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Water Management in Urban Watersheds

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ABSTRACT

Iran is one of arid and semi-arid regions of the world and has experimented many challenges in the sustainability of water resources. With the development of urbanization and the natural and artificial changes in land use, environments called urban watersheds have been created with different hydrological and hydrologic behaviors that design and manage the sustainable management and utilization of water resources in urban areas to rebuild the degradation of nature through urban development. None of the cities in Iran has been studied as a complete network with consideration of all water resources, and no optimization has been done on the allocation of urban water resources. Achieving sustainable development in urban watersheds, requires the development of integrated management models, some of these problems can be solved with using optimum runoff of precipitation in there. The purpose of this research is to investigate how water management in the urban environment and the impact of urban development on the water dynamics and the role of the city's spatial scale and density and their management in urban hydrology. Due to the lack of attention to the engineered water cycle in Iran, in measuring the total city water cycle waste, determining the penetration rate in permeable and impervious urban areas should be among the priorities. It is also important to quantifying the impact of urban areas on climate dynamics in predicting rainfall on a time scale, and should consider the impacts of these events on flood infrastructures, flood risk, and water quality.

Keywords: *Water Management, Urban Development, Urban Watershed, Sustainable Development*

INTRODUCTION

Sustainable systems of water resources have been designed to advance the present and future goals of human societies so that their environment, ecology, and hydrology could be used optimally. Without proper management of water resources, we will never achieve sustainable development and reduce poverty. The aim of sustainable development and management of water resources is to properly meet the water demand of present and future generations. This can be achieved holding two factors in mind, namely, comprehensive and appropriate design of systems, that is, water use efficiency optimization; and, initiating a continuous effort in order to protect and renew the natural environment. Creating a sustainable society requires many social and industrial campaigns. When developing such a model, the sustainable principles, environmental laws, and public participation are taken into account simultaneously (Eslamian and Tarkesh-Esfahani, 2011). So far, none of Iranian cities have been studied as a complete network considering all of water resources (raw water, runoff, and waste water). Moreover, no optimization has been performed toward the allocation of urban water resources with attention to its various resources.

Optimization, aiming at minimizing water transfer costs along with raw water consumption (the water in dam reservoirs and underground waters) would provide a good opportunity to understand the necessity of changing the consumption paradigm of many major urban consumers such as forest parks and urban industries; and operationalizing the use of urban water treatment plants backwater to irrigate urban open spaces and highway and freeway green spaces.

City Region

Cities are spectacular human artifacts and in constant development which might be seen as open and dynamic urban ecosystems incorporating consumption, transfer, and production/generation of materials and energy. The notion of city regions refers to spatial phenomena affecting and being affected by a broad range of surrounding areas harboring one or more cities/megacities (Moosavi and Farzaneh, 2016). Standard definitions for city-region in academic references continue to be vague and ambiguous, assigned to various political, social, and economic fields. In a study of faulty notions in standardizing urban ecology terminology and definitions, McGregor (2011) characterized multiple applications of “city-region” in terms of population density, total population, presence of specific structures such as residences and schools, impermeable surfaces, and the percentage of non-agricultural economic activities, as well as international differences of terminologies. Obviously, it would be difficult to provide a single definition of a city region encompassing a global population distribution diversity, economic approaches, or a range of impermeable areas. In a study on the definition of city regions, Weeks (2010) proved that the most practical way to do so would be to reject the notion of urban-rural dichotomy; and eventually, one should consider the association of such terms with diverse degrees of urbanization, integrated economy, population, and social and environmental indicators. Such an approach would provide a set of traits which would be more informative than simple population, impermeable surfaces percentage, or density statistics, none providing an accurate definition of urban dynamics alone. Although the population is an important facet of an urban environment, city region is a spatial notion defined only to some extent by the population existing within its boundaries (Weeks, 2010). Wandl et al. (2014) proposed a new regional classification approach recently, using a broad range of data including Cover Land Cover Inventory, population and infrastructure statistics in order to separate urban and rural areas from TiBs (Territories-in-Between) going beyond the conventional urban/rural classifications, where rural areas exist within urban areas and vice versa. This could be used as a practical classification tool in order to discern diverse urban areas.

Materials and Method

Dimensions of Water Resources Management in Urban Watersheds

Impacts of Urban Areas on Urban Water Cycle

During recent decades, the science of hydrology has advanced toward a better understanding of some impacts of urban development on natural hydrological processes. However, the impact of civil construction in the environment on natural hydrological dynamism is complicated and our general understanding is limited (Niemczynowicz, 1999; Fletcher et al., 2013). Urban water cycle often differs from the natural hydrologic cycle of confined to ordinary geographic boundaries. The climate of a region, too, could have a significant impact on the quality and quantity of flood runoff. Such factors as draught period records between storms, rainfall average intensity, storm duration, and thaw levels could affect the runoff traits of a region. Regions with low rainfall might have a runoff with a significant concentration of pollutions, especially from hot zones such as roads, parking lots, and industrial areas. Many a geographical factor such as soil typology, slope, land use, and the watershed’s impermeability levels may have a significant impact on the quality and quantity of the runoff from the region. Many studies have investigated urban runoff control, the results of which indicate that instead of taking the flood out of town as quickly as possible, we should reduce its pollution and permeate it into the ground as much as possible (Maryland BMP, 2009). Presence of water engineering systems involving water imports and exports through pipe networks and artificial transfer of water into subsurface drainage systems lead to the separation of those two cycles. However, the use of resulting inefficient infrastructures has led to a corrective perspective; and the intensification of urban hydrologic behavior as a specific surface involving both natural and engineered water dynamics. Generally, the evaluation of urban traits’ impacts on hydrological dynamism in watershed scale has occurred following the study of broad impacts of essential advances in the dynamics of quantity and quality of fresh water systems. However, it is obvious that development in small and local scale, including individual buildings and /or development adjacent to diverse materials, topography, and infrastructures, affects the rate of changes and water flow paths when transferring from the atmosphere to the ground.

Impact of Urban Scale (Size) on Rainfall

The rainfall dispersion across the nation is not the same. In the northern regions and northern skirts of Alborz Range, a high level of rainfall is observed, while the level is very low on the southern side. The overall annual rainfall in Iran is 252 mm –one third of world average- of which, 179 mm is lost directly through evaporation (Abbassi et al., 2006). Thus, it is necessary to use the rainfall and its runoff, ground surface, acute slopes, road surfaces, and using either simple methods such as boxes, tanks and reservoirs; or complex ones such as the study of underground dams (Alazba and Amin, 2011). Efforts towards understanding the dynamic relation between hydrosphere and Earth actually begins with the entry of rainfall. In an investigation concerning the present and future challenges of urban hydrology and water management, Niemczynowicz (1999) proposed rainfall study as a weakness of urban hydrology because urban environment has a significant impact on rainfall dynamism; and the effort to understand the rainfall in the cities is like a working field in research (Changnon and Huff, 1972; Shepherd et al., 2002; Burian and Shepherd, 2005; Ashley et al., 2012). The concentration of heat absorbents, thermogenic processes, and lack of vegetation lead to increased temperature in urban areas (urban thermal effectiveness or HUI 'urban heat island' which also leads to increased rainfall downwind areas (Oke, 1982). This process is mostly affected by the presence of natural and man-made aerosols boosting thermal insulation and act as a dense core for cloud-microphysical processes. Such environment-induced changes could exert a strong impact on both precipitation intensity and variability (Burian and Shepherd, 2005). Indeed, in a study of rainfall modification by major urban areas, Shepherd et al. (2002) examined the rainfall on the downwind periphery of six southern U.S.A. cities. Results indicated 28% increase in warm season and relatively low precipitation enhancement (5.6%) in urban areas. They could establish the major impact of urban local (small) scale. Additionally, a number of studies (Bornstein and Lin, 2000; Shem and Shepherd, 2009; Bentley et al., 2010; Ashley et al., 2012) have established the role of UHI in the emergence of summer lightning in Atlanta and consequently, enhanced precipitation in downwind areas; and also, ascertained the impact of microphysical interactions on climate dynamics on a regional scale. Despite increasing consensus, some studies still address the uncertainty of how urban areas affect the precipitation dynamics. For instance, despite identifying an average of 8% increase in winter rainfall in various European cities, Trusilova et al. (2008) study of the impacts of urbanization on Europe's climate indicate 19% decrease in summer rainfalls in urban downwind areas even though differences are seen in this values across diverse geographic regions. In their study of the climate's response to quick urban growth in southern China, and given the evidence of human influence on rainfall shortage, Kaufman et al. (2007) identified decrease dry season precipitation, increased aerosols cooling the atmosphere, and increased number of condensation nuclei (Chen et al., 2006). The impact of urbanization and expansion of urban watersheds on the climate and precipitation levels in Iran has also been established by a number of studies. Land surface temperature is considered an important parameter in urban weather identification which directly controls the UHI effect. Studies demonstrate, in most areas of Iran, the UHI effect is greater in winter and smaller in summer (Moharrami et al., 2014; Azzizi et al., 2013; Ghazzanfari-Moghaddam et al., 2010; Ramazani and Dokhte-Mohammmad, 2010).

Rainfall Variability-Local Runoff

Scarce water resources, arid and semi-arid climate, and the demands of sustainable development, all make good grounds for an optimal use of water resources. One major problem of the communities, as well as industrial and urban centers, is the rainfall-induced runoff, followed by urban flooding. Flow rate and its measurement constitute the main design parameters of urban and industrial surface water collection networks. The major post-rainfall issue is the surface runoff. With the spread of urbanization and its growing trend, any rainfall and runoff would lead to the flooding of roads and passageways. Given the extended surface of urban passages and their fully impermeable asphalt cover, any incidence of rainfall would create a considerable volume of runoff which if not used quickly in the path of urban drains, would become polluted and inaccessible. In Iran, efforts are made mostly toward directing runoff outside the cities while such runoffs could be used more advantageously for artificial feed and other applications through proper treatment, filtration and decontamination, apparently a necessity given recent and frequent droughts. (Eslamian et al., 2011). Hydrologists and urban engineers evaluate and assess the local responses of urban areas to rainfall, the fate of rainfall in building and street scales, extensively. Starting the hydrothermal studies has been resulted from the evaluation method of moist and heat movement through building surfaces. Rains accompanied by winds lead to cooling of the building facades where diverse materials create various responses in further dynamics (Blocken et al., 2013). For instance, glass buildings mostly create a smooth façade which accelerates the conversion of water into runoff (Carmeliet et al., 2006). In contrast, buildings mainly made of bricks or concrete have porous spaces through which water may permeate the building and be considered a hydrologic drop, especially in old buildings with the walls capable of collapse and having holes. Effects of such dynamics on water balance of larger watersheds are variable. However, the risk of local rainfalls could increase due to specific building materials and inefficient supportive draining infrastructures. In a study conducted in southern England concerning the empirical examination of water currents in a residential area, road permeability, runoff, and evaporation, the results showed that 30 percent of rainfall descending on rooftops is either lost or evaporated (Ragab et al., 2003). High interest in modeling the water volume transformed into runoff from urban rooftops such as rain withdrawal, pursuits the conversion of rain into a sustainable resource and its volume understanding is very important for the purpose of designing supply reservoirs.

During a flood event, rooftops intensify the change levels of rainfall and accelerate the runoff processes in urban environments (Gash et al., 2008; Shaw et al., 2010). Size, slope sharpness, materials and infrastructures of routing in the rooftops also affect the rainfall changes trends. Rooftop slopes with impermeable materials direct the rain into flood drains or reservoir tanks through stream systems and lead to lack of general balance of water. Rooftops have damages similar to the facades because surface unevenness could provide for small reservation spaces to collect water and keep it until this collected water is evaporated or transferred to the porous spaces in building structure (Damien et al., 2013).

As the buildings become denser and adjacent zones larger, a wider area of the impermeable surface would change the direction of rain water transformed into runoff in surface and subsurface strata (Miller et al., 2014). Recently, an investigation by Verbeiren et al. (2013) has established that a small increase in surface areas strength could lead to a considerable increase of peak drains. This is specifically true in peri-urban catchments where effective impervious areas (EIAs) integrating runoff direction with subsurface drainage networks and eventually, near the current channels. Also, the purpose of implementing a sustainable urban drainage i9n recent residential developments is to reduce surplus runoff through the reduction of impervious surfaces (Janke et al., 2011). Continuous implementation of green infrastructure requires breaking the growing EIAs because urban density increases through population growth even though accurate planning and managerial policies require maintenance costs efficiency especially in larger facilities (Section 5).

Hydrological Wastes in Urban Areas

Presence of extensive impervious surfaces lead to dynamic changes of permeability and also, different outcomes in basic flow behavior in various scales (Walsh et al., 2005). Even though some urban areas lead to reduced permeability and flow rate due to extensive crusting of urban soil, some pervious areas inside a city, on the other hand, facilitate water transfer from surface to subsurface. Small-scale developments, among others, lead to the crusting of private gardens to create a path for water passage, reduces the water impermeability distance to permeate into the soil. This method is broadly used in developed nations where both higher flow safety and reduced R & M costs and requirements for the gardens by many owners have attracted a lot of attention (Warhurst et a; 2014). Doing this would decrease permeation, evaporation, and perspiration dramatically; and increase the risk of urban flooding, as occurred in the study by Warhurst and coworkers (2014) on the changes in the permeability of gardens versus parking lots and their impacts on flood regulation in a city southeast of England. Such processes have led local authorities to collect some data on the use of impervious coatings when creating applications (EA, 2008).

In developing nations, too, similar thresholds have been observed, as in a pilot basin in Gaza

Stripe where Eshtawi and coworkers (2014) showed that 1% increase in urban areas would lead to 41% reduction of overall permeability. On the other hand, research has showed that the zero permeability in impervious surfaces hypothesis was not supported as Ragab et al. (2003) showed that almost 10% of annual precipitation permeated into road surface network for a pilot site in southern England. This discussion is more supported by Mansell and Rollet (2006) in their study of water balance and behavior of different cobblestone pavement surfaces. Their results showed that water has different behaviors on various cobblestone surfaces and there are different identifications of permeability and evaporation dynamisms. For instance, brick work facilitates permeation losses by 54% through openings and combined joints. Briefly, asphalt and tar prevent any infiltration and facilitate high evaporation losses (44 and 66%, respectively). Performing sustainable urban drainage methods such as infiltration pits, biofilter basins, permeable cobblestones, extensive plantation of trees, and vegetation, could facilitate infiltration and feeding; and be broadly used in peri-urban areas as well.

Surface Runoff Dynamics

The subsidence phenomenon could create significant changes in regional hydrology by changing a region's topography. For instance, huge and destructive floods could occur in such regions while there have been no records before subsidence occurred. Subsidence and land cracks developing slowly and gradually, perhaps do not have the same effect of sudden and catastrophic hazards such as flood and earthquake. In a subsiding area, perhaps devastation is not observed extensively, even surface impacts induced by it may not be detected easily.

However, the damages from subsidence and irreparable land cracks usually are costly and destructive. Damages to wells in rural and urban subsidence areas is completely predominant, leading to the destruction of wells and a phenomenon termed "well growth". In this phenomenon, it seems that well shafts have protruded the ground while the shaft is fixed and it is the land surface which has descended. Urban areas are especially more vulnerable due to population density, buildings and vital arteries. This phenomenon may damage the roads, bridges and freeways; disrupt the water, natural gas, and sewage lines; damage building foundations, cracking them. In this case, structures with greater width and higher elevation are more vulnerable. For instance, railroads, soil dams, treatment plants, and canals have a higher vulnerability. In general, any structure located on the way of crack or subsidence pit formation is exposed to higher risks and damages.

Presence of urban landscapes affects the surface runoffs dynamics and the runoff generation process considerably (Table 2). Converting the landscapes from pervious to impervious surfaces leads to increased total runoff volume (Dunne and Leopold, 1978; Arnold and Gibbons, 1996); reduced runoff delay times (Leopold, 1968; Veldhuis and Olsen, 2012; Konrad, 2013); increased flood returns periods (Hollis, 2010; Houston, 2011); and peak flow rate elevation during flood event (Packman, 1979; Konrad, 2013). Increased current flexibility, on the other hand, is indicative of urban development and impervious surfaces by which, quick generation of runoff transfers the flow volume to the adjacent flow system through current shortened routes and without need for oversaturation. Runoff, identical to permeability/infiltration dynamism, is affected by the nature of surface materials. For instance, brick work transforms 9% of received water into runoff while concrete, depending on surface slope, turns 69-83% of water into runoff quickly (Mansell and Rollet, 2006). Rim et al. (2010) recently presented some empirical data indicating reduced precipitation intensity required for runoff generation between cobblestone surfaces (a common feature of large cities in England) (>0.04 mm/min) and concrete surfaces (>0.02 mm/min). while local response of specific surfaces may not be seen in larger scales, it is possible that in some cases, floods resulting from intensive local rains occur in even zones with impervious surfaces (e.g., tar) and with relatively low rainfall levels. In some cases, such a process would require engineering features built in surface projects in order to create artificial curved routes or a ditch that might take surface water and direct to a nearby drain. For instance, building new road networks often have some slopes which lead to directing water flow into a specific route and creating potential for catchment drains and next borders of the catchment modification (DFID, 2005).

Table1. *Summary influences of urban areas on natural water cycle compared to undeveloped catchments*

Reference	Urban Influence	Variable
Krajewski et al., 2010	Increased rainfall and focal storms	Quantitative impacts on rainfall
Walsh et al., 2005; O'Driscoll et al., 2010	Reduction	Infiltration
O'Driscoll et al., 2010	Reduction	Evaporation and perspiration
Walsh et al., 2005; Badi'izadeh et al., 2010	Increase	Overall debit
Walsh et al., 2005; Hollis, 2010; Behnam et al., 2012	Increase	Flood rate
Konrad, 2013	Increase	Erosive flow frequency
Veldhuis and Olsen, 2012	Shorter peak debit delay	Return time
Walsh et al., 2005	Reduction	Basic flow
Hardison et al., 2009	Decrease	Qualitative impacts of canal width
Walsh et al., 2005; Hardison et al., 2009	Canals extension	Flow depth (and basin expansion)
Walsh et al., 2005	Increasing both	Macro nutrients (K, P, N)
Meyer and Paul, 2001	Increase	Toxic contaminants; heavy metals
Horowitz et al., 1999	Increase	Pesticides
Brown et al., 2009		
Halling-Sorensen et al., 1998	Increase	Drugs
Walsh et al., 2005	Increase	Remained sediments
Berman and Poole, 2001	Increase	Temperature
Gibson et al., 1998	Increase	Microbial contaminants

As explained in section 3.3, small developments such as paving garden surfaces may modify local hydrologic dynamics including runoff. Increased density in urban areas could change the impact of urban surfaces management on precipitation during high rainfall events. In such cases, the scale factor is specifically important and noteworthy because local changes of slopes and surfaces may affect how to maintain and direct water course on land surface. In fact, EIA has a vital importance in how rainfalls turn into runoffs where a high percentage of EIA assists the quick expansion of runoff flow into adjacent canals and leads to enhanced flood risk in urban areas (Miller et al., 2014). At the same study where the impact of threshold limit on infiltration was evaluated, Eshtawi et al. (2014) concluded that 1% increase in urban areas would lead to 100% increase in runoff. While the impact of impervious surfaces on runoff volume is relatively easily comprehensible, there is no certainty on the role of pervious areas in urban settings. Modeling approaches for hydrologic dynamism often consider and treat pervious areas as rural ones and act accordingly. As explained in Section 3, changes in soil and structures foundations may affect water's behavior; and "rural" appearances of such areas could be considered very simple. Additionally, in permeable urban landscapes, hydrologic connection to impervious areas is important in two ways: 1) runoff from impervious areas passing through permeable lands may accelerate saturation and quickly reduce flow speed; and, 2) flows resulting from saturation located adjacent to impervious zones have low-resistance routes which may facilitate the transferof a great volume of water. The role of such zones in overall water balance is unknown and is subject to continuous studies but such dynamism may have a considerable impact on the increase off small-scale floods and also, the flood hazard raised by them (Seo et al., 2013).

Underground Water Flow Dynamics

Price (2011) identified the complexity of the relationship between urbanization and underground currents' dynamics, complex role of urban surface, presence of water management and drainage networks, as well as more extensive features of catchments (such as geology, soil, vegetation, topography). Hardison et al. (2009) in their study of urban land use, canal destruction, and river water reduction along internal coastal deserts, and also O'Driscoll et al. (2010) by investigating the urban influences on watershed hydrology and current processes in the southern U.S.A., identified the reduction in basic current by observing an increase in the impervious surface. While Lerner (2002), investigating and determining urban current debit, and also Garcia-Fresca (2005) by hydrological study of urban development, both indicated increase of debit in urban areas. The presence of considerable infrastructures underlying urban surface may influence subsurface currents dynamics which due to compression, use the infrastructure of both water supply and urban sewage system to assist in feeding underground waters and reducing the self-cleaning capacity of underground tables (Jacobson, 2011). While the infiltration or inflow (I/I) into sewage networks may reduce access to the water of underground areas, Heywood (1997) in a study of infiltration measurement with a very simple approach, estimated that the infiltration/inflow (I/I) ratio could account for 15 to 55% of overall waste water flow rate. Moreover, Ruban et al. (2007) in an empirical study of a small urban watershed's hydrology in Lyon, France, found a correlation between wastewater basic flow and water level. In fact, elevated water level in urban areas is a joint reserve of underground waters which depends on low regions properties such as basements and water reservoirs, especially in areas affected by lime bed stone or sand and gravel coverage (BGS, 2010). Participation in underground current depends on two major factors: 1) local range of urban infrastructure network; and, 2) life-span and integration of infrastructures, because older infrastructures are more likely to be destroyed than the newer ones installed using new and up-to-date materials.

In recent urban developments, where sustainableurban drainage systems (USDS's) are increasingly emerging, Newcomer et al. (2014) in a study of urban feed levels and small effects of climate changes managed to specify USDS's which facilitated infiltration much more than ordinary green areas such as lawns and subsurface currents.

In many a developed nation, subsurface water tables as drinking water supplies become a" cleaner" alternative for many a surface water area often affected by the contamination from intensive agricultural or industrial operations (park et al., 2014). Over-pumping of underground waters is influenced by three important issues: (i) progressive increase of world population; (ii) limited water supplies; and, (iii)reduced debit considering extensive and speedy crusting of urban soils (Braadbaart and Braadbaart, 1997). As a result of faulty management and weak regulation of underground water resources, many a developing nation are exposed to water shortage especially exhaustion of underground water supplies which have consequences for continued water use, reduced self-cleaning capabilities, and emergence of geophysical hazards (Ozdemir, 2015).

Water Management in Urban Settings

Since long ago, flood has been observed as a hazard in urban areas with complex networks of drainage infrastructures applied to withdraw and direct ground waters from urban areas. Additionally, open canals beneath the urban surface were channeled which would limit the flood danger and also reduce the potential for ecosystem development in urban currents. Local responses across urban areas are implemented to manage the flood in the origin and to reduce the undesirable impacts of urban runoff in their surrounding areas. The shift to sustainable urban drainage has led to urban planning programs which have been implemented in a range of site scales considering the integration of aquatic environment and eco-systemic habitats (Wong, 2007). While extensive networks of urban drainage systems remain a functional component in urban water management, projects in small and middle scale SUDS's are often performed by local and national authorities and enable the households and individual businesses to absorb and use water. Application of SUDS projects was successful in developed counties such as North America, Europe, and Australia but it has not been put to trial in developing countries yet. Instead, many a developing country have relied upon ordinary and conventional sediments drainage systems and in some extreme cases, where there is no proper sewage system, they are based on gravity and open sewers which have a huge adverse impact on environmental and public health quality (Parkinson et al., 2007).

Local Management of River Flood Hazard

Conventional large-scale flood drainage systems are designed with a limited capacity and high rainfall events that further the design thresholds lead to the flooding of drainage networks. Upgrading large infrastructures are both costly and destructive and require extensive excavations in various levels including main road networks therefore, implementing sustainable methods which would absorb the runoff from the flood is desirable (Houston et al., 2011). Individual buildings or new developed compounds generally use a combination of local flood management techniques to reduce the rainfall volume which turns into runoff during rainy events. Rain water collection systems are mostly adopted to meet the main needs (Sauri and Domenech, 2011).

The rain water collection collects the rain falling directly on the surface in question and then is transferred into storage tanks or drainage systems. Such systems, by removing water from extensive urban cycle, reduce the local impacts of rainy local events. The commonest mechanism for rain water collection is to build “rooftop basins” which direct the collected rain water through placed chutes and then, direct it to storage tanks nearby the buildings through pipes (Singh et al., 2013). Such a system not only provides a clean alternative in watershed areas (especially in developing countries) but also prevents rainfall from being a source of danger. Moreover, planted rooftops provide for a multi-purpose method to reduce the environmental impact through reducing rooftop temperature, increasing biological diversity in the city, and maintaining rain water during heavy rainfall events (Keeler and Carter, 2007). They take rain water, maintain it, and return it the atmosphere as vapor; therefore, they reduce the volume of the rain which turns into runoff. The effectiveness of planted rooftop structures is the product of previous conditions, temperature, and moisture maintenance capacity of the vegetation (Mander and Teemusk, 2007; Simmons et al., 2008; Gregoir and Clausen, 2011). Shuster et al. (2013) evaluated the impact of installing 174 rain drums and 85 rain-catcher gardens in individual (or parcel) scale by performing a study concerning the evaluation of rainwater quality in the residences and its use. Based on the results, it was observed that this extra retention capacity, even in small-scales, would affect the overall runoff peak and increased dynamics of plant organs.

Another strategy broadly used to reduce runoff at the scale level is planting trees and vegetation. In urban settings, this could lead to more rain infiltration and consequently, reduced losses in the form of evaporation and perspiration; and facilitates water transfer to roots and soil (Denman et al., 2012). Even though planting trees and vegetation acts as an effective way to infiltrate rain into the ground, it also has some disadvantages including damaging cobblestone and underground infrastructures and subsequently, costly repairs through extending roots of planted species beneath urban surface (Mullaney et al., 2015).

Large-scale Floods Infiltration and Retention Methods

In large-scale residential developments and industrial parks, land retention techniques (e.g., basins, lagoons, and bioretention systems) usually are used to reduce and control the flood-induced runoff (Hirschman et al., 2008). In order to prevent flood and erosion in the down river, runoff is directed into retention basins; and during this period, sediment load and pollutants are collected through sedimentation, freezing, ionic exchange, agglomeration, and bio-absorption (Urbonas and Stahre, 1993). Additionally, such materials are made compatible with urban settlements and biodiversity is promoted for both animal and plant species, colonized in this swampy areas (SEPA, 2013). Efficiency of such structures is the product of basin storage capacity, watershed region, and hydraulic residence time (HRT), and finally, determining the effectiveness of the flood’s qualitative behavior (USEPA, 1999). Retention basins and lagoons require regular maintenance and by aggregation of HRT sediments, eventually it would reduce the level of water that it could retain during each event considerably. In this regard, one could point out Verstraeten and Poesen (1999) who in an investigation by studying the flood’s nature in small-scale, clay flood and lagoon sedimentation, evaluated retention basins in Belgium during flood events. Results of this study indicated that flood-induced sedimentation would lead to high economic expenses to maintain regular dredging operations in order to ensure their continued efficacy; and due to the speedy growth during flood incidence, this method could not act as the best management practice (BMP) to manage floods. Bio retention systems are the commonest flood control techniques in the U.S.A. which mainly are incorporated in both developed and developing nations worldwide similarly (e.g., Fujita, 1997; Wong, 20007; Davis and coworkers, 2009; Trowsdale and Simcock, 2011). Bio retention systems are a combination of grass buffer stripes, sand filter beds, floodgate areas, an organic and biological layer (Davis et al., 2009). Bio retention basins demonstrate different results for removing and reduction of suspended sediments load and heavy metals (Davis, 2008; Li and Davis, 2008; Hatt et al., 2009). Even though there are cases showing success rates of 14 to 99 percent in reducing peak flow in catchment scales (Hunt et al., 2008; Hatt et al., 20009), infiltration systems have been designed to collect rainwater from adjacent impervious areas and provide for a route to infiltrate water into soil and underground areas and natural feed for underground water systems (Butler and Parkinson, 1997). Such systems are built like excavation which have been covered by an intermediate limit filter such as sand, sandstone, or rock grains and sometimes are wrapped in a single geotextile[1] and generally are installed in new residence developments in order to reduce runoff risk (Siriwardene et al., 2007). Such systems, while retaining the flood, absorb it and filtrate it into surrounding soils and deeper underground tanks and the goal of returning the hydrological behavior to the predevelopment state is to remove large EIA zones (Mikkelsen et al., 1996). Another method to break EIA is to use the installation of permeable surfaces which would filtrate rainwater through surface and enter it into underlying soil structure. Brattebo and Booth, (2003) during their study concerning qualitative and quantitative performances of pervious systems in long terms floods, when 121 mm rainfall only created 4 mm (3%) runoff, established the successfulness of permeable pavements in reducing surface runoff. The same study demonstrated a considerable reduction in copper and zinc concentrations in water which had infiltrated through pavement filter and also considerable reduction of engine oil presence revealed their function in water quality improvement. Increased popularity of permeable pavements in parking lots, roads, and asphalts, has led to its widespread use across England (Newman et al., 2013). As many urban measurement parameters such as TIA (total impervious area), EIA, and URB_{EXT} (urban extent) derive from remote measurement images, permeable pavements create a new problem for land use classification because ordinary pavements are not detectable from air images. Accordingly, approaches based on modeling for determining hydrologic response of urban landscapes have more emphasize on local inspection because permeable pavements performance as an 'impervious layer" leads to overestimation of runoff from Platt's scale into sub-catchments and BMP control for flood runoff (Jacobson, 2011).

Discussion and Conclusion

Notwithstanding the many advances which exist in this area, still there are uncertainties concerning urban water cycle and urban development's impact on natural hydrological processes, water quality and ecosystem processes. New monitoring technologies and modeling strategies have advanced so that we might go further in collecting, analyzing, and modeling the data in urban settings but our accurate identification of hydrological processes in plot scales or sub-catchment to a broader catchment scale is very difficult. Sustainable water supply systems have been designed and managed to further the present and future goals of societies so that environment, ecology, and hydrology thereof be used optimally. The purpose of sustainable water resources development and management is to properly meet water needs of present and future generations which considering the dual factors of comprehensive and proper design of systems, that is, water use efficiency enhancement, and, initiating a continuous effort towards protection and renewal of natural environment, could be realized. Some critical regions have left us some studies for our better understanding of urban water cycle which could be summarized as follows:

- Infiltration levels in urban areas are still considered weak; and the work procedure has shown that many present assumptions are unsuitable. Therefore, the research priority is to determine the infiltration rate inside both pervious and impervious urban areas in order to measure the total waste in urban water cycle.
- An empirical method to evaluate perspiration and evaporation levels produced by urbanization is necessary to help overall urban water balance. Evaporation and perspiration are mainly introduced as a sustainable method for runoff management and quantitative value of ET currents in urban areas are very important in designing such systems.

[1] Geotextile has applications for reinforcement, separation, proper drainage, enhancing asphalt's and soil's load bearing strengths, increasing asphalt's life-span, structural protection of coasts and harbors, homogeneous subsidence in marine structures such as wave-breakers, protection of eroding lands, protecting ballast layer in railroads, enhancing the load-bearing strength of road matrix and railways, protecting geomembrane strata and many other cases. Geotextiles are usually produced in the form of woven or unwoven fabric. Woven geotextiles are made by interweaving vertical and horizontal strands the end result of which is the emergence of a strong, resistant, somewhat fabric-like layer. Unwoven geotextiles are produced in different ways. Common methods include heat bonded, needle punched, and chemically bonded. Woven and unwoven geotextiles are formed of generally polymeric strands and fibers, made of polypropylene, polyester, polyethylene, and polyamide. there is a small group of geotextiles formed of fabric fibers and are mainly used in erosion control.

- Quantification of urban areas' impact on climate dynamics for precipitation forecast in time scales is highly important. This requires continued joint research between meteorologists and hydrologists and is very important in understanding the role of UHI versus climatic environments (Arnfield, 2003).
- The share of engineered water cycle is insufficient. New technologies that could be installed along with piping systems could provide new insights into leakage and infiltration monitoring and assessment. Broad implementation requires the description of urban networks participation for natural water cycle and also helps local authorities and software firms reduce missing volumes of the system.
- Complex portions of both pervious and impervious zones and their mutual dynamics lead to complex responses to rainfall-runoff changes which have not been understood yet. While hydraulic runoff dynamics of pervious areas is relatively predictable, in situ dynamics of pervious areas and the role of impervious urban areas is still unknown and is a ground for further research.
- Urban surfaces are sources for various contaminants harmful to humans and aquatic ecosystems. On the other hand, understanding place and time patterns of contamination trends in urban rivers still is an important task. Tracking contamination sources is considered a major requirement of floods' contaminant sediments management because it would provide for a mechanism to discern all contaminants relevant to specific urban applications.
- Since sustainable approaches are more often the focus when executing urban drains, new advancements mostly include sustainable drainage systems to reduce and control floods. The success of this approach is not certain; and to evaluate other measures, more work is needed which have a plausible impact on the overall urban water cycle.
- The impacts of climate change on urban hydrology leads to changes in the quantity and frequency of rainfall events. Thus, there is urgent need to understand such probable changes and measures in which they occur. Moreover, there is a need to understand the impacts that such events have on flood infrastructures, flood hazard, and water quality. Additionally, with continued population growth in urban boundaries, impacts of climate change on water resources will remain unknown while sustainable management of rainfall and flood-induced runoff provides for a considerable performance of renewable waters.

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