# Ecological landscape design in semi-arid areas on basis of water sensitive urban design approach (Case study: Mohajeran City)

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## Expended Abstract

## Introduction

Today cities are facing a variety of complex challenges called "wicked problems". Increase in frequency and severity of rainfall and long periods of heat and drought resulted from climate change, urban population growth and its consequences, water crisis and its' supply challenges, environmental pollutions in all dimensions, and extensive changes in land use are some of these issues. There are different approaches to integrate managing water resources in urban areas, one of which is "Integrated drinking water management" suggested between 1960 and 1970 by the Civil Engineering Society. This approach has been introduced as *low impact development* in the United States, *sustainable drainage system* in the UK, *water sensitive urban design* in Australia and New Zealand, and *the sponge cities* in the Netherlands, which is generally known as the Green-Blue Infrastructure.
Australia is the pioneer in the development of Water Sensitive Urban Design (WSUD) approach due to climate change and drought. WSUD is based on a decentralizing approach in water resources management which focuses on the local Practice. The purpose of this approach is to plan and design the urban fabric in order to manage and protect the natural water cycles in the urban environment in a way that ensures the sensitivity of water management to hydrological, natural and ecological processes. This approach seeks to manage two contradictory problems of flood/ runoff and water stress both caused by drought. For this reason, it tries to conceive the cycle of water as a multi-layered system, avoid isolated and fragmented approaches, and manage the water system in the artificial environment and ecosystem appropriately. WSUD approach is comprised of two key dimensions. The first dimension is water sensitivity consideration and the second dimension is planning and designing. In the first dimension, the integrity of water management in the urban environment is considered while in the second dimension, the planning and design of landscape regarding the management of water resources is regarded.
In hydrology, the concept of ecological design is well defined by WSUD. Ecological design can be considered along with WSUD in landscape design, which embraces any form of design that minimizes environmentally destructive impacts by integrating itself with living processes.
Nowadays, more than 500 cities in Iran are facing water shortage problems. The city of Mohajeran is one of them, which is the study area in this paper. This city has difficult emitting runoff during the rainy season and suffers from the drought in the dry season. We believe that following WUCD principles and employing ecological principles concurrently is the best approach to address these problems in such cities.

## Methods and Materials

In this study, after reviewing the literature about water shortage resulting from climate change, rainwater harvesting, reusing of gray water in urban landscapes, and promoting water consumption efficiency, the ecological principles were applied to create a strategic plan to improve the urban landscape. The second part of the research was conducted based on the ecological design principles, suggested by Van der Ryn and Cowan in 1996, and WSUD concepts, in order to design an effective green landscape. To achieve this goal, it was necessary to estimate the exact volume of rainwater using Equation (1).

$$Q = C_a \times S \times A \times (H \times 10^{-3}) \quad (1)$$

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where Q [$m^3$] is the annual volume of collectible rainwater; Ca is the average runoff coefficient; S is the seasonal loss coefficient (the ratio of rainfall in rainy season to annual rainfall); I is the initial split-flow coefficient (the ratio of rainfall rejecting the first flush to annual rainfall); A [$m^2$] is the rainwater harvesting area; H [mm] is the rainfall with different occurrence probabilities. Ca was estimated by using Equation (2).

$$C_i = \frac{\sum A_i \times C_i}{A} \quad (2)$$

where Ci is the runoff coefficient of different underlying surfaces; Ai [$m^2$] is the areas of different underlying surfaces

Runoff is a precious resource and should be reused in Mohajeran. However, this fact has been neglected and, as the consequence, many problems such as inundation, flooding, and water shortage in dry seasons have been generated. In order to come up with an appropriate solution for this problem, the runoff should be stored and reused. To calculate the capacity of cisterns that are capable of storing water in the rainy season and being used in the dry season, we used Equation (3).

$$V = A \times C_a \times h \quad \times 10^{-3} \quad (3)$$

where Ca is the runoff coefficient of different underlying surfaces; Ai [m2] is the areas of different underlying surfaces; and h [mm] is the rainfall with different occurrence probabilities.

Another uncommon water resource that can be used for irrigation purposes in Mohajeran is grey water. Applying some stages of purification will help this water to be reused for this purpose.

Annual precipitation in the study area is 337 mm. Therefore, using Equation (1), the volume of the collectible water was calculated to be 4021.7 $m^3$ annually. The total volume of runoff belonged to rooftops (2389.8 $m^3$), asphalts (1241.5 $m^3$), and paved. Figure 3 shows the volume of collectible water in different land uses in the study area.

This article assumed that the collectible rainwater in residential areas will be used for sanitary usages every month. Using Equation (3), the volume of cisterns was estimated. The total volume of cisterns was calculated to be 301.1 $m^3$ and 435.4 $m^3$ for rooftops, and 156.5 $m^3$ and 226 $m^3$ for asphalt. The population of the study area in 1395 was 268 people. According to the Water and Sewage Office of Markazi province, each person produces 154 lit gray water. So, the total volume of gray water in the study area was calculated to be about 41.3 $m^3$ per day.

## Discussion

Heavy rain in rainy seasons along with rapid constructions and increase in the rate of impermeable surfaces in Mohajeran put this city in the danger of severe floods in rainy seasons while the city suffers from water shortage for irrigation purpose during dry seasons. Therefore, by the collection and the storage of runoff during winter, fall and spring, and the reuse of the harvested water in summer, we can deal with these natural phenomena.

The ecological strategies that are considered for this area, according to site analysis, are categorized into four categories of protective, offensives, restoration, and opportunistic strategies. In the first category, protection, the native green patches that are adapted to climatic conditions and are resilient will be protected. Species that are scattered in different patches, but they are native, drought resilient and adopted with climatic and environmental conditions are also protected. Obviously, the water infrastructure has been designed to provide water for this sector, based on the previous section. In the offensive strategy, patches that are not adapted to the local conditions of the area are identified and inappropriate or exotic species will gradually be replaced by appropriate species. In order to achieve the objective of this strategy in a better way, the design of the infrastructure for supplying water is also considered. The sample of this group of patches can be found in some parts of the study area.

In the restoration strategy, those parts of the area that are degraded or damaged due to construction or urban infrastructure development will be restored. Restoration actions include the restoration of the degraded patches and ecosystems, rehabilitation of ecological connectivity between patches, and renovation of ecological water streams.

In the opportunistic strategy, the objective is to create green structures in the area or changing some grey infrastructure to green infrastructure. Managing and designing integrated water management, and creating green patches in suitable areas are other practices to make diverse patches, with emphasis on habitat creation. In all these cases, ecosystem resilience and ecosystem integration are considered.

## Conclusion

Landscape design could apply ecological principles in order to deal with climate threats, especially in dry regions. The city of Mohajeran was selected as a study area to examine its potentials for improvement based on ecological design and hydrological planning. The results demonstrated that green spaces in urban landscapes

could be developed by utilizing all water resources, and urban landscape could be improved through appropriate water resource management. As a result, ecosystem services will be improved by the development of urban landscape through ecological design principles and WSUD approach.
It is necessary to focus on the decentralization approach and integrated water management while considering the application of appropriate landscape design strategies in order to reduce the need for water. Through this study, it is demonstrated that water resources management in the WSUD framework in coordination with ecological landscape design could address some of the environmental challenges such as reducing urban water demand.

**Keywords:** ecological design, Mohajeran, water resource, water sensitive urban design, water shortage.