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Urban development scenarios on flood peak discharge in an arid urban watershed using the WinTR-55 hydrologic model

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ABSTRACT

BACKGROUND AND OBJECTIVES: Land use change can directly affect rainfall-runoff relationships. The change in land use is an essential factor in runoff production. This research evaluated the effect of urban development scenarios of land use change on runoff in Gonabad city of Iran. The innovation and importance of this work are to determine which land use changes have the greatest impact on the flood discharge in this urban area. Also, determine how much the minimum development of urban green space is to control and reduce peak flood discharge in this city that is located in a dry area.
METHODS: The effect of urban development scenarios on runoff was evaluated by the WinTR-55 model in 5 sub-basins of Gonabad city. The main data required for inputting to the WinTR-55 model are sub-area and reach characteristics, curve number, and storm data. The storm data in TR-55 are 24-hour rainfall amounts in a return period of 2, 5, 10, 25, 50, and 100 years. The changes in the maximum flood discharge and flow hydrograph in each sub-area and return period were calculated by the WinTR-55 model under existing land use conditions and 9 scenarios of urban development.
FINDINGS: The greatest increase in runoff production was related to the conversion of abandoned fallow and agricultural lands to residential. Also, the most effective increase or decrease of land cover change in peak flow discharge and total flow volume was at the 2-year return period. The decreased effect of the development of green spaces and urban gardens on peak flow discharge and total flow volume was seen only if their development was more than 50%. The average maximum decrease in peak discharge and total flow volume was 22.7% and 16.1%, respectively. While the average maximum increase in peak discharge and total flow volume was 84.4% and 53.9%, respectively.
CONCLUSION: The effect of increasing green spaces and urban gardens on the reduction of peak discharge and volume of runoff was also evident in the study area. Land management and preventing the conversion of permeable land uses such as agricultural, gardening, fallow lands, and rangeland will be much simpler and less costly. Urban land use management to prevent urban floods requires the expansion of permeable surfaces, especially green spaces, and urban gardens. These are the important novelty of this research that can be beneficial for future urban developments of Gonabad city and its flood management activities.

NUMBER OF REFERENCES
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3

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6

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INTRODUCTION

In 2012, the United Nations reported that the world's urban population is growing increasingly as estimated that 53% of the world's population will be settled in cities (United Nations, 2012). This increase in population requires urban development. The development of residential areas is due to the development of roads, houses, and buildings (Torres Navas *et al.,* 2021). This development can lead to negative ecological and environmental effects (Samimi and Shahriari Moghadam, 2020). Increased residential areas change ground surface responses to precipitation. It reduces rain infiltration and the lag time of runoff which increases peak flows and floods (Feaster *et al.,* 2014). Flood is a natural phenomenon that can happen almost anywhere it rains (Eshghizadeh, 2017). Floods are one of the main damaging natural disasters that occur more frequently under the influence of human interventions, especially urbanization development (Zhou, 2022). One of the main effecting factors on floods is land use changes (Gholamian and Ildoromi, 2020). The change in land use and land cover is an essential factor in runoff production and flood estimation (Hashim *et al.,* 2022; Li *et al.,* 2019; Vaziri, 2021). The increase in urban areas can trigger river peak discharge (Barasa *et al.,* 2014). Urban development is usually accompanied by the loss of agricultural lands and rangelands that convert to urban lands (Shehu *et al.,* 2023). These changes increase the potential for runoff and sedimentation in cities (Torres Navas *et al.,* 2021). To determine the effect of the land use change on the peak flow in an urban watershed, many hydrologic models were developed that predict runoff amount from rainfall with acceptable accuracy (Alkan 2016; Muhammad and Khan, 2015). Apollonio *et al.* (2016) evaluated the impact of spatio-temporal changes in land use on the hydrological response of the Cervaro basin in Southern Italy, from 1984 to 2011. They used Landsat imagery and a physically-based lumped approach for infiltration contribution to produce a land use map and estimate flood peak. Dang and Kumar (2017) investigated the effect of the rapid growth of urban development on the increase of flood risk in Ho Chi Minh City, Vietnam. They used QuickBird imagery to create a land use change map and a TR-55 model to estimate flood risk in this urban area. Shrestha (2019) analyzed the changes in land cover in the Pampanga River basin of the Philippines for the years 1996 and 2016 and the effect of them on the flood, the results showed that these changes can increase the flood risk in urban areas in the future. Recanatesi and Petroselli (2020) evaluated the impacts of land cover changes on the runoff in rainfall events in Rome. They analyzed land cover and flood risk changes in 1954, 1967, and 2018 by a hydrological-hydraulic model as a result of urban development. Also, Berkessa *et al.* (2023) showed rapid urbanization has caused vegetation cover in the wetland the decrease over the past decades. This area was converted to urban areas and the surface storage areas of precipitation are decreasing, which can lead to an increase in floods. One of the widely used and reliable methods for estimating peak discharge and flow volume in small and urban watersheds is the TR-55 model. Technical Release 55 (TR-55) is a simplified method to calculate runoff volume, the peak of discharge, and hydrographs of rain storms, especially in urban watersheds. TR-55 was introduced by the Natural Resources Conservation Service (NRCS) in 1975. In 1998 NRCS revised a Windows-based model of Tr-55 as Win TR-55 and computer software for estimated runoff of rainfall events in agricultural and urban watersheds (NRCS, 2005). Many studies have confirmed the ability of this model to estimate runoff in urban and agricultural watersheds (Blair *et al.,* 2014). The studies conducted with this model also confirmed the use of this model for estimating runoff in urban areas. Alkan (2022), evaluated the peak flow in the agricultural watershed of the Kirklareli Vize and Samsun Minoz Stream watersheds. The peak flow is calculated by the WinTR-55 model. The results showed that WinTR-55 can be used for the predicate of flood in the watersheds. Corbin *et al.* (2021) used WinTR-55 and the Regional Regression Equations (RREs) models to assess their accuracy for the peak flow of runoff in the WS80 area. Sutjiningsih *et al.* (2015) simulated the discharge using a WinTR-55 model to estimate the annual sediment yield in a small urban watershed at the outskirts of Greater-Jakarta. Henning (2009), showed that the Win TR-55 model can be used to determine peak flows for storm return periods of 2, 5, 10, 25, 50, and 100 years. Due to the lack of surface water resources in arid regions, the concentration of vegetation covers and other aspects of life are around the water resources, such as the city of Gonabad, where the concentration of population and agricultural lands were due to the existence of qanats (as Qasabeh qanat of Gonabad) in these areas, a decrease in vegetation cover can have a negative effect on their micro-climate. One of the main reasons for the reduction of vegetation in these areas is the conversion of current lands into residential lands due to the development of the city. One of the main urban problems is the occurrence of floods and urban flooding, which has increased in frequency in recent years. Estimation of the flood peak flow is one of the most important factors in managing the runoff in urban areas (Alkan, 2022). The destructive floods in May 2021 and 2022 have caused a lot of damage to this city, and so far, no research has been done on the effects of land use changes on floods in this city. There is little information about the effects of land cover changes on runoff, peak flows, and flooded areas in many arid urban watersheds spatially in Gonabad city. The main purpose of this study is to evaluate the effect of urban development scenarios of land use change on runoff by the WinTR-55 model in Gonabad city as an arid urban watershed. For this purpose, changes in the maximum flood discharge and flow hydrograph in 5 sub-basins of Gonabad city for events with a return period of 2, 5, 10, 25, 50, and 100 years were evaluated under existing land use conditions and possible land use change scenarios. The innovation and importance of this work are to determine which land use changes have the greatest impact on the flood discharge in a dry urban area. Also, determine how much the minimum development of urban green space is to control and reduce peak flood discharge in a city located in a dry area. The current study has been carried out in Gonabad city in 2023.

MATERIALS AND METHODS

This study evaluated the effect of land use change on runoff in an arid urban watershed. The main hypothesis was that urban development can increase the flood in this watershed. This hypothesis was examined by the WinTR-55 model and possible land use change scenarios. Changes in the maximum flood discharge and flow hydrograph were evaluated for rainfall events with a return period of 2, 5, 10, 25, 50, and 100 years in the study area.

Study area

The study area is the city of Gonabad in the northeast of Iran (center coordinate 34°21’28”, N; 58°42’2”, E). The area of the study area is 3619.1 ha and a population of about 40773 in 2016. The general slope is from south to north. The average height of the area is 1150 meters above sea level. The climate of Gonabad city is predominantly arid with a mean annual precipitation equal to 140.3 mm and a mean annual temperature of 17.6°C. According to the drainage conditions of the area, five sub-areas can be determined for this urban area with a total area of 3,626.4 hectares. Fig 1 shows the study area and sub-area.

WinTR-55

WinTR-55 is a single-event rainfall-runoff model. In this model, a watershed is divided into subareas and reaches. A subarea is a surface of the land that has land use and land cover special characteristics, and according to these characteristics, it responds against rainfall events, and the runoff produced on it is drained by a reach. Reaches are flow paths that discharge runoff of the subarea to its outlet. A hydrograph can be generated for each subarea. Also, for each reach, hydrographs can be routed based on the physical characteristics of the channel, or as a reservoir based on temporary storage and outlet characteristics. An accumulated flow can be calculated by combined sub-areas and reaches at the watershed outlet (NRCS, 2005). The TR-55 utilizes the SCS runoff equation to convert rainfall to runoff and predict the peak and total volume of the runoff. The TR-55 to generate the runoff hydrographs uses a simplified tabular method based on land use, land cover, and climate characteristics. The calculations of the tabular method are performed with TR-20. The WinTR-55 is based on the TR-20 (NRCS, 2002) model, and all calculations are done for hydrograph generation, combining hydrographs, channel routing, and structure routing based on it (WinTR-55 User Guide, 2009).

Data collection, input, and analysis

The data was inputted into WinTR–55 through several windows. The main data required for input are sub-area and reach characteristics, curve number, and storm data. For each sub-area be defined name, area, flows to reach/outlet, curve number, and time of concentration. In the TR-55 the weighted CN is calculated by land use details. The land use details can be defined for sub-areas to determine the area of each

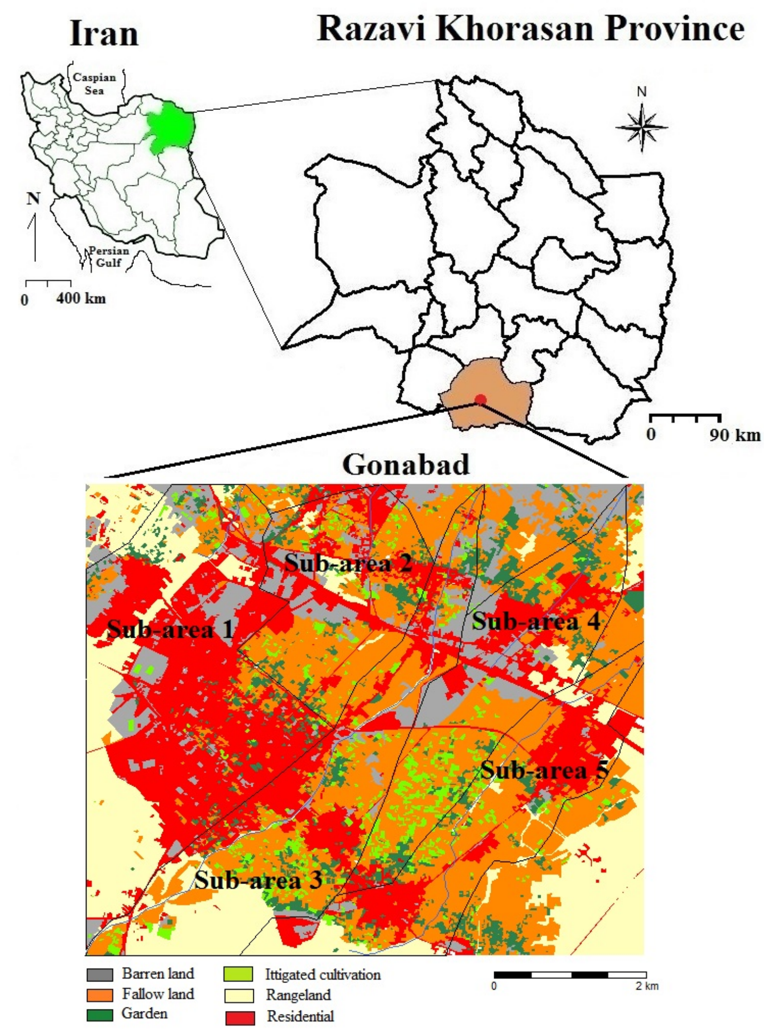

Fig. 1: Geographic location of Gonabad city and their sub-areas in the study (Source: 1:25000 topographic map, soil map, land use map, and field surveys of Gonabad city)

cover description and hydrologic soil group of each land use category in the land use details window. To calculate the time of concentration, enter the data of the length, slope, surface type, Manning's roughness coefficient, flow area, and wetted perimeter via the time of concentration details window. For each reach must be determined data of receiving reach, length, Manning's roughness coefficient, slope, bottom width, average side slope, and structure name. The required data was gathered and calculated based on the aerial photos, 1:25000 topographic map, soil map, land use map, and field surveys of Gonabad city. Table 1 and 2 shows the data of sub-areas and reaches for the study area. Storm data in the TR-55 are 24-hour rainfall amounts in each return period and associated rainfall distributions. The amount of the 24-hour rainfall amounts in the return period and associated rainfall distributions were calculated based on the rainfall data of the Gonabad synoptic weather station. Table 3 shows the 24-hour rainfall amounts in the return period and rainfall distribution for the study area. After inputting the required data, the model was executed and the values of peak discharge, the total volume of surface runoff, and

Table 1: Land use of sub-areas for the study

Sub-basin	Total area (hr)	Residential (hr)	Rangeland (hr)	Agricultural (hr)	Abandoned fallow (hr)	Barren land (hr)	Garden (hr)
Sub-area 1	1138.9	549.4	300.7	15.9	75.1	149.8	48.0
Sub-area 2	490.8	127.2	22.5	23.6	216.4	65.5	35.6
Sub-area 3	799.9	182.2	155.5	50.8	301.6	60.9	48.9
Sub-area 4	601.6	127.8	22.5	53.5	252.8	91.9	53.1
Sub-area 5	587.9	163.8	79.9	23.4	273.7	15.9	31.2

Table 2: Data of sub-areas and reaches for the study area inputted into WinTR-55

Sub-basin	Length of the sheet flow (m)	The slope of the sheet flow (%)	Length of the shallow channel (m)	The slope of the shallow channel (%)	Reach	Length of main river (m)	Slope of main river (%)
Sub-area 1	705	1.8	3897	1.25	1	1275.9	0.8
Sub-area 2	309	1.9	2077	0.7	2	1177.1	0.7
Sub-area 3	878	1.5	1214	0.8	3	8674.2	0.83
Sub-area 4	652	1	1022	0.9	4	2975.7	0.64
Sub-area 5	250	0.8	2488	0.9	5	6150.2	0.84

Table 3: 24-hour rainfall amounts in return period and rainfall distribution

Return period (year)	24-hour rainfall amounts (mm)	Rainfall distribution (SCS)
2	19	II
5	27.4	II
10	33.1	II
25	40.5	II
50	46.1	II
100	51.8	II

output hydrograph were extracted in return periods of 2, 5, 10, 25, 50, and 100 years. The calibration and validation of the model were previously done by the SCS-CN in the Kakhk experimental watershed (Eshghizadeh *et al.,* 2018). Also, to evaluate the accuracy of the model, the obtained results were compared with the hydrograph of the extracted Geomorphological Instantaneous Unit Hydrograph (GIUH).

Urban Development Scenarios

The most important changes that may occur in the current land use in the study area were defined in the form of scenarios in Table 4. Each scenario was defined in the WinTR-55 according to the changes in the area of land use. Then, the model calculated the peak flow, total flow volume, and hydrographs based on these changes.

RESULTS AND DISCUSSION

The results showed the WinTR-55 model can be used to evaluate the effect of land use changes on runoff in the urban watershed. Based on the results, the maximum peak discharge and flow volume occurred in sub-area 1 (Fig. 2). Sub-area 1 in all studied return periods has the most peak flow discharge. This sub-area has the largest area, residential area, rangeland, and barren land compared to other sub-areas. This shows that the increase in the residential areas can increase the floods in urban areas.

The scenarios were defined for urban development in Gonabad city which were related to the reduction of water resources and population growth and the need to develop urban green spaces. Reduction of water resources and population growth causes agricultural and other natural lands to convert to residential lands. Based on the results, this conversion causes an increase in the peak discharge and runoff volume. Because surfaces with lower permeability increase. Developing urban green spaces can increase the infiltration areas. Fig. 3 shows the change of the peak flow discharge in the

Table 4: Urban development scenarios for the study area

Scenarios	Description
Scenario 1	Conversion of urban barren lands to residential lands
Scenario 2	Conversion of abandoned fallow and agricultural lands within the urban area to residential
Scenario 3	Conversion of irrigated agricultural land within the urban area to residential
Scenario 4	Conversion of garden lands within the urban area to residential
Scenario 5	Converting 10% of current rangeland in the urban area to residential
Scenario 6	Converting 25% of current rangeland in the urban area to residential
Scenario 7	Development of green spaces and urban gardens to the amount of 10% of the current situation
Scenario 8	Development of green spaces and urban gardens to the amount of 25% of the current situation
Scenario 9	Development of green spaces and urban gardens to the amount of 50% of the current situation

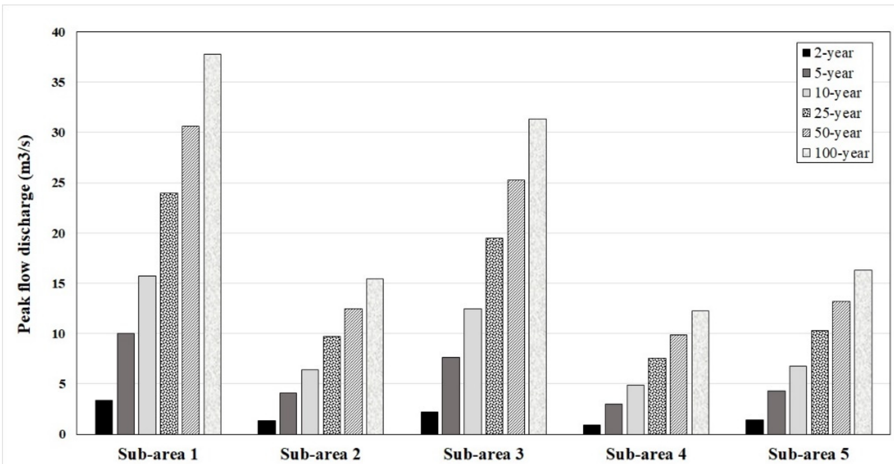

Fig. 2: Peak flow discharge in the studied return period and sub-areas

studied return period and sub-areas in response to land use changes in defined scenarios. Also, tables 5 and 6 show the changes in the peak flow discharge and total flow volume in the studied return period and sub-areas in defined scenarios. In sub-area 1, which has the most residential areas, only scenarios 1, 4, and 6 had an increase in flow characteristics for the studied return periods. Most of their increases were at the 2-year return period. The peak flow discharge was increased by 26.3% and the total flow volume by 17.7% compared to the current situation. Also, scenario 9 showed the most decrease at the 2-year return period to 22.4% in peak discharge and 15.6% in total flow volume. The other scenarios did not show any effect on the flow rates (Tables 5 and 6). In sub-area 2, the largest area of land use was abandoned fallow lands with 44.1 percent. In this sub-area, the highest increase in peak flow discharge and the total flow volume was in scenario 2 for the 2-year return period with 92 and 60.7%, respectively. Also, scenarios 1, 3, and 4 had an increase in peak flow discharge and the total flow volume to 25.5 and 17.6%, respectively. Also, scenario 9 showed the most decrease at the 2-year return period to 22.6% in peak discharge and 15.9% in total flow volume. The other scenarios did not show any effect on the flow rates (Tables 5 and 6). In sub-area 3, scenarios 1, 2, 3, 4, and 6 had an increase in peak discharge and total flow volume. Among these scenarios, scenario 2 showed the most change with an increase to 108% in peak discharge and 64.3% in total flow volume for the 2-year return period. Also, scenario 9 showed the most decrease at the 2-year return period to 25.3% in peak discharge and 16.5% in total flow volume. The other scenarios did not show any effect on the flow rates (Tables 5 and 6). In sub-area 4, scenarios 1, 2, 3, and 4 showed an increase in peak discharge and total flow volume. Among these scenarios, scenario 2 had the most change with an increase to 96.8% in peak discharge and 64.7% in total flow volume for

Table 5: Changes in the peak flow discharge in the studied return period and sub-areas compared to the current situation in percent

Sub-basin	Return period (year)	Scenarios								
		1	2	3	4	5	6	7	8	9
Sub-area 1	2	26.3	0	0	26.3	0	26.3	0	0	-22.4
	5	15.1	0	0	15.1	0	15.1	0	0	-14.2
	10	12.1	0	0	12.1	0	12.1	0	0	-11.1
	25	9.6	0	0	9.6	0	9.6	0	0	-8.6
	50	8.1	0	0	8.1	0	8.1	0	0	-7.5
	100	6.9	0	0	6.9	0	6.9	0	0	-6.9
Sub-area 2	2	25.5	92	25.5	25.4	0	0	0	0	-22.6
	5	15.4	49.2	15.4	15.4	0	0	0	0	-14.1
	10	12.4	39.1	12.4	12.4	0	0	0	0	-10.9
	25	9.6	29.8	9.6	9.6	0	0	0	0	-8.6
	50	8.1	24.8	8.1	8.1	0	0	0	0	-7.8
	100	6.9	21.5	6.9	6.9	0	0	0	0	-7
Sub-area 3	2	30.2	108	66.2	30.2	0	30.2	0	0	-25.3
	5	16.4	54	34.3	16.4	0	16.4	0	0	-14.7
	10	12.4	40.5	25.9	12.4	0	12.4	0	0	-11.8
	25	9.7	30.5	19.7	9.7	0	9.7	0	0	-9.2
	50	8.2	26	16.9	8.2	0	8.2	0	0	-8
	100	7.4	22.3	14.8	7.4	0	7.4	0	0	-6.9
Sub-area 4	2	27.6	96.8	59.6	59.6	0	0	0	0	-21.3
	5	15.9	53.6	34.1	34.1	0	0	0	0	-14.6
	10	12.7	41.3	26.3	26.3	0	0	0	0	-11.3
	25	9.9	31.6	20.8	20.8	0	0	0	0	-9.3
	50	8.4	26.9	17.6	17.6	0	0	0	0	-8.4
	100	7.4	22.8	14.7	14.7	0	0	0	0	-7.2
Sub-area 5	2	0	93	25.9	25.9	0	0	0	0	-21.7
	5	0	49.9	14.8	14.8	0	0	0	0	-14.4
	10	0	39	12	12	0	0	0	0	-11.4
	25	0	28.8	9	9	0	0	0	0	-9.6
	50	0	24.5	8.1	8.1	0	0	0	0	-7.4
	100	0	21.1	6.1	6.1	0	0	0	0	-7.3

the 2-year return period. Also, scenario 9 showed the most decrease at the 2-year return period to 21.3% in peak discharge and 16.9% in total flow volume (Tables 5 and 6). In sub-area 5, scenarios 2, 3, and 4 showed an increase in peak discharge and total flow volume. The most change was by scenario 2 with an increase to 99% in peak discharge and 62.2% in total flow volume for the 2-year return period. Also, only scenario 9 showed the most decrease at the 2-year return period to 21.7% in peak discharge and 15.8% in total flow volume (Tables 5 and 6).

The results showed that the TR-55 model is capable of comparing sub-areas for potential flooding by estimating flow rates in each sub-area in an urban watershed. Many studies have confirmed the ability of this model to estimate runoff in urban and agricultural watersheds (Blair *et al.,* 2014). Alkan (2022) and Corbin *et al.* (2021) confirmed that the WinTR-55 model is suitable and comfortable for predicate floods in watersheds. By combining the SCS-CN model and the physical characteristics of the land surface, the Tr-55 model has a good ability to estimate the peak discharge and flow volume, especially in urban watersheds. Its most important feature can be simple and accessible data. Alkan (2022), compared to other hydrologic models, the WinTR-55 model requires fewer input data to determine the surface flow changes in urban areas. Based on the results, the greatest increase in runoff production was related to the conversion of abandoned fallow and agricultural lands to residential. The sub-area 3 had the most increase in peak discharge and runoff due to the change of land uses to residential. The area of abandoned fallow lands in sub-area 3 was more than other sub-areas. the conversion of them to residential had the most increasing effect on peak discharge and runoff. Can be said, that conversions increase the area of impermeable surfaces. This effect was well

Table 6: Changes in the total flow volume in the studied return period and sub-areas compared to the current situation in percent

Sub-basin	Return period (year)	Scenarios								
		1	2	3	4	5	6	7	8	9
Sub-area 1	2	17.7	0	0	17.7	0	17.7	0	0	-15.6
	5	11.7	0	0	11.7	0	11.7	0	0	-10.7
	10	9.7	0	0	9.7	0	9.7	0	0	-8.7
	25	8	0	0	8	0	8	0	0	-7.5
	50	7.1	0	0	7.1	0	7.1	0	0	-6.7
	100	6.4	0	0	6.4	0	6.4	0	0	-6.1
Sub-area 2	2	17.6	60.7	17.6	17.6	0	0	0	0	-15.9
	5	11.6	38.6	11.6	11.6	0	0	0	0	-10.7
	10	9.7	31.6	9.7	9.7	0	0	0	0	-8.9
	25	8	25.7	8	8	0	0	0	0	-7.5
	50	7.2	22.6	7.2	7.2	0	0	0	0	-6.7
	100	6.4	20.2	6.4	6.4	0	0	0	0	-6
Sub-area 3	2	18.7	64.3	40.1	18.7	0	18.7	0	0	-16.5
	5	12	39.5	25.1	12	0	12	0	0	-11
	10	9.9	32.2	20.6	9.9	0	9.9	0	0	-9.2
	25	8.1	26.1	16.8	8.1	0	8.1	0	0	-7.7
	50	7.2	22.9	14.8	7.2	0	7.2	0	0	-6.8
	100	6.5	20.4	13.3	6.5	0	6.5	0	0	-6.2
Sub-area 4	2	18.8	64.7	40.2	40.2	0	0	0	0	-16.9
	5	12.1	53.3	25.4	25.4	0	0	0	0	-11.2
	10	9.9	32.2	20.6	20.6	0	0	0	0	-9.4
	25	8.1	26.1	16.9	16.9	0	0	0	0	-7.9
	50	7.2	23	14.9	14.9	0	0	0	0	-7.1
	100	6.5	20.5	13.3	13.3	0	0	0	0	-6.4
Sub-area 5	2	0	62.3	18.4	18.4	0	0	0	0	15.8
	5	0	38.8	11.8	11.8	0	0	0	0	10.6
	10	0	31.7	9.7	9.7	0	0	0	0	8.9
	25	0	25.7	8	8	0	0	0	0	7.5
	50	0	22.6	7.1	7.1	0	0	0	0	6.6
	100	0	20.1	6	6	0	0	0	0	6

seen in sub-area 1 due to the large area of residential. Urban development has created certain changes to the hydrology of the urban watershed due to large areas of impervious surface cover (Fang *et al.,* 2020). The change rate of imperious surfaces and vegetated land cover affected the peak discharge and runoff volume in an urban watershed (Elaji and Ji, 2020). The increase of residential areas in urban watersheds has reduced rainfall losses (soil infiltration, surface storage) that increase surface runoff. This process can lead to a higher peak flow discharge and higher flow volume in a shorter time base (O'Driscoll *et al.,* 2010). With the change in land use the soil moisture can be increased or decreased. Rogger *et al.* (2017) emphasized that the change in land use has a very strong effect on floods. Also, Umukiza *et al.* (2021) have confirmed that the peak discharge and flow volume are affected by the land use and land cover scenarios. These scenarios have a direct impact on the CN of sub-areas. The results of Apollonio *et al.* (2016) showed that a decrease in the area of the rangelands, forests, and bare lands can have a direct effect on the increase in floods. Also, Gholamian and Ildoromi (2020) showed that the conversion of agricultural lands to residential is the main reason for to increase in runoff in an urban watershed. Based on the results, the most effective increase or decrease of land cover change in peak flow discharge and total flow volume was at the 2-year return period. The results of Gholamian and Idoromi (2020) showed that the most change in runoff rate had been at the 2-year return period. This result showed that the reaction of nature to their manipulations by humans shows itself quickly. The results of Corbin *et al.* (2021) showed that predicted peak flow rates by WinTR-55 are accurate in lower return periods, it is a capable

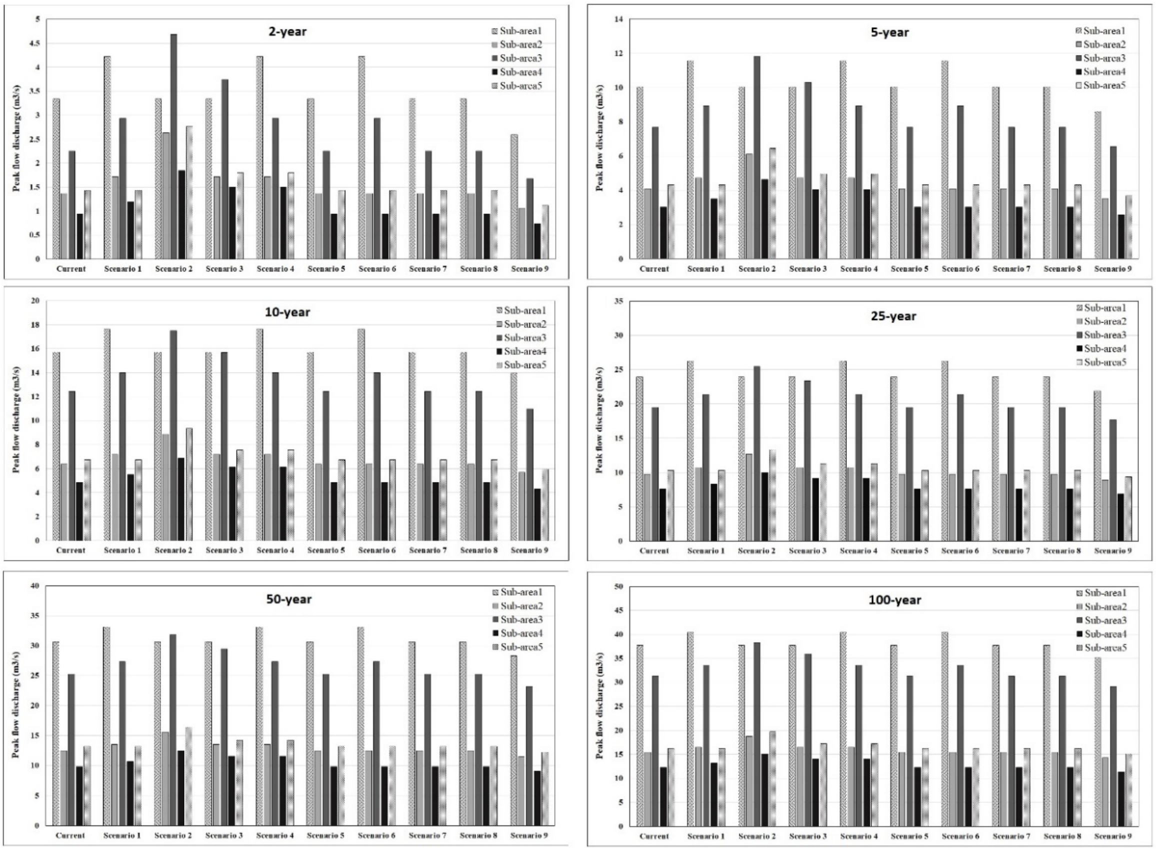

Fig. 3: Change of the peak flow discharge in the studied return period and sub-areas

model to assess the effect of land use change on floods in urban watersheds.

The results showed that the decreased effect of the development of green spaces and urban gardens on peak flow discharge and total flow volume was seen only if their development was more than 50%. Siriwardena *et al.* (2006) have confirmed that uniform changes in land use, especially vegetation, are closely related to the hydrological response of the watershed in floods. A decrease in surface storage areas of precipitation by urbanization can lead to an increase in floods (Berkessa *et al.*, 2023). Vegetation and natural ground cover by interception and increasing infiltration reduce the surface flow (Day and Bremer, 2013). The role of land vegetation cover in reducing peak discharge is more important than the type of vegetation (Henning, 2009). The results showed that the effect of increasing the peak discharge and the total flow volume due to the changes of land use to residential is more than the effect of a 50% increase in green spaces and urban gardens. The average maximum decrease in peak discharge and total flow volume was 22.7% and 16.1%, respectively. While the average maximum increase in peak discharge and total flow volume was 84.4% and 53.9%, respectively. Land management and preventing the conversion of permeable land uses such as agricultural, gardening, fallow lands, and rangeland will be much simpler and less costly. Because with the application of 50% development in green spaces and urban gardens, the effect of its reduction, despite the high costs of its construction, will be less than the ratio of the increase in peak discharge and the total volume of the surface runoff due to the development of residential areas. The results showed that in Gonabad city, converting barren and fallow lands to residential have the most effect on runoff generation. Also, to reduce runoff, the minimum increase of green spaces should be

50%. These are the important novelty of this research that can be beneficial for future urban developments of Gonabad city and its flood management activities.

CONCLUSION

The results showed that WinTr-55 is a capable model for estimating runoff in an arid urban watershed. Based on the results, converting barren and abandoned fallow lands to residential areas has the most effect on runoff generation and flood discharge in Gonabad city. Also, the minimum increase in green spaces should be 50% to reduce the peak discharge and volume of runoff. The TR-55 model showed that the urban development of Gonabad city increases surface runoff in all sub-areas. The greatest increase in discharge has occurred for urban development scenarios in sub-area 3. The conversion of abandoned fallow and agricultural lands to residential (scenario 2) had the greatest effect on increasing the peak discharge and volume of runoff. The effect of increasing green spaces and urban gardens on the reduction of peak discharge and volume of runoff was also evident in all sub-areas. The results showed the minimum amount of development should be more than 50% of the existing area of green spaces and urban gardens in each of the sub-areas. Also, the WinTR-55 model can be used to estimate the changes in land use on discharge in urban development. Based on the results, WinTR-55 is a simple and available model that can be used to examine various scenarios of urban development on the changes of surface runoff. The limitations or uncertainties of this study can be divided into two groups. The first group is related to the conditions of the study area which includes factors such as large area, low slope and not clear boundaries of sub-areas, low density of residential areas, and high interference of different land use within the urban area. The second group is related to the bases of the TR-55 model. The runoff calculation part of this model is based on the SCS-CN model. All the limitations and uncertainties of this model will also exist for the TR-55 model. These limitations include the tabulated curve numbers are questionable spatially in urban areas with low density of residential areas. Also, Bias from inconsistencies in the derivation and the inability to define the quality of the tabulated curve numbers. Cannot be used if weighted CN < 40. Not applicable for snow melt. Variation in rainfall duration and intensity during storms is not considered. Infiltration rate and capacity, and thus the explicit subsurface storage of moisture is not considered. Long-term evaporation and transpiration losses are not considered. It is suggested to use physically-based models instead of experimental models in arid urban watersheds. Also, user changes can be dynamically defined using remote sensing data for models. The results of this study contribute to the existing body of knowledge in the fields of hydrology, urban planning, and flood risk management. Because showed that in an arid urban watershed, the conversion of abandoned and fallow agricultural lands into residential areas has a great impact on the increase in flow rate. Urban land use management to prevent urban floods requires the expansion of permeable surfaces, especially green spaces, and urban gardens.

AUTHOR CONTRIBUTIONS

M. Eshghizadeh performed the literature review, compiled the data, and experimental design, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. compiled the data and manuscript preparation.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. The ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

CN	Curve number
GIUH	Geomorphological Instantaneous Unit Hydrograph
hr	hour
SCS	Soil Conservation Service
TR-55	Technical Release 55

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