of NSATs for optimized performance.

4. Results and Discussion

The results obtained are geared towards understanding the research direction of NSATs and prediction of areas that NSATs would need to consider in order to adapt to the ever-changing sustainability requirements of neighborhoods and cities. The section investigates the types of research conducted, the trends, the research themes in terms of sustainability categories, the location of research and the methods involved in the research analysis. Essentially the study also aims to provide methods of better analysis for NSATs performance to give more relevant and accurate observation thereby improving the quality recommendations that assessment tools may adopt.

4.1. Type of research conducted on NSATs

Generally, research can be in form of qualitative, quantitative or mixed method approach. These can be further broken down into various subgroups under primary or secondary data with each having their distinctive advantages and disadvantages. These subgroups include experiments, case studies, surveys, simulations, observations, derivations etc [6,13]. After analyzing 117 articles, the results showed that majority of the published articles predominantly focused on reviewing the content within the operations manual (i.e. a document with instructions detailing the processes and steps of the evaluation and assessment of the sustainability of a neighborhood). Essentially, a qualitative review of the NSAT documents to address the intended aim of the study. The implication is that this form of investigation limits the accuracy of the outcomes on certain topics or issues. For instance, it is more impactful to investigate renewable energy-based installation after construction, when determining the impact of the renewable energy criteria/indicator for NSAT (experimental method) than to scrutinize the practicality of the theoretical or design performance from the operational manual or software (theoretical or simulation method). The argument is that if the instructions of the manual were followed, implemented, and observed on a real-time basis, then benefits and shortcomings of the actual operational values on site (e.g. KWH, KgCO₂ on site) can be recorded to

give a more accurate performance rating of the site while still under development. However, as shown in Fig. 2, various qualitative analyses in form of qualitative and quantitative content analysis of NSATs are quite popular as compared to field observation. Another instance can be seen from a study conducted by Szibbo [49] on environmental injustice under the ‘affordable homes’ category, where several developers were interviewed to determine why categories such as the affordable housing were often neglected for more attractive options within NSATs. The responses from this survey gave the authors a better understanding of the issues and challenges and allowed for more impactful recommendations on how to effectively select appropriate indicators from the opinions of developers, this included making such categories mandatory, increasing their weighting average, etc. [49]. Also, [54] argued in their study, NSATs need to move away from prescriptive methods of criteria development into more performance-based methods. Thus, based on Fig. 2, though comparative analysis, reviews, qualitative content, and case study analysis do provide a level of qualitative based information on NSATs, a move to more quantitative analysis such as quantitative cases studies (regression, modeling and simulation), as well as experiential investigations such as interviews, questionnaires, and field observations (qualitative) may be more adequate. This is because experiential and experimental methods would be more proficient in drawing out more accurate information on the characteristics and performance of NSATs. Therefore, research that would yield more accurate, context relevant and real time results need to adopt a performance-based investigations route that incorporate survey, field observation, experiential and experimental results to proffer useful recommendations to practical issues. An alternative approach is the mixed methods approach (which represents 14% of studies – see Fig. 2) where both qualitative and quantitative approach are combined to give both more evidence-based results (from quantitative route) and to contextualize the results via the qualitative route. It should be noted that though qualitative and quantitative content analysis is conducted as mixed method (10%), these investigation focus on the weighting of assessment tools and the qualitative review of the assessment tool manual. Also, the subcategories of research methods are based on the number of research methods used in a particular NSAT paper or article.

Regardless, the 39 studies alone (see appendix 2), on qualitative review and content analysis which represents 31% dwarf both quantitative methods (content analysis and modeling) that combine to make just 6% of the study. Thus, this study is proposing a shift from assessment tool manual review analysis to more performance, experimental and experiential based analysis. This analysis should be based on real-time situations such as the analysis of actual water use or energy consumption from a BREEAM buildings or the evaluation of indoor and outdoor thermal comfort requirements of people in LEED buildings. Thus, there is room for improvement in the type of research conducted currently.

4.2. Implications of NSAT development

The results reveal that publication in the field NSATs emerged around 2007 and peaked around 2018. NSATs gained much popularity from the successes of the building assessment tools [22,43]. Using BREEAM as an example, the governing body was formed in 1921, but the rating tool itself was released in 1990. Initially, in the 1920's, BRE focused on issues such as building materials, heating, ventilation and insulation, and war effort research (explosive resistant concrete) [29]. However, with the advent of sustainability science and the realization that the carbon footprints and environmental impacts due to their production and development activities could not be ignored, a new motivation for the built environment emerged [12,32]. This was centered around sustainability and balancing the three dimensions of sustainability [47,55]. Although the term and concept were not novel (e.g. IUCN, UNEP, WWF 1980), the Brundtland commission is widely credited with popularizing the concept of ‘sustainable development’ by introducing it into international policy discourse. Thereafter, the institutionalizing of ‘sustainable development’ continued with the ‘Rio Process’, which was initiated at the 1992 Earth Summit in Rio, where the world’s political leaders pledged their support to the principles of sustainable development and Local Agenda 21 ([7]; A. [17]). These occurrences were the key motivation and genesis of the building assessment tools and by proxy NSATs. As highlighted by Sharifi and Murayama [[43], 2014], shortly after this, it was not enough to simply investigate individual buildings, as these buildings were interrelated to

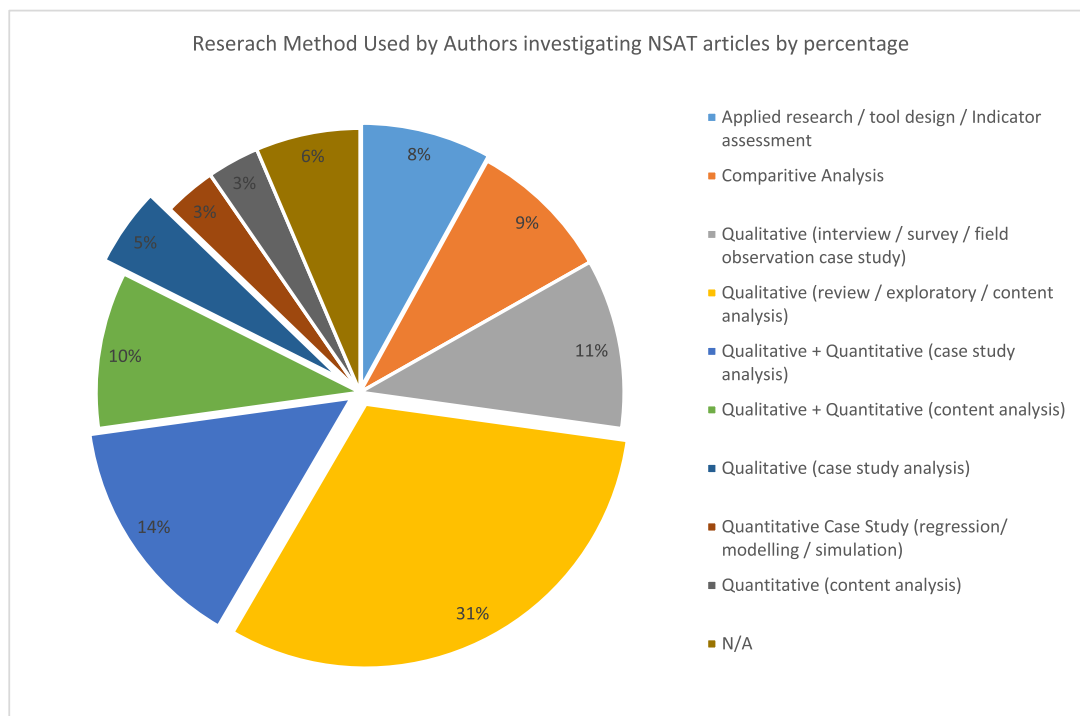


Fig. 2. Type of research conducted by authors by percentage.

other component parts of the built environment and each function affected another. Chogull [11], p.1 best put that “no single city can contribute to overall sustainability if its own component parts are found not to be sustainable”. Thus emerged investigation into neighborhood level sustainability. Interestingly, though BREEAM was one of the first building tools to be created in 1990, which was followed by HQE (1994), LEED (1998) and then CASBEE (2001), in the case of NSATs, publications started with CASBEE in 2007, and HQE2R and LEED ND in 2008 followed by BREEAM-communities in 2010 (the same year the tool was released) (See Fig. 3). It should be noted that although LEED-ND was officially released in 2009, a pilot version existed from 2006 leading to the first research output two years later in 2008 (see Fig. 3). The Japanese tool CASBEE on the other hand emerged a decade after BREEAM’s Building Sustainability Assessment Tool (BSAT) in 1990, however their conversion to Neighborhood based research occurred in 2006 before BREEAM-Communities followed by their research publication a year later (see Fig. 3). Therefore, the development of NSAT was motivated by the principles of sustainable development, the successes of BSATs and the need to consider inter-related components of the built environment. Still, even though NSATs emerged from BSATs frameworks, the timeline shows that an early development of BSAT tool (BREEAM for example) does not translate to an early development or adoption of NSAT within that region or publication of NSATs related research.

BREEAM emerged first as a BSAT followed by HQE2R and LEED, yet CASBEE had the first publication based on the literatures reviewed [50]. Also, the French tool, HQE2R can actually be identified as a key pioneer of NSAT (Fig. 3), but research in tools such as LEED-ND BREEAM-Communities, CASBEE-UD eclipse the research conducted on HQE2R. Even Green Star communities, an Australian tool developed 6 years later has had more research publications in comparison to HQE2R. This could be due to the usage limitation imposed by the language of the tool which is in French without English translation, thus limiting researchers’

ability to investigate the tool. In contrast to this, BRE improves their tools’ usability by incorporating translations as seen from BRE China which translate new versions of BREEAM assessment tools into mandarin to ensure ease of use and acceptability within the country. Also, Fig. 3 indicates that research on tools such as DGNB, Green Star Communities, IGBC, HQE2R, GSAS and GBI are published at least 2 years after release of the tool.

4.3. Trends and future direction of NSAT research

Fig. 3 also shows that by 2011, there was a spike in research, predominantly associated with LEED-ND in North America. This could be easily associated with increased interest in green and sustainable buildings due to the traction gained from sustainable development projects, impacts of climate change, and risk assessment tools (Cheshmehzangi and Dawodu, 2019). The result in Fig. 3 also indicates that LEED-ND constituted a large fraction of all publication from 2011 to 2014 because of the popularity of LEED construction which influenced the popularity and uptake of LEED-ND. Between 2006 and 2016, LEED-certified projects had a compound annual growth rate of 77 percent, making China the global leader for LEED projects outside of the United States. The “2017 China Green Building Report: From Green to Health” notes, additionally, that as of August 2017, more than 48 million square meters of projects across 54 Chinese cities have been LEED-certified (CBRE, 2017). This popularity of LEED certifications established the basis for numerous publications and investigation into LEED based projects (ND inclusive). Another key factor in this is the collaborative relationship UGSBC established with different states and cities in America [1]. As a consequence, a few states enforced the requirement of LEED certification in new development projects. The early institutionalization of this assessment tool through strong bonds with the governmental agencies enabled the easy execution of the pilot projects

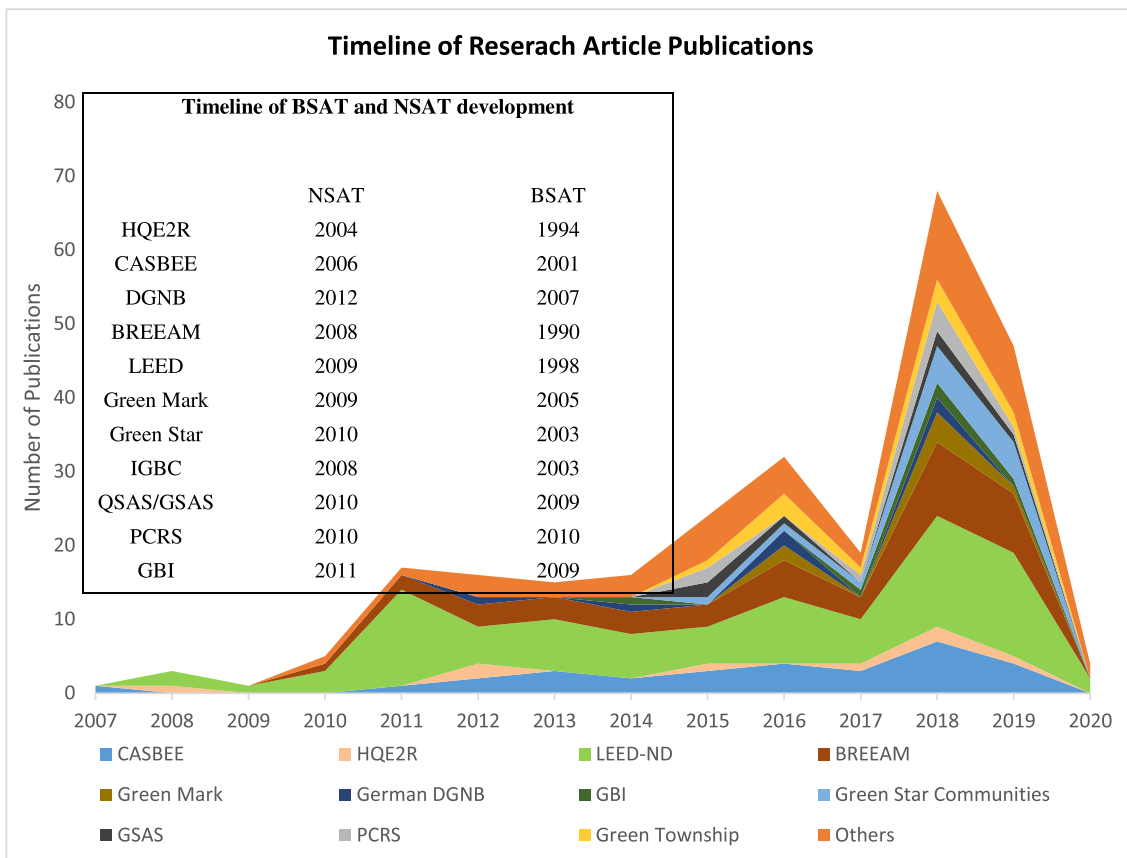


Fig. 3. Timeline of BSAT and NSAT creation versus Journal Publication on NSAT.

such as the three LEED-ND pilot participants—the Brewery in Milwaukee, Wisconsin; the SALT District in Syracuse, New York; and Tassafaronga Village in Oakland, California. These projects among many others illustrated how to successfully incorporate sustainability principles into their design, while ensuring affordability, historic preservation, and public space were not compromised. Furthermore, LEED outreach spread internationally, especially in China, because by 2011, developers in China started constructing 1.9 billion square meters of floor space and invested ¥6.2 trillion (\$983 billion) in property development, according to the PRC National Bureau of Statistics. This was further supported by China's 12th five-year-plan (FYP) to reduce carbon dioxide emissions by 17 percent per unit of GDP by 2015 (CBRE, 2017). In 2005, the first building in China to be awarded a LEED certification was the PRC Ministry of Science and Technology office building in Beijing which received a gold rating. Shortly afterwards, the LEED-ND and New construction was used for the development of the Beijing Olympic Village and other facilities for the 2008 Olympics, and by the end of 2011, roughly 800 construction projects had been registered in China for certification while nearly 200 had been LEED certified (China Business Review, 2012). Interestingly, the three star system which is the Chinese version of sustainability assessment has fewer projects, but has similar growth trends, increasing from 10 projects certified in 2008 to 83 in 2010 (China Business Review, 2012). Essentially, the institutionalization of LEED, the smart and aggressive online marketing, and the execution of pilot projects in different regions of the world helped create several projects that would eventually create cases for investigative research.

Finally, Fig. 3 also shows a peak in 2016 and 2018 which could be attributed to three main factors - increase in visibility of the benefits of NSATs, increase in number of developed NSAT tools and influence of SDGs. A plausible reason for this surge in research can be linked to the emergence of other tools, leading to a broader investigation. The emergence of these tools could be related to the lack of context-specific indicators and inadequate weighting and indicators which results in unsuitability and ineffectiveness of LEED-ND or BREEAM-Communities in tackling local sustainability issues in other regions of the world ([20]; Garde, 2009). For instance, LEED-ND often referred to codes and standards within ASHRAE while other internal or local standards are utilized by some locales in their development projects. Thus, context specificity has become a popular recommendation in many studies and is the likely reason for novel tools emerging (Ayotunde [18]). Another likely key reason for the spike in 2016 is the emergence of the SDGs in September 2015 when 193 countries came together to ratify a set of 17 SDGs to serve as a roadmap towards a more sustainable future for the world. One of the key goals was SDG 11 (sustainable cities and communities), which essentially motivated and created the incentives for tools such as NSATs to thrive as the aims and objectives within this SDG 11 was in line with the targets of NSATs ([9]; Hák et al., 2016). These SDGs are also instrumental in directing investors, governments and other relevant stakeholder's on sustainability topics and empowering them to make proposals that emphasized greater accountability among corporations, developers and their executives. The emergence of these SDGs transformed into a surge in sustainability-related projects that ranged from sustainability banking to sustainable urban development. Subsequently, a surge in research and development projects and publications centered on NSATs oriented topics and the development of assessment tools.

Another noteworthy trend is the dip in 2017 which can be explained by the time required (years) for the development and assessment of sustainable urban development projects linked to NSATs. Hence, a lot of projects were most likely under investigation during this period but not reflected in publication until 2018 and afterwards. Also Fig. 3 also shows that tools such as DGNB, Green Star Communities, IGBC, HQE2R, GSAS and GBI publish research articles at least 2 years after release of the tool. This would likely have a longer time gap if the research were focused on detailed case studies of certified projects and/or survey analyses involving developers and end-users of certified projects. Unfortunately,

there has been a dramatic dip in the output of projects in 2020, this is most likely due to the COVID pandemic and reallocation of resources for presenting projects centered on health, the ongoing lockdown/quarantine that might restrict interactions, construction and development activities, etc. For example, a study by Venkatesh [52] presents five research directions related to COVID's impacts on jobs—i.e., job loss, job changes, job outcomes, coping, and support. Of primary concerns is job outcomes, with the author indicating that COVID would likely constrain research in general and data collection in particular [52]. Also, [51] conducted a study through bibliometric analysis from Web of Science, and Elsevier's Scopus discovered that a surge in COVID related papers with 23,634 unique documents, 9960 of which were in common to both databases, were published between January 1 and June 30, 2020 [51]. These publications include research articles, letters, editorials, notes and reviews. As one example, amongst the 21,542 documents in Scopus, 47.6% were research articles, 22.4% were letters, and the rest were reviews, editorials, notes and other [51]. Also based on both databases, the top three countries, ranked by volume of published COVID papers, are the USA, China, and Italy [51]. An alternative perspective would be integrating both research direction i.e. research could combine both NSAT and COVID related issues, such as the recent publication by [46] which investigates the 'impacts of COVID on tourism for advancing and resetting industry and research'. This suggests that there is an opportunity to investigate epidemics and pandemics such as COVID along with urban sustainability to create new sustainability paradigms such as the study by Corburn et al. [14] that investigates mitigating impacts of COVID-19 whilst improving the well-being in urban informal Settlements (Slum settlements) [14]. Thus it is likely that though the NSAT projects have generally been on the rise, the tools may need to incorporate more health and resilience-based dynamics in the future as well as more flexible research techniques to remain consistent and relevant in solving the world's current urban issues.

4.4. Timeline for progression in research: evaluating research themes

Fig. 4 illustrates the topics of discussion that were considered in the published NSATs research and the timeline associated with the publications. Fig. 5 supports Fig. 4 by providing the percentage distribution and giving the overview of the most and least popular topics. Based on the data shown, the most popular topic is climate change mitigation (as shown in Fig. 5) which is expected because this is one of the core premises that NSATs were developed upon (see discussion in Section 4.2). The emphasis on this topic is also reflected in the NSAT categories incorporating energy-based themes which possess higher number of credits. Thus, making them an attractive focus for developers, and hence researchers ([3]; Charoenkit and Kumar, 2014; Dawodu et al., 2018).

Similar to the observation made for SDGs in Section 4.2, Fig. 4 indicates a gradual emergence and steady focus on topics related to resilience in 2015 and Fig. 4 shows it's the second most considered topic. This topic is relatively new and has gained momentum from 2010 (Ayyoob [40]). To date, the highest studies of resilience were from [15] who provided an overview of 27 resilience focused tools and (Ayyoob [40]) who analyzed 36 resilience focused tools. The study of resilience conducted by Sharifi's (2016) which looked at the optimization of resilience-focused tools observed that no resilient tool has emerged from BSAT or NSATs i.e., the resilience tool were standalone tools developed by governmental and Non-profit organization. Yet, NSATs are predominantly private enterprises that are driven majorly by achieving sustainability and generating income. Such observation can be linked to the emerging argument of environmental justice. Putting environmental justice into the context of NSATs, the price of buildings or communities designed by BREEAM, LEED, CASBEE and other assessment tools generally increase due to the investment in sustainable techniques which can be capital intensive, thereby making it unaffordable for certain groups of people. Thus, environmental injustice becomes another potential avenue for investigation for both NSATs and

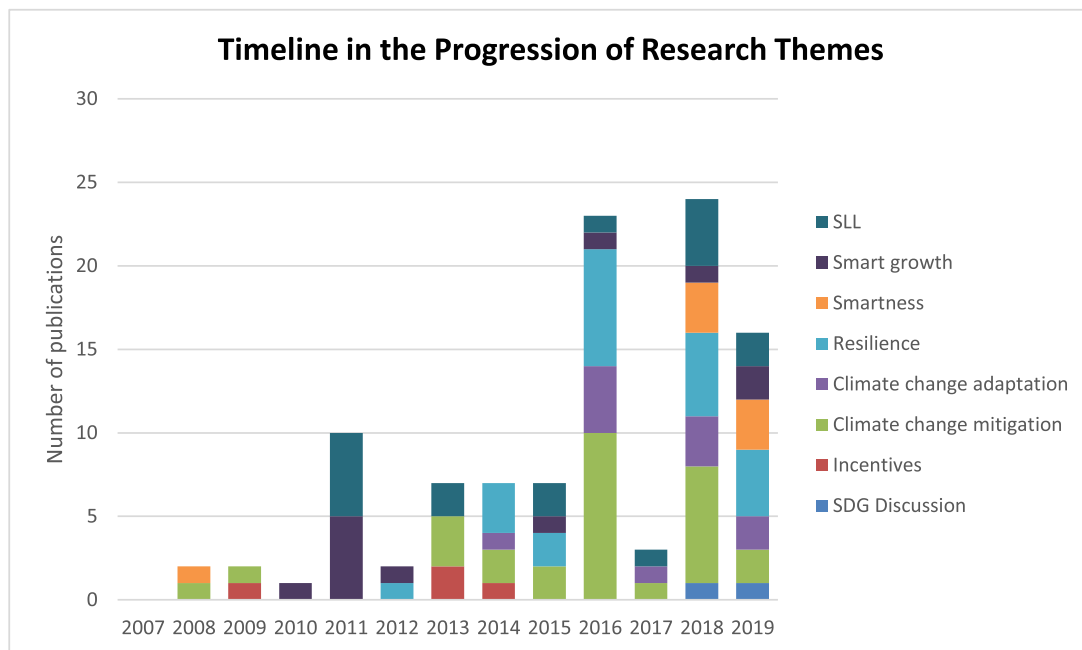


Fig. 4. Timeline for progression in research topics and trends.

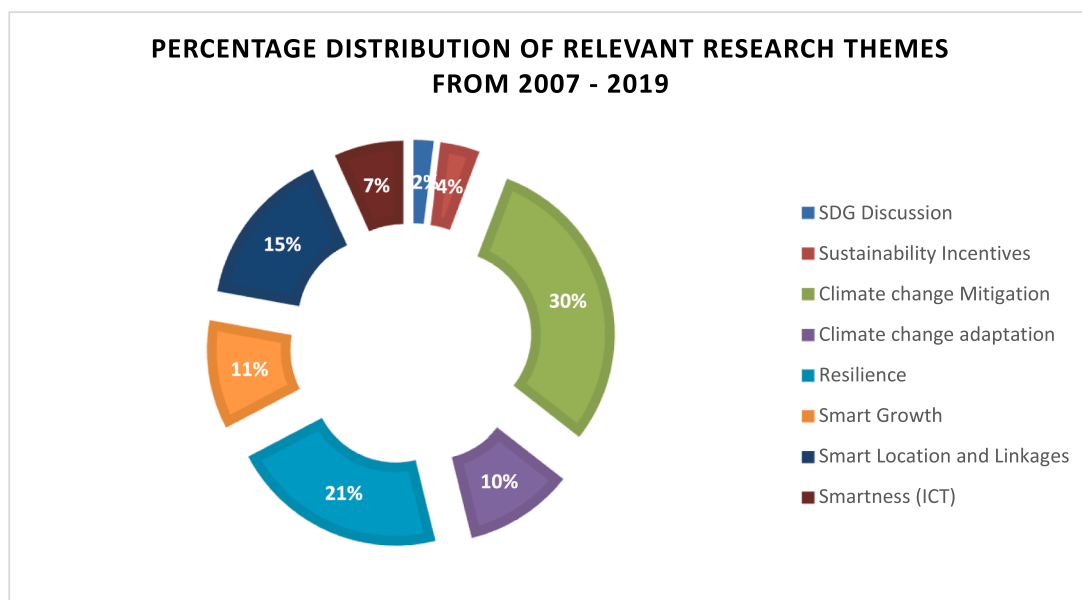


Fig. 5. Percentage distribution of research topics and trends.

resilience-focused tools.

Following this, resiliency research revealed the recognition of resilience as an overarching concept that can play an essential role in guiding their sustainable development policies and disaster risk management activities within communities (Ayyoob [40]; Ayyoob [45]). Furthermore, by 2016 the SDG narrative had fully emerged and the need to enhance community resilience was highly emphasized in SDG 11 which aims to “make cities and human settlements inclusive, safe, resilient, and sustainable”. This argument shows the link between SDG, sustainability (in general), and resilience. Thus providing a strong reason for the growth in resilience based research in NSATs after 2016. In conclusion, resilience will continue to play a strong role in NSATs research themes with potential growth in the effectiveness of NSATs in addressing urban resilience issues. This could be from a disaster perspective such as

destruction of infrastructure or from a pandemic perspective such as the health and wellbeing and COVID-19 (see Section 4.3).

Smart location and linkages is noticed as the third most popular theme. This is mostly attributed to the large percentage of publications focused on LEED-ND, in which smart location and linkages is a key category due to the major challenges posed by transport and urban sprawl in the U.S (Stone, 2008). Thus, this focus on the connectivity category results in reduced fuel cost, improved convenience for commuter and reduced cost for transport. Hence, most of the publications which explored the concept of smart linkages are directly tied to studies on LEED-ND.

In 2018, the notion of smartness emerged which involved the utilization of big data, automation, and other ICT/ technology-related approach for improving sustainable development (Ayyoob [41]).

Sharifi [41] mentioned that ICT-related research have been on the increase since late 2000s but gained more popularity in recent years. It should be noted the ICT based tools initially investigated by Sharifi [41] are not necessarily third part assessment tools as some of the tools do not require rating and point systems. Hence, Fig. 4 and 5 specifically identifies studies that considered smartness in terms of third-party assessment tools. This is shown to emerge from 2018, though a previous research article on a LEED-ND project discussed laying the foundation for automated and ICT related services that would enhance future installation of door control, card access, security, and lighting control [38]. Excluding this, no other publication has discussed smartness in terms of ICT, digital technologies, and NSATs until 2018. The growth in popularity of this research theme has been credited to increased awareness of the importance of smartness to sustainability [41]. Integration of Smartness components has several advantages such as - the maintenance of competitive edge in a globally interconnected economy; create an appeal to the most talented and creative citizens; provide solutions to overcoming sustainability challenges and resource limitations that necessitates efficiency improvements; contribution to climate stabilization by speeding up the transition to low-carbon society; improved transparency of urban management; improved Quality of Life (QOL) and resolving multiple socioeconomic challenges such as inequality, insecurity, unemployment, and aging population; and contributes overall to making strides towards achieving the Sustainable Development Goals (SDGs) (Ayyoob [41,42]).

In future, topics like urban resilience would continue to rise since it centers on how tools can deal with and adapt to external shock. The area of smartness would also continue to grow in NSATs development due to their ability to enhance the process of sustainability and due to the migration of built environment development towards the digitization of the economy. Thus, more research on Smart and big data research related to urban sustainability should be encouraged. Whilst the SDG initiatives may cease due to the time limit attached (end of 2020), NSATs research may need to adapt to a shifting sustainability focus which may swing away from environmental issues and may center around socio-economic issues centered on health, security, safety, and economic

empowerment.

4.5. Timeline and progression of research: geographic implications

In terms of geographic information, a few conclusions can be drawn from Figs. 6 and 7. Firstly, Fig. 6 depicts the geographical locations that were investigated in the research publications. The US is the highest contributor to NSAT research (reason explained in Section 4.2 and 4.3). Europe comes in second due to BREEAM communities and the various version BREEAM communities that exist around Europe. Other key tools that play a vital role in Europe's contribution include Germany DGNB and French tool HQE2R. A key observation from Fig. 6 is the low uptake in regions such as Africa. Essentially, very few studies have studied NSATs within Africa (Ayotunde [20,24]) and till date, no NSAT based project has been executed in any African city. This could be due to the lack of any NSAT contextually developed for an African city (Dawodu et al., 2018; [50]). Alternatively, this could be related to authors preference to investigate familiar regions where their institutions are located or their own countries/cities of origin. Fig. 8 further illustrates this by showing many Americans as authors, which corroborates the large amount of research from the region.

This preference could be based on the availability of resources, convenience (ease of accessibility to information/case studies, and close proximity to author's base of operations), biased interest in improving local areas of authors or institutions origin, and requirements from external and/or local funding to investigate funding region. Arguably, Africa might be the next frontier in terms of urban sustainability and potentially has the most to gain from NSAT principles ([4]; A. [17]). This is informed by the higher probability of African regions to be affected most by the consequences of inadequate actions for addressing the issues of climate change globally. Particularly with issues related to climate change adaptation, urban resilience, high rates of urbanization and population increase, various types of shocks, economic empowerment, and technological development [36]. The data from Figs. 6 and 9 also indirectly suggest that there is a gap in knowledge by African cities towards the benefits and development of assessment tools due to the gap in

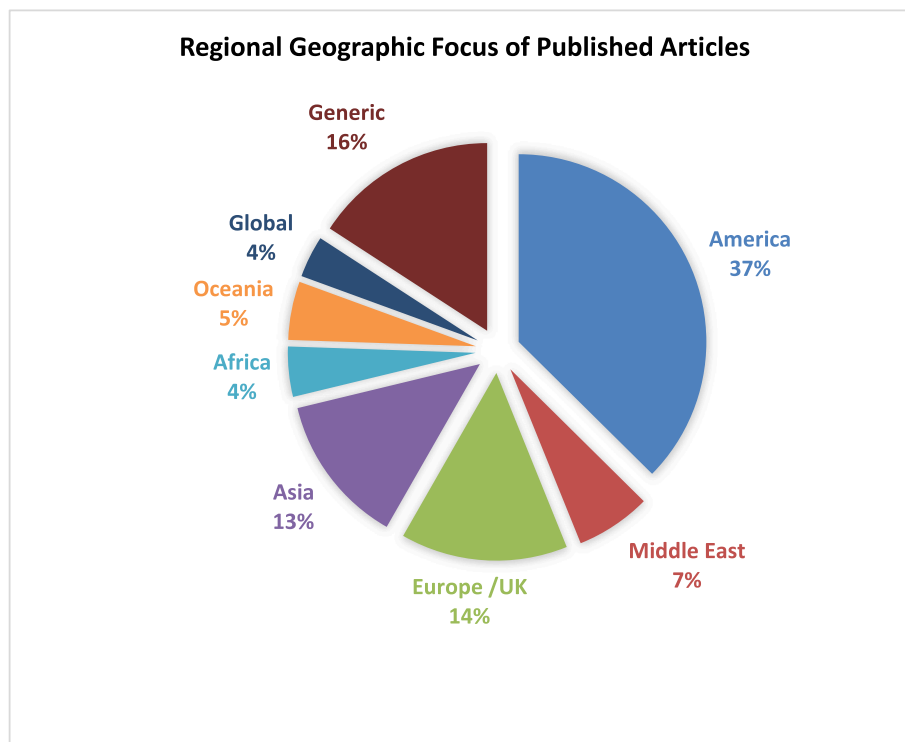


Fig. 6. Regional geographic focus of published research articles.

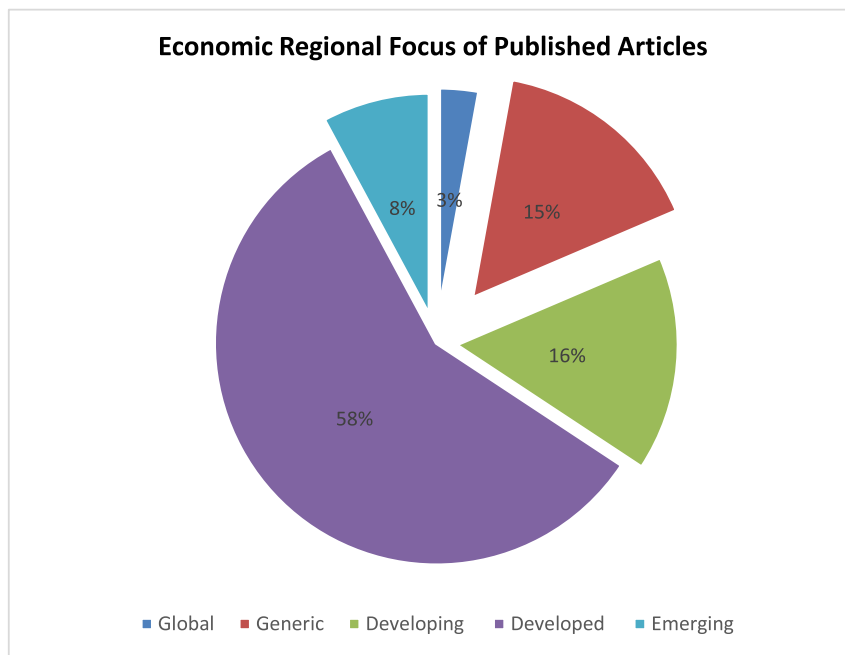


Fig. 7. Economic regional location of NSAT research articles.

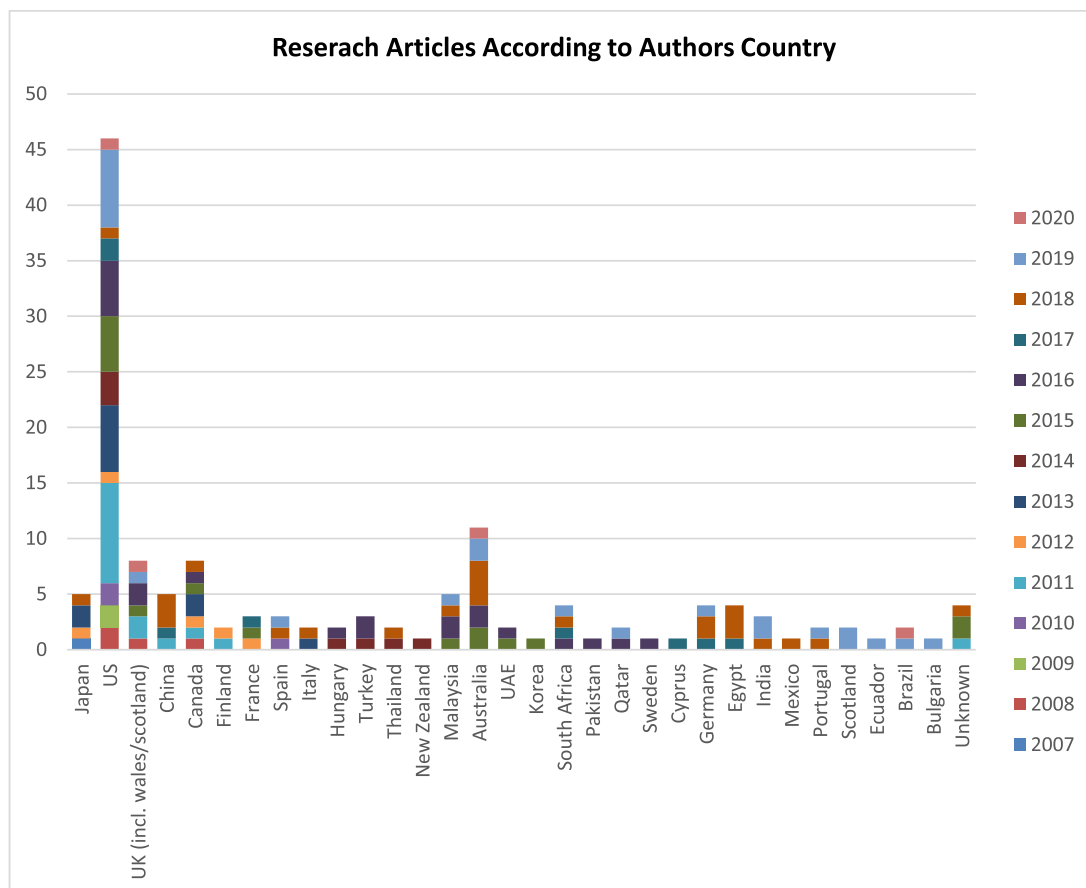


Fig. 8. Timeline of Published Articles according to Authors Country.

publications and researchers. Alternatively, in other developing and emerging economies such as the Philippines, UAE, India, Hong Kong, there is steady growth of research in this area. Consequently, more needs to be done to encourage research interests in urban sustainability in

Africa or focused on African regions, particularly with the use of NSATs to address the aforementioned sustainability issues.

Hence, the first step in addressing this issue is for African countries to realize the importance of NSATs and ideally develop their own NSAT

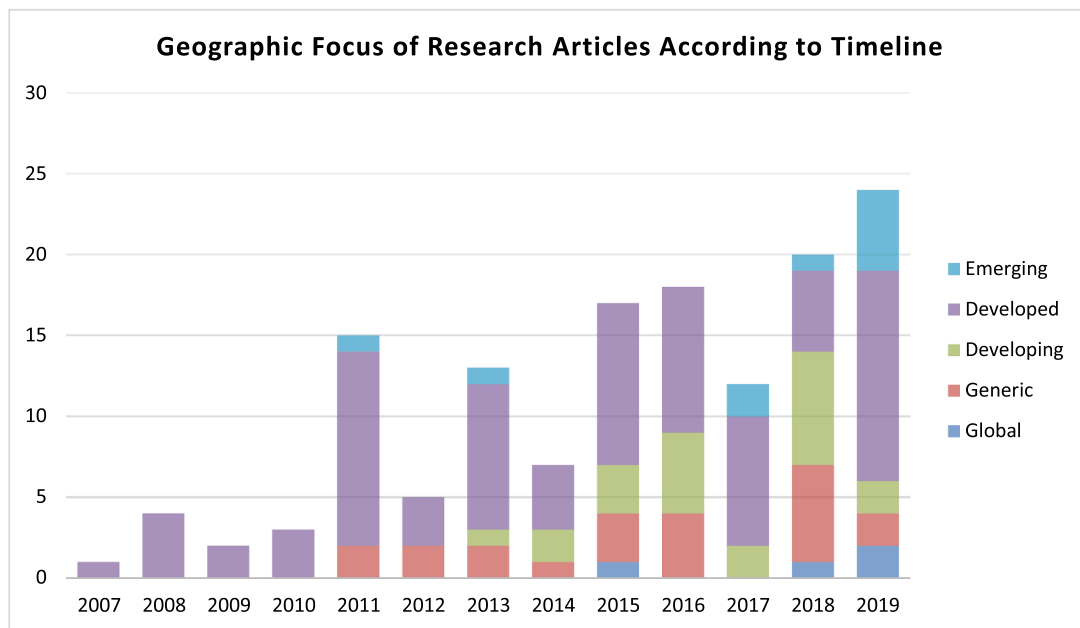


Fig. 9. Timeline of NSAT articles according to Economic region.

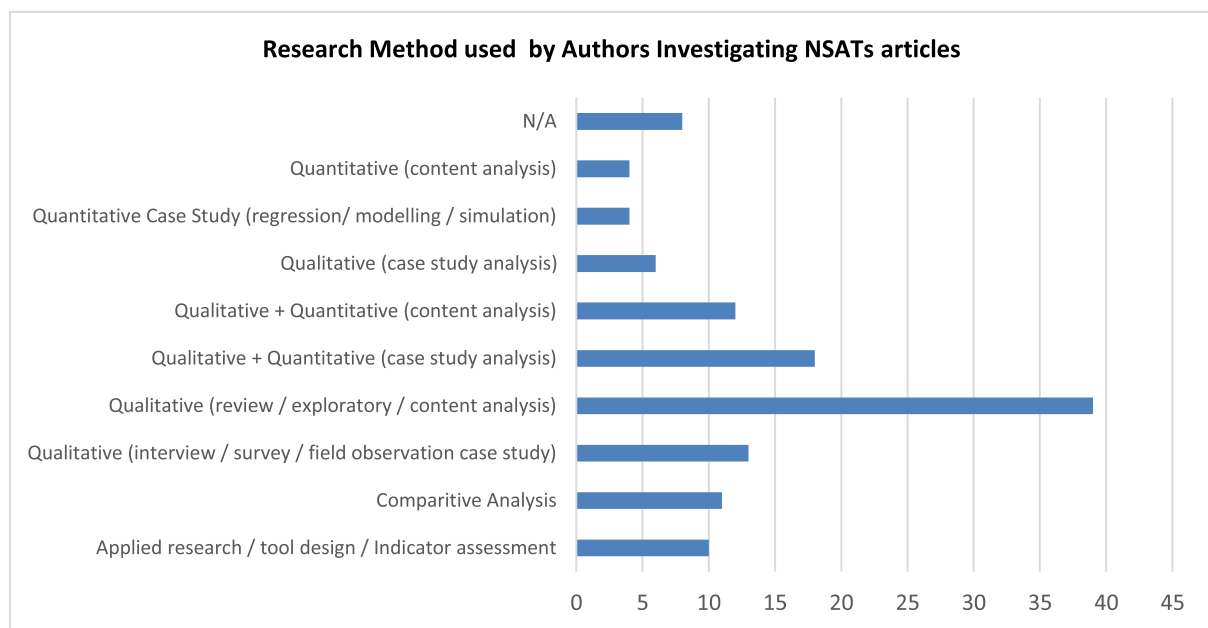


Fig. 10. Type of research conducted by authors investigating NSAT articles.

toolkit or adopt an NSAT from other regions and modify to suit their context. Similar adaptations have been executed for BREEAM in regions all over Europe and Asia [10,35,56]. This enhances the usage of these rating tools in project execution. Furthermore, institutional support would be essential for market penetration in African cities. For example, with BREEAM communities and LEED-ND, the support of the government and associated policies that mandate and/or give incentives for the use of these tools have been significant for NSAT market penetration and the overall boom of urban sustainable development initiatives (Ayotunde [18]). Until this is implemented, a proper case study research on the performance of the NSAT within this region cannot be achieved. Although there are a few BSAT certified buildings in some African cities, this is not enough to address the interconnected nature of the built environment which transcends the assessment of just one building [35].

Fig. 7 depicts the outcome of investigating the trends from the economic regions of these publications, it is observed that the developed region constitute 58% of research in NSAT based projects. However, when viewed from a timeline perspective (see Fig. 9), an increase in publications from developing and emerging countries is detected in more recent years. This is likely due to the development of more third-party assessment tools for instance; the Hong Kong NSAT known as BEAM Plus (Building Environmental Assessment Method Plus Neighborhood) emerged in 2016 and the Philippines also developed their tool known as BERDE NC (Building for Ecologically Responsive Design Excellence – Clustered Residential Development) in 2013. This improves the potential of more research outputs from developing and emerging regions in the future, as it generally takes 2 to 4 years for projects (depending on project scale) to be completed by developers and then

later on investigated by researchers. It should also be noted that research categorized as ‘global and generic stats’ in Figs. 6,7 and 9 refer to the investigation that covers all parts of the world and is not focused on the region but rather on parameters of NSATs.

4.6. Interlinkages between research on various NSATs

The list in Table 2 indicates the publications that were focused on investigating only one NSAT. This was predominantly LEED-ND, the focus was on self-improvement or optimization of either the entire tool or specific criteria and indicators of the tool. For example, a study investigated the optimization of LEED-ND’s method of intersection density measure versus route directness [48]. Their findings suggest that the route directness measure provided a measure of connectivity that is more accurate and effective at ensuring ease of movement in all directions than the method recommended by LEED-ND. Another study, which investigated the Australian developed tool ‘Greenstar’ measured the anticipated uptake of the Green star system and the impact it will have on the Australian construction industry and future urban development [34]. This illustrates the self-improvement theme of the aforementioned tools when studied independently. Elements of individual NSAT studies also involved testing of parameters or indicators to gage or compare local best practices to other/international standards. Generally, most individual analysis tend to test the efficacy of tools in meeting up with some criteria of sustainable urban development. Hence, other publications focused on one just one NSA tool gave an overview and explanation of the properties of the tools and focused on the local implementation, the selection of appropriate indicators or criteria, and the dimension of sustainability involved. An example is the study of Yaman et al. [57] on the Malaysian Green Building Index (GBI) Township tool to evaluate whether the GBI-Township assessment criteria and its variables fulfilled their adaptations to the holistic sustainability dimensions towards sustainable neighborhood development in Malaysia.

Furthermore, a lot of research articles focused on LEED-ND alone in Table 2 executed case study projects [25] which is expected due to the highest number of successful implementations of LEED-ND at both building and urban levels [50]. This high rate of implementation is attributed to the ease of penetration with minimal resistance due to the commercial popularity of LEED-ND and also the geographic size of the US and Northern America in comparison to the UK and Japan (Ayotunde [18]). For tools such as BREEAM-Communities and CASBEE-UD to meet up with the capacity of LEED-ND, they would need to penetrate other markets within other countries of Europe and Asia whose legislation would vary significantly from that of the NSAT origin country. For instance, modified variations of BREEAM-Communities is needed before it is fit for use in other regions of Europe such as BREEAM-NOR and if met with resistance, then such European nations tend to develop their own version of tools, such as the German tool DGNB [35,50].

Interestingly, the UK based BREEAM-Communities is not widely investigated independently by researchers as much as LEED-ND. Exploring further into this observation revealed a trend in the analysis of BREEAM-Communities which tends to be investigated with multiples

Table 2
Number NSAT article that investigated only one tool.

Singular tools investigated	Number of NSAT Articles	Percentage of NSAT Articles
LEED-ND	47	70%
BREEAM-Communities	4	6%
Green Township	3	4.5%
HQE2R	1	1.5%
CASBEE-UD	1	1.5%
Green Building Index GBI	1	1.5%
Green Star Communities	1	1.5%
OTHERS	9	13.5%
	67	
>1 tool studied	50	

tools in different locations such as analysing tools under the context of US, France, Brazil, Vietnam, or analysing several cities within one location or region [16,23,26,53]. This was particularly the case for Europe and America. For instance, LEED focused more on several cities within the US and BREEAM is mostly utilized in the cross-evaluation analysis for optimizing an existing tool or assisting in the development of future tools (see Table 3). Essentially, Tables 2 and 3 presents the analysis of the 100 plus articles indicate that LEED-ND is the predominant tool of investigation by authors (see Table 1) while investigations on BREEAM-Communities are seldom performed without comparison or evaluation with other tools (see Table 2). Similar argument can be made for CASBEE-UD. Although, other tools like PCRS, DGNB, GSAS when investigated are also rarely studied alone [2,27,58], this is likely due to the fact that research under these tools focus on optimization and enhancement. These three tools represent unique cultural, climatic, geographical, and institutional variables that would provide insight to communities deemed to be developing or emerging. A key reason for investigating several tools in one study is for filtering context-specific themes, determining commonalities within the tools and the potential for application to a wider audience (e.g. cultural diversity, calculation methods, and indicator selection methods) and knowledge sharing for inapplicable projects (what went wrong?, what were the reason?), thus providing insight into market penetration and optimizations strategies ([3,10]; Ayyoob [43]).

Such investigations would synergize and compare best practices and commonalities that may be adopted by other tools or neglected. Therefore, the pioneering tools i.e. BREEAM-Communities, LEED-ND, and CASBEE-UD are mostly used for improving or assisting in the development of new tools or improving the performance of an existing tool from developing or emerging nations. This is particularly true for BREEAM-Communities. Meanwhile, LEED-ND research also strongly focused on self-improvement and self-optimization.

5. Summary and Conclusions

This study has explored NSAT-related research articles published over the last two decades, in total 117 articles were reviewed, and key observation and recommendation have been made to determine the research trends and impact of NSATs on the built environment since the first emergence of NSATs research in literature. In terms of the research method utilized, it was observed that research was predominantly qualitative (review/exploratory/content analysis) in nature. However, more accurate, context-relevant and real time results would be achieved from more performance-based investigations that incorporate survey and field observation results. The results also indicate the impact of international frameworks such as SDGs in promoting research into various NSAT related topics. This has covered topics such as resilience, smartness, health and wellbeing, security, etc. Whilst NSAT projects and publications have generally been on the rise, the tools may need to incorporate more health and resilience-based dynamics to remain relevant in solving most of the world’s current issues such as COVID-19. The tools may also need to factor in the effects NSAT approach on

Table 3
Number NSAT articles that investigated multiple tools in one article.

>1 tool studied Breakdown	Number of NSAT Articles	Percentage of NSAT Articles
LEED + BREEAM + CASBEE + (others)	28	56%
BREEAM + LEED	3	6%
LEED + BREEAM + others	3	6%
BREEAM + CASBEE + (others)	1	2%
BREEAM + others	2	4%
LEED + others	10	20%
Others >1	3	6%
	50	

Table 4
NSATs studied in the reviewed literature and represented - Fig. 1 to Fig. 10.

No.	Tool	Main developer (s)	Origin	Year	Latest version	Count
1	SNM (Successful Neighbourhood Model)	Moroke et al., (2019)	South Africa	2019	-	1
2	Comprehensive Assessment Method for Sustainable Urban Development (CAMSUD)	Ali-Toudert et al., (2019)	[2]ny	2019	-	1
3	Assessment Standard for Green Eco-districts (ASGE)	Ministry of Housing and Urban-Rural Development of the People's Republic of China	China	2018	-	1
4	Green Star SA (South Africa)	Green Building Council South Africa	South Africa	2017	-	1
5	Building Environmental Assessment Method (BEAM) Plus Neighbourhood Assessment Tool	Hong Kong Green Building Council	Hong Kong (China)	2016	-	1
6	Conavi CEV Mexican Code	National Housing Commission	Mexico	2015	-	1
7	Green Rating for Integrated Habitat Assessment (GRIHA LD)	GRIHA Council and The Energy and Resources Institute	India	2015	-	2
8	Circles of Sustainability	UN Global Compact Cities Programme	Australia	2014	-	1
9	Living Community Challenge	International Living Future Institute	US	2014	2017	1
10	EcoDistricts	EcoDistricts	US	2012	-	2
11	EcoQuartier	Ministères Transition écologique Cohésion des territoires	France	2012	2020	1
12	Green Star Communities	Green Building Council Australia (GBCA)	Australia	2012	2016	11
13	DGNB for Districts	German Sustainable Building Council	Germany	2012	-	5
14	STAR Communities	STAR Communities (now merged with the USGBC)	US	2012	2016	4
15	AQUA Bairro e loteamento label	Fundação Vanzolini	Brazil	2011	-	2
16	GBI Township	Greenbuildingindex Sdn Bhd (GSB)	Malaysia	2011	-	5
17	2030 Districts	Architecture 2030	US	2010	-	1
18	EEWH Assessment System for Eco-community	Architecture and Building Research Institute	Taiwan	2010	-	1
19	Pearl Community Rating System	Abu Dhabi Urban Planning Council	UAE	2010	-	8
20	Sustainable Sites Initiative (SITES)	American Society of Landscape Architects	US	2009	2015	1
21	LEED-ND	US Green Building Council (USGBC)	US	2009	2018	88
22	BREEAM Communities	Building Research Establishment (BRE Global)	UK	2009	2012	40
23	BCA Green Mark for districts	Building and Construction Authority (BCA)	Singapore	2009	2017	5
24	GreenTRIP	TransForm	US	2008	-	1
25	IGBC Green Townships	Indian Green Building Council	India	2008	-	6
26	CASBEE-UD	The Institute for Building Environment and Energy Conservation (IBEC)	Japan	2007	2014	30
27	Global Sustainability Assessment System (GSAS)	Gulf Organization for Research and Development	Qatar	2007	-	6
28	Sustainable Building Tool (SBTool)	International Initiative for a Sustainable Built Environment (iisBE)	Canada	2007	2020	2
29	Sustainable Community Rating (SCR)	VicUrban, the Victorian Government's land development agency	Australia	2007	-	2
30	EnviroDevelopment	Urban Development Institute of Australia (UDIA)	Australia	2006	-	4
31	VicUrban Sustainability Charter (Master Planned Community Assessment Tool)	Government of Victoria	Australia	2006	-	1
32	Wulvern Indicators of Neighbourhood Sustainability (WINS)	Wulvern	UK	2006	-	1
33	Neighbourhood Sustainability Framework (NSF)	Beacon Pathway	New Zealand	2005	2014	4
34	EarthCraft Communities	Greater Atlanta Home Builders Association, the Atlanta Regional Commission, the Urban Land Institute, etc.	US	2005	2014	3
35	Enterprise Green Communities	Enterprise Community Partners	US	2004	2020	1
36	One Planet Communities	BioRegional Development Group	UK	2004	-	3
37	Ecocity	EU research project	EU	2002	-	3
38	HQE2R	Scientific and Technical Center for Building (CSTB)	France	2001	-	8
39	SPeAR (Sustainable Project Appraisal Routine)	ARUP (Arup Group Limited)	UK	2000	2017	1
40	Green Township Index	Siew (2018)	Malaysia	No data	-	2
No.	Tool	Main developer (s)	Origin	Year	Latest version	Count
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7	Green Rating for Integrated Habitat Assessment (GRIHA LD)	GRIHA Council and The Energy and Resources Institute	India	2015	-	2
8	Circles of Sustainability	UN Global Compact Cities Programme	Australia	2014	-	1
9	Living Community Challenge	International Living Future Institute	US	2014	2017	1
10	EcoDistricts	EcoDistricts	US	2012	-	2
11	EcoQuartier	Ministères Transition écologique Cohésion des territoires	France	2012	2020	1
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13	DGNB for Districts	German Sustainable Building Council	Germany	2012	-	5
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15	AQUA Bairro e loteamento label	Fundação Vanzolini	Brazil	2011	-	2

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Table 4 (continued)

16	GBI Township	Greenbuildingindex Sdn Bhd (GSB)	Malaysia	2011	-	5
17	2030 Districts	Architecture 2030	US	2010	-	1
18	EEWH Assessment System for Eco-community	Architecture and Building Research Institute	Taiwan	2010	-	1
19	Pearl Community Rating System	Abu Dhabi Urban Planning Council	UAE	2010	-	8
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21	LEED-ND	US Green Building Council (USGBC)	US	2009	2018	88
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39	SPeAR (Sustainable Project Appraisal Routine)	ARUP (Arup Group Limited)	UK	2000	2017	1
40	Green Township Index	Siew (2018)	Malaysia	No data	-	2

Environmental justice. Furthermore, the emerging importance of smartness and big data analytics globally necessitates its inclusion within the built environment and NSAT research, as this is crucial for enhancing the ability of assessment tools in achieving urban sustainability.

The impending SDG deadline calls for the creation of a similar international framework committed to the sustainability of the global community which is essential for driving innovation and improvements in NSATs research. Additionally, an improvement in the participation of developing regions in NSAT research and development were observed in recent years. Further increase in this trend is required to provide comprehensive improvements and insights towards the context-specific requirements of NSATs in these regions. The lack of NSAT research in African regions is quite concerning due to the vulnerability of the regions to the consequences of inadequate actions in addressing climate change issues. Thus, awareness programs, local and international funding agencies, Government parastatal need to target incentives and grants that could aid and raise research interest in areas specifically dedicated assessment tools. The academic institution within these regions also needs to upgrade their institutional policies and incentives to motivate researchers into this field of study.

Language translation was noted to be another key consideration that improves the uptake and research interests in NSAT tools. The results indicated that LEED-ND contributed largely to the research articles in this field due to its proportionately larger number of implemented projects. In addition, the growth in the emergence of regionally developed context-specific tools was discerned. This approach should be encouraged as it creates a new industry that facilitates sustainability and stimulates job creation. This would be particularly advantageous for developing and emerging economies. Overall, results showed dominant research focus on the big three, in particular BREEAM-Communities has had a strong impact on the research and development of NSATs, which has subsequently led to development and/or improvements of newly developed tools. It should be noted that with the method used there are chances of missed publications for instance journals published in various other languages. However, the sample set obtained represents the most

comprehensive approach due to the databases chosen, which represent the largest repository on the coverage of NSAT related articles.

In conclusion, this study has reviewed the trend and gaps of NSAT-related publications over the last decade to determine areas of improvement and enhancement in the ever-changing landscape of sustainable urban development. The observations and recommendations given in this study are not only pertinent to developers and industry experts, but they also consider the role of researchers in enhancing the development of NSATs. The recommendations proffered are crucial in the age of big data and climate change where smart and resilience-based research has gained momentum with more emphasis on health and wellbeing due to the recent pandemic. Thus, it becomes imperative to focus on the aforementioned areas in future studies and implement some of the recommendations made to address the current situation of NSAT development.

Declaration of Competing Interests

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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Appendix A: Search String

TITLE-ABS-KEY ("neighbo*rhood sustainability assessment" OR "neighbo*rhood sustainability framework" OR "LEED for neighbo*rhood development" OR "LEED-ND" OR "BREEAM Communities" OR "CASBEE for urban development" OR "CASBEE-UD" OR "EarthCraft Communities" OR "HQE2R" OR "HQE2R" OR "Haute Qualité Environnementale et Economique Réhabilitation" OR "High Quality

Environment and Economy in Regeneration” OR “HQE for Urban Planning & Development” OR “VicUrban Sustainability Charter” OR “Master Planned Community Assessment Tool” OR “sustainable community rating” OR “Aqua for Neighborhoods” OR “BEAM Plus Neighborhood” OR “BERDE for Clustered Residential Development” OR “Climate Positive Development” OR “DGNB for Business Districts” OR “DGNB for urban Districts” OR “DGNB for Industrial Locations” OR “Enterprise Green Communities” OR “EnviroDevelopment” OR “GBI Township Tool” OR “Green Building Index Township Tool” OR “Global Sustainability Assessment System for Districts” OR “Global Sustainability Assessment System” OR “Green Land Development” OR “Green Mark for Districts” OR “Green Star Communities” OR “Green Townships” OR “One Planet Communities” OR “Pearl Community Rating System” OR “Signature Sanctuary Program” OR “2030 Districts” OR “AARP Livability Index” OR “Living Community Challenge”, OR “EcoDistricts”)

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