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Progress and Methodological Approaches in Urban Trees and Forests Research in Africa

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Abstract
The numerous benefits of urban trees and forests are being increasingly recognised globally but grossly under studied in the developing world. This paper reviewed the methodological approaches to urban trees and forests assessments in Africa in relation to the growing number of publications in the field between 2012 and 2017. It adopted a comprehensive search of online publications related to urban trees and forests in the Google Scholar, Springer, Science Direct, Scopus, IEEE, Tailor and Francis and African Journals databases. Number of publications increased steadily from 2 in 2012 to a cumulative total of 44 in 2017, most of which were however, from South Africa, Nigeria and Ghana with little contributions from Kenya and Rwanda. Although remote sensing may facilitate detailed studies of urban trees, most researchers used the traditional and time-consuming field surveys and to some extent, interview and questionnaire surveys. African cities are highly diverse in both native and exotic tree species but the exotic species dominate in many areas. Urban trees in Africa provide both tangible and intangible benefits which include provision of income, fruits, medicines, fuelwood and recreation opportunities. Others are micro-climate modification, erosion and desertification control, pollutants removal, spirituality and aesthetics. Advances in urban tree assessments such as the use of i-Tree Eco and i-Tree Streets, high resolution remote sensing images and LiDAR should be explored. Governmental and private organizations need to be more committed to urban trees research and management through enhanced funding.
Keywords: Africa; Urbanization; Urban Trees; Urban Forests; Diversity; Remote Sensing
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1. Introduction

As the world populations increasingly become urban, cities need to adopt integrated urban planning and management (du Toit et al., 2018) which may include a nature-based approach that allows humans to access the various benefits of nature (Ostoić, Salbitano, Borelli, & Verlič, 2018), such as those provided by urban trees and forests (Fuwape & Onyekwelu, 2011). In Africa, urbanization is envisaged to continue and possibly account for 21% of the global total by the year 2050 (United Nations, 2014). This will continue to expose global urban ecosystems to serious pressure and damages (Roy, Byrne, & Pickering, 2012) hence reducing the quality of life in urban areas (Ostoić et al., 2018). In order to achieve sustainable urban development therefore, there is the need for a corresponding increase in integrating trees into urban planning (Dobbs, Kendal, & Nitschke, 2014; Li, Wang, Paulussen, & Liu, 2005) and developing sound strategies and policies to manage them (Gong, Yu, Joesting, & Chen, 2013).

Urban trees and urban forests are both subsets of the broader term of urban green space. Their roots could all be traced to urban forestry which emerged as a distinct field of study at the University of Toronto in 1965 (Randrup, Konijnendijk, Dobbertin, & Prüller, 2005) even though it was first mentioned in the United States in 1894 (Konijnendijk, Ricard, Kenney, & Randrup, 2006). The term urban tree was typically defined as a woody perennial plant growing in towns and cities, having a single stem or trunk and usually having a distinct crown (Roy et al., 2012). It may be recently planted or old-growth remnant forests on public or privately owned land (Ferrini, Bosch, Fini, Morgenroth, & Östberg, 2017). Urban trees thus refer to all publicly and privately owned trees within an urban area including individual trees, trees along streets and in backyards, as well as stands of remnant forests (Nowak et al., 2010). Urban forests on the other hand include all urban trees, shrubs, lawns, and pervious soils located in urban areas with humans primarily determining their types, amounts, and distribution (Escobedo, Kroeger, & Wagner, 2011).

Urban trees and forests are natural and important components of biodiversity in urban landscapes which provide ecological, economical, and social benefits to the people (Gong et al., 2013; Hernández & Villaseñor, 2018). Their composition and diversity are becoming increasingly relevant (Dahlhausen, Biber, Rötzer, Uhl, & Pretzsch, 2016; Jim & Chen, 2009) for both academic (Morgenroth et al., 2016) and overall urban sustainability purposes (Blood, Starr, Escobedo, Chappelka, & Staudhammer, 2016; Konijnendijk, Sadio, Randrup, & Schipperijn, 2004) hence the need for their protection and promotion (Alvey, 2006). These are crucial for maintaining ecosystem processes and services (Hooper & Vitousek, 1997) such as controlling natural enemies, reducing the risk of pest damage and ensuring the health and growth of the saplings (Riihimäki et al., 2004).

Urban tree composition and diversity insure the security of ecosystems against environmental changes and stochastic events by increasing their potential for adaptation and survival (Alvey, 2006). They facilitate the provision of important services such as shaping, protecting and modifying the micro climates of urban landscapes (Agbelade, Onyekwelu, & Apogbona, 2016a), carbon storage and sequestration (Nowak et al., 2013; Tang, Chen, & Zhao, 2016), providing shade and habitat for people and birds (Agbelade, Onyekwelu, & Oyun, 2017), providing recreational and spiritual amenities (Babalola, Borokin, Onefeli, & Muchie, 2013; Sheona, Chinyimba, Hebinck, Shackleton, & Kaoma, 2015; van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012) as well as aesthetics (Kuruneri-Chitepo & Shackleton, 2011) which people enjoy. In the light of this, scholars and policy makers focus attentions on evaluating and developing the potentials of urban trees to curve some of the menaces associated with urbanization including noise, carbon pollution, soil erosion, habitat loss, and species loss (Roy et al., 2012).

2. Background and Purpose

Although a relatively new field of study (Nilsson, Konijnendijk, & Randrup, 2005), research in urban trees and urban forests in general has gone a long way in the developed countries and has covered a variety of topics ranging from composition, diversity and distribution (Avolio et al., 2015; Nock, Paquette, Follett, Nowak, & Messier, 2013; Sjöman, Östberg, & Bühler, 2012; Wang, Qin, & Hu, 2015), ecosystems services and disservices (Escobedo, Giannico, Jim, Sanesi, & Lafortezza, 2018; Luederitz et al., 2015), economic benefits (Song, Tan, Edwards, & Richards, 2018), biomass and carbon stock (Nowak et al., 2013; Raciti, Hutyra, & Newell, 2014) and vulnerability and invasiveness (Steenberg, Millward, Nowak, Robinson, & Ellis, 2017) among others. Much of these studies were carried out mainly in North America and Europe (Escobedo et al., 2018; Kuruneri-Chitepo & Shackleton, 2011; Nielsen, van den Bosch, Maruthaveeran, & van den Bosch, 2014; Roy et al., 2012; Shackleton, 2012; Zhao et al., 2013) but there is also a growing number of studies being conducted in Asia (e.g. Intasen, Hauer, Werner, & Larsen, 2017; Nagendra & Gopal, 2010b, 2010a; Sreetheran, Adnan, & Azuar, 2011).

In the developing world and especially Africa however, urban trees and forests are not adequately studied (Seburanga, Kaplin, Zhang, & Gatesire, 2014) even though these countries have higher levels of biodiversity. This may partly be due to weak planning institutions and policy directions, inadequate development and management guidelines (Cobbinah & Darkwah, 2016) and lack of substantial research commitment and funding (Shackleton, 2012). Roy et al (2012) for instance, conducted a global review of urban tree benefits, costs, and assessment methods but found only six publications from Africa. Nielsen et al. (2014) focussed specifically on methods used to collect urban tree data at single-tree level but found no study from Africa that suited their inclusion criteria. In 2015 however, little improvement was recorded by Luederitz et al. (2015) who found 20 publications from the continent.

Some researchers thus found it pertinent to echo their concerns about the relative neglect of the discipline in these areas. Shackleton (2012) expressed concern about the low popularity of urban forestry in the developing world which was poorly represented in the urban forestry peer-reviewed literature. This was partly due to relative lack of research funding and personnel from these countries. Hosek (2014) also reviewed literary works in the area to identify and discuss issues that have so far received limited attention. Although the review revealed a gradual increase in the number of publications, most of the papers were from South Africa, Nigeria, Ghana, Kenya and Ethiopia. Mensah (2014b) also assessed the nature and challenges of green spaces in Africa and found that they were to a great extent, determined by the ecological zones and climate of the continent rather than by human management which is negligible or non-existent.

In 2018, Toit et al. (2018) reviewed studies on urban green infrastructure and their associated ecosystem services in sub-Saharan African cities and found an impressive number of 68 studies distributed across 74 cities of 20 African countries. Escobedo et al. (2018) also found appreciable participation of African countries in the global research constellation of the nexus between urban forests, ecosystem services and nature-based solutions. This study expressed optimism that Africa is coming up and will likely catch-up with the United States and Europe or even exceed them. It could thus be deduced that, although urban trees and forests have not been given adequate and appropriate scholarly attention in the continent over the years, there is growing trend of awareness and research commitment in the area and thus, the benefits of these resources are being continuously uncovered and communicated to the wider African public.

Despite the seeming promises, not much has been discussed about the methodological approaches employed in the African context. The purpose of this paper therefore, is to fill this gap by examining the methods used in assessing urban trees and forests in Africa parallel to the increase in the number of publications in the field between 2012 and 2017. This information is crucial for defining the present status and future prospects of urban trees studies in Africa. The paper adopted a comprehensive approach where all materials published in English language between January, 2012 and December, 2017 were included. Searches were conducted in Google Scholar, Springer, Science Direct, Scopus, IEEE, Tailor and Francis and African Journals databases using the phrases “urban tree”, “urban forest”, “urban area” and “Africa”. Research and policy gaps that need to be filled in the future were also highlighted.

3. Urban Trees and Forests Assessments in Africa

Urban tree assessments are designed to collect information about tree species, their location and overall health. The data gathered is useful for diversity conservation and management, teaching and learning as well as advocacy for forest programs and support (Alvey, 2006). To achieve this, a number of approaches are employed. The selection of an appropriate method however, depends on the amount of precision and detail needed for the final product (McCoy, 2005). Our review found a total of 44 papers spanning the different aspects of urban trees and forests published between 2012 and 2017 in the continent (Table 1).

Table 1: Studies carried out on Urban Trees and Forests in Africa between 2012 and 2017

S/N	Publication	City/Country	Methodology									
			Field Survey	Desktop Analysis	Economic Valuation	FGD	Household Survey	Interview	Observation	Questionnaire Survey	Review	RS/GIS
1	Bigirimana et al. (2012)	Bujumbura, Burundi	✓									
2	Shackleton, C. M. (2012)	Developing World		✓								
3	Babalola et al. (2013)	Ibadan, Nigeria	✓									
4	Barau, Ludin and Said (2013)	Kano city, Nigeria	✓					✓				✓
5	Cilliers et al. (2013)	Africa									✓	
6	O'Donoghue and Shackleton (2013)	Eastern Cape Province, South Africa	✓									
7	Oyebade et al. (2013)	Uyo, Nigeria								✓		
8	Schäffler and Swilling (2013)	Johannesburg, South Africa			✓							
9	Seburanga and Zhang (2013)	Kigali, Rwanda	✓	✓								
10	De Lacy and Shackleton (2014)	Grahamstown, South Africa	✓							✓		
11	Eludoyin et al. (2014)	University of Port Harcourt, Nigeria	✓									
12	Hosek, L. (2014)	Africa									✓	
13	Kaoma and Shackleton (2014a)	Limpopo and North-West provinces, South Africa	✓					✓				✓
14	Kaoma and Shackleton (2014b)	Tzaneen, Bela Bela and Zeerust towns, South Africa	✓					✓				✓
15	Lwasa et al. (2014)	Africa	*								✓	
16	Mensah, C. A. (2014a)	Kumasi, Ghana				✓		✓	✓			
17	Mensah, C. A. (2014b)	Africa									✓	
18	Mosina et al. (2014)	Limpopo Province, South Africa	✓					✓	✓			
19	Seburanga et al. (2014)	Kigali, Rwanda	✓	✓				✓				✓
20	Chishaleshale et al. (2015)	Limpopo and Eastern Cape Provinces, South Africa						✓				
21	Cilliers and Cilliers (2015)	Potchefstroom, South Africa			✓							
22	Ezeabasili et al. (2015)	Awka, Nigeria						✓		✓		
23	Gwedla and Shackleton (2015)	Eastern Cape province, South Africa	✓					✓				
24	Kaoma and Shackleton (2015)	Limpopo and North-West provinces, South Africa					✓	✓				
25	Shackleton et al. (2015)	Northern South Africa					✓	✓				
26	Agbelade et al. (2016a)	Ibadan, Nigeria	✓									
27	Agbelade et al. (2016b)	Abuja and Minna, Nigeria	✓							✓		
28	Furukawa et al. (2016)	Nairobi, Kenya	✓									
29	Nyambane et al. (2016)	Nairobi, Kenya	✓									
30	Hungerford & Moussa (2016)	Niamey, Republic of Niger	✓				✓					

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S/N	Publication	City/Country	Methodology									
			Field Survey	Desktop Analysis	Economic Valuation	FGD	Household Survey	Interview	Observation	Questionnaire Survey	Review	RS/GIS
31	Ogwu et al. (2016)	University of Benin, Benin City Nigeria	✓									
32	Shackleton and Shackleton (2016)	Grahamstown, South Africa					✓					
33	Shackleton et al. (2016)	Eastern Cape Province, South Africa					✓	✓				✓
34	Uka and Belford (2016)	Kumasi, Ghana	✓									
35	Shackleton, C. M. (2016)	Grahamstown, South Africa	✓									
36	Agbelade et al. (2017)	Abuja, Nigeria	✓							✓		✓
37	Dingaan and Preez (2017)	Bloemfontein, South Africa	✓									
38	Gwedla and Shackleton, (2017)	Eastern Cape province, South Africa	✓									
39	Muchayi et al. (2017)	Chinhoyi, Zimbabwe	✓									
40	Nero, B. F. (2017)	Kumasi, Ghana										✓
41	Nero et al. (2017)	Kumasi, Ghana	✓									
42	Nero et al. (2017)	Kumasi, Ghana	✓									✓
43	Ogunkalu et al. (2017)	Kaduna, Nigeria								✓		
44	Woldegerima et al. (2017)	Addis Ababa, Ethiopia	✓									

Only two of these were recorded in 2012 but this number consistently increased over the years. The highest number of publications were however recorded in 2014 and 2016 (Figure 1).

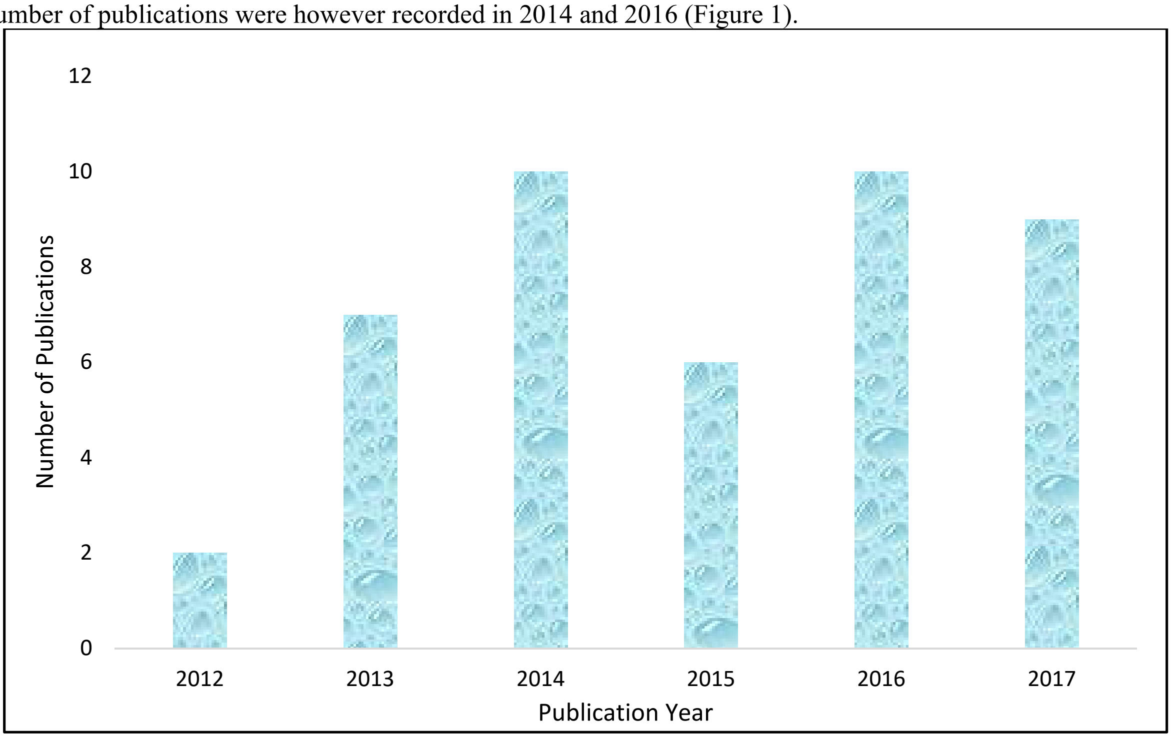

Figure 1: Annual Urban Tree and Urban Forest publications in Africa 2012 – 2017

The spatial distribution of these publications (Figure 2) showed that they came from only nine with South Africa (38.6%), Nigeria (22.7%) and Ghana (11.6%) having the highest number of the publications. Kenya and Rwanda had two publications each while Ethiopia, Burundi, Republic of Niger and Zimbabwe had 1 publication each. One publication focussed on developing countries as a whole while 4 (9%) focussed on Africa in general.

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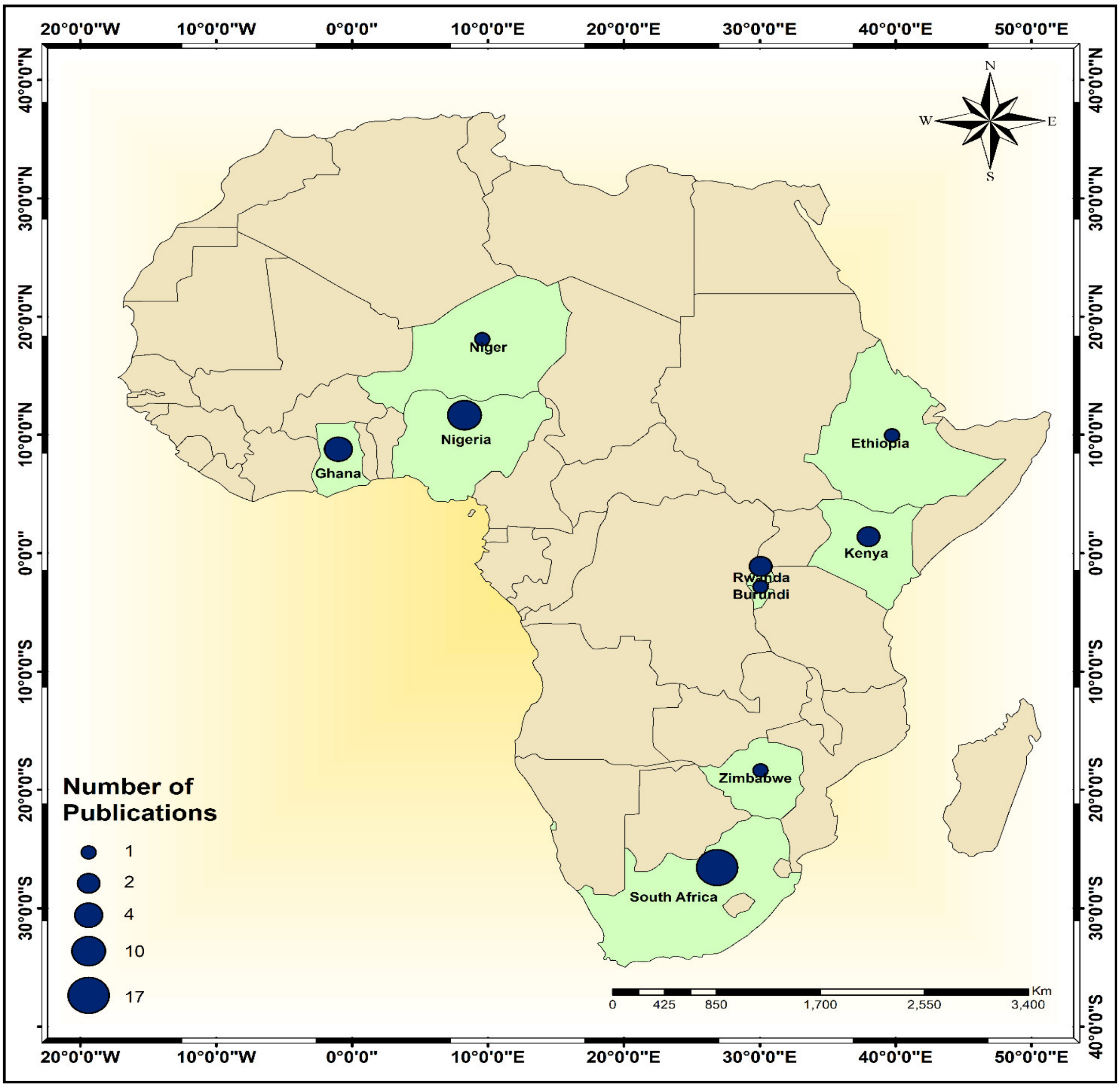

Figure 2: Distribution of Urban Tree and Urban Forest publications in Africa between 2012 and 2017

From this review, field survey which was used in 48% of the papers form a greater portion of the approaches to urban tree assessment in Africa (Figure 3). This was in some cases combined with interviews for optimum results (e.g. Agbelade et al., 2017; Kuruneri-Chitepo & Shackleton, 2011; Shikur, 2012) or photogrammetric data (Seburanga et al., 2014; Seburanga & Zhang, 2013). In their study, Fuwape and Onyekwelu (2011) combined the analysis of secondary data and questionnaire survey to determine the benefits and problems of urban forestry in West Africa sub region. Seburanga et al. (2014) also combined desktop assessment, interviews, vegetation surveys and a photogrammetric analysis of remotely acquired imagery in assessing amenity trees in Kigali, Rwanda. Interviews and questionnaire surveys were also widely used as 18% of the papers used interviews while 6.5% used questionnaire surveys.

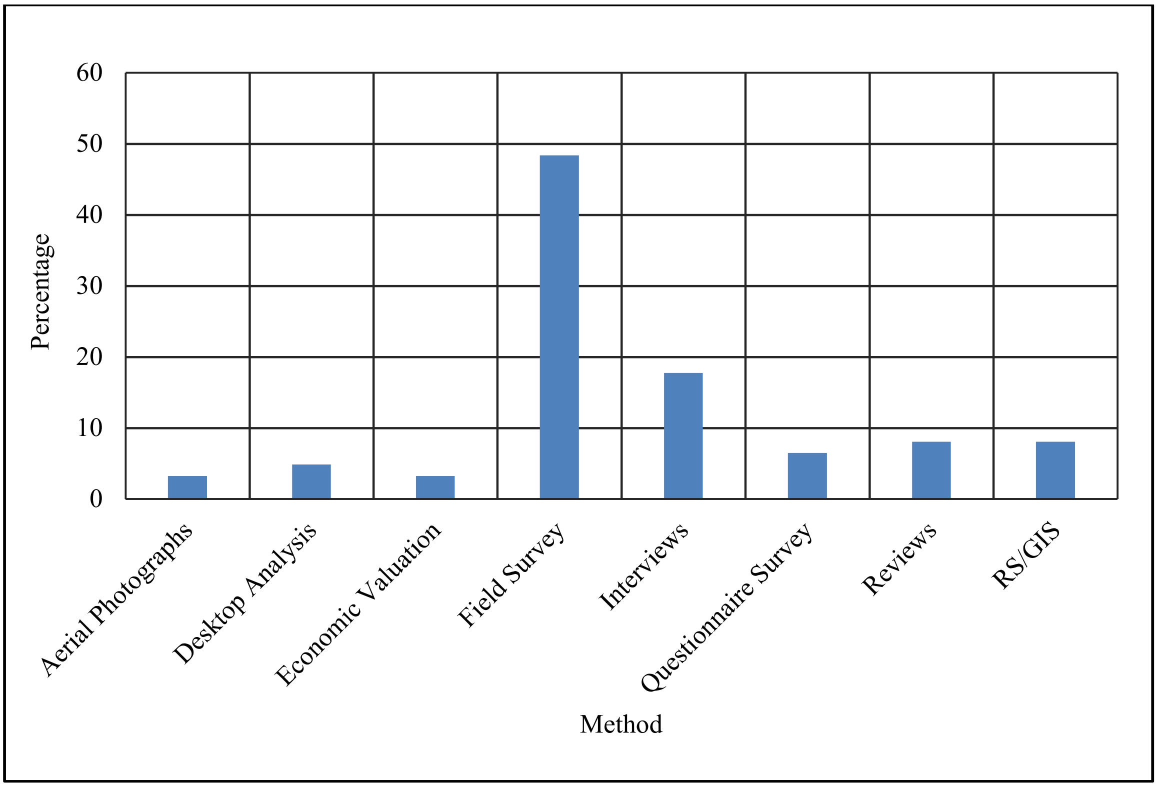

Figure 3: Methodological approaches to urban trees and forests studies in Africa 2012 – 2017

Remotely sensed satellite images, aerial photographs or a combination of the two provide promising results in urban tree assessments (Miller, 1996). Remote sensing especially using high resolution satellite images such as QuickBird, IKONOS, GeoEye, RapidEye, Worldview-2 and SPOT or light detection platforms such as LiDAR (light detection and ranging) allows for a wider and refined observation of objects (Shugart, Saatchi, & Hall, 2010). This approach is however plagued by relative inaccessibility to high resolution data due to its prohibitive cost (Fisher et al., 2016). In Africa however, little is documented on the use of remote sensing for urban tree and forest assessments. Only about 8% of the studies used an aspect of RS and GIS and the few studies that were identified (e.g. Nero, 2017; Thenkabail et al., 2003) used the freely available, moderate resolution Landsat data or combined it with one high resolution data for either comparison or complementation. Aerial photographs on the other hand was used in only two studies.

4. Urban Trees and Forests Diversity in Africa

Urban areas in Africa and other tropical areas house a great diversity of tree species (Dolan, Aronson, & Hipp, 2017; Kjelgren, Baguinon, & Yok, 2011; Morgenroth et al., 2016). These urban areas therefore have higher probabilities of sampling effects which connotes having species that optimally utilize environmental opportunities (Downing, van Nes, Mooij, & Scheffer, 2012) thus enhancing their productivity and stability over time (Oehri, Schmid, Schaepman-Strub, & Niklaus, 2017). In most urban areas of Africa, trees are usually planted around houses, squares and along streets for the tangible ecosystem services they provide such as provision of fruits and nuts, fuelwood and fodder and shade for socio-cultural gatherings (Agbelade et al., 2017; Fuwape & Onyekwelu, 2011; Nowak & Dwyer, 2007). In most cases however, the selection and design of trees along streets and in institutional areas in the continent reflect colonial forestry programmes (Hungerford & Moussa, 2016).

Urban trees and forests in the continent are typically composed of both native and exotic species though their respective percentages differ across landscapes. The composition, diversity and values of urban trees and forests are more often, unevenly distributed. It has been shown that these attributes are to a great extent affected by the relative wealth of towns or socio-economic status of the people (Bigirimana, Bogaert, De Cannière, Bigendako, & Parmentier, 2012; S. Cilliers, Cilliers, Lubbe, & Siebert, 2013; Gwedla & Shackleton, 2015). Similarly, the environment in which urban trees are found had a significant bearing on tree density (Kaoma & Shackleton, 2014b), carbon density (Woldegerima, Yeshitela, & Lindley, 2017) and growth rates (De Lacy & Shackleton, 2014).

Although the dominance of native species over the exotic ones was highlighted (Nyambane, Njoroge, Watako, & Onyango, 2016; Uka & Belford, 2016; Yan & Yang, 2017), studies show increasing dominance of exotic species and their accompanying richness above the surrounding natural or semi-natural habitats (Morgenroth et al., 2016). Shackleton (2016) for instance, found tree species composition in Grahamstown (Eastern Cape province of South

Africa) to be 64.6% alien and 35.4% native. Similarly, Shikur (2012) found exotic tree species to account for between 60 and 80% in Addis Ababa, Ethiopia while Seburanga et al. (2014) found exotic species to account for 75% in urban settlements of Kigali, Rwanda. In Nigeria, Babalola et al. (2013) and Agbelade et al. (2017) reported more exotic than native species in Ibadan and the Federal Capital Territory, Abuja respectively.

This implies an increasing dominance of exotic trees species in the continent hence, raising the fear of gross alterations in the abundances of native species and their exposure to increased risk of local extinction (Farmilo et al., 2014). The native species may thus be outcompeted in the long run (Morgenroth et al., 2016) thus agreeing to McKinney's (2006) concept of biotic homogenization. Although the exotic species have some negative impacts on ecosystems, they may influence the ecological and economic value of urban forests (Riley, Herms, & Gardiner, 2016). There is thus the need for careful selection and monitoring of urban tree schemes which can be achieved with better understanding of the composition and diversity of urban trees in the continent as well as the various factors and processes that affect it.

5. Values of Urban Trees and Forests in Africa

Biodiversity in general has both tangible and intangible benefits which include economic, ecological, climate and physical, aesthetic and social benefits (Tyrväinen, Pauleit, Seeland, & De Vries, 2005). As summarized by Fuwape and Onyekwelu (2011), urban trees in Africa were variously reported to provide urban populations with the above functions in varying capacities. The tangible benefits that trees provide include provision of fruits and other edible plants, medicine, fuel wood and timber for construction. The intangible benefits were referred to as the environmental services such as provision of shade against the scorching effects of the sun, amelioration of high temperatures in the Sudan and Sahel Savannah zones, wind breaks and desertification control in arid regions, reducing erosion in erosion prone areas (e.g. Imo, Anambra, Abia, and Enugu states in Nigeria). These trees also mitigate climate change impacts by sequestering and storing carbon and improving the mental health of people through their cultural and spiritual values. Bertrand et al. (2017) reported a reduction of up to 2,180,845 metric tonnes of carbon by trees in Kumasi, Ghana.

A number of studies in Nigeria (Agbelade et al., 2016a; Babalola et al., 2013) and South Africa (Sheona et al., 2015) have revealed that urban and peri-urban trees provide environmental/ecological values such as beautification, protection of houses and provision of shade, habitat for some birds, serving as phorophytes for orchids and other epiphytes and generally improving peoples' social interaction and children outdoor playing. They also have economic values such as being sources of food, nutrition supplement, fuelwood and animal fodder (Agbelade et al., 2017). Another important value of African urban trees and forests pertains to spirituality and cultural attachments (La Rosa, Spyra, & Inostroza, 2016; Peter & Shackleton, 2017; Sheona et al., 2015). Some trees are attached to spirits or serve as shrines for worships (Babalola et al., 2013; Oyebade, Popo-ola, & Itam, 2013) and therefore serve as connections between urban dwellers and various divinities. In their study also, Shackleton et al. (2015) found urban in Northern South Africa to provide homes for birds and small animals.

Along with their beneficial services, urban trees are also associated with some environmental and social disservices (Dobbs et al., 2014). These are in other words, costs or negative effects of ecosystems on humans (Vaz et al., 2017). In Africa, Cilliers & Cilliers (2015) reported a reduction in residential property value with increasing proximity to green spaces. According to Shackleton et al. (2015) also, urban green spaces provide hideout for criminals while Ogunkalu et al (2017) reported that urban trees in Kaduna, Nigeria may harbour dangerous animals and are expensive to maintain. These disservices may however have lighter weights compared to the teeming benefits of urban tress and urban forests confirmed by many studies.

6. Urban Trees and Forests Development and Management in Africa

In view of their pivotal roles in keeping cities liveable, Gulsrud (2013) opined that green spaces and biophysical infrastructure should be given a greater collective priority by green space managers, urban planners and citizens alike. However, Government policy on forest management in many African countries was not designed to integrate community participation (Fuwape & Onyekwelu, 2011). Similarly, due to high population growth, town planning and development in Africa and many other developing countries are primarily focussed on the supply of basic infrastructure and services while urban sustainability and recreation which are facilitated by the urban forests (Gwedla & Shackleton, 2017) receive little attention.

In Africa, poor or inadequate enforcement of planning regulations, problem of ownership of green space lands and poor maintenance culture highlighted by Mensah (2014a) were some of the problems facing urban tree management. Others include inadequate resources (Gwedla & Shackleton, 2015) such as funds, personnel and equipment (Chishaleshale, Shackleton, Gambiza, & Gumbo, 2015) for the establishment and maintenance of street trees as well as inadequate research funds in urban forestry (Shackleton, 2012).

For urban forests to continue performing the vital ecosystem services expected, appropriate planning and management mechanisms must be put in place (Fuwape & Onyekwelu, 2011). The Food and Agriculture Organization of the United Nations (FAO)'s guidelines on urban and peri-urban forestry recommended an effective governance framework for urban forests which focusses on policies, incentives, laws and regulations through "multi-actor and multi-sectoral approaches" that recognise all relevant economic, social and environmental dimensions of the urban forest. This framework must also have a solid foundation that harmonizes planning, design and management of present and future urban forests (Salbitano et al., 2016).

7. Research and Policy Gaps

Only a few countries feature in the review which indicates a wide research gap in the understanding of urban trees and urban forests in Africa. Although there has been appreciable progress in publications since 2012, the distribution was uneven as most of the publications were from South Africa, Nigeria and Ghana. The information generated in these countries was grossly inadequate for effective urban tree and urban forest management in the continent. Chishaleshale (2015) found no municipality in South Africa that had estimates of the tree stocks under their jurisdiction or which had carried out inventories of trees on their lands. Urban tree research and inventory are thus desirable to compliment planning and management efforts. Such studies can highlight the ways in which cities are best developed and how green infrastructure are structured to serve the preferences and priorities of urban populations (Nitoslawski & Duinker, 2016).

In addition, most studies relied on the traditional field survey and interviews with little or no exploration of other approaches. Although field survey may be more accurate and may provide more information about the urban forests, it is expensive, labour-intensive and time-consuming (Nielsen, Östberg, et al., 2014; Ren et al., 2015). Interviews on the other hand may not yield detailed information since they rely on the respondents' perceptions (du Toit et al., 2018). Active remote sensing permits viewing of the biosphere in three dimensions and provides refined measurements of horizontal, as well as vertical structure of trees (Shugart et al., 2010). Use of high-resolution satellite images such as QuickBird, IKONOS, GeoEye, RapidEye, Worldview-2 and SPOT or light detection platforms such as LiDAR provides better opportunities for cost-effective and more detailed study of urban trees. According to (Morgenroth & Östberg (2017) aerial LiDAR especially when combined with hyperspectral imagery provides promising opportunities for successful urban forest inventory. This is because, it can be used to cover large areas while its inability to directly measure DBH can be overcome by using height to estimate DBH (Saarinen et al., 2014).

The i-Tree Eco and i-Tree Streets are models of increasing popularity in urban forest assessments, though relatively underutilized in the African context. On the one hand, i-Tree Eco model has the capabilities for both urban forestry analysis and tree inventories (Vogt et al., 2017). It focusses on quantifying the multiple functions of urban forests such as structure, carbon storage and sequestration, and also highlights species which are most effective at improving local air quality (Saunders, Dade, & Niel, 2011). The i-Tree Streets on the other hand specifically deals with street trees with emphases on their structure, function, and management needs as well as the environmental and aesthetic benefits they provide in urban areas (McPherson, 2010). Another important tool of urban forest analysis is the CITree (http://citree.ddns.net/index.php) which is freely available for users.

Citizen involvement in the management of urban trees in the continent is inadequate while tree planting schedules and plans seem to be weak or non-existent. According to Chishaleshale (2015), only 20% of municipalities in South Africa followed planned tree planting schedules while Soladoye & Oromakinde (2013) reported poor support, management and maintenance of planted trees in Lagos, Nigeria. These areas need to be adequately explored so as to improve our knowledge of the urban trees and maximize the benefits they provide.

8. Conclusion

Urban trees in Africa are diverse and provide ecological, economic and social benefits but research in the area is still developing with many areas unexplored. Although there was a gradual increase in urban trees and forests publications in the continent since 2012, the studies were distributed in few countries including South Africa, Nigeria and Ghana which makes generalizations difficult. Urban trees and forests managers face daunting challenges of inadequate funding, equipment as well as public involvement and support and inadequate or weak policies.

Most of the studies used the traditional, expensive and time-consuming field surveys and interviews with limited use of high resolution, remote sensing images or urban tree models. The need for increased research funding to cover more African cities using state of the art techniques and models is stressed.

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