Opportunities for and barriers to the adoption of green roofs in Lagos, Nigeria

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Abstract **- The use of green roofs especially the extensive type has become an important component of the "soft" engineering approach to environmental management of urban areas. Green roofs have been used in many parts of the world where they have been found to be beneficial in storm-water management, noise and thermal insulation as well as for mitigation of urban heat island effects. Lagos, a highly urbanized Nigerian city is characterized by a rapidly growing population within a very limited land area. The resultant development pressure on land has given rise to dense urban fabric with associated loss of green cover thereby eliciting suggestions for the adoption of green roofs. This aim of this paper is to examine opportunities for and identify barriers to the adoption of green roofs in Lagos, Nigeria. A combined quantitative and qualitative research strategy was adopted for the study. Questionnaire administered to 54 purposively selected built environment professionals in academics, consultancy and in government is the primary data collection instrument. This was supported by interview of government physical development regulators and property development companies. Secondary data were obtained from literature. Primary data were analysed using descriptive statistics and relative importance index while content analysis was used for qualitative data. The study found that while opportunities for adoption of green roofs exist, they were not popular in the study area because of cost, technical challenges, poor knowledge as well as limitations imposed by the interpretation of planning laws. The paper proposed context-relevant application of green roofs as a complement to ongoing green infrastructure programme in the study area.**

Index Terms – Barriers, Green Roofs, Lagos Megacity, Opportunities, Sustainable Development.

I. INTRODUCTION

Rapid urbanization coupled with physical development pressure on land, increased physical density as well as ineffective urban governance structures combine to make many cities of developing countries difficult to live in. Lagos, Nigeria's most populous city is a typical example. With a projected population of over 20 million people by the year 2015accommodated within a highly limited land area in comparison to other cities in Nigeria [1], the pressure on land for development is real. The land challenge is also indicated by the vast areas of wetlands which are being depleted through uncontrolled reclamation for development purposes in spite of the difficulties associated with developing such lands. Such invasion of wetlands depletes the vegetative cover of the wetlands and renders them ineffective as natural sinks for carbon and storm-water. Evidence abound of land-use and land cover variations in Lagos indicating that the naturally available soft green infrastructure is vanishing at a fast rate [2, 3, 4].

As a result, the administrative authorities of Lagos megacity are driving a green agenda which includes provision of soft green infrastructure such as parks and gardens, climate change advocacy programmes, sustainable environmental management policies, sustainable and low energy building practices as well as the renewable energy initiatives [5]. A specific aspect of the green programme is the regulation through approval order of the minimum green coverage area for all types of developable plots of land in different parts of the city. However, in order to promote the greening programme in the densely built up areas especially the inner city areas, green roofs are being proposed for adoption. In addition, the Lagos administrative authorities are also embarking on a programme of densification that would increase both physical and population densities as a way of maximizing access to existing infrastructure while at the same time discouraging sprawl which has negative effects on available green-fields [6].

This paper therefore examined the characteristics, advantages, opportunities for, as well as barriers to the adoption of green roofs in Lagos mega city. The following questions were posed as research questions: what level of knowledge of green roofs do built environment stakeholders in Lagos, Nigeria possess; what are the perceived advantages of green roofs; what barriers impede the widespread adoption of green roofs and what measures can be adopted for an increased uptake of green roofs in the study area.

II. Literature Review

As continuous physical development characteristic of rapid urbanisation depletes natural green landscapes, interest in green roofs is growing especially in the world urban areas. Green roofs are, however, not of recent origin as they have been used in the past in vernacular architecture which tended to emphasize architecture that is in harmony with the natural ecosystems. Architecture that is responsive to the natural ecosystem has been of interest to architects over the years. Distinguished American architect Frank Lloyd Wright strove to design buildings that were in harmony with nature in expression of the concept of organic architecture [7]. Even at the peak of the international style strand of modern architecture, one of its greatest exponents, Le Corbusier recognised the value of buildings being in harmony with nature. In the five points of a new architecture, Le Corbusier espoused the value of the roof garden as an attempt to recapture, at the roof level, the natural green landscape that has been displaced by the building [8]. In fact, green roofs predate the cited examples above and could be traced back the hanging gardens of Babylon [9].

In modern times, green roof have been used extensively especially in Northern Europe and America. However, Germany is regarded as a clear leader in the use of green roofs [10]. The leadership role of Germany in the use of green roofs has been linked to favourable government policy in the form of legislation, municipal grants and financial incentives for green roof adoption [11, 12]. A green roof, variously referred to as roof garden, vegetated roof, eco-roof and living roof is a roofing system that incorporates vegetation planted in a growing medium placed above an underlying waterproof membrane material on top of the roof of a building [13]. Typically, green roofs have eight layers including the roof structure which is usually a deck. Other layers as shown in Fig. 1 are waterproof membrane, root barrier, protection fabric, drainage layer, filter bed, a growing media and vegetation. Sometimes an insulation layer is added between the roof deck and the waterproof membrane.

Conceptually, green roofs are usually considered in the broader context of the low impact development strategy and more specifically within the context of green infrastructure. The concept of green infrastructure has been understood in many different ways but the underlying principle is that it emphasizes ecological and biodiversity conservation and engenders the evolution of resilient landscapes in support of ecological and community interests [14, 15]. Green infrastructure's emphasis on the ecosystem approach to development and its link to climate change mitigation underscores its relevance to environmental sustainability [15]. In this respect, the ecosystem can be both natural and engineered. Green roofs fall within engineered ecosystems.

Green roof research in the literature has proceeded along two main research directions: conceptual research and practical applications [16]. Conceptual research has developed along such themes as green infrastructure multi-functionality, connectivity, access, smart conservation, as well as policy and practice integration [16, 17]. Practical research tends to emphasize the ecological and social benefits of green infrastructure as a sustainable environmental management practice [16]. Green infrastructure has also being perceived in terms of the scale of operation. The Landscape Institute [18] categorized green infrastructure assets into three scales: local or neighbourhood, city or district, and regional or national scales. Green roofs are local scale green infrastructure assets in terms of operation but their effects can assume urban dimensions.

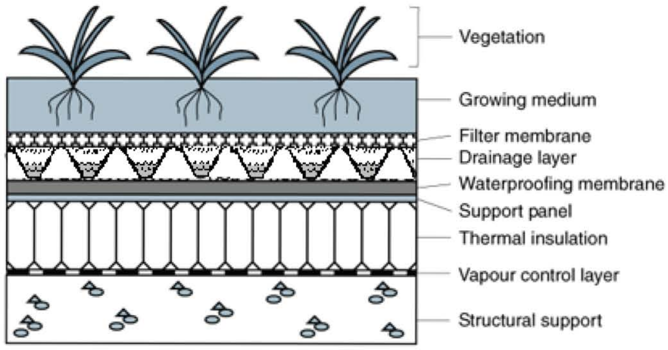

Fig. 1. Typical Structure of Extensive Green Roof [19]

Broadly, there are two main types of green roofs: extensive green roofs and intensive green roofs. The two types are differentiated by the depth of growing medium, type of plant and by implication, the cost of construction and maintenance of the green roof [11]. Intensive green roofs have deep growing media (usually greater than 150mm thick) and present opportunities for wide variety of plants and vegetation. Intensive green roofs are more expensive to construct and maintain than extensive green roofs. Extensive green roofs, which are gradually replacing intensive green roofs are characterised by thinner (less than 150mm thick) and lighter growing media [20]. In addition, [19] identified a third type known as semi-intensive which falls between the intensive and extensive types. A pictorial comparison of the three green roof types according to the International Green Roof Association (IGRA) is presented in Fig. 2 [21].

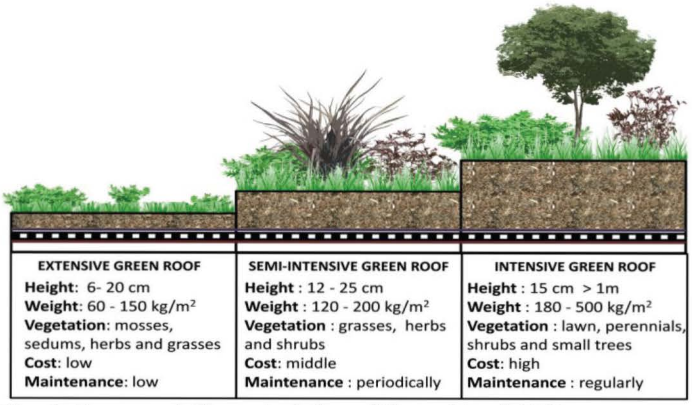

Fig. 2. Types and Characteristics of Green Roofs [21].

Renewed interest in green roofs has been associated with attempts to mitigate decline in the quality of the urban environment as well as by the need for environmental sustainability. Urban greenery is usually considered as an important part of urban ecosystem. According to [22], there are seven types of urban ecosystem which include (i) street trees, (ii) lawns and parks, (iii) cultivated land, (iv) wetlands, (v) urban forests, (vi) lakes and seas, and (vii) streams. The above urban ecosystems perform a number of functions which include acting as a natural sink for carbon and other noxious emissions to the environment. With rapid urbanisation, the green component of urban ecosystems is depleting at a high rate. Green roofs are therefore seen as opportunity to bring back the lost green component of the urban ecosystem.

Green roofs have been shown to be beneficial in many ways. In general, green roofs confer both private benefits to the occupants and property owners and public benefits to the immediate and wider environment [23]. The public benefits of green roofs are particularly of importance to the environment and they include: storm-water management, mitigation of urban heat island effect, improving biodiversity, and emissions regulation [19, 23]. The private benefits of green roofs include roof membrane longevity, improved indoor environmental conditions, reduction of requirement for air conditioning and noise insulation [23, 24].

In more specific terms, green roofs help in the management of storm water by delaying run off from roof to the storm water drainage system thereby preventing the drains from overflowing. Delays of between 95minutes and four hours have been reported in the literature [24]. The urban heat island effect, a phenomenon that accounts for the temperature difference between highly urbanised areas and their surrounding rural areas, can be mitigated by the use of green roofs. Urban heat island is often linked to the low albedo effect in urban areas relative to rural areas. Green roofs have been shown to cool the interior and surrounding environment [12]. Also, green roofs provide natural habitats for birds and other organisms thereby enhancing biodiversity in the urban environment [25]. As a natural sink for nitrogen, lead and zinc and as a filter for particulate matter, green roofs reduce environmental pollution [24].

The private benefits are equally noteworthy. Roof membrane longevity as a result of reduced membrane temperature and protection from ultraviolet radiation is an acclaimed advantage of green roofs. Diurnal temperature fluctuations are also lower in green roofs than in non-green roofs [26]. Temperature moderation is believed to increase the life span of roof membranes by reducing the stress associated with daily contraction and expansion of the roofing membrane materials [18].The low temperature range between exterior and interior spaces ensure thermal comfort of the occupants thereby reducing the need for air conditioning and associated energy consumption. In an experimental study of thermal behaviour of green roofs in tropical Brazil, [21] confirmed that green roof had the lowest temperature range when compared with four other roof types. Green roofs have also been shown experimentally to increase sound transmission losses which makes them able to mitigate low frequency noise in buildings [28].

The above benefits of green roofs notwithstanding, a number of barriers to their use in urban areas have been identified in literature. In a Hong Kong study, [29] identified the four major barriers to be, in order of importance, (i) lack of promotion by government,(ii) lack of incentive by government, (iii) increase in maintenance cost, and (iv) lack of awareness. The above finding is corroborated by another study which attributed the high rate of green roof uptake in a country like Germany to favourable government policy and incentives [11]. The additional construction and maintenance costs of green roofs constitute another barrier. Closely related to the above is the increased structural load on the building as a result of increased weight of the roof. It has been estimated that green roofs can add structural loads of 73 – 976 kg/m2 to a building depending on the green roof type [30]. The increased structural load is important in the study area because building structural failures have been linked to overloading of existing buildings [31]. The structural implication of green roofs is more critical in existing buildings where green roofs are installed as retrofits. Even in new buildings where the structural implication would have been properly considered, the additional cost of green roofs is of special importance to property developers given that the potential private benefits of green roofs are limited when compared to the public benefits. In cost-benefit terms, according to a study conducted in Helsinki, Finland, private benefits are mostly not high enough to induce private property developers to embark on the additional investments required by green roofs [23]. As a result, incentives are considered necessary in view of the overriding public benefits of green roofs.

The study area of Lagos is highly urbanised. According to a report by the United Nations on the ranking of the world urban agglomerations, Lagos was ranked 33rd in 1990 and 19th in 2014 with a projected ranking of 9th in the year 2030 [32]. Urbanisation in Lagos, a fast growing megacity has given rise to a myriad of challenges especially with respect to sustainability at the urban scale. As a response to the challenge of urban sustainability in the study area, green infrastructure development is evolving with such initiatives as the green Lagos programme which incorporates street tree planting, provision of public parks and gardens as well as encouraging property owners to include green areas within residential areas [5]. However, green roofs have not been comprehensively examined in the study area. Roof gardens in the form of potted plants, plants in free-standing containers and planters as well as vertical gardens do exist in the study area but they are not green roofs as described in this study. With the high percentage of built up area which is about 50% for an average urban residential plot and the additional need for car park spaces, opportunity for green roof abound.

III. Research Methods

This research is an exploratory study. It incorporates both quantitative and qualitative research strategies. Given the low prevalence of green roofs in the study area, the exploratory study targeted only built environment practitioners who are more likely to know the intricacies involved in green roofs. Hence, a sample of 54 (nine each from the listed professions) built environment practitioners in such professional areas as architecture, engineering, quantity surveying, estate management, building technology, and town planning was purposively selected for the survey. The sample was evenly distributed among professionals in academia, private practice and in government employment who were known to be involved in built environment research, management and practice within the study area. The data collection instrument used is the questionnaire which was divided into five parts namely: (i) background information of respondent, (ii) level of awareness of green roofs, (iii) advantages of green roofs, (iv) barriers to the use of green roofs, and (v) measures to improve the uptake of green roofs. In parts (iii), (iv) and (v) of the questionnaire, respondents were required to rate the advantages, barriers and recommendations on a 5 point Lickert scale. Descriptive statistics and relative importance index were used to analyse questionnaire responses. The relative importance index was calculated as follows:

$$\text{Relative Importance Index } \mathbf{(RII)} = \frac{\Sigma w}{AN}, \quad \mathbf{(0 \leq RII \leq 1)}$$

Where w is the sum of individual scores; A is the possible highest score and N is the total number of responses.

For the interview aspect of the research, the Lagos State Ministry of Physical Planning and Urban Development (MPP&UD), the Lagos State Parks and Gardens Agency (LASPARK), and two property development companies were targeted. The two companies were: Lagos State Development and Property Corporation, a government-owned company and UAC Properties PLC, a publicly quoted company. Senior personnel such as departmental heads were chosen to represent each of the organisations. Both companies are strong players in the Lagos property market with the former being a dominant player in the low and medium income segment while the latter is a dominant player in the medium and high income segment. Content analysis was used for analysing the interview responses.

IV. Findings And Discussions

The findings of the study and the associated discussion of findings are presented below under the following sub-headings: background information of respondents, advantages of green roofs, barriers to the adoption of green roofs, and recommendations on how to improve green roof use in the study area.

Background Information

Out of the 54 practitioners surveyed, 46 representing 85% responded. As shown in Table I, 9 architects, 9 engineers, 8 quantity surveyors, 8 builders, 6 estate surveyors and 6 town planners responded and returned the questionnaire. Similarly, out of the 46 that responded, 18 (39%) were in private practice, 16 (34%) were in teaching/research while 12 (26%) were in government employment. In terms of experience, about 70% of the respondents had a minimum of 11 years post-qualification experience, indicating that those surveyed were well experienced built environment practitioners. When asked to rate their familiarity with green roofs, the responses showed that 36 (78%) were very familiar with green roofs, 7 (15%) were somewhat familiar while 3(7%) were slightly familiar, indicating that all the respondents had some knowledge of green roofs.

Advantages of Green Roofs

Green roof benefits or advantages identified from previous studies were listed and the respondents were asked to rate the benefits in order of importance on a 5point scale. The factors rated include: reduction of urban heat island effect, improvement of air quality, improvement in indoor thermal comfort, management of storm water, improvement in biodiversity, improved aesthetics, reduction of air and noise pollution, and increase in the life span of roof membrane.

TABLE I: BACKGROUND INFORMATION OF RESPONDENTS

Category	Frequency
Type of Practitioner	
Architects	9 (19.6%)
Engineers	9 (19.6%)
Quantity Surveyors	8 (17.4%)
Builders	8 (17.4%)
Estate Surveyors	6 (13.0%)
Town Planners	6 (13.0%)
Experience of Practitioners	
0 – 5 years	4 (8.7%)
6 – 10 years	10 (21.7%)
11 – 15 years	18 (39.1%)
16 – 20 years	12 (26.1%)
21 – Above years	2 (4.3%)
Type of Practice	
Private Practice	18 (39%)
Teaching / Research	16 (35%)
Government employed	12 (26%)
Familiarity with Green Roofs	
Very Familiar	36 (78%)
Somewhat Familiar	7 (15%)
Slightly Familiar	3 (7%)
Not Familiar	0 (0%)

TABLE II: RANKING OF GREEN ROOF BENEFITS

s/no	Green Roof Benefits	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII	Ranking
1	Reduces Urban Heat Island Effect	0	0	4	28	14	0.843	4
2	Improves Air Quality	0	0	9	17	20	0.848	2
3	Provides Indoor Comfort	0	0	6	18	22	0.870	1
4	Helps to manage storm water	0	10	12	10	8	0.591	7
5	Encourages Biodiversity	0	3	15	16	12	0.761	5
6	Improves aesthetics	0	0	10	16	20	0.844	3
7	Reduces air and noise pollution	1	5	10	18	12	0.752	6
8	Increases life span of roof membrane	15	10	5	10	6	0.522	8

The result is presented in Table II. Accordingly, the ability of green roofs to provide thermally comfortable indoor environment was rated the most important while the ability of green roofs to prolong the life span of roof membrane was rated least. The most important benefits were found to be: indoor comfort, air quality improvement, aesthetics, urban heat island reduction, and improved biodiversity. The storm water management and roof membrane longevity benefits received the lowest ratings. While it could be inferred from observation that green plants enhance visual amenity, create habitats for birds, and play a moderating role on the micro environment in terms of air quality and cooling effect, its role in managing storm water and improving roof membrane longevity is not easily discernible. Such can only be proved or disproved through research on green roofs which is not yet well established in the study area.

Barriers to Green Roof Use

Seven factors considered as constraints to green roof adoption in the study area were rated by the respondents and the result is shown in Table III. From Table III, all the listed barriers were rated highly. However, the barriers that most negatively affect the adoption of green roofs in the study area were found to be: cost of construction, cost of maintenance, absence of government regulation, and low knowledge and technical capacity. The above findings agree substantially with previous findings in a Hong Kong study where the major barriers were found to be lack of promotion and incentive from government and increased maintenance costs [20].

In addition,, construction cost is usually high in the study area and any item that would add to the cost of construction without necessarily contributing directly to the use of the building is usually discarded. Green roofs may therefore be seen as unnecessary additions to the basic components of a functional building. The above is corroborated by the property development companies interviewed who preferred the cheaper option of providing green area at the ground level. Furthermore, green roofs are mostly placed on reinforced concrete roofs which have the capacity to withstand the envisaged additional load. Reinforced concrete roofs are comparatively more expensive than non-concrete roofs. While properly sloped non-concrete roofs within the study area are easy to maintain, green roofs require frequent maintenance.

Similarly, no specific government planning regulation on green roofs was found in the study area. According to an official of MPP&UD interviewed, a reinforced concrete flat roof is usually interpreted to mean that an additional floor may be added later. This is because instances of increasing the height of an existing building abound in the study area. In many cases, such modifications do not follow the statutory procedures and have often resulted in serious building failures.

TABLE III: RANKING OF GREEN ROOF BENEFITS

s/no	Green Roof Barriers	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII	Ranking
1	Increased Construction Cost	0	0	3	10	33	0.930	1
2	Increased maintenance cost	0	0	4	9	33	0.926	2
3	Absence of government regulation	0	0	3	12	31	0.922	3
4	Lack of government incentives	0	0	3	13	30	0.917	4
5	Increase in structural load of building	0	0	6	12	28	0.896	7
6	Challenge of installation on existing roofs	0	0	4	15	27	0.900	6
7	Low knowledge and technical capacity	0	0	3	16	27	0.904	5

TABLE IV: RANKING OF GREEN ROOF STRATEGIES

s/no		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	RII	Ranking
1	Educating the public	2	4	15	13	12	0.726	5
2	Encouraging research and development	1	3	10	10	22	0.813	3
3	Government policy on green roofs	0	2	11	10	23	0.835	2
4	Government incentives for green roofs	0	2	9	11	24	0.848	1
5	Use of modular green roof panels	3	5	15	10	15	0.752	4

Measures to encourage use of Green Roofs

Five strategies aimed at improving the use of green roofs in the study area were ranked by the respondents and the result presented in Table IV. Government incentives with an RII score of 0.848 was ranked highest and was closely followed by government policy with a score of 0.835. The third strategy in order of importance with an RII score of 0.813 was encouraging research and development. The result underscores the important role of government in driving the adoption of green roofs which is largely in agreement with literature [10, 11, 23]. Also of particular importance is the role of research and development which not only has the potential of improving the knowledge base but also reducing the installation cost of green roofs.

CONCLUSIONS

Green roofs are desirable in the study area because of the obvious environmental advantages derivable. Such advantages as found in the study include improved indoor comfort, better air quality, improved aesthetics, reduction of urban heat island effect and improved biodiversity. A number of barriers beset the widespread use of green roofs in the study area which include increased construction and maintenance costs, absence of government regulation, lack of appropriate government incentive, and low level of knowledge and technical expertise. In order to encourage the adoption of green roofs in the study area, the study found that strategies such as appropriate government policy, government-driven incentives and encouraging research and development in green roofs. In all, given the public benefits of green roofs, government should be at the forefront of promoting the adoption of green roofs. In this respect, it can be made mandatory for government buildings in urban areas to incorporate in their designs, an extensive green roof at the least. Other property owners can be encouraged to incorporate green roofs in their buildings through appropriate incentives from government.

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