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Research Article

Storm Water Management within the Scope of Green Infrastructure Systems: Malatya City Case[&]

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Abstract

Excessive urbanization and the infrastructure problems it brings with it can lead to a number of environmental problems caused by rainwater.

lead to problems. In our growing and developing cities, dense construction over time leads to an increase in the amount of impermeable surfaces such as concrete, asphalt, etc. and a decrease in permeable surfaces such as green areas. As a result, rainwater falling on the earth's surface cannot be absorbed by impervious surfaces and causes surface runoff, resulting in environmental problems such as floods, floods, etc. As a solution to these problems, there is a worldwide trend towards alternative approaches. One of these approaches is green infrastructure/low impact development components. In this study, alternative approaches such as green infrastructure/low-impact development components were tried to produce solutions to the problems caused by stormwater. In this context, various simulation studies were carried out by applying a process-based storm water management model SWMM (Storm Water Management Model) in order to determine the surface runoff caused by storm water and to evaluate the effectiveness of low impact development components in the city center of Malatya, where construction is taking place. Four different low impact development components; green roofs $_{(1)}$, rain barrels $_{(2)}$, permeable pavements $_{(3)}$, and rain gardens $_{(4)}$, were integrated into the appropriate parts of the planned area in certain proportions, resulting in a 2.15% reduction in total runoff with the use of green roof systems, 8.10% with the use of rain barrels, and 6.60% for both components with equal proportions of permeable pavements and rain gardens. When all components are used in integration with each other, it was determined that these systems can be used as an alternative to traditional infrastructure systems in urban areas with a 22.20% reduction in stormwater runoff.

Keywords: Low Impact Development, Stormwater Management, Green Infrastructure, Runoff

Stormwater Management Within the Scope of Green Infrastructure Systems Malatya City Example

Abstract

This research was carried out to determine the stability of vegetable type cluster bean (Cyamopsis tetrag Excessive urbanization and the accompanying infrastructure problems cause a number of environmental problems caused by rain water. In our growing and developing cities, as a result of the intense construction that takes place over time, it causes the amount of impermeable surfaces such as concrete and asphalt to increase and the permeable surfaces such as green areas to decrease. As a result, the rain water descending to the earth cannot be absorbed by the impermeable surfaces and causes surface flow, and as a result, floods and so on. Cause environmental problems such as. There is a trend towards alternative approaches around the 1088orld, as it provides solutions to these problems. One of these approaches is green infrastructure/low- impact development components. In this study, it has been tried to produce solutions to the problems caused by rain water with alternative approaches such as green infrastructure / low-impact development components. In this context, various simulation studies were carried out by applying a process-based storm water management model (SWMM) in order to determine the surface runoff caused by rain water and to evaluate the effectiveness of low-impact development components in the city center of Malatya, where intensive construction is experienced. In the simulation studies carried out by integrating four different low-impact development components green roof(1), rain barrels(2), permeable pavements(3), and rain gardens(4), into the appropriate parts of the planned area, in total runoff; There was a decrease of 2.15% with the use of green roof systems, 8.10% with the use of rain barrels, and 6.60% with the use of equally permeable coating systems and rain gardens for both components. It has been determined that these systems can be used as an alternative to traditional infrastructure systems in urban areas and the surface flow is reduced by 22.20% when all components are used in integration with each other.

Key words: Green Infrastructure, Low Impact Dewolopment, Stormwater Management, Surface Runoff

Introduction

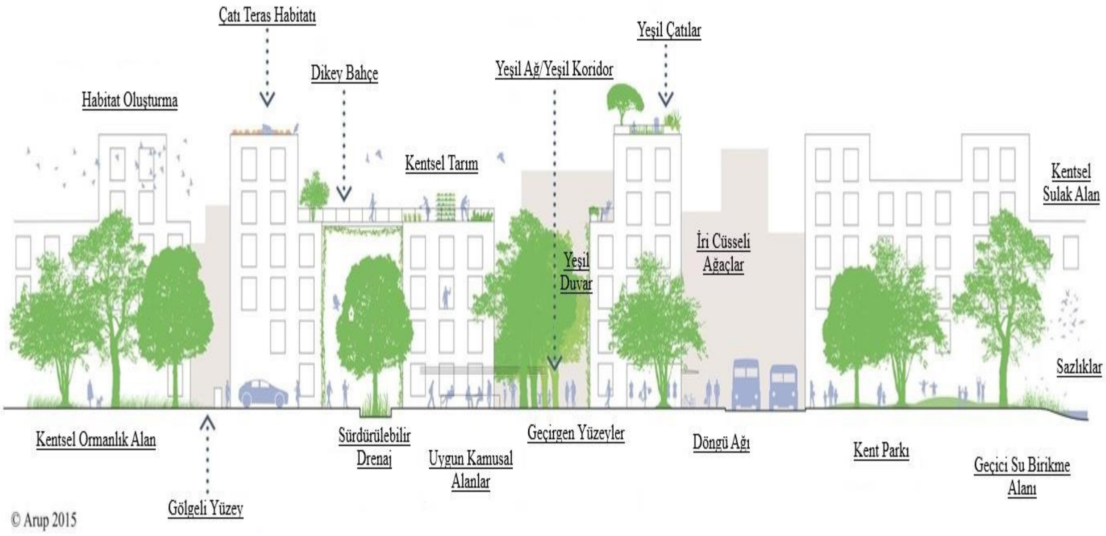
According to data from the United Nations, the global urban population rate has increased since the 1950s.
While it was 30%, it has increased day by day in the intervening period and reached 55% today. Considering long-term expectations, this rate is estimated to reach 68% by 2050 (UN, 2018). When urban population rates in Turkey are taken into account, urbanization rates have already exceeded global long-term expectations, reaching 76% (The World Bank, 2021).

This urbanization due to population growth leads to an increase in impervious surfaces such as concrete, asphalt, etc. in urban areas and a corresponding decrease in permeable surfaces such as green areas. Rainwater falling on the ground cannot be absorbed by impermeable surfaces and causes surface runoff, resulting in environmental problems such as floods and water overflows. These environmental problems caused by global urbanization lead to the deterioration of the natural balance in urban and rural areas and damage to biodiversity. It also leads to irreversible changes in land use changes associated with urbanization as a result of reduced vegetation cover, the characteristics of the runoff hydrograph of cities, and the natural water and evapotranspiration cycle (Goonetilleke et al., 2005; Raei et al., 2019; Abi Aad et al., 2010).

Increasing urbanization rates and the inadequacy of traditional infrastructure systems necessitate the development of alternative and sustainable approaches to stormwater management. Sustainable practices such as green infrastructure are now being planned in many countries for urban runoff management, both to reduce rainfall volumes and to improve water quality. Green infrastructures (RW) is divided into two categories: structural and non-structural practices. Structural BMPs include green roofs, rain gardens, permeable pavements, rainwater retention systems, rainwater storage tanks (rain barrels and cisterns) and wetlands. Non-structural LID aims to increase permeable soils and vegetation to increase infiltration capacity in urban areas, providing alternative solutions for structures such as roads and buildings where impervious areas are higher (Elliott and Trowsdale, 2007; Jayasooriya and Ng, 2014). Figure 1 shows the components of Low Impact Development (LID) in urban areas.

Studies in this field show that DEG components can be an alternative to traditional infrastructure systems in stormwater management. Studies in this field are summarized in Table 1.

The aim of this study is to find solutions to the stormwater runoff caused by impervious areas, which are increasing day by day due to excessive urbanization and dense construction in cities, and the environmental problems it brings with it, with sustainable innovative approaches such as Green Infrastructure (GI) / DEG components, and to produce alternative solutions by reducing the pressure on the traditional sewer network or gray infrastructure systems that are inadequate. The extent to which surface runoff is reduced as a result of the application of impervious areas to a certain part of four different DEGs has been determined by simulation studies. It is aimed to transfer the obtained data to the physical plan decisions prepared by the local administration and to use them as a basis in urban planning. This research aims to create awareness for sustainable urban design.



Material and Method

Material

The main material of the study consists of an urban basin within the borders of Malatya city center where there is dense construction. Location; 38^o 20' 27.31''' N latitude and 38^o 17' 57.78''' The area between longitude D covers a total area of 225.20 hectares (Figure 2). The area includes private residential areas, government offices and institutions, urban and neighborhood parks, highways and parking lots that form the traffic axis, and sidewalk areas that form the pedestrian traffic. The residences in the area generally consist of 4 to 6 storeys. It is an example of traditional roof structures, mostly made of tiles. The area is located within the borders of two central districts of Malatya (Yeşilyurt-Battalgazi), which have the most populous population, and covers a certain area with dense construction and intensive commercial activities. As a result of the measurements, the study area consists of 84.61% impervious areas (asphalt, concrete and roof surfaces) and 15.39% pervious surfaces (green areas and soil areas).

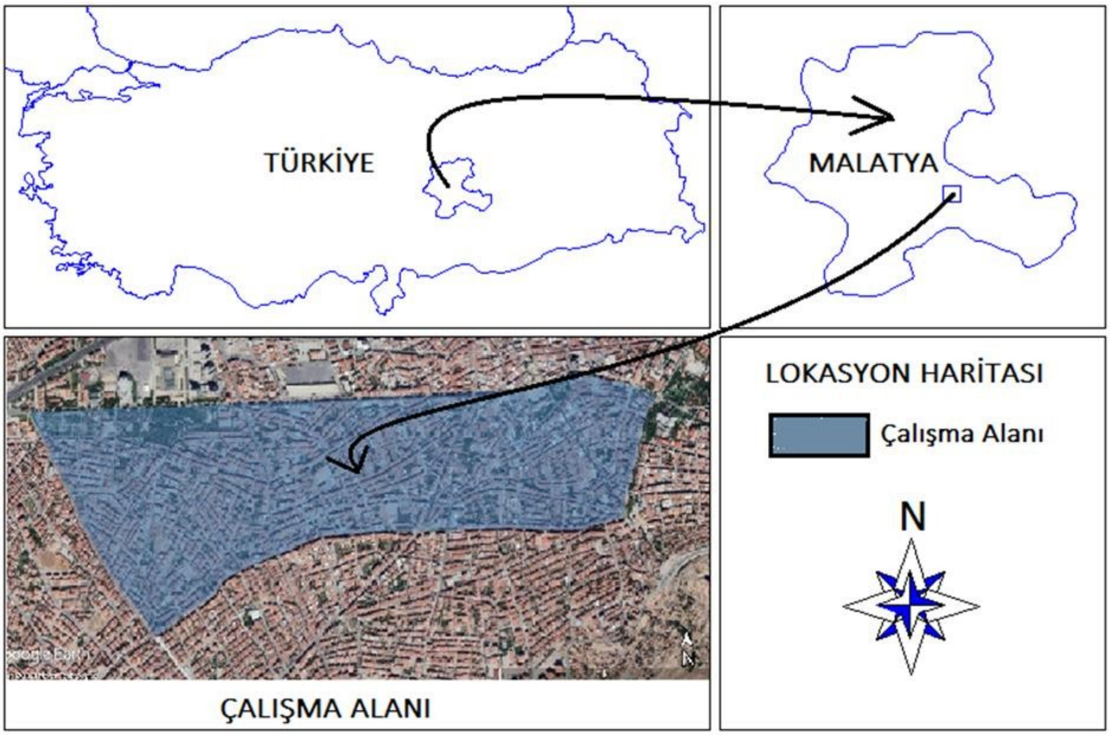


Figure 2. Study area

Table 1. Previous studies

WORK SUBJECT	CITY	METHOD	RESEARCH FINDINGS	REFERENCE
Alternative in storm water management approaches cost	USA general	Analysis	Green infrastructure practices reduce gray infrastructure costs by $120 million per year and waste water and pumping costs by $661 million per year has been identified.	(Mittman and Kloss, 2015)
Managing rain water alternative approach	Michigan	Analysis	Green infrastructure components other than green roofs are less expensive than gray infrastructure costly.	(Nordman et al, 2018)
Impacts of DEG components on urban flooding	Shenzhen	Simulation (SWMM)	DEG techniques have been found to be a more sustainable solution than conventional systems and reduce urban flooding events.	(Qin et al., 2013)
Green Infrastructure systems hydrological potential	Beijing	Simulation (SWMM)	100% the surface runoff of storage ponds from YA components, The combination of permeable pavements and green areas was found to prevent 95% of surface runoff.	(Liu et al., 2015)
The hydrological performance	Connecticut	Analysis	Low Impact Development practices reduce stormwater runoff by 42 has been found to decrease.	(Bedan and Clausen, 2019)
Life cycle evaluation of	Odense	Simulation	Green infrastructure systems can reduce damage to ecosystems has been identified.	(Brudler et al, 2019)
Hydrological management of rain gardens performance	Virginia	Analysis	A rain garden installed in a parking lot area reduced peak runoff rates by 99 by a percentage of total number of patients.	(DeBusk and Wynn, 2011)
Hydrological management of rain gardens performance	Melbourne	Analysis	Rain gardens have been found to reduce runoff volumes by 33 has been established.	(Hatt et al., 2009)
Rain gardens sewer capacity	Quebec	Simulation (SWMM)	12.7% when 21% of impervious areas are designed as rain gardens 19.4% reduction in surface runoff.	(Autixier et al, 2014)
Rain water volumes effectiveness in reducing	Cincinnati	Simulation (SWMM)	38% volume when 3.9% of an area is designed as a rain garden reduction in number of patients.	(Abi Aad et al, 2010)
Hydrological management of rain gardens performances	Ohio	Analysis	Rain gardens can be used to collect rainwater surface runoff on soils with low permeability. decreased flows by 42%, 56%, 59%.	(Winston et al, 2016)
Rain from their garden water harvest	Edirne	Literature	Rain gardens planted in a housing estate are 400 times more likely to be planted in a year than in a normal housing estate. tons of water savings.	(Ertin et al., 2012)
Green roofs hydrological performance	Sheffield	Analysis	The annual water retention capacity of a comprehensive green roof is 50.20%. has been established.	(Stovin et al, 2012)
Green roofs hydrological performance	Maharashtra	(SWMM)	Green roofs were found to reduce peak flows by 10.80%.	(Paithankar and Taji, 2020)
Rainwater harvesting	Istanbul	Research	water collected from 40% of the factory roof in rain barrels It was determined that daily toilet cleaning needs were met by storing them.	(Kantaroğlu, 2009)
Green roof systems are water and Energy balance evaluation in terms of	Sarıyer	Analysis	During a heavy rainfall, runoff from green roofs can be reduced by 25 decreased.	(Ekşi and Uzun, 2016)
Rainwater harvesting	Sakarya	Research	Water collected from the roofs of buildings on campus is used for irrigation on a daily basis. It was stated that 10.90% water savings were achieved.	(Eren et al., 2016)
Low Effective Urbanization practices superficial impact on flow	Hunters	Simulation (SWMM)	When all roadways on a campus are paved with permeable pavement It was found to reduce runoff by 100%.	(Gülbaz et al., 2018)
Hydrological performance of porous asphalt pavements	New Hampshire	Analysis	Permeable asphalts were found to reduce peak flows by 90% over an 18-month period.	(Roseen et al, 2012)
Rainwater harvesting	Florianopolis	Experiment	A porous asphalt pavement installed in a parking lot area is 53-54 by reducing the need for non-potable water.	(Hammes et al, 2018)
Rain ditches hydrological performance	Gardabaer	Experiment	Rain in cold water areas as the water level in the soil rises infiltration capacity of the ditches was to be reduced.	(Zaqout and Andradottir, 2021)
Biological Filtering the potential of canals to prevent surface runoff	Xianyang	Experiment	Biological filtration channels installed on two sides of a highway, respectively 98.25% and 77.65% of the flow volume was reduced.	(Jiang et al., 2017)
Biological Filtering channels impact of trees used on water budget	Chicago	Experiment	Used in biological filtration channels installed in a parking lot It has been determined that 46%-72% of the trees send water back to the atmosphere through transpiration and thus provide volume reduction.	(Scharenbroch et al., 2016)
Low effective development effectiveness of its components	Indianapolis	Simulation	25% of the roofs of high-density building areas are of appropriate dimensions When systems such as rain barrels and cisterns were integrated, a 6% reduction in total runoff was found.	(Ahiablame et al, 2013)

Rainwater harvesting	Bursa	Research	The water that will be collected from a residential area will be used daily by green areas. irrigation, it was determined that 14% water saving was achieved.	(Kılıç and Abuş, 2018)
Rain barrel and flooding and flooding of cistern systems prevention capacity	San Luis	(SWMM)	In urban areas, rain barrels increase stormwater volumes by an average of 3% - 14.3% less than cisterns, but 9 times lower than cisterns. has been established.	(ReyValencia and ZambranoNájera, 2019)

Method

In the study with each other integrated A progressive method that can work has been determined. Firstly, ArcGIS model was preferred and statistical data and land use characteristics of the area were determined by this model. Then, the stormwater management model called SWMM, a dynamic rainfall-runoff simulation developed by the United States Environmental Protection Agency (USEPA), was chosen as the method. This model was developed by the United States Environmental Protection Agency (USEPA) as publicly available software in 1971 to meet the need for managing rainfall quantity and quality in urban areas (Huber et al., 1988). The model simulates the runoff of the area using real short- and long-term precipitation data entered into the system. The model is also one of the most useful models for measuring the effectiveness of the DEG components included in the system. Currently rain gardens, green roofs, biological filtration (bioretention) cells, permeable pavements, rain barrels, vegetated ditches,

It can model 8 different DEG components such as infiltration trenches and roof disconnection to green space (Rossman, 2010). Figure 3 shows the method flow chart of the study.

Data pertaining to the area (high resolution orthophoto image of the area, existing stormwater drainage infrastructure project of the area and hourly precipitation amount falling on the area during the study period) were obtained from various institutions and processed in ArcGIS software. In the next stage, the obtained and processed data were manually entered into the Stormwater Management Model (SWMM) and the area was planned. Simulations were run with data analysis and surface flows were determined. The potential of DEG components to reduce stormwater runoff was evaluated by integrating 4 different DEG components at certain ratios in appropriate parts of the study area and performing various simulations.

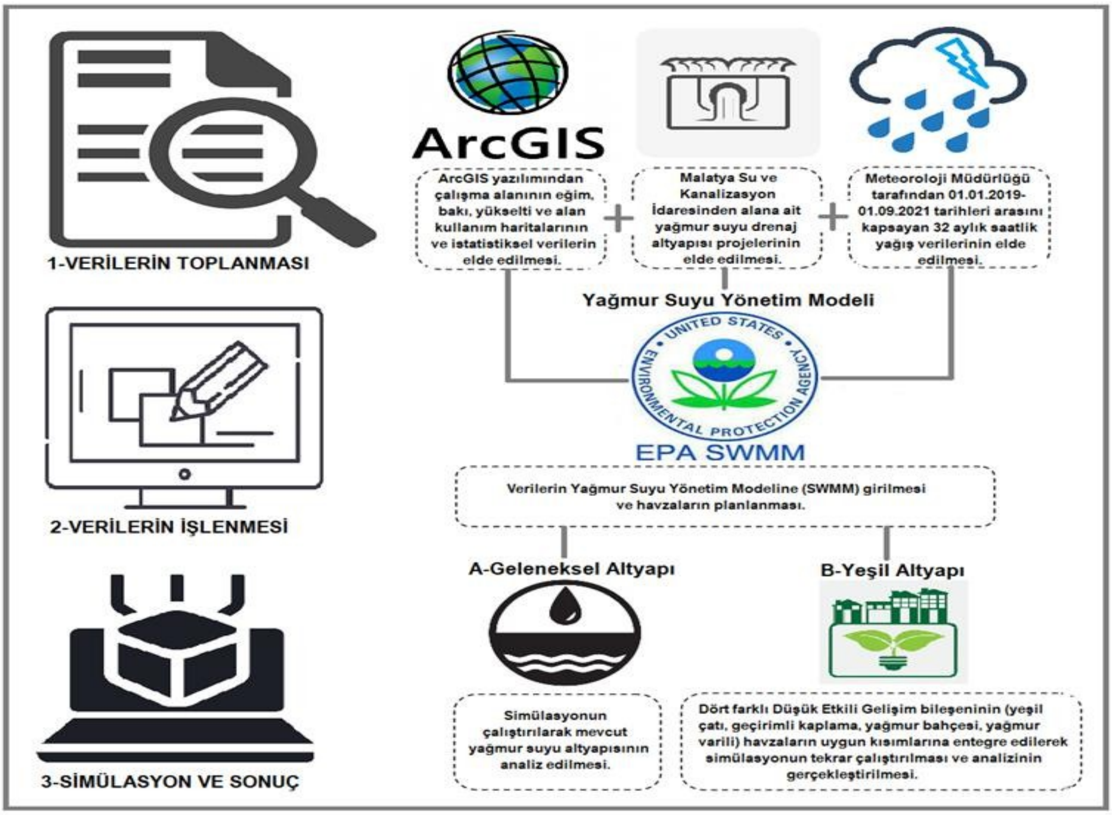


Figure 3. Method flowchart

Results and Discussion

Space Planning in SWMM Model

Model on Planning First of all, when making work area of high resolution orthophoto image and existing stormwater drainage infrastructure data were uploaded to the system and the area

Subcatchments were divided into 197 subcatchments according to the location of storm water drainage channels and building islands. Then, the land use characteristics (amounts, widths, slopes, percentages of permeable and impermeable areas) of all areas divided into 197 subcatchments were determined using ArcGIS program and the obtained data were manually entered into the system. Systematic values were used for Manning's n values of permeable and impermeable areas of all basins. Then, the existing stormwater infrastructure data obtained by Malatya Water and Sewerage Administration (locations, elevations (invertelevetion) and depths of junction nodes; lengths and maximum depths of pipe connections (conduit); elevations of outfall nodes) were placed in their current locations on the program and the relevant values were manually entered into the system. Finally, the data obtained from Malatya Meteorology Regional Directorate

The 32 months of hourly precipitation data covering the period between 01.01.2019 and 01.09.2021 were converted into a file and uploaded to the program and the study plan was completed by assigning the data to the rain gauge (raingage) in the program. After the study plan was completed, the simulation was run without using any DEG component and the surface runoff of the existing infrastructure was determined according to the relevant rainfall data. Then, various scenarios were developed by integrating DEG components into each sub-basin at certain ratios and simulations were repeated to determine the rates at which DEG components reduce surface runoff. Figure 4 shows the plan of the area created in the Stormwater Management Model (SWMM). Blue lines indicate stormwater infrastructure, divided areas indicate watersheds, black dots on the blue line indicate intersection nodes (manholes) and dots at the end of the blue line indicate outlet nodes.

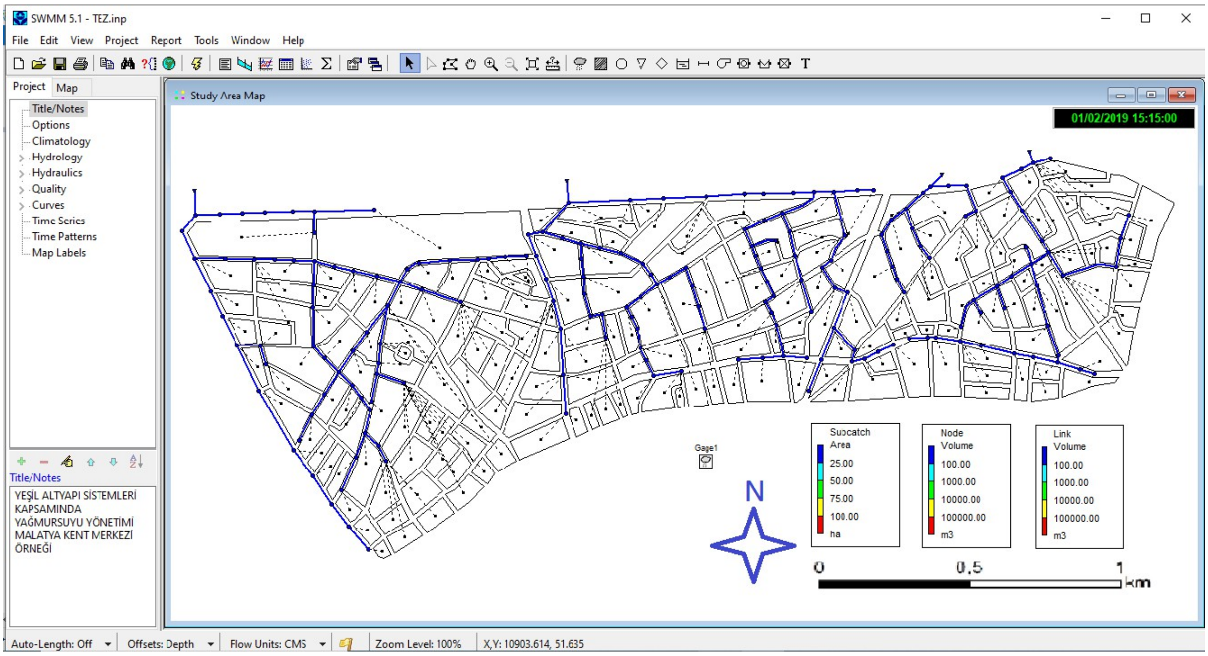


Figure 4. Plan of the area created in the Stormwater Management Model (SWMM)

Scenarios Developed for the Workspace

The study area was first simulated without using any DEG component and necessary measurements were made in order to understand the potential of the existing stormwater infrastructure and to determine the amount of runoff generated by the existing infrastructure in the light of available data. Then, 6 different scenarios were developed and the effectiveness of 4 different DEG components (green roof, rain garden, permeable pavement and rain barrels) were determined separately and in combination. The developed scenarios are as follows.

- Scenario 1: Analysis of existing infrastructure without any Low Impact Development component,
- Scenario 2: 20% of the total roof area in all basins is planned as green roofs,
- Scenario 3: Integrate rain barrels to collect rainfall from 20% of the total roof area in all catchments,
- Scenario 4: outside impermeable roof areas in all basins

Designing 20% with permeable pavement,

- ❖ Scenario 5: Designing 20% of the total impervious areas in all basins as rain gardens,
- ❖ Scenario 6: All systems are designed together in the specified proportions.

Scenario 1: Analysis of Existing Infrastructure without any Low Impact Development Component: The planning area was simulated using existing infrastructure data and the simulation results were 0.062 It has shown that there is a very negligible mass balance with a continuity error. According to the measurement results; it was determined that 804.689 mm of the total 907.20 mm of precipitation falling in the study area in a period of 32 months was transferred to surface runoff. The maximum total value of the surface runoff occurring in the basins at the outlet points was measured as 8,378 m^3/s. The total runoff value occurring in the basins was 88.70%. Figure 5 shows the rainfall/surface runoff graph as a result of existing infrastructure data.

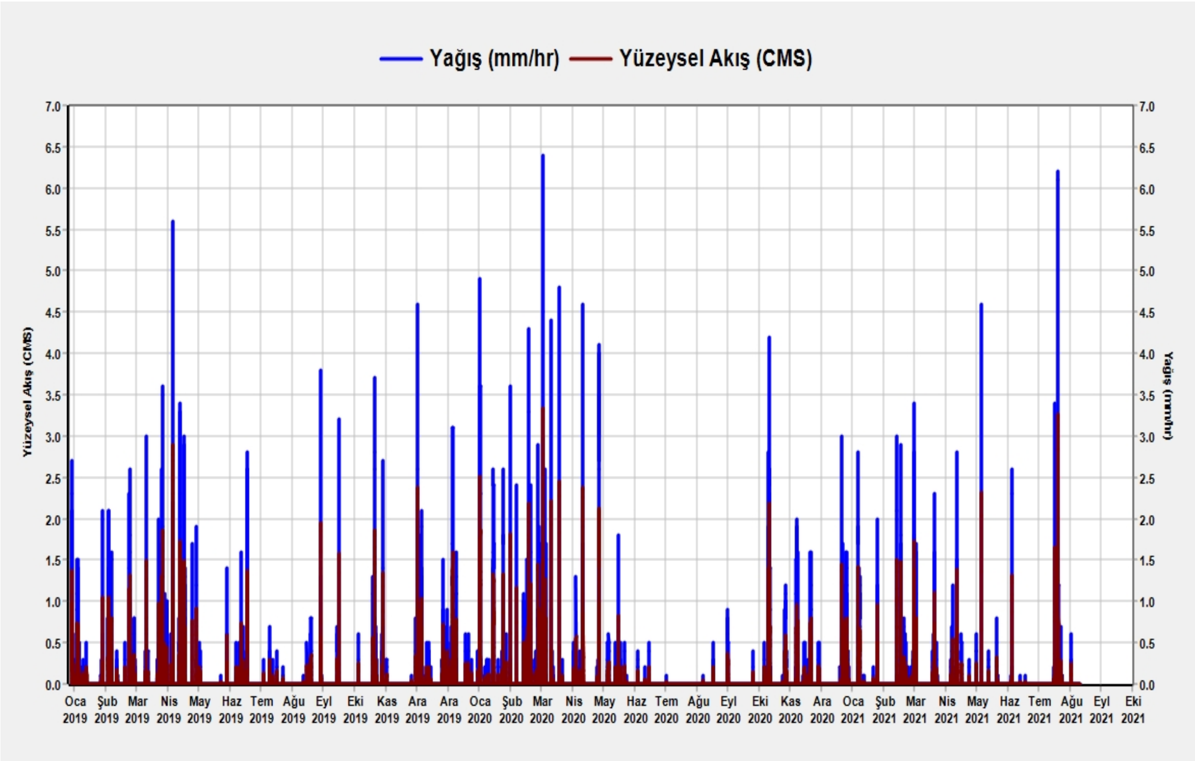


Figure 5. Rainfall/surface runoff graph as a result of existing infrastructure data

The maximum amount of surface runoff occurring in the basins was measured as 3.34 m^3/s on 31.03.2020 when the rainfall intensity was 6.40 mm.

Scenario 2: Integrating a Green Roof Component in the Basins: In addition to the existing infrastructure, a green roof component was integrated in the planning area to cover 20% of the total roof area of each catchment (189,658 m^2, corresponding to 9.72% of the total area) and the simulation results were repeated. The green roof components were installed in 50 m$^{(2)}$) units in each basin and the total basin proportionate to their area. Rainwater discharged by the drainage layer of the units was directed to the permeable areas. The simulation results revealed a very negligible mass balance with a continuity error of 0.064%. According to the measurement results; the total amount of runoff occurring in the basins 787,786mm and the percentage of runoff was 86.80%. Figure 6 shows the rainfall/surface runoff graph as a result of integrating the green roof component into the basins.

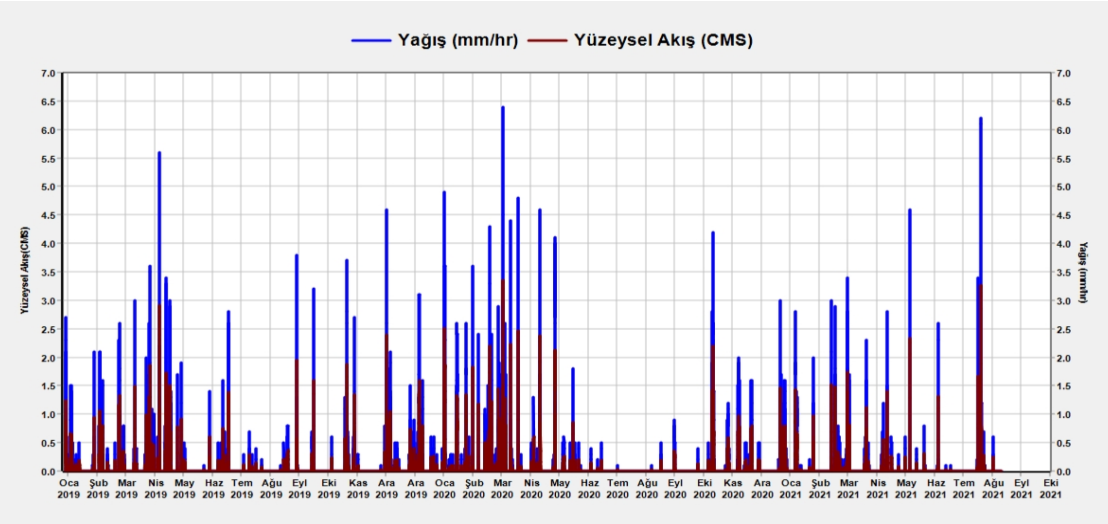


Figure 6. Rainfall/runoff graph with the integration of green roof components

When green roof systems are planned in an integrated manner with existing infrastructure systems, there is a 2.15% decrease in total runoff. According to the time-dependent rainfall-runoff graph, the maximum runoff amount occurring in the basins was realized as 3.35 m^3/s.

Scenario 3: Integration of Rain Barrel Component in Basins: Rain barrels with a storage volume of 4m³ (Height: 2000 mm, Diameter: 1600 mm) (Height: 2000 mm, Diameter: 1600 mm) have been integrated into each basin, 1 unit per 500m² of roof area, in order to store rainwater flowing from 20% of the total roof area in each basin in the planning area and to be used for subsequent non-potable water needs. These storage units A total of 1872 units were placed in each basin in proportion to their area. The total storage volume of these units is 7.488m³ and can be filled to full capacity 23 times during the operating period, provided that each unit is used when full. In this case, a water saving of 172,057 m³ will be achieved. Considering the data of Tema; it is stated that 26% of the water used in residences is used in toilets and 217 liters of water is used from the municipal network per person per day. In this case, the amount of water used in toilets per person per day is 56.50 liters. Figure 7 shows the rainfall/runoff graph resulting from the integration of the rain barrel component into the basins.

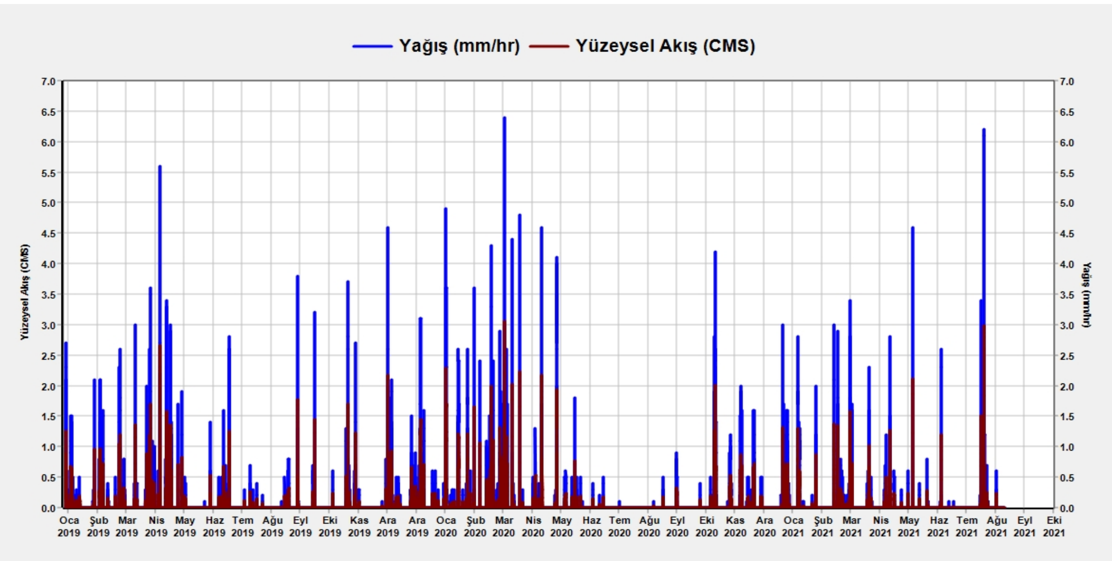


Figure 7. Rainfall/runoff graph with integrated rain barrel components

Simulation results revealed that systems such as rain barrels/cisterns used in long-term rainfall events reduce total runoff. Simulation results show that 731.079mm of the total 907.20mm of rainfall that fell during the study period caused runoff and the runoff rate was 80.60%. Considering the findings of the existing infrastructure, the total amount of runoff decreased from 88.70% to 80.60%, resulting in decrease of 8.10%.

Scenario 4: Integration of Permeable Pavement Component in Basins: The use of impervious surfaces (concrete and asphalt surfaces) except for the roof areas of the divided basins in the planning area.

The simulation results were repeated by integrating permeable pavement in 20% of the area. The areas where the permeable pavement is integrated correspond to approximately 6.73% of the entire area. According to the simulation results; 751.60 mm of the total 907.20 mm of precipitation that fell during the study period passed into surface runoff and 155.11 mm of the remaining precipitation was infiltrated by permeable surfaces. The percentage value of the surface runoff occurring in the basins is,
was determined as 82.85%. Figure 8 shows the rainfall/runoff graph resulting from the integration of the permeable pavement component in the basins.

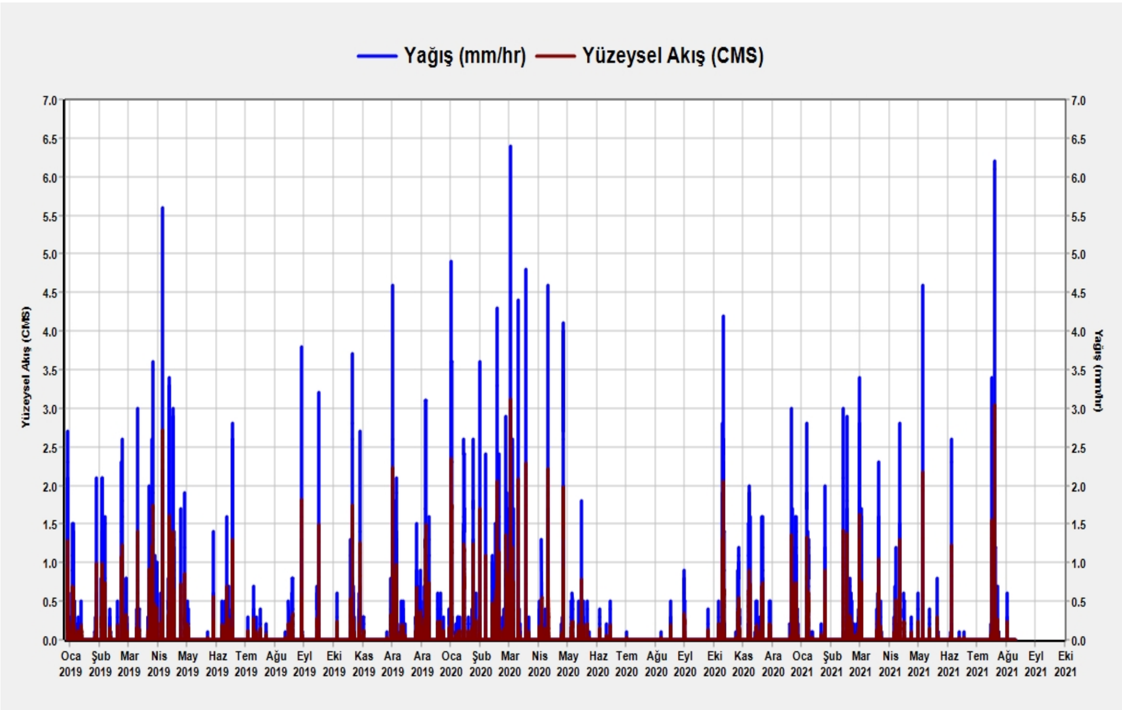


Figure 8. Rainfall/runoff resulting from the integration of permeable pavement components
graph

The maximum amount of runoff occurring in the basins was determined as 3.12m(3) in the time period when the rainfall intensity was 6.40mm. According to the time-dependent runoff-precipitation graph, the total runoff rate decreased from 88.70% to 82.85% with the installation of permeable pavement components in the basins, resulting in a 6.60% decrease.

Scenario 5: Integration of Rain Garden Component in the Basins: In the study area, rain garden units were placed in proportion to the areas of the basins, and the simulation results were repeated, with each basin retaining 20% of the runoff from the other impervious areas except the roof areas. Simulation results
A negligible mass with a continuity error of 0.060

equilibrium. According to the simulation results, 152,763 mm of the total 907.20 mm of precipitation that fell within a 32-month study period was absorbed and infiltrated by permeable surfaces and DEG units, while 751.60 mm, 82.85%, caused surface runoff (Figure 9). The initial storage of the DEG units placed in the area was 3.35mm and the final storage was 6.74mm. The maximum runoff during the study period was 3.12 m^3/s. The maximum runoff volume at the outlet points of the basins was measured as 8.16 m^3/s. The daily maximum peak flow was 3.12 m^3/s on 01.04.2020.

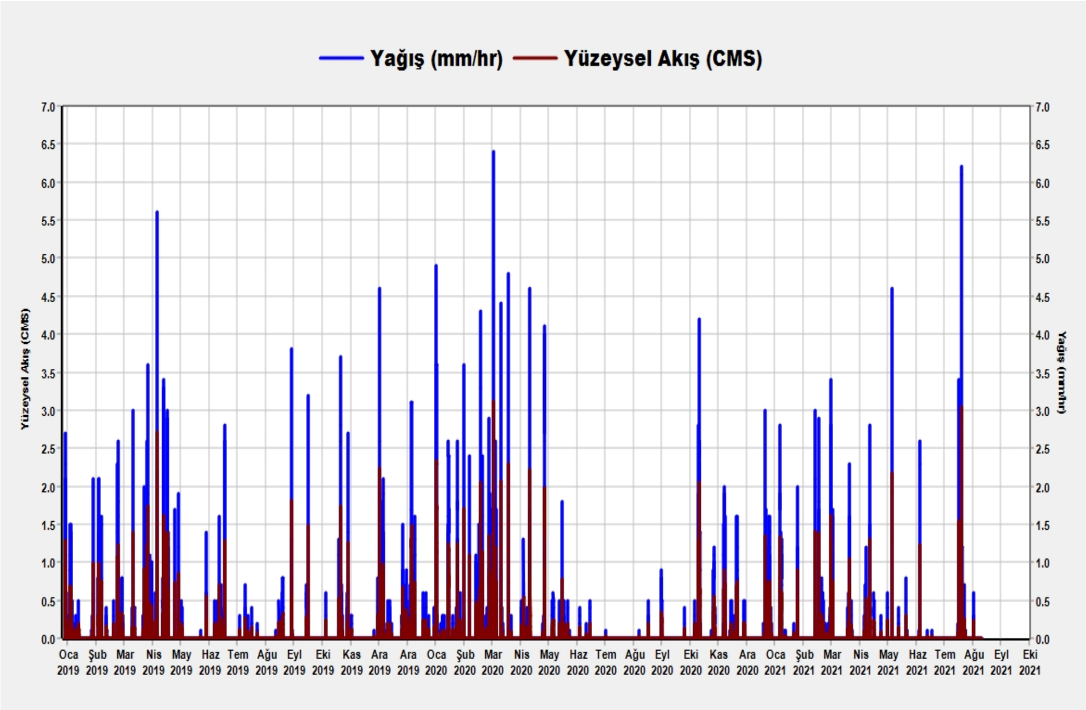


Figure 9. Rainfall/runoff resulting from the integration of rain garden components graph

Scenario 6: Integration of All Components into Basins: A 6th scenario was developed as a combination of the first 5 previously simulated scenarios and all systems were evaluated together. The ratios of the DEG components placed in the basins according to the total area are as follows.

- Green Roof: It corresponds to 20% of the total roof area and covers 9.70% of the entire area.
- Rain Barrels Total roof area
  Rainwater harvesting is planned for 20% of the area, which corresponds to 9.70% of the entire area.
- Permeable Pavements: It covers 20% of the other impervious areas excluding roof areas and corresponds to 6.70% of the total area.
- Rain Gardens: 20% of the impervious areas excluding roof areas and corresponds to 6.70% of the total area.

After all systems were placed in the basins, DEG components indirectly accounted for 32.8% of the total area. After the DEG components were added, the simulation results were repeated to cover the study period and

It has shown that there is a very negligible mass balance with a continuity error of 0.061%. According to the simulation results; 626 mm of the total 907.20 mm of rainfall per square meter during the study period caused surface runoff. The runoff rate was realized as 69% (Figure 10).

Considering the total runoff generated by the existing infrastructure (88.70%), the addition of DEG components resulted in a total reduction of 22.20%. According to the graph, the maximum amount of runoff occurring in the basins was determined as 2.69 m^3/s in the time period when the rainfall intensity was 6.40 mm.

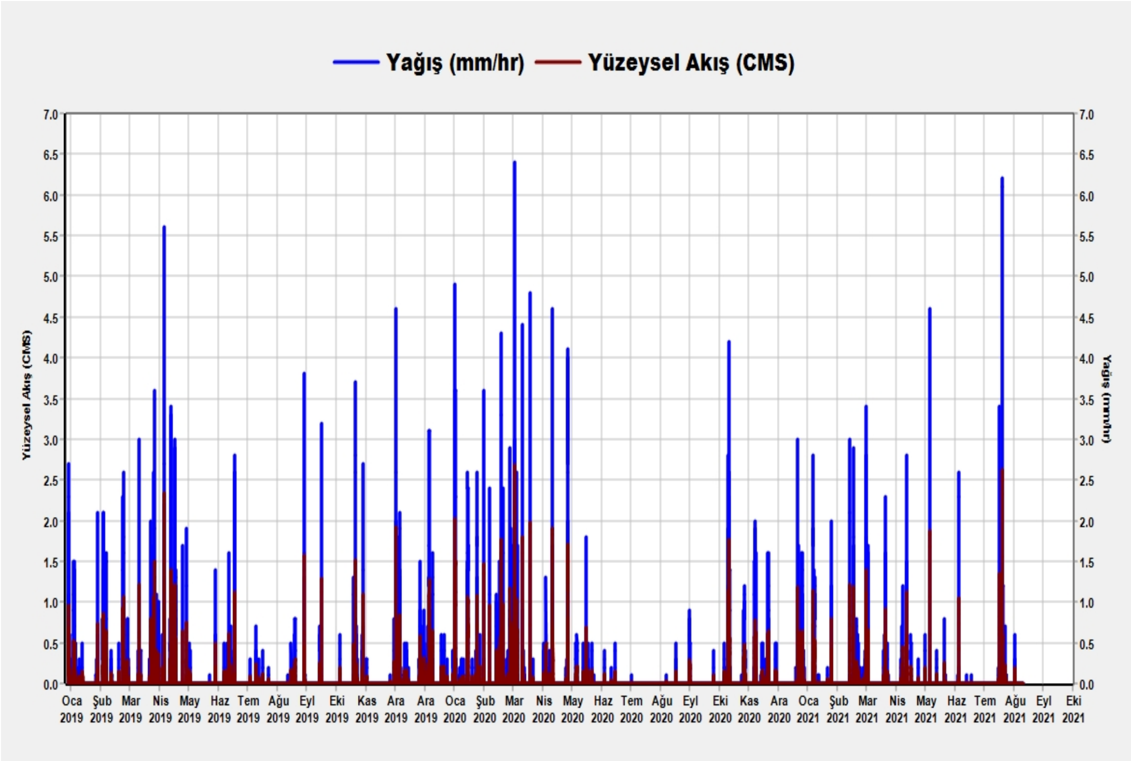


Figure 10. Rainfall/runoff graph with integration of all components

According to daily peak flow statistics; 269 events during the total study period.

Conclusion and Recommendations

The study found that YA / DEG components can be used as an alternative to traditional gray infrastructure in cities and reduce the surface runoff caused by stormwater to a certain extent. Using 32 months of rainfall data, it was determined that the existing stormwater infrastructure causes 88.70% of surface runoff with the existing area data. On the other hand, the total roof area

When 20% (about 9.72% of the total area) is covered with green roof components, total runoff is reduced by 2.15%, and when water collected from 20% of the total roof area is directed to rain barrels , runoff is reduced by 2.15%.

8.10%, when 20% of the other impervious areas other than roof areas (approximately 6.73% of the entire area) are planned with permeable pavement, surface runoff decreases by 6.60%, and when 20% of the impervious areas other than roof areas are planned as rain gardens, surface runoff decreases by the same rate.

It was determined that it decreased by 6.60%. Table 2 summarizes the addition rates and flow percentages of the components. In the studies, these systems volumetric traditional infrastructure by reducing significant amounts of stormwater volume and thus helped to prevent problems such as possible flooding and flooding. In similar studies, Bedan and Clausen, (2019) found that DEG components reduce the pressure on conventional sewerage systems by retaining rainwater and thus prevent flood risk, while Qin et al, (2013) found that these components are a more sustainable solution than conventional systems and are a more effective method to reduce flood events in cities.

When green infrastructure / DEG components are planned in an integrated manner with traditional infrastructure applications, they reduce the pressure on the existing infrastructure and reduce the negative impacts caused by stormwater. It has been determined by measurements that total surface runoff is reduced by 22.20% when all systems are planned in an integrated manner with the existing infrastructure. Among these systems, green roof systems were found to be the least effective despite having the most area with rain barrels, while systems such as permeable pavement and rain gardens were found be more effective despite having 30% less than the average green roof area. Bedan and Clausen (2019) found that stormwater runoff was reduced by 42% with the use of DEGs, while Gülbaz et al. (2018) found that 4 different DEG components (green roof, infiltration trench,

permeable pavement, rain garden) reduced total runoff by 12%. The reason for the difference in the rates is that the amount of impervious area, the size and technical characteristics of the components used (infrastructure drainage systems, slopes, depth of the soil layer, etc.) are different, and in addition, the designed
The climate and precipitation conditions of the region and the number of dry days are different. In such studies, the microclimate, geographical and physical characteristics of the area must be taken into consideration. Because these will directly affect the result.

Table 2. Addition rates of components and runoff percentages according to the developed scenarios

Scenario	Added Component	Component Attachment Surface	Percentage of Annexation by Total Area	Percentage of Total Runoff	Available According to Infrastructure Decline Rate
1	Existing Infrastructure (No Component)	----------------------------	--------	%88,70	--------
2	Green Roof	20% of Roof Areas	%9,72	%86,80	%2,15
3	Rain Barrel	20% of Roof Areas	%9,72	%80,60	%8,10
4	Permeable Coating	20% of other impervious areas excluding roof areas	%6,73	%82,85	%6,60
5	Rain Garden	20% of other impervious areas excluding roof areas	%6,73	%82,85	%6,60
6	All Systems Using Together	40% of Total Roof Area and 40% of total impervious areas	%32,90	%69	%22,20

Considering the maximum runoff amounts occurring in the basins, the maximum level of runoff was realized in the time period when the rainfall intensity was 6.40 mm. This rate was 3.35 m^3/s in green roof systems, 3.12 m^3/s in permeable pavement and rain gardens, and 3.05 m^3/s in rain barrels. When all systems are planned in an integrated manner, this rate was measured as 2.69m^3/s. In similar studies; Ahiablame et al, (2013) reported a 6% reduction in surface runoff by storing water collected from 25% of the total roof area in high density residential areas in rain barrels, Hatt et al, (2009) reported that large volume rainwater harvesting systems reduce annual surface runoff
20-100%, ReyValencia and Zambrona, (2019) found that rain barrels reduce surface runoff by 3-14%. In addition, in studies conducted in terms of water supply, Kılıç and Abuş, (2018) found that 14% water savings were achieved by storing water collected from the roofs of residential areas and Eren et al. (2016) reached similar results by determining that water collected from the roofs of a campus area provided 10.90% water savings.

Green infrastructure / DEG components partially prevent the concretization caused by urbanization green space in cities and reduce the amount of impervious surfaces that do not absorb rainwater. In the study, the whole area
When 9.72% of the total area is planned as green roof systems and 6.73% of the total area is planned as rain gardens, 16.45% of the impervious areas in the total area will be converted into green areas and the amount of green areas will increase.

Due to their high water retention potential, green infrastructure / GI components allow rainwater to be stored and reused for future needs and to use water resources more efficiently in the face of global climate change. In this study, the total roof area
By storing rainwater flowing from 20% of the rainwater in a total of 1872 rain barrels with a volume of 4m^3, it has been determined that 10 thousand families of 3 people can meet 101 days of toilet cleaning needs. In addition, when the initial storage volumes of other systems are compared, it is determined that the initial storage volume of permeable pavement systems is 1.00mm, green roofs 1.94mm and rain gardens 3.35mm. With the integrated use of all components, this ratio was measured as 6.30mm. Rain gardens were found to be the most effective system in terms of initial storage amounts. The most advantageous scenario was found to be rain gardens with the integrated use of all systems.

will be provided. Many studies on stormwater management show that green infrastructure systems can be a more cost-effective solution in the long term compared to gray infrastructure. It is envisaged that similar studies with different scenario components will provide advantages in terms of transferring the results to plan decisions and implementation by local governments.

[&]This study was produced from the Master's Thesis of **Turgut DİNÇER,** a student of Atatürk University, Institute of Natural and Applied Sciences, Department of Landscape Architecture.

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