International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

https://gssrr.org/index.php/JournalOfBasicAndApplied/index

Review of Water-Sensitive Urban Design and the Current Situation in Egypt

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Abstract

Global urbanization and climate change have resulted in many environmental problems, including pollution, water scarcity, and other water-related disasters. As a result, urban solutions classified under design sustainability are needed to reduce the impacts of urbanization and climate change. Water-sensitive urban design (WSUD) promises to reduce freshwater pollution, provide additional water, decrease flooding potential, protect ecosystems, improve urban amenities, and preserve the aesthetic nature of blue and green areas. These objectives are vital as we face rapid urbanization, rapid growth in population, serious water scarcity, and climate change impacts on urban water resources, However, we find that these studies are limited, especially in developing countries, and do not match the importance of the subject. So, the fundamental techniques of WSUD are thoroughly outlined in this paper, emphasizing how WSUD contributes to the increased livability of metropolitan regions. The search in research databases from 2016 to 2024 included research papers, theises, books, and international and local reports. This review aims to raise awareness regarding the present situation in Egypt and to enhance comprehension of optimum planning methods for WSUD. This paper main contribution is to enhance the understanding of WSUD by identifying the gap (future trends for researchers) in this topic.

Keywords: WSUD (water-sensitive urban design); Urban water cycle; Climate change.

Received: 10/14/2024
Accepted: 12/14/2024
Published: 12/24/2024

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1. Introduction

The United Nations (UN) Sustainable Development Goal 17 establishes clear objectives to improve and sustain urban development, mitigate and increase resource efficiency, foster resilience to climate change and disasters, and address aging infrastructure. However, reaching these goals is especially challenging in countries undergoing rapid urbanization due to population and economic growth. By 2050, it is projected that more than 80% of the metropolitan population worldwide will live in underdeveloped regions [1,2,3,4,5,6,7,8]. Rapid urbanization results in more impermeable surface area, which increases surface runoff and causes flooding, the depletion of natural streams and greenery spaces, the decline in water quality, and the depletion of groundwater supplies [9,10,11,12,13,14].

As this study explains, urban water difficulties include contaminated water sources, scarce potable water supplies, solid waste management, stormwater flooding, subsidence, illnesses, environmental effects, climate change, and ongoing urbanization. Hence, the primary objective is to comprehensively comprehend the Egyptian scenario to assist decision-makers, stakeholders, and researchers [15,16]. Where we find that these studies are limited, especially in developing countries such as Egypt, and need to match the importance of the subject. So, the fundamental techniques of WSUD are thoroughly outlined in this paper, emphasizing how WSUD contributes to the increased livability of metropolitan regions.

Most literary reviews, such as [10,17,18,19,20] do not address developing countries due to their delay in catching up, despite the need to assess their situation to develop appropriate plans, which was focused on here in the research.

The recently released UN guidelines on water governance outlined four components: the political, social, economic, and ecological dimensions. Integration establishes an intricate and mutual sensitivity between WSUD systems and the urban areas in which they are implemented [21].

- Despite increasing global water consumption, over four billion people can still not access clean and safe water [22].
- By 2030, 50% or more of the population will reside in high-water-stress areas.
- According to the UN, around 3.6 billion individuals, nearly 50% of the population, reside in regions that experience water scarcity [23,24].

The aforementioned issues make it abundantly evident that urban water management requires more sophisticated solutions.

2. Materials and Methods

2.1 Research Design & limitations

The review includes studies available in scientific databases, namely Google Scholar and Science Direct, up to 2024. It focuses on the terms "water-sensitive design," "water-sensitive city," and "WSUD." Article selection process: keyword search, text analysis, and abstract screening. The findings of a Scopus search of published papers from 201٦-2024 with "Water Sensitive City" WSC and/or WSUD in the title, abstract, or keywords.

2.2 Data & Statistical Analysis

The paper content has been meticulously developed through the review of more than one hundred and twenty papers, books, theises, and reports. This comprehensive approach ensured that the most recent findings concerning WSUD effectiveness were considered while outdated or inconsistent perspectives were excluded. The charts that were analyzed for the collected information were also consistent with the analytical charts of the Scopus platform, further enhancing the thoroughness of this review. We also relied upon systematic reviews, substantial syntheses, and meta-analyses: PRISMA. Figure 1 Shows the distribution of publications annually. The authors suggest that the reason behind having the majority of publications in 2022 is the period following the spread of COVID-19, and the matter is related to a major, important, and influential resource such as water.

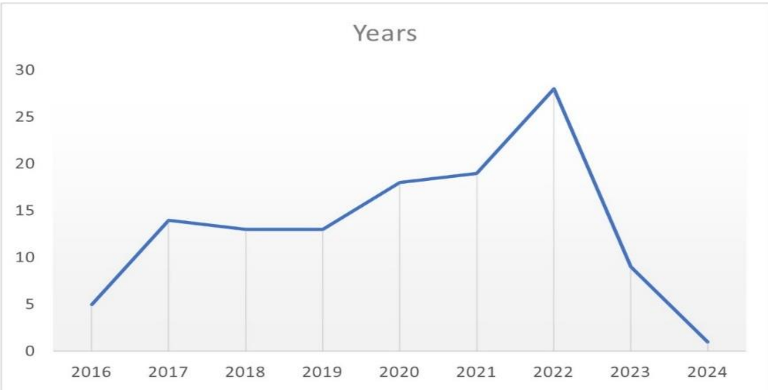

Figure 1: Annual distribution of publications

Figure **2** Shows the diversity of the data gathered from books, theses, reports (both national and international), and various types of articles (reviewed, conference, and research). Data analysis and evaluation clarify the definitions of WSUD terms, principles, and objectives and address these gaps.

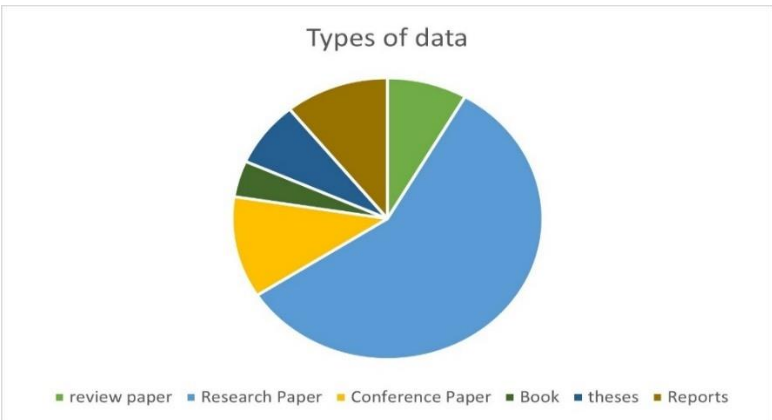

Figure 2: Diversity and differences in the collected data

3. Water problems in urban cities

Water is necessary for the following purposes: agricultural, drinking water supply, mollusk production, people consumption, commercial and recreational fishing of edible fish and crustaceans, industrial water usage, natural aquatic habitats and animals, and water-based recreation [25]. Water resource scarcity is widespread worldwide, particularly in the MENA region, where countries are semiarid or desert. With time, aridity causes water shortages since more water is needed to meet the growing demand. Figure 3[26,27,28,29].

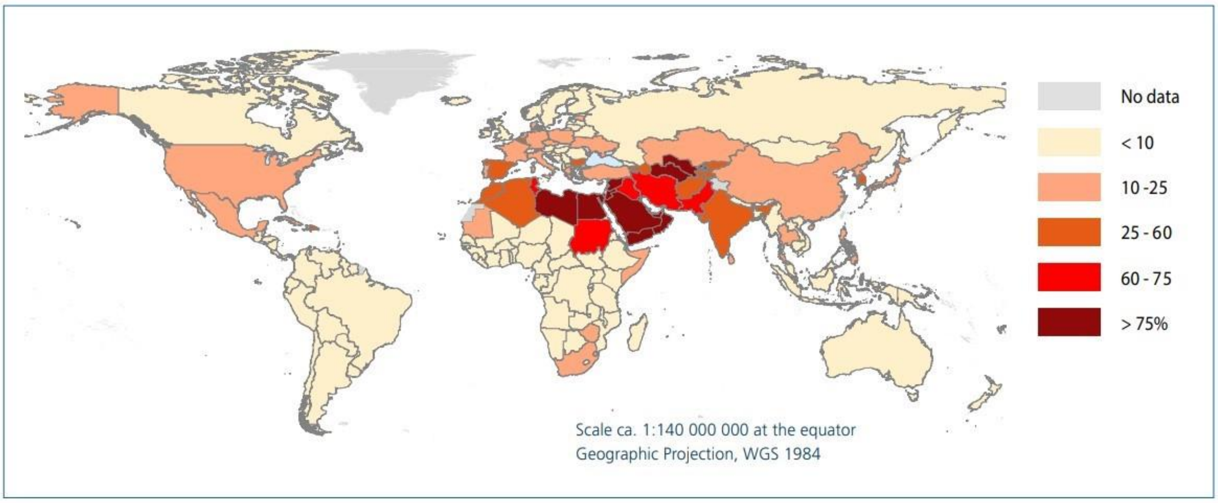

Figure 3 : Percentage of renewable water resources withdrawn [23]

The words "water sensitive" and "urban design" are combined to form the term "WSUD." [30] However, given these circumstances, the water cycle and utility operate independently rather than as part of a more extensive system. The existing water management system separates three urban streams: stormwater, wastewater, and drinking water. The dominance of a linear system and a specialized infrastructure strategy is a significant factor in the functioning of many services unrelated to the water cycle or urban planning. It is crucial to decrease water use and implement strategies for sustainable water management that augment the water supply [31].

The constant flow of water at and below ground is known as the natural (hydrological) water cycle. Most life and ecosystems on Earth depend on the water cycle for survival. Nevertheless, this cycle is disturbed and unable to proceed normally in metropolitan environments. In a natural system, soil and plants collect, absorb, and filter rainfall throughout a watershed. This infiltration lessens the likelihood of runoff while keeping the soil moisture and groundwater levels relatively constant. Plants and soil are the same thing. It functions like a sponge, gathering and absorbing runoff while holding and releasing water.

Because of paved surfaces, this cycle is disturbed in metropolitan places and cannot proceed normally or soak into the ground. It does not have time to evaporate because it is rapidly collected and released into municipal sewer systems. Floods can occur when flow rates rise quickly. Local streams and open channels. The erosion of riverbanks and channels caused by these unnatural extreme events can lower fish populations, diversity, and habitat [32].

Currently, cities occupy 2% of the planet's land area. According to ecological research, cities can have an environmental footprint 10–150 times larger than they should be. This exerts significant pressure on the constructed environment, encompassing issues like soil, air, and water contamination, as well as the availability of water, treatment of wastewater, and recycling of solid waste. As a result, cities depend more on rural areas to supply them with food, building materials, electricity, water, garbage collection, etc. Figure 4 [8].

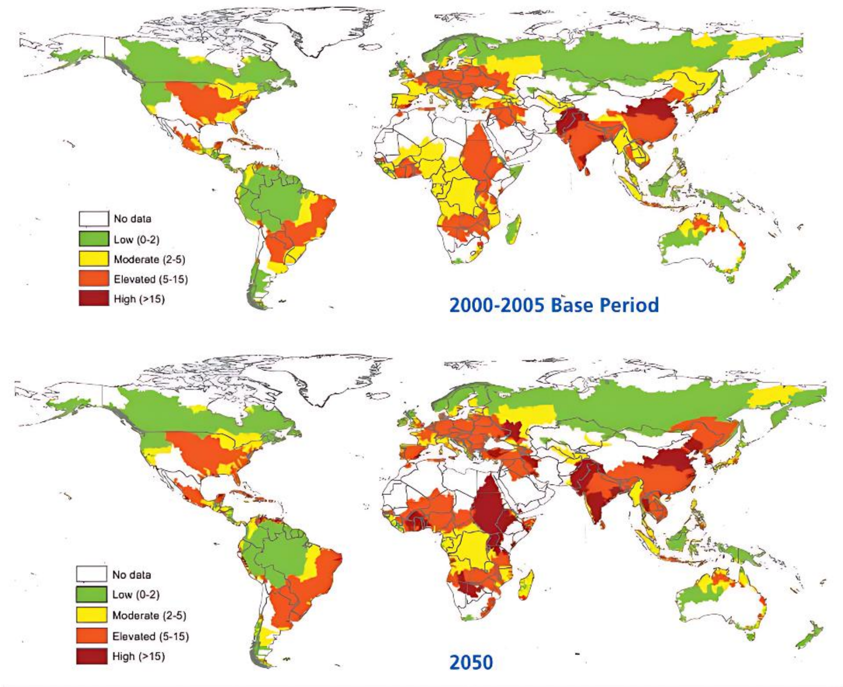

Figure 4: Comparative risk indices for water quality in major river basins for the period (2000-2005) and projected for the year 2050 [23]

Water usage is 67% for agriculture, 31% for industry, and only 2% for household water, so the main water usage is irrigation. Agricultural activities are responsible for about 90% of the total reduction in freshwater. Urban infrastructure is expensive. According to projections from the [26] , By 2030, approximately US$41 trillion will be required to build new urban infrastructure, mostly in developing countries, and renovate existing infrastructure in affluent countries. Water infrastructure is predicted to cost US$22.6 trillion. The majority of this $22.6 trillion is attributed to wastewater infrastructure [27] .Executing sustainable development goals related to water requires between 1.8 and 2.5% of the world's annual gross product. However, some developments are too significant to ignore:

UN projections indicate that by 2025, almost 2/3 of the global population will face water scarcity, with over 2 billion people experiencing an utter lack of water. The projected water demand in 2030 is 40% greater than available. Many cities are located in dangerous regions. Drought is a notable natural calamity in Europe, impacting 37% of the European Union in the last ten years. The region of Southern Europe is seeing a heightened vulnerability to drought conditions, whereas northern Europe's dry-year probability has decreased. Droughts can result in water scarcity, food shortages, wildfires, land and water degradation, and heightened health hazards for the population. Drought and temperature surges are frequently interrelated. Two-thirds of the largest cities on Earth are predicted to be at risk from increasing sea levels. Many delta cities experience substantial ground subsidence at the same time. There is an expectation that extreme precipitation events will occur more frequently, be more severe, and last longer. Additionally, droughts are expected to occur more often and last longer. Managing water resources sustainably is a significant task. This is likely also why, in terms of both likelihood and impact, There is an expectation that extreme precipitation events will occur more frequently, be more severe, and last longer. Additionally, droughts are expected to occur more often and last longer. Numerous other international organizations, including the UN, the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the Organization for Economic Cooperation and Development (OECD), have water as a top priority. The European Union (EU) projected that the combined economic effects of drought events and water scarcity during the previous 30 years amounted to €100 billion. The average yearly impact doubled between 1976–1990 and the subsequent 1991–2006 period, reaching € 6.2 billion annually. An estimated € 8.7 billion was spent during the unprecedented heat wave that ravaged Europe in 2003, leading to a total of 70,000 avoidable fatalities during four months in both Central and Western Europe [23,8].

4. WSUD Background

WSUD is referred to by various names, such as Stormwater Best Management Practices (BMPs) and Low Impact Development (LID) in the U.S., Sustainable Urban Drainage System (SUDS) in the UK, Water Sensitive Urban Design (WSUD) in Australia, Low Impact Urban Design and Development (LIUDD) in New Zealand, ABC (Active, Beautiful and Clean) Waters Program in Singapore, and, more recently, the Sponge City initiative in China, Green Infrastructure (GI), Blue-green Infrastructure (BGI) and Nature-Based Solutions (NBS). The number 60 is enclosed in square brackets. The initial application of LID was in a land-use planning report. Subsequently, strategies such as 'water-sensitive urban design' that emphasized environmental sustainability were established. These systems have been researched and implemented worldwide to control the amount of stormwater, enhance the quality of stormwater, and enable the collection of stormwater to increase freshwater resources. WSUD was first developed in Australia twenty years ago, while LID has been commonly utilized in New Zealand and North America. In North America, the phrase BMP refers to systematic methods employed to mitigate pollution in water bodies. In the United Kingdom, efforts to manage stormwater began in the late 1980s. In 1992, the 'Scope for Control of Urban Runoff' guidelines were produced to guide several technological alternatives for controlling stormwater. GI, which encompasses more than stormwater management, originated in the United States throughout the 1990s. This phrase has its etymology in both landscape architecture and landscape ecology. NBS, an abbreviation for Nature-Based Solutions, is a European concept that involves incorporating elements of nature into urban architecture. It encompasses ideas that are inspired by or generated from nature. Structural approaches to water-sensitive urban design (WSUD) in the United States and France have been referred to by several terms, including stormwater control measures (SCMs), compensatory techniques (CTs), alternative techniques (ATs), and source control [28,33,34,35,36,37,24,38,39,25].

The urban water transition framework has six progressive achievement levels as a city grows. The initial three stages of development entail the establishment of a water system that offers essential services such as the provision of potable water ("Water Supply City"), safeguarding public health ("Sewered City"), and preventing floods ("Drained City"). The subsequent designations for the city include the "Waterways City," "Water Cycle City," and ultimately the WSC. The latter has numerous advantages, such as providing social amenities like green spaces and reducing urban heat islands. It also contributes to environmental protection and resilience to climate change. These goals are similar to those pursued in the "sponge cities" concept. They also provide reliable water services under resource constraints. [25] Developing cities are typically seen in the first three stages of development when infrastructure is focused primarily on one purpose. However, mature cities are typically found at the latter three levels, with more sophisticated water management due to multifunctional infrastructure. Multifunctional infrastructure integrates secure and useful areas with urban ecosystems, making them appealing to society. Figure 5 [31].

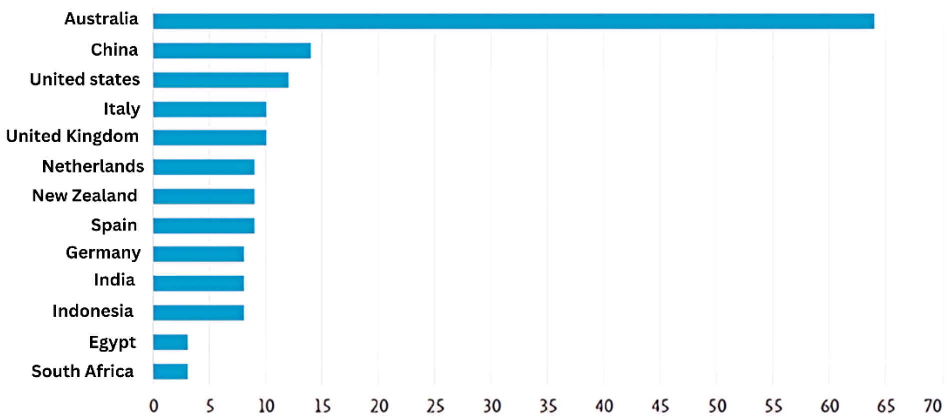

Figure 5: Location distribution for the reviewed

Owing to science, technology, and pertinent laws and regulations, the hypothesis has advanced through four stages: modern sustainable stormwater management (BMPs, LID, and GI/GIS), single drainage, water quantity, quality management, and the sponge city concept **Error! Reference source not found.** [37].

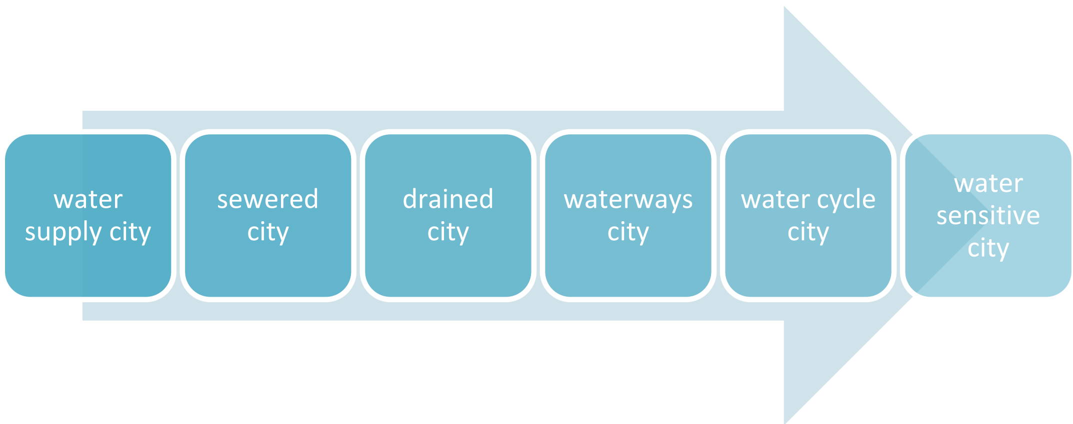

Figure 6: The water transition framework by the author inspired [40]

5. (WSUD) definitions

WSUD is analyzed from three distinct viewpoints: hydrological planning, urban planning, and water governance Reference [21].

WSUD is a comprehensive method encompassing the complete urban water cycle: water supply, wastewater, stormwater, and groundwater. It prioritizes environmental conservation [41,11,42].

(WSUD) is the collaborative integration of water management, urban planning, urban design, and landscape architecture [43,44,45] .It encompasses all aspects of the urban water cycle and integrates water management functions with urban design principles. WSUD focuses on developing comprehensive sustainability plans encompassing ecological, economic, social, and cultural aspects [40,28,10,46,12].

WSUD is a philosophical approach to urban planning and design that seeks to mitigate the impact of urban expansion on the hydrology of the surrounding ecosystem. The stormwater management (WSUD) component can collect stormwater for non-potable purposes, such as supplementing the main water supply. It also helps with flood control, regulating water flow, and enhancing water quality [10].

WSUD systems can be implemented at the individual household level, on a larger scale inside development regions, or in suburban communities. At the urban level, guidelines exist for sponge cities and water-sensitive cities.
The UN set an agenda for 2015 to eliminate poverty and safeguard the environment. The agenda highlights the significance of ecosystem functioning in sustaining the well-being and economic activity of the local community. The sixth aim of the SDGs focuses on ensuring access to clean water and sanitation.

The WSUD integrated the natural water cycle with the positive features of the urban design grid to design systems that use vegetation, soil, and natural processes to lower stormwater runoff volume and velocity and improve drainage water quality [21,38].

"Treatment," in this case, does not traditionally mean collecting rainwater and discharging it into the city's sewer system. In WSUD, the "method" means reducing runoff and increasing stormwater infiltration and evaporation via rainwater harvesting techniques (e.g., for use or storage). This is intended. The concept aims to complete the cycle by returning water to the city's nature-oriented water cycle, conserving and reusing water [47,48].

6. WSUD Principles

• safeguard the integrity of the natural water cycle within urban areas.

• Safeguard water quality by employing filtration and water retention methods to preserve the purity of groundwater and Surface Rivers.

• Reduce impermeable surfaces in metropolitan areas and implement decentralized retention systems to decrease stormwater runoff and peak flow.

• Diminish the necessity for developing and constructing new stormwater drainage infrastructure, reducing costs.

• Minimizes the volume of wastewater generated and discharged.

• Expands the potential for water recycling.

• lowers the need for water by offering substitute sources [49,10,11,50]. (Reservoirs, tanks) [24].

7. WSUD Objectives

WSUD approaches, also known as systems, aim to achieve various outcomes that can be categorized into nine groups: enhancement of stormwater quality; management of flow regime; collection of stormwater for future use; control of floods; reduction of heat island effects; preservation of stream ecosystems; promotion of sustainability, social benefits, landscape aesthetics, and economic value; and mitigation of climate change impacts [61,50,17,45].

7.1 Demand reduction

Methods for reducing demand and managing rainfall include installing rainwater tanks, rainwater gardens, green roofs, and infiltration systems. Other strategies include using pervious pavements, urban water harvesting and reuse, gross pollutant traps, bioretention systems for streetscapes, swales and buffer strips, sedimentation basins, and artificial wetlands [24].

7.2 Stormwater Quality Improvement

This is done to protect or improve the water quality in urban streams and receiving rivers. WSUD technologies such as bioretention systems, vegetated swales, infiltration systems, and permeable pavements effectively enhance water quality by managing nutrients, heavy metals, and sediments in stormwater [14,32].Various WSUD stormwater quality management strategies will offer varying degrees of treatment. Three tiers of WSUD therapy are distinguished: primary, secondary, and tertiary treatment. Trash racks, oil collectors, sediment traps, and gross pollutant traps are primary treatment methods that target coarse silt, litter, and pollutants. Secondary stormwater treatment methods that eliminate bacteria, sediments, and partially exposed heavy metals include infiltration trenches, infiltration basins, vegetated buffer strips, detention basins, bioretention filters, and partially exposed heavy metals. Constructing wetlands is a tertiary treatment to eliminate germs, nutrients, heavy metals, and fine particles [45].

7.3 Flow regime management

Urbanization causes multiple alterations to stream flow regimes. The introduction of decreased evapotranspiration, infiltration, and interference are the leading causes of these alterations. The lowest flows may also fluctuate due to sewage and water supply system leaks. Reestablishing the water equilibrium is challenging since it requires collecting and utilizing a substantial amount of water [51,13,52].

7.4 Rainwater and stormwater harvesting for reuse

This is good because stormwater is redirected away from rivers, but there is still work to do to ensure the water is properly used. Two important concerns are upkeep and installation quality. Stormwater can be gathered and stored for later utilization on a larger magnitude. This is the collection of water straight from stormwater pipes, open drains, waterways, and treatment wetlands. Here are a few illustrations of storage alternatives:The different types of storage systems include aquifers, abandoned quarries, artificial lagoons, tanks, cellular systems,and natural surface storage[42,53].Stormwater facilities known as retention ponds or basins (henceforth referred to as "retention basins") store stormwater runoff to be retained during storm events and then are gradually released through a planned outlet. Stormwater infiltration is another possibility for retention basins during the retention time. Thus, the primary goal of retention basins is to restrict the quantity of stormwater. Some retention basins feature an infinite pool of landscape features and places for recreation. However, under arid conditions, the pool can be completely dry Reference [45].

7.5 Protection of stream ecosystems

Excessive runoff from traditional drainage systems has been the primary cause of degradation in stream ecosystems. WSUD techniques provide an alternate by understanding the causes of urban development's physical degradation rather than only managing the symptoms [54].

7.6 Sustainability, social benefits, landscape amenities, and economic value

The idea of "healthy and liveable suburbs" offers modern connections with "water supply and demand" (WSUD) that can be used to benefit communities economically, socially, or both and to advance sustainability. Residents of developments built with WSUD elements were said to enjoy on-site amenities, green space, the outdoors, onsite social events, recreational opportunities, and a safe water source. Furthermore, WSUD enhances sustainability by promoting a cohesive community and ensuring easy access to open spaces.

7.7 Mitigating climate change impacts

Rainwater harvesting (RWH) systems consume more energy than gravity-based reservoirs, but they can potentially decrease greenhouse gas emissions associated with water storage reservoirs. In comparison to desalinated water sources, they also require less energy. Consequently, they can reduce climate change[55].

7.8 Management of sewer overflows

A combined sewer system (CSS) is a type of sewer system that uses a standard pipe system to transport both sanitary sewage and stormwater. The CSS can transmit all flows in dry weather or during light to moderate rainfall; however, during severe rainfall, the CSS may surpass its capacity. One of the main issues in many large cities is combined sewer overflow (CSO). Techniques to deal with this issue are focused primarily on lowering runoff quantities and enhancing stormwater quality [46].

7.9 Demand reduction and reuse of gray water after treatment

Reuse by ozonation at first, but also by UV irradiation and super chlorination later on, as well as coagulation, flocculation, filtration, microfiltration, reverse osmosis, and enhanced oxidation and disinfection. A significant approach to recycling was through groundwater replenishment, which was feasible.

The utilization of treated gray water and rainwater should be banned for the following purposes:

(a) Consumption by humans or animals

(b) Culinary preparation or dishwashing or kitchen appliance cleaning

On the other hand, it should be utilized for the subsequent applications:

(a) Water cliff (WC) or urinal flushing.

(b) General washing services do not include high-pressure jet cleaning or washing services provided at markets and for autos.

(c) Watering of crops or plants using methods other than irrigation sprinklers.

8. Egypt's current situation

Egypt is susceptible to climate change and is one of the water-poor countries in the Middle East and North Africa[56]. This is evident through rising temperatures, sea level rise (SLR), and rainfall patterns across Egypt and the Nile basin. These factors may also have an impact on Egypt's water. Agriculture accounts for almost 12% of the GDP and uses approximately 85% of yearly freshwater resources. Additionally, several consequences of Renaissance dam development could lower Egypt's share of Nile River water. Egypt is now experiencing a 13.5 billion cubic meter annual scarcity of water (BCM/yr.), which is predicted to worsen over time. Drainage reuse is used to compensate for this water scarcity, which lowers the water quality[29,57,47,58,59,60]. The lack of proper agricultural water management in the face of growing water shortages may ultimately lead to unsustainable agricultural productivity [61].

A changing climate necessitates more proactive adaptation processes and understanding the best ways to execute policies and actions for adaptation. Disasters, in particular, swiftly increase awareness of issues, such as managing drought or protecting against flooding. Rainfall is generally believed to occur less frequently but in greater quantities. Such high rainfall flows are beyond the capacity of the city's rainwater collection infrastructure. Another significant aspect of the city is the high proportion of concrete regions. Typically, the water over pavement and streets seeps into the ground and replenishes groundwater. Water cannot percolate in squares and courtyards with installed asphalt driveways or paving stones. Rather, they accelerate runoff in the direction of the lowest-lying places [8].

The Egyptian Water Regulatory Agency (EWRA) must release and publicly disseminate publications, findings, and recommendations. The European Union provides financial support for implementing the National Water Resources Plan for Egypt from 2017 to 2037 (NWRP-2037), which protects water resources while considering socioeconomic factors. Regarding infrastructure, there has been a noticeable increase in the proportion of processed wastewater, rising from 50% in 2015 to 68.7% in 2019. Access to drinking water has also improved, from 90% in 2015 to 97% in 2019. Additionally, sanitation has shown progress, with the percentage predicted to reach 70.6% in 2019, up from 50% in 2015. However, Egypt is conscious of the urgent need to take the required steps to guarantee water security. The government developed a national plan to optimize available resources and rationalize water use through 2037, budgeting USD 50 billion to provide alternative water sources through groundwater extraction stations, coastal governorate desalination, and treated water reuse [62,29].

The main water sources in Egypt:

-The Nile River supplies 86.2% of the needed water. Unfortunately, industrial effluents, city sewage, and agricultural runoff have all recklessly contaminated the river. Pollutants such as heavy metals, herbicides, and pesticides are found in discharges. In addition, nations bordering the Nile, including Ethiopia and Burundi, are beginning to assert greater authority over the watercourse, in addition to rising temperatures, increased rates of evaporation, and increased water requirements, putting the country in a severe water scarcity situation. Therefore, by the 1959 treaty about the allocation of Nile River water, Egypt's water allocation amounted to 55.5 billion cubic meters while the population stood at around 23 million. According to CAPMAS, the population grew significantly, surpassing 100 million in 2020, with an annual average rise of at least 2.5 million individuals. The average annual per capita freshwater availability in Egypt declined consistently from 1,893 m3 in 1959 to 900 m3 in 2000 and 700 m3 in 2012. This places Egypt below the World Bank's water scarcity criterion of 1,000 m^3 renewable water per capita per year. By 2030, the per capita water availability is projected to decline to less than 534 m3, below the international threshold for water poverty.

This issue can be worsened by the operation of the Grand Ethiopian Renaissance Dam (GERD). The GERD will have a devastating impact, resulting in an 18.5 billion cubic meters decrease in Egypt's annual water allocation. If the filling is coordinated with a flood season that is below average, the consequences will be devastating. Egypt faces a significant water scarcity issue, with a severe shortage of 34% (19 billion cubic meters) and an average shortfall of 20% (11 billion cubic meters) for the six-year filling period. A four to five billion cubic meter deficit in Nile water is the equivalent of millions of acres of destroyed agricultural land. The result will be an increase in Egypt's food gap from 55% to 75% of our total food demand. The cessation of electricity production by the High Aswan Dam and the construction of Mediterranean desalination plants in the coastal cities will further burden Egypt's economy [57].

-Rainfall: The rainy season in Egypt typically spans from October to March, with the highest levels of rainfall occurring in December, January, and February. Rainwater harvesting (RWH) is a practical and promising option for addressing water scarcity and flooding problems. The annual water precipitation in Egypt is 0.97 billion cubic meters. Implementing rainwater collection techniques in Egypt can augment the country's water resources for diverse purposes and mitigate the expanding disparity between water supply and demand. Nevertheless, the practice of rainwater harvesting (RWH) from urban catchments has not been well addressed. Between 1957 and 2017, rainfall at the Cairo International Station ranged from a minimum of 1 mm in 1959 to a maximum of 197 mm in 2016.

We have recently observed increased rainfall extremes, occasionally resulting in major flash floods. Furthermore, Egypt's precipitation increased by approximately 75%, from 2.86 mm in December 2015 to 3.78 mm in December 2020. For example, in March 2012, Luxor, the fabled old city in Upper Egypt, experienced 1.2 inches of rain in a single day—nearly thirty times the average annual rainfall. In 2015 and 2016, Egypt saw numerous flash floods that destroyed hundreds of homes and resulted in numerous fatalities from rainstorms over 50 millimeters per day. Several areas of Cairo, Giza, and Ain Sokhna-Zafarana Road experienced torrential rainfall in April 2018, which resulted in property damage and multiple fatalities from road accidents[37].The rainwater system can also be filled during the rainy season, typically from October to March. Throughout this period, any precipitation gathered from the rainwater collecting system might also be redirected to the greywater treatment system [57].

Groundwater: The overall volume of groundwater is approximately 40,000 BCM. Nevertheless, due to the significant depths, which might reach 1500 m in certain locations, the present water extraction is expected to be 2.0 billion cubic meters per year.

-Desalination: Seawater desalination in Egypt has been deemed a low-priority water resource due to the comparatively high cost of treatment from alternative sources. In recent years, Egypt has prioritized expanding desalination projects to address water poverty. The urban development plan in the new coastal communities includes complete reliance on seawater desalination. In 2020, Egypt ran 58 desalination plants with a total capacity of 440,000 m3 daily. Thirty-nine more desalination plants are now being built [62].

-Treated domestic sewage: This particular sewage is being repurposed for irrigation, alone or in combination with fresh water. 52 wastewater treatment plants are now under construction in Upper Egypt, with a combined annual capacity of 418 million cubic meters. Over time, the proportion of treated wastewater to total wastewater has increased, reaching 68.7% in 2019. In 2020, the Bahr al-Baqar water station was declared the largest wastewater treatment plant globally, capable of processing 5 million cubic meters of water daily.

As part of the Sinai Peninsula Development Plan, 342 thousand acres will be farmed and cultivated using treated plant water [62,61,29].The Ministry of Housing, Utilities, and Urban Communities (MHUUC) is the primary governing body responsible for managing urban water and sanitation services. The MWRI is accountable for overseeing the advancement, dissemination, upkeep, formulation of policies, effectiveness, quantity, and quality of water resources and managing any prerequisites and authorizations for their utilization. The Ministry of Agriculture and Land Reclamation is responsible for supervising land reclamation, agriculture, and agricultural research and extension. Egypt has a wealth of expertise in utilizing water user associations (WUAs) for agricultural purposes. They allow farmers to manage water systems and operate and maintain them.

Nevertheless, WUAs lack legal standing, which has limited their capacity to operate as independent organizations with complete private ownership and to raise funds, among other reasons. Low participation rates, a lack of understanding of options and activities, and a lack of cooperation between organizations and MWRIs have all been observed in WUAs in Egypt. Furthermore, explicit directives from higher governmental levels are needed [29].

The most crucial element in attaining national security is water resources, which is why the state decided to host "Cairo Water Week" (CWW) in October 2018; in collaboration with over 50 national, regional, and international organizations, more than 1,000 participants and 70 international experts of various nationalities addressed five subthemes through 50 technical sessions. Additionally, 25 businesses took part in the exhibition. The First CWW has effectively created a forum for all parties involved to assist governmental and nongovernmental initiatives to deal with water scarcity and to improve the policy-making process. The Ministry of Water Resources and Irrigation plans to conduct CWW yearly with several partners. It is considered the largest water-related event in Egypt. It seeks to raise awareness of water issues, encourage creative solutions to the most urgent water-related problems, inform water stakeholders of international efforts to address water issues and pinpoint cutting-edge instruments and methods for resource management [63].

9. Conclusions

To successfully implement Water Sensitive Urban Design (WSUD), it is crucial to consider several site-specific factors: the unique requirements of the location, prevailing climate conditions, the local community's acceptance, and the available project budget[64]. Prioritizing the development of intelligent water systems is essential to enhancing water resource management standards. Advances in science and technology can significantly improve the management and regulation of sewage discharge, increase sewage treatment capacity, and optimize the use of reclaimed water. These initiatives have substantial implications for improving the natural environment, maximizing water resource utilization, and reducing vulnerability to water scarcity [15].

Despite efforts to transition to WSUD in Egypt, the country has yet to fully embrace the specific modifications necessary for water management that align with WSUD principles [65] .During the initial phase of the Water Sensitive Design Community of Practice (WSD CoP) program, key areas of focus included:

Enhancing Communication: Creating opportunities for cooperative and interactive dialogue among all stakeholders through awareness-raising and targeted WSD training initiatives.

Stakeholder Collaboration: Connecting various stakeholders in urban water systems to facilitate collaboration among researchers, local stakeholders, and users. This collaboration aims to establish common goals, evaluate alternatives, and effectively develop innovative approaches for managing urban water systems [48,66,31].For progress toward developing Water Sensitive Cities (WSCs), gaining residents' commitment and actively engaging them in this transformation is imperative. These designs must reflect public behaviors, values, and needs related to water [67].

Given the global interest in water-sensitive urban design and the limited research available in Egypt, several gaps have been identified for future research. A thorough evaluation of the literature reveals that:

Post-Implementation Assessment: There is a need for comprehensive systems monitoring to understand real-world performance, ensuring that outcomes align with intended functionality and design goals and bridging the gap between theory and practice.

Furthermore, proposals and recommendations for the World Summit on Sustainable Development should consider the challenges rapidly urbanizing cities face in developing countries. These cities experience high demands with limited funding and regulatory resources, making targeted strategies essential for sustainable water management [21,41,8].

10. Declarations

Competing interests: The authors declare no competing interests in this section.

Acknowledgments

Not applicable.

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