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Prioritization of Low-Impact Development Methods for Management of Urban Surface Runoff, Using the Fuzzy TOPSIS and TOPSIS Method (Case Study: Sepahan-Shahr Town, Isfahan)

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ABSTRACT: In recent decades, the percentage of residential areas has increased due to the expansion of urbanization. This has led to an increase in the percentage of impermeable areas, thus increasing surface runoff in cities. Therefore, it is necessary to control surface runoff values using strategies such as low-impact development (LID) methods in cities. In this study, 6 LID methods have been used, namely permeable pavement, rain barrel, infiltration trench, bio-retention system, impermeable pavement-infiltration trench, and rain barrel-bio-retention system. These methods have been evaluated by 4 criteria which are: reduction of runoff volume, reduction of peak discharge of runoff, economic and social criteria. The SWMM model has been used to determine the values of hydrological criteria. To determine the values of the economic criteria (cost), the price analysis list, and the social criteria, a questionnaire has been used by experts in the field. To prioritize LID methods, the Fuzzy TOPSIS and TOPSIS multi-character decision-making criteria have been used, in terms of the weighted entropy of the fuzzy Shannon for the Fuzzy TOPSIS method and terms of the weighted entropy, equal, emphasis on hydrological criteria and emphasis on economic criteria, for TOPSIS method. The results showed that in the TOPSIS method in terms of the weighted equal, emphasis on economic criterion and emphasis on hydrological criterion, bio-retention system & rain barrel and, in terms of the weighted entropy, rain barrel, selected as the best scenario. In the Fuzzy TOPSIS method, the rain barrel scenario was selected as the most efficient scenario and ranked first in the study area..

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1- Introduction

Floods are one of the most important natural events that can cause many problems if not managed properly [1]. Factors such as changes in land use and increasing urban impermeable areas have a significant impact on runoff volume and floods [2]. On the other hand, due to the lack of water resources, the existence of arid and semi-arid climates, etc., the need for water resources as well as their optimal use is very important [3].

In this study, the surface runoff of Sepahan-Shahr town has been simulated using the SWMM model and the effect of using LID methods on runoff volume and peak discharge of runoff has been investigated. To prioritize these methods in the study area, based on 4 decision criteria (Runoff Volume and Peak Discharge of Runoff criteria, Economic criteria (Cost), Social criteria), TOPSIS algorithm, and Fuzzy TOPSIS algorithm have been used. Weighted entropy, equal, emphasis on hydrological criteria, and emphasis on economic criteria were used for the TOPSIS algorithm and the weighted entropy of the fuzzy Shannon was used for the Fuzzy TOPSIS algorithm. Finally, the best methods are introduced in the study area.

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2- Methodology

2- 1- The Study Area

In this study, Sepahan-Shahr town is divided into 17 sub-catchments and we studied LID methods in 16 sub-catchments. Fig. 1 shows the sub-catchments of the study area and the output of the catchment.

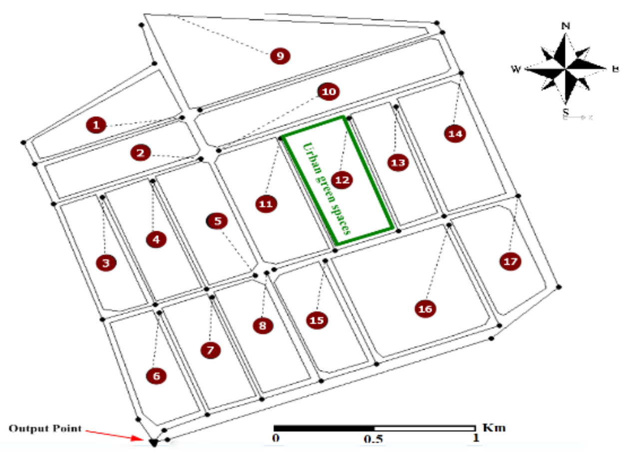

Fig. 1. Location of sub-catchment and output point of the catchment.

2- 2- Hydrological criteria

Urban runoff simulation in the study area was performed in two modes (By considering LID methods and without considering LID methods). The effect of each LID method on the reduction of runoff volume and reduction of peak discharge of runoff was measured.

2- 3- Economic Criteria (Cost)

The cost of implementing each LID method in the whole catchment was determined according to previous studies and the price analysis list.

2- 4- Social Criteria

To determine the acceptance level of each LID method, several questionnaires were prepared and completed by experts. Finally, the qualitative questionnaires were quantified by a Likert scale to prioritize scenarios.

3- Results and Discussion

3- 1- . Results of Hydrological Criteria

The highest volume of runoff and peak discharge of runoff decreased is related to the "permeable pavement-infiltration trench" method. By implementing this method, the volume and discharge of runoff peak are reduced by 3337 cubic meters and 0.417 cubic meters per second, respectively.

3- 2- Results of Economic Criteria (Cost)

The highest cost is the permeable Pavement-Infiltration Trench scenario and the lowest cost is the Bio-Retention system scenario.

3- 3- Results of Social Criteria

The combined scenario of the permeable pavement-infiltration trench, with an average of 7.5, has the highest acceptance level and the infiltration trench, with an average of 3.4, has the lowest acceptable level.

3- 4- Results of the TOPSIS Method

The results of prioritization of urban runoff management scenarios using the TOPSIS method in different weighting modes are presented in Tables 1 to 4

3- 5- Results of the Fuzzy TOPSIS Method

The results of the fuzzy TOPSIS method in the fuzzy Shannon entropy weighting mode are given in Table 5.

4- Conclusion

The results showed that in the TOPSIS method and the equal weighting modes, emphasis on economic criteria weighting mode and emphasis on hydrological criteria weighting mode, the Rain barrel bio-retention system

Table 1. Ranking of urban runoff management scenarios using the TOPSIS method in Shannon entropy weighting mode

Method	$C_i^{(*)}$	Ranking
Permeable pavement	0.174	5
Infiltration trench	0.812	4
Bio-retention system	0.83	3
Rain barrel	0.93	1
Rain barrel bio-retention system	0.92	2
permeable pavement - infiltration trench	0.172	6

Table 2. Ranking of urban runoff management scenarios using the TOPSIS method in the equal weighting mode.

Method	$C_i^{(*)}$	Ranking
Permeable pavement	0.472	6
Infiltration trench	0.476	5
Bio-retention system	0.498	4
Rain barrel	0.827	2
Rain barrel bio-retention system	0.944	1
permeable pavement - infiltration trench	0.5	3

Table 3. Ranking of urban runoff management scenarios using the TOPSIS method in the emphasis on economic criteria weighting mode.

Method	$C_i^{(*)}$	Ranking
Permeable pavement	0.316	6
Infiltration trench	0.644	4
Bio-retention system	0.665	3
Rain barrel	0.88	2
Rain barrel bio-retention system	0.93	1
permeable pavement - infiltration trench	0.34	5

Table 4. Ranking of urban runoff management scenarios using the TOPSIS method with the emphasis on hydrological criteria weighting mode.

Method	$C_i^{(*)}$	Ranking
Permeable pavement	0.642	4
Infiltration trench	0.313	6
Bio-retention system	0.333	5
Rain barrel	0.818	2
Rain barrel bio-retention system	0.95	1
permeable pavement - infiltration trench	0.67	3

Table 5. Ranking of urban runoff management scenarios using the Fuzzy TOPSIS method in the fuzzy Shannon entropy weighting mode.

Method	CC_i	Ranking
Permeable pavement	0.255	5
Infiltration trench	0.167	6
Bio-retention system	0.428	1
Rain barrel	0.301	3
Rain barrel bio-retention system	0.319	2
permeable pavement - infiltration trench	0.278	4

scenario and in Shannon entropy weighting mode, Rain barrel scenario were selected as the best scenario. Also in the Fuzzy TOPSIS method, the Bio-retention system scenario was selected as the best scenario. The selection of an efficient scenario should be done by local experts and according to the importance of each criterion, appropriate to the study area. The Bio-retention system scenario, obtained from the Fuzzy TOPSIS algorithm, is proposed in the study area due to considering the uncertainty factors and easy implementation of this scenario. In addition, Sepahan-Shahr town has a lot of areas to implement this scenario, and visually, it gives a special effect to the city view.

Using the results of this study, better planning can be done to manage and control urban surface runoff in Sepahan-Shahr town. Also, city officials and managers can prioritize and select the best solution for urban surface runoff management based on other management scenarios and according to their different goals and perspectives.

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