https://dx.doi.org/10.4314/dujopas.v9i2b.15
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 9 No. 2b June 2023*

Prospects and Challenges of Urban Pond Ecology: A Review

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Abstract
Increase in human population has led to intense pressure on bionetworks that provides various services vital for living organisms survival. This steered to the increase in interest in exploring the panorama and encounters of pond ecology for policy implementation, sustainable utilization that will guarantee sustainable management. This paper review the basic concepts of pond ecosystem, ecosystem service, challenges and prospects of the pond ecosystem. Relevant materials were collected, reviewed and synthesis with a view to understand the level of contribution, area of weakness therefore, the study could contributes in the area. Fish production, irrigation, groundwater storage and discharge, reduction of flash flood and aesthetic were identified as part of ecosystem services rendered by the urban pond. Garden production, research and aesthetic are some of the prospect while, waste disposing site, eutrophication, pollution are considered as some of the challenges confronting pond ecosystem.

Keywords: Ecosystem service, Ecology, Fish pond, Pollution, Irrigation

INTRODUCTION
The natural ecosystem provides valuable goods and services to the community therefore, interest in understanding the ecosystem services is a step towards sustainable natural resources management (McKenzie *et al.*, 2014). Ecosystem services are highly susceptible to numeral impacts due to the multifaceted things of humanoid use of natural resources and consequent land utilization change (Badamasi *et al*., 2018). Valuation of the impact of change in land utilization with regard to ecosystem services is essential in order to contrivance suitable land uses that enhance ecosystem services (Arunyawat and Shrestha, 2016; Badamasi *et al*., 2018). The anthropogenic and artificial forms of pond arise in all biogeographical regions, globally (Downing *et al*., 2008). Estimates recommend that there are 277,400,000

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ponds less than 1 hectare in size, plus 24,120,000 water bodies ranging from 1 to 10 ha, thus representing over 90% of the global water bodies, or 30% of global standing water by surface area (Downing *et al*., 2008). Therefore, an ecosystem is considered as vigorous multifaceted of living organisms interacting as a serviceable unit (Graves *et al*., 2009). Ponds have been used as an economical and efficient reservoir of water for livestock and irrigation purpose.

Moreover, farm ponds were involved in providing food, cover and nesting habitat to various kind of wildlife species such as amphibians, reptiles, fish, birds, (Wild life Habitat Management Institute, WHMI, 2005). Some Asian countries like Bangladesh, China, India, Indonesia, Malaysia, Thailand and Vietnam have adopted the concept of Integrated Agriculture Aquaculture (IAA) (Prien, 2002). This concept is based on the use of aquatic reservoirs adjacent to the agricultural lands for agriculture as well as aquaculture purposes. After China, India has become second largest aquaculture producing country in the world because of successfully facilitating integrated approaches for aquaculture along with agriculture (Sharma and Leung, 2000). Pond ecosystems have been reported as the most prominent means of irrigation in the Taoyuan area, Taiwan. However, in 1970s there were more than 3,290 ponds existing but only 1,800 ponds are left now which are protected by Taiwan government due of their ecological and cultural importance (Huang *et al*., 2012). Huang *et al*. (2006) observed that the concern of food safety and environmental contamination is increasing very fast in peri-urban zones of Asian region. Moreover, usually urban farming is mainly practiced in peri-urban areas other than rooftops, backyards and in community gardens. However, peri-urban areas are shrinking because of massive expansion of urbanization areas and population explosion which cause ecosystem disturbances. According to an estimate, world's half population are already living in cities (Dye, 2008) and it will reach up to more than two-thirds the year by 2050 (UN, 2010). Peri-urban areas are having more threat due to massive urbanization rate, continuously increasing populations and ecosystem disturbances. Moreover, it is catalyzing the impacts of climate change (Huang *et al*., 2012). Therefore, it is the demand of time to conserve the ecological systems, water reservoirs, peri-urban land use for a better future. Ponds serve various purposes such as irrigation, livestock, fish cultivation, field and orchard spraying, safety from fire, recreation, biodiversity conservation, soil erosion control, etc. Studies on pond ecosystem advantages and its conservation are very limited.

The ponds ecosystem services have been used as a ways of identifying, classification and valuing the benefits that environments provide and therefore is now firmly established as an analytical tool in policy agenda. The services are very pertinent to the wellbeing and survival of the populace around the metropolis, consequently some group of people depends on these services for their wellbeing especially where the services are fundamental in their livelihood. Urban ponds contribute greatly to green space and habitat for biodiversity which play a role in in improving individual and community health and environmental sustainability.
In Kano Nigeria, pond serve various purposes such as source of water for urban and peri-urban irrigation, waste disposal site, extracting some aquatic animal such as fish and also collection of aquatic plant such as water Lilly for medicinal use.

Ponds are biodiversity hotspots both in terms of species composition and biological traits, and have a significant role to play in the provision of ecosystem services (EPCN, 2008). Ponds are very pertinent part of our socio-cultural norm, due to their intrinsic historical value thereby it can be used to trace the origin of the human settlement and mode of our life. It is very important to explore the number of ponds their dimension and dynamics within the last twenty years with a view to understanding various services rendered to community, the factors influencing their dynamics and their conservation measures for optimum ecological

services collection. Moreover, the ponds around Kano metropolis face serious threats from anthropogenic activities such as waste disposal, gentrification, commercialization and urban land use conversion, European Ponds Conservation Network (EPCN, 2008). Sequel to the aforementioned problems, little attention has been made for guarding and restoring the ponds despite the various benefits emanating from them, therefore there is need for the assessment of nature, dynamic and ecological service of ponds around Kano metropolis.

The economic values of ponds such as agricultural activities, source of building materials and recreation have changed over time. Ponds have the prospective to hold water back at source, recharge aquifers, and reduce the volumes of water generated to avoid flooding, thereby offer bearable resolutions to vital societal and environmental problems such as water management and carbon sequestration (EPCN, 2008). However, research-based information is needed for potential route in the management of ponds and to contribute in connexion the breach for sustainable environmental management. Based on these issues raised, pond conservation accentuates the importance of seeing the pond resource as a whole rather than as individual sites.

Pond Ecosystems

Ponds serve as homes and sometimes act as refugia for rare species not found in other freshwater bodies (Epele and Miserendino 2016; Drinan *et al.* 2020). Ponds contain invertebrates that are a major food source for water birds, such as rails (Sanders, 2000). Ponds also serve as stepping stones for frogs, enhancing their movements across different ponds (Howell, *et al.* 2020). Ponds are not only important as aquatic habitats; they also provide ecosystem services such as recreation, mineral extraction, nutrient cycling, agriculture, and water management. They have significant aesthetic, ecological, geochemical, cultural, and economic value (Hassall, 2014; Mueller *et al*., 2016). Furthermore, microbial communities in ponds are useful in bioremediation (breaking down pollutants) (Hassall, 2014). Because they are responsive to environmental variation, ponds are ecosystems that give early warning signs about climate change when studied over time (Epele and Miserendino, 2016; Oertli *et al.* 2018). As a consequence of their relatively small surface area, ponds are vulnerable to climate change and species loss. Therefore, exploring the ecosystem services of ponds is important for managers to develop a comprehensive approach to pond ecology conservation (Naselli *et al*. 2016). Ponds are considered discontinuous habitats, and due to their patchy nature, any land management activity undertaken close to them will likely impact the pond ecosystem (Naselli *et al*. 2016). Any changes in land use activities may lead to considerable pressure on pond biodiversity, threatening their viability and consequently loss some services expected from the ponds (Kuczynska and Joniak 2016).

Structures of a Pond Ecosystem

A pond can be visualized as an artificial and sometimes natural water reservoir that develops around human settlement or around streams or river basin. It resembles a dam only that it does not necessarily exist along a river course. In Kano metropolis, ponds emerge whenever land is dug the ground for the purpose of obtaining earth, mud or clay for the purpose of building houses, road and other uses. The resulting pit burrow becomes a pond which usually traps an enormous amount of rain water and/or sewage coming from the neighbouring settlements. Burrows/ponds also serve the function of a source of domestic water, in addition to their role as source of building materials (Mukhtar and Oyeyi, 2005).

In some area that lack the modern drainage systems, the ponds tend to overflow into their neighbouring house(s) and can lead to many disastrous consequences such as collapse of houses and contamination of the environment and agricultural produce (Adikwu *et al*., 2003). Indabawa and Muktar (2010) reported that ponds containing a large volume of water are now

scattered all around Kano metropolis. More so, domestic leftover containing a large quantity of waste and organic and inorganic chemicals that may serve as nutrient for aquatic plants, animals and microorganisms, find their way into these ponds. As a result they distort the aesthetic value of these waters as they become polluted. The actual source of pollution is the sewerages from where these water reservoirs in the city get their name as sewage/ponds (Indabawa and Muktar, 2010).

Ponds were originally not known to serve as sewage systems but merely as burrows. However, with increasing population density which leads to congestion of houses and a resultant high release of wastewater, refuse and even "night soil" (faecal matter), these previously attractive ponds have now been turned to be a collection of garbage and recalcitrant polythene as well as plastic matter which chase away any on-looker with its unbecoming odour and poignant or rather nuisance site. These characteristics of sewage ponds are known to cause serious health havoc to its neighbouring inhabitants even to downgrade their original usefulness enjoyed by the people around them. It is therefore imperative to attempt to look at the nature and type of ponds, their ecological and/or biological importance as well as their cultural purposes.

The pond ecology has some feature as described by Millennium Ecosystem Assessment (MEA, 2005) which include:

1. The pond is stagnant.
2. The pond ecosystem has natural or artificial borders.
3. Littoral, limnetic, profundal, and benthic are the pond's zones.
4. Different levels of biotic components in the pond prevent survival competition.
5. Bottom level: scavengers and decomposers, middle level: fish. Small animals and insects are protected by the pond's plants.
6. Pond ecosystems vary in size.
7. The pond bottom lacks oxygen and light. Here, decomposers and scavengers eat dead matter.
8. Midwater is mostly fish. The pond bottom and surface both have food. Stickleback fish, water fleas, and dragonfly nymphs breathe through skin or gills.
9. Pond surface animals breathe through gills, skin, or lungs. Oxygen and light abound. Ducks, boatmen, midge larvae, and tadpoles live here.
10. Pond margin plants shelter insects and small animals like frogs. Marsh marigolds thrive in light and oxygen.

ANTHROPOGENIC STIMULI ON THE POND ECOSYSTEM

The physicochemical and the biological community of a pond are mainly determined by Land Use/Land Cover (LULC) within the catchment area and the local climate (Novikmec *et al*.. 2016). An increasingly dominant land use type in Kano metropolis is urbanization and urban guarden landscapes (Bhat *et al*., 2020). As urbanization intensifies, the shape, size and connectivity of ponds are altered, affecting the biological community derived nutrients, such as phosphorus and nitrogen, are also highest in urban and agricultural areas, which negatively impact macroinvertebrate communities (Atique and An 2020; Bhat *et al.* 2020; Gadd *et al.* 2020; Usio *et al.*, 2017). Despite this concern, there has been limited effort to quantify ponds' nutrient levels or even assess pond water quality (Greig and Galatowitsch, 2016; Snelder *et al.*, 2020). Furthermore, although there is a high rate of freshwater species extinction, data on ponds' biodiversity are inadequate (Weeks *et al*., 2016). Many ponds have recently been constructed in modified landscapes, predominantly urban areas, to prevent flooding and retain excessive nutrients from runoff. These artificial ponds also support biodiversity (Oertli 2018; Sun *et al.,* 2019). Therefore, the lack of research on ponds represents a fundamental

knowledge gap in freshwater systems, mainly due to the increase in freshwater habitat loss and degradation (Maxted *et al*., 2005). It is essential to assess the role of ponds in species conservation and how LULC and anthropogenic activities affect biodiversity. Such an assessment will be informative in developing appropriate conservation or restoration strategies.

Seasonality in Pond Ecosystem

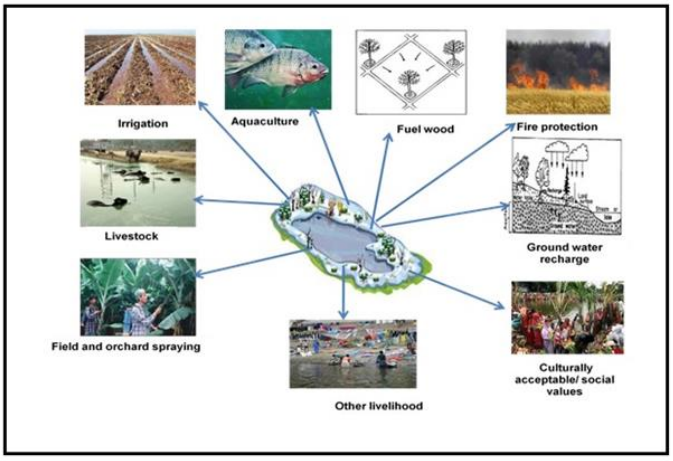
Seasonality is an environmental feature that influences water quality and biodiversity in ponds by affecting the chemical composition and food availability (Tonkin *et al.* 2017; Desalegne, 2018). Wet seasons can increase individual chemical components in the water through runoff or soil percolation. In contrast, high rainfall can also reduce the concentration of nutrients due to dilution (Jeppesen *et al.*, 2015). On the contrary, seasons characterised by low or no rainfall and high temperature lead to increased conductivity, nutrient load, and pH (Chowdhury and Husain, 2020). Temperature, water volume, and photoperiod, which influence the hatching of macroinvertebrate eggs, are also seasonally variable (Boix *et al.,* 2016). Hence seasons affect the composition and distribution of macroinvertebrate communities in ponds (Greig and Galatowitsch, 2016; Jayawardana *et al.,* 2017; Desalegne, 2018).

Delivering Ecological Services Index

Delivering Ecological Services Index (DESI) approach proposed an ecological services model linked to classes developed by the Millennium Ecosystem Assessment (MEA, 2005). MEA (2005) acknowledge that land must be developed and used to support human communities, and the recent increase in more intensive agriculture and forestry practices has generated new income, improved lifestyles and reduced rural poverty (Modrego *et al*., 2011). However, the development of land at the expense of natural ecosystems involves a trade-off between improving human economies and degrading natural and semi-natural ecosystems–degradation that often reduces ecological services provided by healthy ecosystems. DESI is designed to be sensitive to reduce impacts of more sustainable land use practices within land use categories, e.g., sustainable viticulture, careful use of water, buffering of aquatic ecosystems, or zero tillage agriculture.

Nature and Uses of Ponds

A pond can be envisioned as an artificial and sometimes natural water reservoir that develops around human settlement or around streams or river basin. It resembles a dam only that it does not necessarily exist along a river course (tributary or distributor). In Kano metropolis, a pond emerges as a results of digging the ground for the purpose of obtaining earth, mud or clay for houses and city wall construction. The resulting pit becomes a pond which usually traps an enormous amount of rain water and/or sewage coming from the neighbouring settlements. The use of pond water for irrigation, fishing and recreation ground for those that wade into swimming are also what makes them indispensable to many people in urban areas. This is especially observed in Kano metropolis at quarters that lack the modern drainage systems. Sometimes, these ponds too tend to overflow into their neighbouring house(s) and can lead to many disastrous consequences such as collapse of houses and contamination of the environment and agricultural produce (Muktar *et al*., 2010). Thus, various services were harnessed from pond ecosystem which are presented in figure 1.



Adapted and modified from Prein, (2002).

Fig.1: Benefits of Pond

Fish production

Ponds provided with different species of fish where many land users have found fishing as good profitable business. Good fish cultivation in the ponds can also provide recreation and enhance the source of income. In 1997, Asian countries produced total 91% of the global aquaculture production ~36 million tons, particularly dominated by China followed by India (Prein, 2002).

Field and orchard spraying

Ponds provide water for orchard spraying. Generally, the small amount of water is needed for spraying. Hence, it can be useful in water conservation. For example, about l00 gallons of water is required for one acre and it is found enough for the most of the common crops, United State Department of Agriculture (USDA, 1984).

Protection from fire

Ponds provides a dependable water supply which is always needed to fight fire. The pond is located close to agricultural lands and houses, therefore provide safety from fire. Therefore, it would be better to have any aquatic reservoir near by the agricultural fields and residential area (Huang *et al*., 2012).

Irrigation

Ponds are an important source of irrigation water especially in the rural as well as in peri-urban areas, where does not have the organized irrigation system. Water requirement for irrigation is always found greater than other purpose. However, pond capacity must be adequate to meet the requirement of crops in growing season and also try to overcome water losses (Prajapati and Srivastava, 2013). The irrigated area covered by a pond may be about five times more than the capacity of pond (Huang *et al*., 2012). The required storage capacity of a pond used for irrigation depend on various factors such as water requirement of the crops, expected rainfall during the growing season, efficiency of irrigation method, water loss due to evaporation, seepage, expected inflow to the pond etc. Ponds provide irrigation water, freshwater habitats that enhance biodiversity as well as the most important fact their involvement to harmonize the local micro-climate, regulate flooding, provide water for fighting fires, and create a unique rural landscape (Huang *et al*., 2012).

Production of Vegetables

Production of vegetables on the pond bank throughout the year will provide an additional benefit over traditional pond management systems. Generally, small farmers do not have facility of irrigation for production vegetable. In this regard, vegetables production through integrated pond management can increase availability of vegetables for family consumption. Moreover, cash from the selling of vegetables will also increase the total income of the households. This approach of vegetable production has exhibited remarkable benefits to the poor farmers in terms of income generation and family nutrition. Production of fresh vegetables in peri-urban areas throughout Southeast Asia has attracted special attention (Jansen, 1992; Midmore *et al*., 1996). So, pond waters can help to make free the vegetables cultivation from the potential contaminants and toxic chemicals and pathogenic microorganisms (Huang *et al*., 2006).

Other Benefit of pond ecosystem

Three advantageous aspects of pond ecosystems like economic, environmental and social were presented in table 1 however, some Social benefits cannot be measured quantitatively like religious values and cultural activities (Ajay *et al*., 2015).

Table 1: Economic, social and environmental advantage of pond

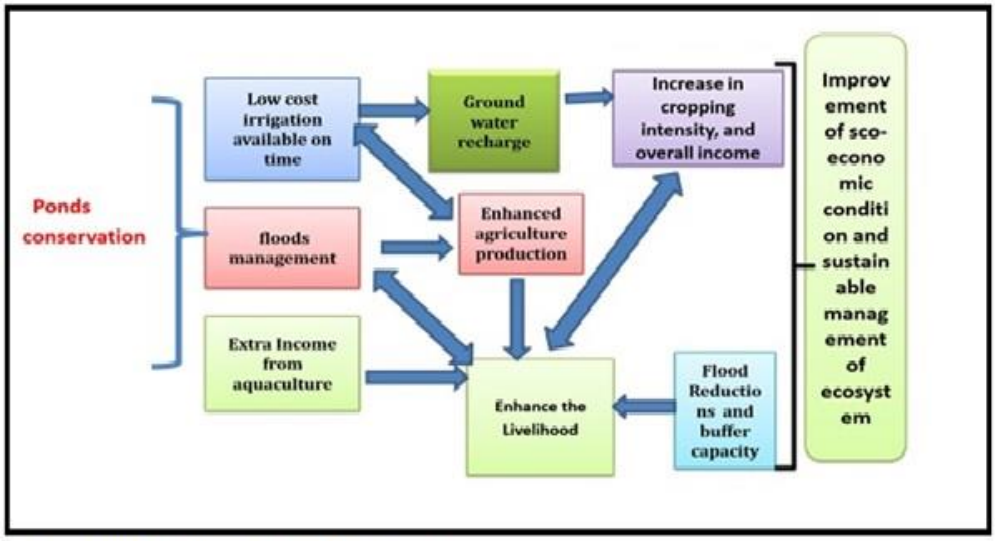
S/No.	Resilient options	Advantages		
		Economic	**Social**	**Environmental**
1	Pond conservation	Irrigation, wages, and management of water logging/flood	Cultural, drinking, animal bath, distribution of equal recourses	Increasing groundwater table and improve soil fertility
2	Use of surface water/water conservation	Save the fuel, low labour cost	Alternative options of irrigation, mixed farming and marketing	Flood management
3	Ground water extraction through bore well	Timely irrigation facility, enhanced production	Lesser conflict, agricultural interest increase among farmers	-
4	Conservation of open/agricultural area	Less damage to the crops due to Water logging /flood	Livelihood of community, social harmony, cultural activities	Increasing groundwater, buffering capacity of the flood
5	Promote the agricultural sub- system like pond	Increase cropping intensity, Increase in overall income, minimum risk	Livelihood and food security ,dignity	Increasing buffering capacity of flood, biomass and soil fertility
6	Bonding around farm	Weed control and less use of fertilizers	Equal nutrition to the soil, check the runoff of rain water	Ground water recharges and maintain moisture level in soil

Adopted and Modified from Ajay *et al*. (2015)

Concept of Biodiversity and Ecosystem Services

Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of

ecosystems" (MEA, 2005). The importance of this definition is that it draws attention to many dimensions of biodiversity. It explicitly recognizes that every biota can be characterized by its taxonomic, ecological, and genetic diversity and that the way these dimensions of diversity vary over space and time is a key feature of biodiversity. Thus, only a multidimensional assessment of biodiversity can provide insights into the relationship between changes in biodiversity and changes in ecosystem functions and services (MEA, 2005). Biodiversity include all ecosystems (managed or unmanaged ecosystems). It is the foundation of ecosystem services to which human well-being is intimately linked. No feature of earth is more complex, dynamic, and varied than the layer of living organisms (i.e. biosphere) that occupy its surfaces and its seas (MEA, 2005). Biodiversity contributes directly (through provisioning, regulating, and cultural ecosystem services) and indirectly (through supporting ecosystem services) (MEA, 2005). It represents the foundation of ecosystems that, through the services they provide, affect human well-being (MEA, 2005). These include provisioning services such as food, water, timber, and fiber; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfilment; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA, 2005). There are many measures of biodiversity; species richness (the number of species in a given area) represents a single but important metric that is valuable as the common currency of the diversity of life but it must be integrated with other metrics such as Shannon Winner's diversity index, important value index, etc to fully capture biodiversity. Variability, dynamics, trophic position, and functional attributes of many species are poorly known. Ecological indicators are scientific constructs that use quantitative data to measure aspects of biodiversity, ecosystem condition, services, or drivers of change. Ecological indicators form a critical component of monitoring, assessment and decision-making and are designed to communicate information quickly and easily to policy-makers (MEA, 2005).



Adapted and modified from MEA (2005)

Fig.2: Concept of Change in Pond Ecosystem

PROSPECTS OF POND ECOLOGY

Garden ponds

It was reported that 16% of gardens in the United Kingdom contain pond and extrapolated from these surveys to give a predicted garden pond resource of 2.5-4.5 million ponds across the country, with an estimated surface area of 3.5 Km^2 (Davies *et al*., 2009). The difficulty with monitoring this resource is the size and the lack of detailed mapping data: estimates of mean

garden pond size vary and these are not shown on maps. Furthermore, difficulty with access for researchers to garden ponds may have deterred earlier work (Wood *et al*., 2003). However, garden ponds are well-used by amphibians, which show little habitat preference but may be influenced by the presence of fish. Attempts at experimental supplementation of garden ponds using small mesocosms (0.21 m^2) suggest that a range of animals may readily and rapidly colonise even these small wetlands, and that there could be an additional value as supplementary habitat for amphibians (Gaston *et al*., 2005). This resource must be incorporated into urban ecology in a more comprehensive way in order to adequately evaluate aquatic ecological processes.

Green Space

Increasing urbanisation involves not only the sprawl of urban margins but also the intensification of land use within already built-up areas and this reduction in land per unit population leads to a concomitant reduction in available green space (Danks, 2001). It is generally accepted that green space has a positive effect on a range of health outcomes and environmental quality such provision of fresh air (O_2) and removal of carbon dioxide (CO_2) through photosynthesis (Lee and Maheswaran, 2011). In particular, biodiversity seems to be strongly associated with ecological as well as psychological benefits (Danks, 2001). Consequently, clearing of green space has attracted attention because of the potential ecological effects on land degradation (like erosion, increased run-off and flooding) increasing carbon dioxide concentration, climatological changes, loss of habitat and biodiversity (Mas, 1999; Badamasi *et al*., 2018). For example, figures from the World Conservation Monitoring Centre indicated that out of the 1,417 known species of amphibians, birds, mammals and reptiles in Nigeria, 1.2% are endemic and 3.5% are threatened, International Union for Conservation of Nature (IUCN, 2004). However, the construction of new developments necessitates the construction of drainage which can provide pond ecosystem and these wetlands can contain considerable biodiversity (Scher, 2004; Scher and Thiery, 2005; Vermonden *et al*., 2009). The creation of ponds within such developments can be guided by ecological theory, but this will require ecologists to turn our observations of variation in biodiversity in artificial, urban pond into guidance for developers. Further opportunities may lie in the green buildings themselves, into the walls and roofs of which pond ecology features can be integrated.

Research

Urban ponds provide a replicated set of habitats that are close to centres of research as well as large numbers of lay people. This opens the way for citizen science, a growing area with many innovative and extensive research projects (Silvertown, 2009). Particular ecological questions that can be raised such as investigations of meta-population and meta-community ecology, within the context of network theory (Briers and Warren, 2000; Cottenie *et al*., 2003; Fortuna *et al*., 2006). The harsh environmental pressures exerted on urban ecosystems also provide opportunities to study evolutionary processes on the aquatic ecosystem. The developing world, where systems are far closer to natural prior to urbanisation, would give a clearer picture of the impacts of urbanisation than the space-for-time urban-rural gradient studies that are conducted in Europe and North America (Shochat *et al*., 2006). In parallel to the opportunities presented for fundamental research, applied research must also be directed towards the needs of end-users. These include hydrologists who use storm water facilities to manage surface flow – while some studies show evidence of successful use of ponds to reduce flooding, conservation agencies require evidence for the efficacy of particular designs and configurations of ponds in order to maximise benefits from limited resources. Interest in nutrient and pollutant retention has also tended to rest on observational studies, while studies

of the efficacy of different methods of pollutant retention and of the impacts of urban pollutants are required (Collins *et al*., 2010).

CONCLUSION

Ponds are among the various freshwater habitats and niche for biodiversity. It provide various services to the environment such as carbon sequestration, fishing, groundwater recharge and reduce flood incident. Some human activities like urbanization and waste disposal disrupt the quality of the ponds thereby making it difficult to provide some ecological services. Maintaining pond ecosystem will enhance the proper exploitation of services provided and environmental sustainability.

Acknowledgement

The authors acknowledged the support of TETFund for sponsoring the research (BUK/DRIP/TETF/0012) also acknowledge and appreciate the Directorate of Research Innovation and Partnership, Bayero University Kano, Nigeria for coordinating the entire research process.

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