

Review

Green roofs: A possible best management practice for enhancing the environmental quality of Ghanaian cities

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City expansion typically erodes the natural ability of the locale to perform its ecosystem services. This paper discusses green roofs and their potential benefits for Ghanaian cities in terms of improving environmental quality. Limited analysis shows that daily minimum temperatures of cities like Accra are rising faster than the daily maximum thereby decreasing the comfort index of city dwellers. Electricity consumption is increasing amid challenges in supply while the frequency of flooding after rainstorms is also on the rise. Green roofs have demonstrated reduction of these issues in several parts of the world and could help minimize the magnitudes of these issues in Ghanaian cities if adopted as an urban best management practice. Since this technology is new to Ghana with no local research, this paper also discusses the potential economic gains and associated research opportunities as well as some strategies to consider if the green roof technology is to be pursued. Successful introduction and implementation of green roofs in Ghana will depend on awareness creation, research and development of growing substrate, plant species and other structural components, formulation of guidelines for the industry, government support through legislation and provision of incentives to promote its adoption. We hope this paper will initiate discussion between various stakeholders in sustainable city development in Ghana in this era of climate change and variability.

Key words: Green roof, urban, environmental quality, best management practice, ecosystem services.

INTRODUCTION

Green roofs, which are simply roof tops planted or covered partially or completely with vegetation, provide several benefits to the built environment. They are essentially one way to reintroduce the foot prints of nature into

urban environments where forests, grasslands and agricultural fields and other natural systems have been replaced with impervious surfaces in the form of buildings, roads, driveways, parking lots and paved

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compounds. While paving the landscape may be regarded as development, such paved surfaces disrupt natural hydrologic cycles and create energy imbalances in the urban ecosystem. Population growth in Ghana mirrors the overall world trend towards ever increasing urbanization (Figure 1), resulting in expansion of the built environment and its consequent negative impacts on ecosystem performance. This population condition puts Ghana 25 and 20 years respectively ahead of countries south of the Sahara and Africa, in general, in terms of percentage urban population growth.

Although Ghana has a relatively low overall population growth rate of 1.25%, the exponential growth rates of Accra and Kumasi, the two largest cities in Ghana (Figure 2), clearly support the aforementioned shifts in Ghana's population distribution from rural to urban.

The result increased demand for housing and other physical infrastructure, with increasing paved area at the expense of vegetated area. For example, until the mid-1980s, only two main real estate subdivisions were added to the original city of Accra, namely the Teshie - Nungua and the Dansoman Estates. However, since 1988, private real estate developers have built over 10,954 new homes (BOG, 2007) in addition to other residential and infrastructural development projects resulting in a drastic increase in paved areas in Accra. Furthermore, Tema, a near-by port city that was originally about 11 km from Accra, has expanded and is now joined to Accra forming one sprawling built area. Similar trends are occurring in the other Ghanaian cities where the urban population is rapidly growing like Kumasi where the population grew from 99,000 in 1950 to more than 1.5 million in 2005 (UNDP, 2008).

Alongside these developments are two common observations. First, there is an increase in the frequency of flash floods, even from rather small (~15 mm) rainfall events. For almost the past two decades, flooding in Accra has become a common issue. For example on 21 June 2010, flash floods reportedly claimed 23 lives, disrupted transportation to and from Accra, and caused substantial loss of property (BBC, 2010). This year, floods arising from heavy rains in the first week of June and its associated accidents killed about 150 people in Accra. Though these occurrences are often blamed on poor city planning, poor drainage infrastructure and lack of alert systems, a major contributor is the scale of paved and hard surfaces in the city. Studies in the USA have shown that a typical city block produces nine times more storm runoff than a woodlot of the same size because of its impervious nature (USEPA, 2004). This is because forests absorb approximately 95% of precipitation, while cities soak up only about 25% (Scholz-Barth, 2001).

The second observation is that there is an increasing trend in both day (T_{max}) and night time (T_{min}) temperatures in Accra with the difference between the two decreasing as a result of a faster increase in night time temperatures (Figure 3). These suggest that Accra is

is becoming warmer each year and the net result is increased energy consumption. There has been a dramatic increase in the use of air-conditioning for cooling by the government, businesses and residences as fans can no longer meet cooling expectation.

In fact the total peak energy demand for Ghana's three largest cities, Accra, Tema, and Kumasi, increased from 48 to 52% between 2000 and 2009. Similarly, increases in energy consumption for the same cities within the same timeframe were 41, 159 and 62%, respectively (Essah, 2011). One of the factors cited for the increased electricity consumption is expansion (Essah 2011; ISSER, 2005). It is conceivable that the low water storage capacity of the paved impervious and heat absorbing layers in Accra are limiting water availability for evapotranspirative cooling eliminating the ability of the city environment to perform ecosystem services like storm runoff management and temperature moderation as would have occurred in their absence. Data from the Urban Heat Island Pilot Project, a joint venture of the United States Environmental Protection Agency (USEPA) and the National Aeronautics and Space Administration (NASA), showed that in the center of Salt Lake City, temperatures of paved surfaces and rooftops (44°C) was much higher than the ambient air temperature (29°C), and vegetated areas had even lower surface temperatures (28°C) (Lo et al., 1997).

As a tropical developing country with relatively plenty sunshine and rainfall, Ghana's city planners and law makers should proactively develop policies that would minimize the effect of the paved and built environment on the natural ecology of cities if urban areas are to remain livable in the future. There is the need to move towards sustainable city development and introduce systems that can serve as urban best management practices (BMPs) with regard to key needs like storm water control and mitigation of urban heat island effect and indoor energy consumption. Green roofs have demonstrated moderation of these conditions and more in other parts of the world. As a result, it is important to consider including green roofs in local deliberations on sustainable urban planning in Ghana. In fact, it is a crucial necessity in this era of climate change when temperatures in Africa are expected to increase by between 3 and 4°C which is about 1.5 times the projected global mean temperature (Christensen et al., 2007; Gualdi et al., 2013). Given that this technology is "new" to Ghana with no local research on the subject matter, it is necessary to review the basic science behind green roofs in a discussion like this. A review of green roof science and technology will promote awareness on green roofs, provide understanding on the current technology and facilitate dialogue among scientists, meteorologists, architects, engineers, contractors, politicians and urban planners.

Therefore, the objectives of this review paper are to (1) provide an overview of green roofs and discuss their potential as an urban best management practice for cities

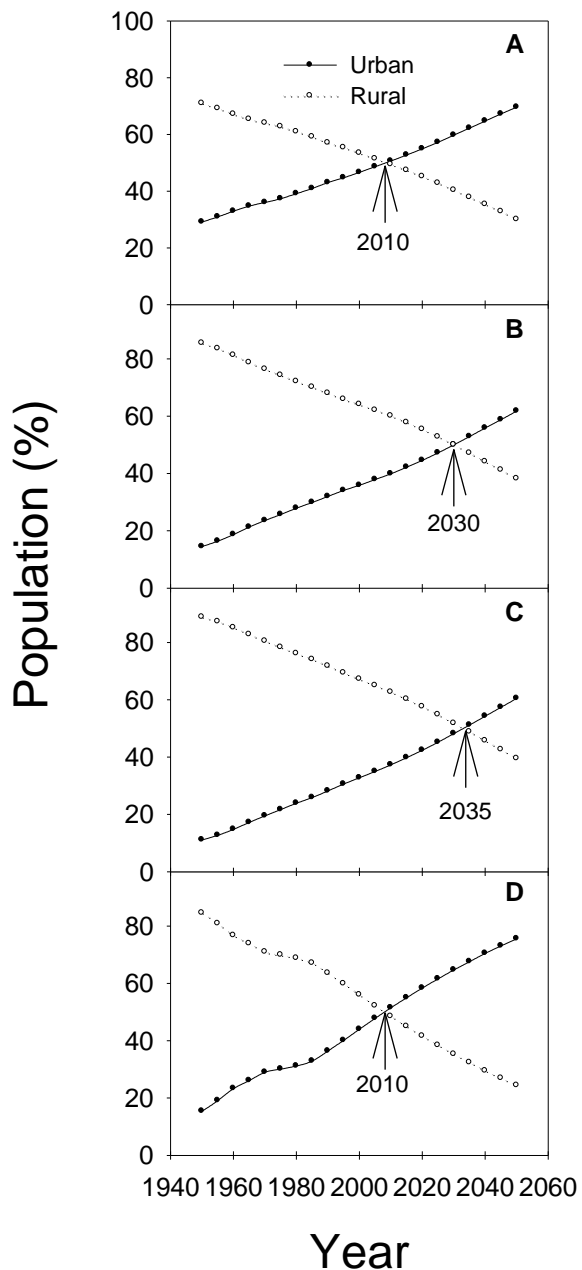


Figure 1. Ghana's urban-rural population trends (D) in comparison to the World (A), Africa (B) and Sub-Saharan Africa (C). The arrows point to the years when urban populations either equaled or surpassed rural populations in the various regions. The population data was obtained from the UNDP population database (UNDP, 2008).

in Ghana, (2) highlight some of the technology's potential benefits in terms of business and research and, (3) suggest some ways to introduce and promote the technology in Ghana.

INFORMATION COLLECTION

Information was gathered for this paper using a desk

review approach (Mapoma and Xie, 2014). The references cited were obtained from a variety of sources including textbooks, peer reviewed journals, conference proceedings and internet sources.

DISCUSSION

Part A - General overview of green roofs

Origin and description of green roofs: The roots of green roofs date back to the seventh and eighth centuries B. C. in the ancient civilizations of the Tigris and Euphrates River Valleys. Popular examples were the Hanging Gardens of Babylon (Dunnett and Kingsbury, 2008). However like a lot of technologies, green roofs have evolved overtime into better systems. Modern green roofs are often regarded as a system because they comprise several layers like water/root proof membrane, drainage layer, filter mat, growing substrate, vegetation and edge protection (Figure 4). As a result, Boivin and Challies (1998) define green roof systems as a complex for growing plants that consists of an array of specific materials with particular functions.

Characteristics of green roof systems: Green roofs are generally divided into two systems, namely extensive and intensive, based on maintenance needs, plant materials used, type of growing medium or substrate and its depth (Panayiotis et al., 2003). Hybrid systems comprising characteristics of both systems are known as semi-extensive systems (Dunnett and Nolan, 2004). Extensive green roof systems are usually designed to be lightweight with substrate depths varying between 2 and 15 cm. They support ground covers and hardy self-propagating small herbaceous plants (Panayiotis et al., 2003). They are of low maintenance and require little or no inputs in terms of irrigation, fertilizer and labor (Dunnett and Nolan 2004; Köhler, 1990). They are therefore a cheaper option compared to the intensive systems which are high maintenance requiring frequent irrigation and fertilization (Dunnett and Nolan, 2004; Panayiotis et al., 2003). Substrate depths for intensive green roof systems vary between 30 and 125 cm and support a variety of plants including ground covers, shrubs and even trees (Panayiotis et al., 2003). These are often designed to be accessible for recreational use and therefore are well maintained to look attractive (Dunnett and Kingsbury, 2008; Köhler, 1990). Semi-extensive green roofs are also usually light weight and require low inputs like the extensive types except that they have deeper substrates of up to 20 cm and therefore expand planting options (Dunnett and Nolan, 2004) since the kinds of plants supported by a green roof is largely dependent on the depth of the substrate (White and Snodgrass, 2003) as well as the ingredients present in the substrate (Sloan et al., 2010). They provide similar

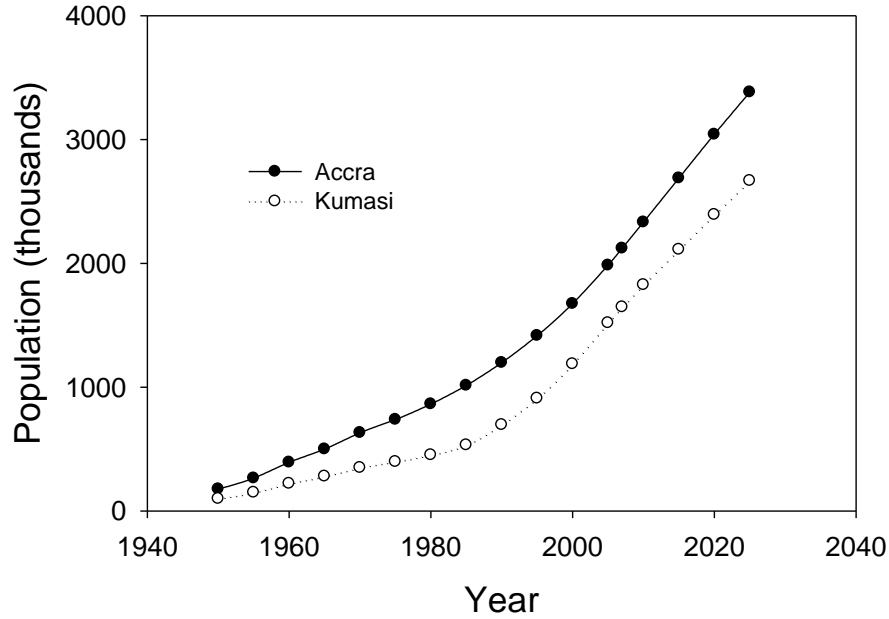


Figure 2. Population estimates for Accra and Kumasi spanning 1950 to 2025. Estimates were obtained from the UNDP population database (UNDP, 2008).

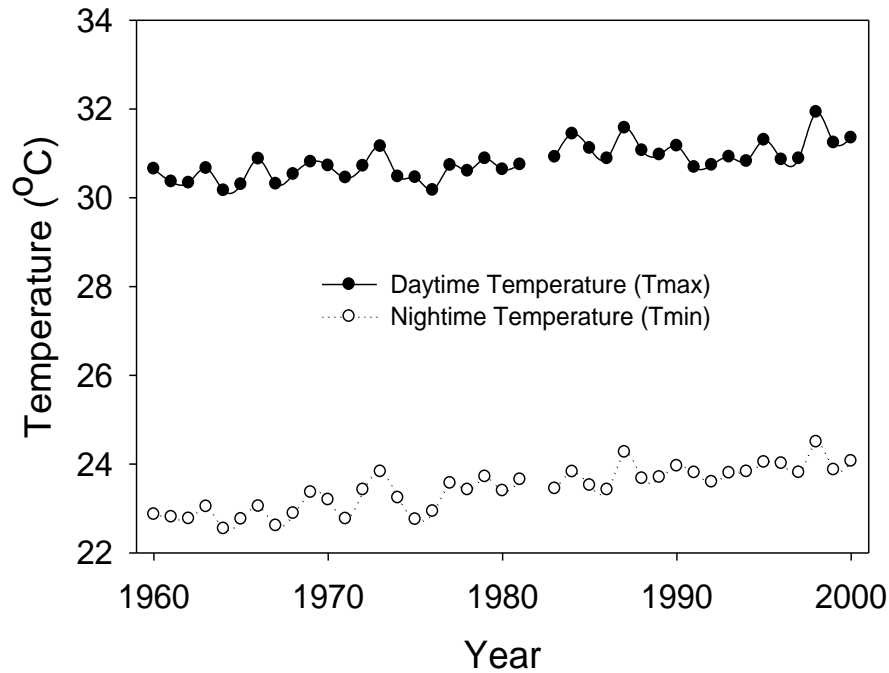


Figure 3. Accra day (T_{max}) and nighttime (T_{min}) temperatures from 1960- 2000.

service benefits like extensive green roofs but are more attractive. At the same time, they are cheaper to build and maintain compared to intensive green roofs. Green or vegetated roofs may also be called different names depending on the context. For example, green roof may

be called “ecoroofs” to differentiate them from other roofs with ecological functions like roofs covered with photovoltaic cells. They may also be called “living roofs” to emphasize the fact that they may not be green at all times (Dunnnett and Kingsbury, 2008).

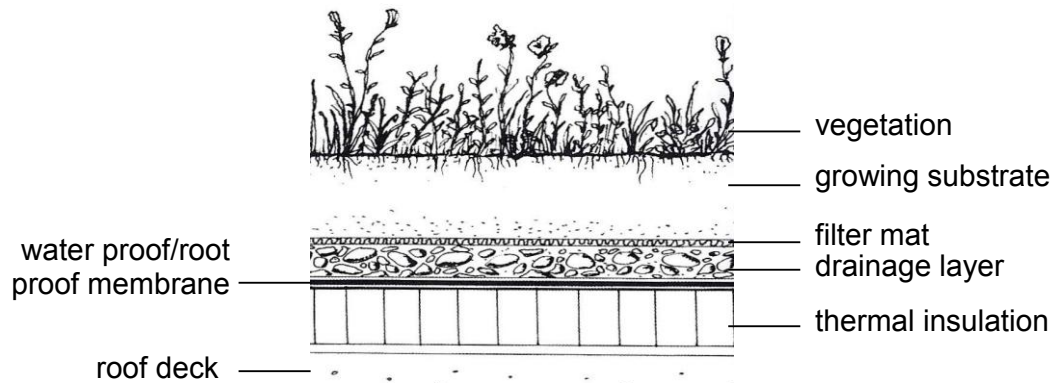


Figure 4. A schematic of a typical extensive roof (modified from Dunnett and Kingsbury, 2008). The filter mat prevents materials from the substrate from clogging the drainage layer while the water and root proof membranes act as sealants for preventing water and root penetration of the roof deck and building. The roof deck provides structural support for the entire green roof system.

Scientific basis of green roofs: Like natural ecosystems, green roofs have two major effects on the environment. First, they modify the components of the water balance equation, which can be stated as:

$$dW = P - R - D - ET \quad (1)$$

Where, dW is the change in water storage (mm), P is precipitation (mm), R is runoff (mm), D is drainage (mm) and ET is evapotranspiration (mm). For a green roof, the growing substrate acts as a reservoir for precipitation water because of its porous nature. The drainage layer of the green roof system drains excess water or underflow away via percolation and prevents saturation of the substrate (which is synonymous to “over spill” of the reservoir) and hence reduces the onset and volume of runoff. Water evaporating directly from the growing substrate and the volume intercepted on the green roof vegetation, as well as the quantity transpired by the plants, represent the evapotranspiration term. This term reduces water stored in the growing substrate over time to make room for receiving future precipitation. This provides green roofs the capacity to delay runoff, reduce flow rates and runoff volume. On the other hand, paved surface provide negligible storage, drainage and evapotranspiration resulting in almost immediate runoff initiation after the beginning of precipitation.

Secondly, green roofs alter the energy balance of the environment. Consider a simplified energy balance equation given as:

$$R_n = H + LE + G + A \quad (2)$$

Where, R_n is the net solar radiation (cal/cm^2), H is the energy flux that heats the air or sensible heat (cal/cm^2), LE is the latent heat of evaporation (cal/cm^2) and is the energy available for evaporating water, G is the heat of

conduction to the ground or the rate of energy storage in a system (cal/cm^2). For a green roof system this represents heat conduction to or storage in the growing substrate and vegetation. A is the energy consumed during photosynthesis (cal/cm^2). This implies that water stored in a green roof growing substrate is a significant factor for the cooling service green roofs provide. Research has shown that green roofs use 60% of the solar radiation they receive for evapotranspiration (that is, latent heat of evaporation), reflect 27% and transfer only 13% to the growing substrate (Eumorfopoulou and Aravantinos, 1998) implying that the substrate and the vegetation can offset 87% of the solar radiation that hits a green roof. Smaller heat fluxes and storage (G) result in the moderation of both environmental temperatures and those inside buildings. On the contrary, bare roofs and other exposed paved surfaces absorb 100% of the incident solar radiation which is ultimately transmitted into buildings and/or back to the environment as sensible heat. The science behind how green roofs work show that the technology will be useful to Ghana as an urban BMP since it receives copious amounts of both rainfall and sunshine.

Part B - Potential environmental benefits and disadvantages of green roofs

Benefits of green roofs: Reported benefits of green roofs are numerous. They include: storm water management, temperature moderation (that is, air temperature, energy consumption and urban heat island reduction), provision of urban habitats for biodiversity and wildlife, carbon sequestration, reduction of air and noise pollution, enhanced aesthetic appearance of cities, roof protection and space for roof top gardening (Dunnett et al., 2008; Berardi et al., 2014). However, the discussion

in this paper will be largely limited to storm water and air temperature control. This is because they may be the benefits of greatest interests to urban planners and dwellers in Ghana as these are currently a challenge.

Storm water management and quality: Research has demonstrated that green roofs can retain roof runoff and as a result minimize peak flows and total volumes reaching sewers. Depending on factors like substrate depth, slope, vegetation type of the green roof and rainfall patterns, rainfall amount, season and local climate (Dunnnett et al., 2008; Getter et al., 2007; Mentens et al., 2006; VanWoert et al., 2005, Spolek, 2008), green roofs could capture up to 100% of precipitation (Bengtsson et al., 2005; DeNardo et al., 2005; Hutchison et al., 2003; Köhler et al., 2002; Simmons et al., 2008, Spolek, 2008) because of the combined effect of storage in substrate, vegetation and evapotranspiration (Bengtsson et al., 2005).

It has also been found that green roofs have the capability to delay runoff by 95 min (Liu, 2003) to 4 h (Moran et al., 2004) compared to conventional or bare roofs. This is significant because it can lead to a remarkable reduction in the erosional strength of runoff water entering stream channels either directly or through sewers (Getter and Rowe, 2006). Similarly, some studies have demonstrated that green roofs show no first flush effects during storm events like impervious surface with respect to phosphorus, sulfate, nitrogen, chemical oxygen demand, pH and turbidity (Bliss, et al., 2009). Nutrient and heavy metal retention by green roofs have also been demonstrated by other researchers (Czemiel et al., 2009, Köhler et al., 2002; Steusloff, 1998). All these observations suggest that green roofs have the capacity to enhance the health and quality of urban surface water ecosystems through reducing pollution caused by urban runoff and combined sewer overflows.

In addition, these findings expose the need for exploring the use of green roofs as a tool for managing urban storm water and environmental health especially because science has proven that there is a link between water quality, human health and runoff from impervious surfaces. Fergusson (1998) reported that the quality of streams in a watershed can be affected by 10% impervious cover. Similarly, urban runoff has been identified as the number one and three sources of impairment to estuaries and lakes respectively in the U.S. (USEPA, 2004). More so, Dwight et al. (2004) observed that surfers in the U.S. suffered twice as many health problems on public beaches receiving untreated urban runoff than on those beaches not exposed.

Though Ghana probably lacks these kinds of scientific documentation with regards to urban runoff, it is likely that the picture there is similar or worse. The increasing urban population in Ghana (UNDP, 2008) will be accompanied by more impervious cover and its associated changes in hydroecology and environmental

effects like increased pollution of developed hard surfaces, flooding from sewers and pollution to urban water bodies. While conventional storm water infrastructure like storage reservoirs/retention basins, ponds, constructed wetlands, sand filters and open channels may be useful for containing urban runoff, using them extensively in urban areas may be cost prohibitive because they require large land spaces which are usually a scarce commodity in most cities (Czemiel Berndtsson, 2010; Santamouris, 2014). Most Ghanaian city plans may lack provisions for sophisticated storm water management facilities but they all abound in roofs. This makes the consideration of green roofs attractive. Coupling existing storm water infrastructure with green roof mitigation could be a viable way to minimize urban runoff and its impacts in Ghana.

Energy savings and mitigation of the heat island effect:

In general, urban areas are usually warmer than surrounding suburban and rural areas (Oberndorfer et al., 2007) because of higher concentrations of buildings and paved surfaces (Dunnnett and Kingsbury, 2008). This phenomenon of built areas experiencing hotter temperatures in contrast to nearby less built or rural areas is known as the heat island effect. For example, a city of about a million people is likely to have a mean yearly temperature of 1-3°C higher than its environs with the differences in evening temperatures reaching as high as 12°C (USEPA, 2010). The rising temperatures in Accra may be an indication of this phenomenon as analysis of long term temperature records show that the average temperature in Accra is higher than Somanya a nearby small rural town (Goethe Institute, 2012).

Urban climates are also usually characterized by increased humidity emanating from limited air movement through buildings, air pollution, emission of greenhouse gases (Dunnnett and Kingsbury, 2008; USEPA, 2010), and waste heat from vehicles, factories and air conditioners (Wong, 2005). The higher urban temperatures are likely to promote the formation of smog which can lead to public health problems like higher risk of asthma and other respiratory diseases in addition to heat-related illnesses and general discomfort (Dunnnett and Kingsbury, 2008). In a similar way, increased urban temperatures also lead to higher energy demand and air conditioning or cooling costs (USEPA, 2010).

Green roofs have demonstrated the ability to save energy required to either cool or heat the buildings they cover. Green roofs absorb and store large amounts of heat when they are wet, thereby reducing temperature fluctuations. When dry, green roofs act as insulators decreasing heat flow through the roof thus reducing cooling energy needs of the buildings they cover (Del Barrio, 1998; USEPA, 2003). In the summer, green roof vegetation reduces the temperature of roof surface and ambient air resulting in a lower energy demand for cooling (USEPA, 2003). Thus green roofs improve the

energy efficiency of buildings through a combination of shading, evaporative cooling and insulation from both green roof plants and growing substrate and the thermal effects of the growing substrate (Liu and Baskaran, 2003).

Several studies have consistently shown the energy savings potential of green roofs though it is difficult to quantify. In Singapore, Wong et al. (2003) found that heat flow through a green roof over a typical day was less than 10% the amount transferred through a reference roof. In Japan, Onmura et al. (2001) estimated heat flux reductions by green roofs as much as 50% per year. In Canada, Liu and Baskaran (2003) found that heat flow moderation through roofing systems by green roofs lowered average daily energy demand for space cooling by more than 75% in the summer. Peck et al. (1999), also in Canada, found that when outdoor temperatures ranged between 25 and 30°C, green roofs reduced indoor temperatures by 3 to 4°C. Similarly, Saiz et al. (2006) found that a green roof in Spain lowered the cooling load on an eight-story residential building during the summer by 6%. In Central Florida in the U.S., Cummings et al. (2007) demonstrated that average heat transfer through a green roof was more than 40% less than that for a nearby light-coloured roof. This heat transfer moderation effect of green roofs can result in huge energy consumption savings because it has been estimated that every 0.5°C reduction in internal building air temperature can lead to 8% less electricity use for air conditioning (Dunnett and Kingsbury, 2008).

In Ghana, most modern style buildings have significant glass components including windows and doors which entrap heat and increase interior temperatures. As a result, city dwellers are increasingly resorting to the use of air conditioning for cooling leading to a rise in the installation of air conditioning units in cities, especially Accra. The consequence is a hike in demand and consumption of electricity which is not always readily available. The research findings outlined suggests that the adoption and promotion of green roof technologies in Ghana would likely help alleviate the energy demand for cooling purposes, provide some relief for the energy sector and save citizens money. However, it must be emphasized that the extent to which green roofs perform the cooling function varies with factors such as characteristics of the building, the green roof and the local climate as depicted by the aforementioned research findings.

Disadvantages of green roofs: Though the environmental benefits of green roofs are well documented and confirmed (Berardi et al., 2014) there are some disadvantages associated with the technology. Using green roofs may be difficult in areas that are extremely hot and dry (Schweizer and Erell, 2014). Consequently, green roofs may not be as suitable for the dry regions of Ghana because they experience low rainfall. Other less

costly technologies like cool roofs may be as effective as green roofs with regard to mitigation of the heat island effect in the short term (Santamouris, 2014). However, cool roofs cannot provide the other environment benefits that come with green roof installation. More so, coupling conventional surface storm water technologies which require large tracks of land with cool roofs may be more expensive. This is because land is limited in urban Ghana and, as a result, is typically expensive. Some of the environmental benefits of green roofs like improved city aesthetics may be difficult to quantify. The use of petroleum based products in green roof structures as water resistant layers may portray the technology as not truly “green” because these products are not considered eco-friendly (Berardi et al., 2014). In this regard, researchers are exploring the use of recycled materials like low-density polyethylene, but the general consensus is that pollution caused by manufacturing polymers used in green roofs is usually offset by the environmental benefits green roofs provide in the long-term (Berardi et al., 2014).

PART C – Green roof technology opportunities, promotion and development in Ghana

Job and Research Opportunities: Since green roof technologies cut across several disciplines, the introduction of green roofs in Ghana can lead to an outburst of opportunities including businesses associated with the installation, maintenance and marketing of green roof components and products, green roof designing and research. The business opportunities can lead to new jobs for nurseries, contractors and irrigation specialists and many other people that will engage in the industry directly or indirectly.

Major research avenues green roofs can trigger studies to quantify the benefits of green roof for building owners, occupants and city communities as well as entire city environments. In general, these kinds of data are scarce for many parts of the world and existing data sets are not transferable from one location to the other because of vast differences in climatic conditions across the world. For example, high rainfall and high evapotranspiration characteristics of most hot and humid tropical climates present a different set of challenges to roof greening compared to temperate climates. In the same vein, rainfall events that may be perceived as 100 year events in temperate climates may just be yearly events in the tropics (Köhler et al., 2001). Consequently, local research on green roofs could potentially generate and document lots of new information on the requirements and procedures for sustainable management of green roofs in tropical West Africa. Research on the growing substrate, potential plants, the effects of building characteristics and the development and/or use of available green roof models will help scientists quantify the environmental

benefits and describe sustainable local management methods.

The substrate, which is the most important component of a green roof system, can provide multiple research areas including composition determination, depth, slope and fertility management effects on the establishment and performance of green roof vegetation and system as a whole. Since green roofs are essentially engineered ecosystems, researching the short and long term interaction effects of the substrate and vegetation on the physical, biological, and chemical nature and function of substrate should be an area of key interest (Ampim et al., 2010). Similarly, the effects of building attributes such as orientation, aspect and slope, and shading should be unique research questions that must be integrated into green roof research because cities are likely to grow more vertically than horizontally in the future as pressure on land increases (Ampim et al., 2010). Since rooftops are very challenging locations for establishing plants, plant related green roof research must evolve around ensuring plant survival and performance regardless of climatic conditions. This implies that green roof plant research should involve studying plant attributes like establishment, hardiness, aesthetics, resourcefulness, bioremediation potential and maintenance. This also creates an avenue for molecular modification of plants to suit roof conditions. Developing robust mathematical models or adapting existing ones to quantify the various benefits of green roofs independently or in an integrative manner is another research option.

Social and income opportunities: Green roofs can also offer avenues for outdoor activities including gardening and food production for urban dwellers. In New York City, U.S.A., the green roof constructed on top of the Earth Pledge building is used to demonstrate urban agriculture and the garden also provides food for Earth Pledge workers (Cheney, 2002; Loder and Peck, 2004). Similarly, in Vancouver, Canada, the Fairmont hotel uses its green roof, which covers 195 m², to produce all the herbs used in its restaurant translating to cash savings of CDN \$ 30,000 per annum (Peck, 2005).

Promoting and developing green roof technologies in Ghana: In the long term, successful implementation of green roof technologies in Ghana will require establishing conditions to minimize potential challenges.

As mentioned earlier, there is the need for research on developing the technology in Ghana because turning out and testing the key components of the system locally will be best. As such, substrate development and testing as well as identification of suitable native plants could be a starting point. While it is necessary to investigate the various plant species present in Ghana for their green-roof suitability, attempts must also be made to explore other options including breeding and biotechnology techniques to either improve or develop new cultivars

suitable for the rooftop conditions in Ghana. Universities and Polytechnics may have to expand their programmes to include turf science since it is currently absent from the curricula of these institutions. Besides the possibility of its use as a green roof planting material, turfgrass is very good for establishing attractive landscapes and can provide several environmental benefits including erosion control around residential and commercial areas, open areas, recreational parks and cemeteries within city landscapes. Developing and producing turf cultivars and other ornamental plants suitable for green roof applications will be one way to increase planting choices for green roof systems locally. It is foreseeable that the most of the other structural components of green roofs may have to be imported and foreign experts may have to be consulted on certain design questions. However, experienced local architects could easily produce roof designs to match the Ghanaian context of building with little or no further training. Nevertheless, courses on such roof designs and the production of the structural components should be incorporated into architecture and engineering programmes over time to localize the technology and make it cheaper. In addition, incorporating green roof modeling in the curricula will also be very important because models are a useful tool for performing cost-benefit analysis studies. Performing integrated cost-benefit analyses of green roofs may be a practical way to express the benefits to Ghanaians more clearly. For example, in Singapore, research has shown that though the initial costs of extensive green roofs are higher than conventional flat roofs, the life cycle costs for them are lower with or without factoring in the energy cost savings extensive green roofs provide (Wong et al., 2003).

Second, there is the need to embark on aggressive awareness creation through education using generated research data or knowledge. Pilot demonstration projects of the green roof technology should be established and supported for open learning needs. Such educational activities must target the public, industry and decision makers because their understanding and appreciation of the benefits and costs of green roofs are a catalyst to the advancement of the industry. Involving environmental NGOs in educational activities and advocacy may enhance success.

Third, industry guidelines must be formulated including technical information on how to construct green roofs. It may be necessary to consult experts and refer to the standards and codes developed for other countries who are leaders in the industry to develop guidelines to meet the needs of Ghana. Once established, architects, building technologist, engineers, landscape and construction contractors and other professionals involved in the industry must operate within the set guidelines.

Fourth, policy makers must develop green roof legislation that will provide direct and indirect incentives for residential home owners, developers and other businesses

interested in installing green roofs. However, legislators must ensure that pricing mechanisms are fair and affordable by both ordinary home owners and commercial groups or big businesses. Research has shown that the area occupied by residential roofs is eight times that occupied by roofs of commercial buildings. As a result residential development causes more environmental problems like deforestation than commercial development (Carey, 2004). More so, it is important to make incentives accessible to all because that may enhance establishment of green roofs in clusters rather than in isolation.

Research has also shown that green roofs established in clusters around a city are more effective at solving environmental problems than in cases where they are scattered (Currie and Bass, 2005). Incentives could be in the form of grants or subsidies provided to home owners, developers and corporations for constructing green roofs on new buildings or for retrofitting selected existing roofs for their installation. In addition, a system can also be created for valuing buildings or apartments with green roofs and awarding them credits which should translate into increases in their financial value.

Finally, the establishment of competitive green roof programs for Ghanaian cities and establishing prizes for winning cities will be another way to promote green roofs in Ghana. In addition, new government buildings and selected old buildings should be retrofitted and covered with green roofs as way of showing government commitment to the green roof technology in the country.

CONCLUSIONS

Green roofs are progressively becoming a popular and important component of the urban landscape in many regions of the world because they provide multiple ecological, economic, building and amenity benefits including mitigation of the urban heat island effect, reduced energy use, improved storm water management and water quality, reduction of dust, smog and noise levels, provision of habitat for animals and plants and enhanced quality of life.

The paper has addressed the need, the benefits, the possibilities, the challenges and has provided some suggestions on the way forward. We contend that the green roof technology is adaptable to Ghana and can be made local though it appears foreign. Ghana has the perfect climatic conditions to support green roofs. The challenge is, are the people willing to embrace it? The world's population including Ghana's is increasingly concentrating in urban areas which as a result are expanding in size and density exacerbating environmental issues that go with expansion. Consequently, it is necessary to boost the natural capability of city landscapes to perform the ecosystem services they provided the environment prior to their development

through building of green roofs. Green roofs are one way to return destroyed natural habitats back to the built environment. Research has shown that in cities, roofs cover 21 to 26% of residential and non-residential areas (Wong, 2005). As an underutilized asset, roofs provide unique space in urban settings for greening and for engaging solar energy and rain for society's benefit. Even though there are other technologies like evaporative and cool roofs that can perform some green functions, they cannot be substituted for green roofs because they lack the ability to provide the total benefits of green roofs. As result, they should be used in combination with green roofs to build synergy if necessary but not as replacements.

In addition to the vast array of environment benefits green roof can provide, they have the potential to create viable new markets and job opportunities for the green industry in Ghana. Nurseries, contractors, architects, engineers and other artisans stand to accrue economic benefits. Similarly, green roofs can open up research opportunities for universities, research bodies like the Council for Scientific and Industrial Research (CSIR) and probably promote collaborations between these institutions and other government entities like the Ministries of Water Resources, Works and Housing and Environment Science and Technology. In this era of ever increasing population growth, climate change and environmental uncertainty growing our cities sustainably is a must and not a choice. Green roofs offer that opportunity. It is therefore necessary for Ghana to give green roofs a thought and if possible desire to become a leader of the technology in Africa.

Conflicts of interests

The authors have not declared any conflict of interests.

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