Urban stormwater harvesting for domestic water supply: a water evaluation and planning approach

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ABSTRACT

Renewable groundwater and surface water supplies are insufficient for the current worldwide urban population as water demand is increasing rapidly. Usage per capita in urban areas transcends 160 liters per day. Climate change is projected to increase water demand even more. Sources of surface water from stormwater runoff can be used to fulfill this requirement. The main objective of this work is to assess the water supply and demand in the dry conditions of the Coimbatore region, Tamil Nadu, India, and to use the water evaluation and planning method to create a model for supply and demand in the future. There are more than three dozen surface water bodies in and around the metropolitan center. Most sources are heavily encroached upon. By linking stormwater runoff from its respective elevation to the accessible surface water bodies, an additional water supply source can be obtained. By using the water evaluation and planning framework as a guide, models were developed to determine potential needs, and to compare demand and supply, water usage, lack of water use, and population coverage. The enhanced stormwater drainage system for Coimbatore city was designed in such a way that the various roads were connected to the major water bodies. The domestic water demand in the future is predicted to be around 27 million cubic feet (MCFT). Meanwhile, the possible amount of stormwater collected in the selected water bodies is predicted to be 50 million cubic meter (MCM) to 320 MCM. This study concluded that 100% of urban domestic water demand can be met if the urban stormwater is utilized by harvesting and storing in surface water bodies.

Key words: contour, per capita demand, reservoir inflow, storm water, unmet demand, WEAP

HIGHLIGHTS

• Urban infrastructure development.
• Urban watershed management.
• Urban drainage.
• Urban water reuse.
• Unmet demand study.

1. INTRODUCTION

The Smart City Project focuses mainly on meeting potential water demand. According to the census, 63% of India’s gross domestic product (GDP) comes from urban areas. In 2030, 40% of the country’s population is expected to be in cities. Therefore, the contribution of metropolitan areas to the GDP of the country will increase by 75% (Mohammed Shahanas & Bagavathi Sivakumar 2016). Much of the world’s major cities will have dramatic population growth, and by 2030 water demand will be 2.5 times the present situation (Kumar et al. 2018). During summer, the urban water demand would be six times greater than in winter and rainy seasons (Kofinas et al. 2014). To meet urban water demand, programs such as conservation, increased stormwater usage, recycling, water reuse, and increasing groundwater usage should be investigated. Scenarios like climate change, population growth, recycling initiatives, and water prices can be evaluated to forecast potential water usage. Yet the need for water is still driven by population and water price rises rather than climate change and conservation (Ashoorn et al. 2017). Therefore, it is not appropriate to recognize the effects of climate change to forecast future water demand. When the scenario is built based on population growth, it would cover the effects of climate change on water.
demand, as well as other factors such as recycling initiatives and water price. In this study, the rapid population growth and the rapid urbanization caused by industrialization were used to predict the future water demand. To meet the demand, stormwater harvesting was chosen as a solution because of its feasibility compared to other measures. This can be termed as a supply and demand measure (Kifle Arisso et al. 2017), in which the urban water supply can be increased by utilizing surface water bodies as stormwater detention ponds. The unmet demand for various rainfall scenarios must be determined to study the feasibility of the method adopted. Urban surfaces are mostly impermeable, which makes the selected measure more feasible, as it depends on annual average rainfall. This is known as the natural rainwater retention measure (Zelenáková et al. 2017) and is suitable for urban areas that have been studied for successful stormwater harvesting. This measure will help urban flood management. For the study area, the distribution of rainfall over the year was studied, which is more important than the total rainfall depth for flooding (Elshorbagy et al. 2018).

2. STUDY AREA

Coimbatore is one of the major cities in the State of Tamilnadu, India, and is as shown in Figure 1. It is situated on the banks of the river Noyyal and surrounded by the Western Ghats. Coimbatore is by area and population the second-largest city in the state. It is one of India’s fastest-growing cities. Because of the large producers of cotton and textile industries, the region is also called South India’s Manchester. The number of wards was 75 until 2014; it is now 100 because of rapid urbanization and the increase in population as shown in Figure 2. Water shortage is getting worse due to its rapid growth in population. There is not enough preparation in place to satisfy the potential water demand. Due to industrialization, educational institutions, and urban development, there has been an increase of 45% in population over the last 10 years. Land use and city cover trends play a significant role in the decision-making process.

Any improvements in this trend directly impact the management of the available domestic water and solid waste (Misra et al. 2018). New satellite cities must be built due to the massive changes in land cover, or the population density will increase.
Based on the changes in land cover, appropriate plans for meeting potential water demand will be suggested. Population data for the study area is available from 1901. Until 1951, the increase in population was very low, and it cannot be used for projection. Thus, data from 1961 was considered and projected using the geometrical increase method. Figure 2 shows the projection until 2051 as the model for water demand.

3. WATER SUPPLY

The two major sources of water supply to Coimbatore are the Siruvani and Pilloor reservoirs, which are maintained by the corporation. The city is supplied with water from the Siruvani reservoir by gravity and from Pilloor reservoir by pump. When the water requirement increases, the corporation struggles to satisfy demand. There is an inadequate plan to meet future demand, as the population could rise by more than 200% within 40 years. Coimbatore is experiencing demand in water supply and the rapid urbanization and industrialization development, along with population growth, is challenging the city’s water supply network. To drastically reduce the water supply-demand problem in Coimbatore, stormwater can be utilized. Due to climate changes in the region, differences in rainfall over the study period were also considered, along with the increase in temperature as a result of global warming, which causes an increase in domestic consumption, water evaporation, and loss of water. The other community activities recommended by the state government also reducing the water demand instantly. For example, the groundwater recharge is increased by rainwater harvesting systems in each home and by some public sector units, and thus the impact of community activities can also affect the demand (Haque et al. 2015).

The purpose of this work is to investigate how to increase water quantity for the available reservoirs. The efficiency of water supply can be improved for any metropolitan area by, for example, introducing a water reuse scheme, executing desalination plants for coastal towns, and creating a new reservoir. All these can be checked for reliability, and the best one can be implemented. By introducing a reuse system, 30% of reliability can be attained; by having a new reservoir 19% can be attained, and by combining desalination and a new reservoir, the reliability can reach up to 35% (Paul & Elango 2018). The reservoir available is entirely reliant on freshwater from rivers and stormwater runoff in the study region. Therefore, only the reliability of study by harvesting storm water is considered. The available water system can be connected with this proposed work to decrease the demand. Hydro-basins can be constructed to transfer water from areas where water is abundant to areas where it is scarce. The reservoir capacities can also be expanded (Lima et al. 2018).

4. RIVERS, DRAINAGE, LAKES

The Noyyal River originates in the Western Ghats, and Periyar, Sadiyar, and Kanchimanadhi are the major rivers. The Periyar and Sadiyar Rivers both originate in the horseshoe-shaped mountains in the west of Coimbatore from the south-western Hills...
and merge into Sadivayal to form Chinnar. There are about 36 streams/rivulets that flow into the Noyyal River from either side, starting from the sources, all the way up to Coimbatore. Of these 36 streams/rivulets, 24 flow from the southern hills to the Noyyal River from south to north and the remaining 12 streams/rivulets from the northern hills flow from north to south to join the river. Each stream varies in average length from 7 to 12 km.

The Noyyal River expanded its supply to some of the Coimbatore’s man-made reservoirs, including Periyakulam, Krisnampathi, Selvampathi, Narasampathi, Kuruchi Kulam, and Singanallur Lake. Due to its connected structure, the overall flow of the river in the city area is used to prevent flooding on rainy days. The tanks are interconnected, and the water from one tank enters another tank when the water overflows. In the past, these tanks were used primarily for agriculture, but it is used nowadays for fishing and for other purposes such as recreation and tourism. Figure 3 shows the water flow chart of the Noyyal River system and how the river drains water through branches to the surface water bodies of Coimbatore urban area and the outflow of lakes back to the Noyyal River system.

As the flow of water in the Noyyal River decreased over the years, the inflow to the lakes also decreased. Thus, the lake source depends primarily on rainfall. If the stormwater system in the city area is improved and maintained well, and is, connected to the lakes, it is possible to achieve flood prevention and an increase in inflow to the lakes. Figure 4 shows the location and layout of the Noyyal River, Sanganur Stream, and lakes in and around the town of Coimbatore, as well as the stormwater drainages available. This was prepared using ArcMap, with state corporation and shuttle radar topography mission (SRTM) data.

**Figure 3** | Water flow chart of the Noyyal River system (from Western Ghats toward Coimbatore west to the east).
5. METHODOLOGY AND DATA ANALYSIS

5.1. WEAP

The Water Evaluation and Planning Program (WEAP) modeling software developed by the Stockholm Environmental Institute is an object-oriented computer modeling kit and Integrated Water Resource Management (IWRM) tool designed for water supply program simulation. It is a balanced approach between IWRM and hydrology. It is scalable and can evaluate various scenarios (Psomas et al. 2016). Water evaluation and planning is a method in which both the quantity of water and the efficiency parameters can be examined. In any urban region, water demand can be projected for future scenarios such as population development, variability in precipitation, and climate change based on representative concentration pathway projectiles (Kifle Arsiso et al. 2017). Such forecasts indicate variations in usage and the need for water reuse. Scenarios of water quality can also be established, and the demand for water and quality depression such as biological oxygen demand, chemical oxygen demand, and nitrate can be predicted for the study period (Kumar et al. 2018).

The estimated predicted water demand must be accurate for usage by all the planners and water resource managers. The precision depends on the periodicity of demand, forecast horizon, method of forecasting, model specification, and sample size. The demand should be predicted with the aid of artificial neural networks, regression analysis, or any hybrid model to achieve this accuracy (Sebri 2016). A hybrid model called Arsenal has been used in this analysis.

WEAPI differs from other modeling tools in that it uses its own global precipitation data. Combining this with our own collected historical data, such as rainfall, it can predict future precipitation. In this way, the predicted precipitation for the basins in the study area can be used to calculate runoff volume using geographic information systems (GIS). Additional features such as node creation on required locations for basins, rivers, lakes, ponds, tanks, etc., are available to input values for the population of a particular basin, surface area, rainfall depth, runoff volume, and the storage capacity of lakes, ponds, and tanks. This procedure of modeling helps determine the unmet water demand of a particular basin.
Thus, the inflow of runoff volume to the reservoirs and outflow or discharge of reservoir can be compared for purposes such as flood management during monsoon seasons, maintaining inflows during the lean period, and decreasing the intensity of high flows (Bhave et al. 2013).

The method adopted in this study is as follows: (1) corporation area geography, population, rainfall, soil characteristics and classification, runoff potential, characteristics of surface water bodies, and possible future water demand were analyzed; (2) population, rainfall, water demand, and land-use land cover was predicted; (3) basin distribution for the corporation area using SRTM elevation data analysis was carried out and a contour map prepared; (4) runoff volume, which considered soil parameters such as infiltration, runoff potential, land-use land cover, and permeability, was calculated and a hydrological group of soil was classified; (5) properties of surface water bodies including storage volume, discharge, evaporation losses due to surface area, infiltration, etc., were studied; and (6) WEAP analysis using the analyzed data as input was carried out, and supply-demand analysis determined the unmet demand.

5.2. Analysis of data

Data collection must be based on a modeling tool’s appropriate performance and capacity, and also depends on the adequate data available. Such data includes climate data, and data on land cover, topography, water sources, present water supply, water reuse, and population. These data are needed for any water management tool. To determine irrigation demand, characteristics should be specified for the selected area by the amount of precipitation, solar radiation, surface temperature, and pervasiveness. Such data can be used to assess the quantity and runoff of stormwater. Indoor demand is calculated by population and household data (Sharvelle et al. 2017). For the proposed work, data for determining indoor demand was collected and the surface water sources were analyzed for utilization. The runoff from precipitation was also used to improve the surface water sources.

Nowadays, the water bodies in the city are affected by extreme drought and climate change, and inadequate maintenance of the lakes leads to the link breakage between some of the lakes and the Noyyal River; however, the Periyakulam and Kurichi Kulam lakes use the river’s water supply. Rainfall plays a key role in filling the reservoirs. Thus, the amount of rainfall for the preceding ten years was taken for future study and prediction.

The rainfall data can be modeled using several models or neural networks for the study period. There is a choice in the WEAP model to forecast future precipitation using the percentage of variability in each year regarding the final known precipitation. The research found that the forecast climate data can be used in the analysis rather than the original data (Kokila et al. 2015). This research depends mainly on runoff volumes. The quantity and timing of runoff differ greatly between rural and urban surfaces because urbanization is causing an increase in impermeability and the amount of runoff. As the amount of runoff increases, the inflow to the drainage tanks increases, but the infiltration to the ground decreases, reducing the recharge of groundwater (Miller & Hess 2017). The recharge parameter was not considered in this work. The length of runoff is critical to reduce losses from evaporation. The runoff timing is minimized if the surface is fully paved. For distributed urban development with a paved surface, there is a high possibility of pluvial flooding (Mikovits et al. 2017). This pluvial flooding rapidly collects in the drains. Some urban water retention measures, including green roofs, permeable surfaces, trenches for infiltration, rainwater harvesting, and rain gardens (Zeleňáková et al. 2017), were implemented to reduce this flooding and reduce the runoff. The permitted flooding should not affect the urban environment. Most of the water retention mechanisms have been eliminated, and the city area surface must be kept impervious. This will increase the amount of runoff. Apart from the risk analysis for stormwater, the hourly rainfall affects the volume and length of the runoff more than the 24-hour rainfall (Elshorbagy et al. 2018). Use of the retention pond would be appropriate if the amount of runoff is high, as our area of analysis is considered to be completely impermeable. Furthermore, urban stormwater is often known as dirty water and can be contrasted with wastewater. Implementation of source control methods eliminates both emissions and discharge at pipe ends. The explanation behind this is infiltration, the recycling of rainwater, as well as the reuse of stormwater, which is practiced by individual people, municipal managers at the street and urban level. This results in a reduction in the discharge of stormwater (Chouli et al. 2007). Even though the source control technique affects the discharge of stormwater on a minimum scale, this can be ignored for the full potential of the methodology used.

5.3. Average annual rainfall in mm (1985–2045)

Rainfall data was projected from 1985 to 2045 using WEAP model. National rainfall data has been downloaded in the model for the last 70 years from 1950 onwards. From this database, we used 30 years of data from 1985 to 2015 to forecast rainfall.
from 2016 to 2045. The rainfall data cannot be used for all locations in the selected metropolitan area. Using ArcGIS, the urban area was initially delineated into basins via the elevation data derived from SRTM. For the study region, more than 50 basins were identified. Through the stormwater drainage network, 22 basins are connected directly to the surface water bodies. The rainfall data were therefore collected separately for each basin using the WEAP model.

The rainfall data for all the basins is projected for the next 30 years. Research-led rainfall studies indicate that the estimation of rainfall is not be feasible beyond 2 years of forecast. However, for this analysis the forecast must be made for a minimum of 30 years. The prediction in this study can therefore be considered as variations in rainfall each year. This is useful in studying the different runoff parameters for different basins. Through the new stormwater collection program, the demand for the future population can be met.

Figure 5 displays the rainfall forecast for Basins 1–15, 21, and 22 only, because the data for these basins are adequate to measure the runoff volume for other basins. This forecast shows the huge amount of variability in some years, for example almost 250 mm of average annual rainfall in 2038 but less than 50 mm of average annual rainfall in 2035. Thus, the development was designed to cover the upcoming demand for both of these variants. Figure 6 displays the Basin 1 sample rainfall estimate, which is the city’s largest basin. Basin 1 was used to discharge the runoff water to the Singanallur Lake as a pour point.

5.4. Stormwater layout

Stormwater drainage of the city area exceeds 570 km. However, the usage is limited because of heavy encroachment. In this study, the drainage length is assumed in such a way that all types of roadsides were taken into consideration, and the drainage layout is shown in Figure 7. The stormwater infrastructure should be able to withstand extreme climatic factors. Climate change adaptation strategies should therefore be followed. Strategies are named in relation to their capability and function: nominal (replacement of damaged structure), concurrent (capacity is increased during a replacement), anticipatory (capacity is increased before normal replacement), reactive (switch from normal to concurrent strategy), and options-flexibility (strategy is specific depending on the variable characteristics) (McCurdy & Travis 2018). The stormwater drainage should be designed in such a way that it must adapt to all the possible climate changes in the study area.

Models like reliability analysis should consider three failure modes, such as when the runoff value exceeds its capacity, when the runoff velocity exceeds the maximum limit, and when the velocity is lower than the minimum for deposition control (Gouri & Srinivas 2015). Thus, for the present study, the reliability was analyzed so that the efficiency of the proposed system was not affected. As the success of this work fully depends on the functionality of stormwater infrastructure, the layout should be analyzed for any future waterlogging. The layout was prepared with the available roads. Previous water logs were surveyed, and questionnaires were carried out. A field survey is necessary for determining the viable locations, depth, duration, and frequency of logging. By integrating these data with precipitation, land use, and soil profile, the vulnerability of logging can be determined, and the logging can be predicted (Akter et al. 2017). Finally, the stormwater system must be developed sustainably by assessing the impact of climate change (De Paola et al. 2015).

5.5. Topography

Ground profile, nature of the soil, and permeability of the soil are the most important parameters considered for the study to achieve the required runoff volume, which can be discharged into the selected water bodies. ArcGIS was used to run the hydrology, and the nature of ground and slope was defined. More than 50 basins were delineated using elevation data from SRTM. Among these, 22 basins were selected for discharging stormwater into the water bodies as the pour points. These pour points are naturally located at the surface water bodies, or the flow can be routed to the water bodies. To run the hydrology, the contour and slope of the ground is necessary using the GIS tool. Figure 8 shows the contour map of Coimbatore city prepared using the ArcGIS tool and data collected from SRTM. Along with the topographical study, soil parameters such as type of soil and permeability were studied and analyzed using GIS to determine the amount of runoff volume. These processes will be explained in another paper.

6. RESULTS AND DISCUSSION

Analysis in WEAP requires previous as well as real-time data. Before inputting data into the tool, the study area must be well defined for its accurate location by georeferencing. The required nodes were then placed in particular locations. Nodes such as resource node and demand site nodes were created. Each resource node was linked with the demand site node using a
transmission link. Data for resource nodes such as Inflow and Loss due to evaporation were given as input. Because the water sources in this study were lakes, the reservoir node was considered and storage capacity included. The volume elevation curve was neglected because the data for the study period was insufficient compared to a man-made reservoir.

**Figure 5** | Average annual rainfall in mm for Coimbatore City basins (prepared using WEAP).
Data for demand site nodes such as annual activity, annual water use, yearly consumption, and monthly variation have been given as input. As demand sites were delineated into more than 50 basins, the population and consumption were calculated separately because the beneficiaries of the selected lakes were defined separately, so that the supply-demand parameters were analyzed for each basin. Using land-use land cover maps, the total population can be distributed on the

**Figure 6** | Monthly rainfall projection for Basin 1 for inflow into Singanallur Lake (prepared using WEAP).

**Figure 7** | Storm water layout of Coimbatore Corporation (drainage on sides of all kinds of road).
respective basins. All the lakes selected for the study can be considered as a single unit, and the supply-demand parameter can be analyzed for the whole city population.

Monthly variation was calculated through a percentage increase in consumption during summer for April, May, and June. WEAP can run with various scenarios such as climate change, urban settlement variation, and seasonal water use. Variation and frequency in rainfall change every year and are classified as a dry year, normal year, and full dry year (Lévite et al. 2003). In this study, the city has more normal years than dry years due to rainfall from two different monsoons. The study area is predicted to have average annual rainfall based on historical data, and to produce a sufficient runoff volume to fill the surface water bodies. Even after maximum discharge from the lakes, the storage would be sufficient to meet the demand.

Thus, the scenario considered is for normal years, i.e., average rainfall for the study period. Urbanization, industrial structure adjustment, and policy change of water allocation are also taken into account through WEAP (Li et al. 2015). In this study, the gradual increase in urbanization was considered to be between 2001 and 2011, with a sharp increase in urbanization after 2011.

As the basins were separated for analysis, the stormwater drainage layout was also prepared separately for each basin by disconnecting the drainage path in the basin boundaries. This was done by breaking and diverting the drainage path above the pour points. This paper improvises the demand analysis for the urban population. Inflow to the lakes was calculated based on the runoff volumes from soil water analysis from the basins with pour points at the respective lakes. Figure 7 shows the lakes at different basins assumed to be connected to the urban water supply system. Figure 9 shows the urban water demand calculated using the predicted population and the assumed annual water usage rate. Urban per capita consumption of 160 L/day was used for the current situation, which was increased by 20 L/day for every 10th year because the future consumption may increase due to reasons such as climate change, cultural changes, habitual changes, etc., As the demand coverage for the study area mainly depends on the amount of inflow to the lakes, all the major variations were considered.

Figure 6 shows that the predicted rainfall for the year 2033 is very low, and for 2038 it is very high. The runoff volume for these years was determined to study the variations in runoff volume and the possibility of meeting water demand coverage.

Figure 8 | Contour map for the Coimbatore Corporation area (prepared using ArcGIS and SRTM).
The runoff can be affected widely through other community measures such as domestic rainwater harvesting systems. Implementation of such harvesting systems decreases the overall runoff as the individual domestic rainwater harvesting system decreases the flow to the stormwater harvesting system by 25–33% (Palla et al. 2017). In this study, the overall runoff could be affected by up to 30%. The runoff losses due to permeability of the soil on the respective catchments were calculated and considered as input to the water bodies. Other losses such as evaporation from the surface of the lakes and losses to the groundwater were not considered as these losses are minimal, and do not affect the proposed system. By using this system, the lakes will be at the maximum water level throughout the year, even in the minimum rainfall year predicted for 2033. The variation in demand in various months was also analyzed. The demand doubles in the summer months compared to the demand in winter, due to an increase in consumption. Thus, the collection of stormwater must be sufficient to meet this summer demand.

Figure 10 shows the study area water demand for the period 2011–2045. It shows that the increase in demand for the upcoming years is based mainly on the population increment. The geometrical increase method is used to predict the population for the study period.

Figure 11 shows the runoff inflow directly into the various lakes selected for the study. Among these, Achankulam is the only lake located outside the Corporation area. This lake is so important that 30% of the city area will be draining its runoff into this lake. Singanallur Lake, which has a storage volume of 52.27 MCFT, will also receive major runoff. Periyakulam is the biggest of these lakes, with a capacity of over 97 MCFT. The smallest is Krishnampathi, with a storage volume of over 7.67 MCFT. With the calculated volume of runoff, all of the selected lakes will be overflowed; and thus, the surplus water will be diverted to the Noyyal River, which flows through the southern part of the city. These reservoirs can be utilized for treating and supplying the water for domestic usage as well as for industries. The domestic water demand in 2045 is predicted to be around 27 MCFT. The possible amount of stormwater collection in the selected water bodies for the same year is predicted to
be more than 200 MCM through the seven water bodies collectively. The maximum rainfall year, 2038, will collect 320 MCM of stormwater. This will rapidly reduce the demand for water from available sources such as the Siruvani and Pillur schemes. When considering the lowest rainfall year, 2033, the consolidated runoff volume is around 180 MCM, which is sufficient compared to the predicted demand volume of 27 MCFT. This study concludes that, even if the losses of runoff and storage volume were considered high, the amount of demand coverage would not be affected. Thus, 100% coverage of demand will be achieved.

7. CONCLUSION

Using WEAP as a tool allowed the impact of stormwater collection on domestic supply to be analyzed. Stormwater harvesting in the available surface water bodies in and around the city area enables the demand for water for any upcoming year to be

![Water Demand](image1)

**Figure 10** | Annual urban water demand for the study period – 2011 to 2045.

![Inflows to the lakes](image2)

**Figure 11** | Annual inflow to the lakes.
reduced to 100%. Because Coimbatore City receives water from Siruvani and Pillur, when water demand and drought occurs, there is no alternative source other than water tanks and borewells. This study therefore suggests the reduction of demand by implementing this system. Further, the demand for water can be reduced through planned urbanization. Due to urbanization, the demand for water increased until the 1990s all over the world, but from the 1990s onwards the demand has reduced despite the population increasing drastically in urban areas. The reason behind this based on: (1) individual houses and villas have a lower population density and therefore require more water than densely populated areas such as apartments and high-rise buildings. For example, individual dwellers need water for their own gardens and pools, but apartments share a single pool and garden. As the present urbanization mainly focuses on apartments and high-rise buildings, this results in an overall reduction in demand. (2) Another important factor is the increase in awareness of water usage. There was a big change in consumption patterns as people started reusing water (Morote & Hernández 2016). Irrespective of these factors, from the 1960s due to the same rapid urbanization, the population increase has caused the water demand to be higher. In this study, the scenario representation mainly focuses on variation in rainfall and population. Further, the water system available for urban locality can be adapted to climate changes. The water systems such as stormwater drainage, water quality, water supply, wastewater treatment system, and aquatic ecosystems can be integrated by implementing the Integrated Urban Water Management System (Kirshen et al. 2018).

Water demand management policies will be a better strategy for reducing demand. To reduce the residential consumption, policies such as maintenance and renovation of networks, water-saving campaigns, installation of rapid leak detection, and municipal regulations can be followed (Stavenhagen et al. 2018). Although the collection of stormwater in man-made reservoirs and its usage for the urban water supply is analyzed in this paper, the effects of rainfall on urban water requirement was not analyzed. The urbanization effects on the behavior of rainfall and the volume of storage in reservoirs should be analyzed, along with the effects of increasing global temperature on rainfall patterns (Lima et al. 2018).

DATA AVAILABILITY STATEMENT
All relevant data are included in the paper or its Supplementary Information.

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