# Quantification of Flood Mitigation Services by Urban Green Spaces in City of Tashkent Using InVEST Model

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**Abstract**: In urban areas, impervious surfaces and dense networks of buildings significantly limit the infiltration of rainwater and increase surface runoff. As a result, pluvial floods occur in such urban areas during the seasons of heavy rainfall. Although most of these floods are small in size and shallow, they cause direct and indirect damage to people and city infrastructure. Such flash floods cause traffic jams, difficulties for pedestrians, damage to roads and buildings, and injuries to physical and mental health of citizens. Floods are one of the main problems in the city of Tashkent in the rainy seasons of the year. The role of green spaces in reducing such urban floods in the city of Tashkent has been quantitatively assessed in the InVEST model. In the city of Tashkent, the flood retention coefficient is equal to 0.38 in urban trees, 0.62 in grasslands, 0.22 in croplands and open areas, and 0.06 in impervious surfaces. Grasslands are the most effective ground cover type in reducing city floods in city of Tashkent.

[Khayitmurodov Alijon Olimjon ugli, Sharipov Shavkat Mukhamajanovich, Mingaliyev Ravshan Olim ugli. **Quantification of Flood Mitigation Services by Urban Green Spaces in City of Tashkent Using InVEST Model.** *Nat Sci* 2024,22(9):22-28]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature 04. doi:10.7537/marsnsj220924.04.

**Keywords:** biophysic table, greeen spaces, pluvial flooding, curve number, InVest software, hydrologic soil types.

## 1. Introduction

Nowadays, more than half of the population of Uzbekistan lives in urban areas. In Uzbekistan, the population of cities is increasing due to the natural increase and rural-urban migration, and at the same time, their areas are also increasing. The growth of cities and the rapid construction of facilities are causing many environmental problems.

Despite the fact that Tashkent is a very ancient city, the city was almost completely rebuilt after the 1966 earthquake. That the city master plan is not developed on time and is not approved by the city administration had led to the chaotic construction of structures throughout the city. As a result, among social and economic problems, environmental problems also have arisen. One of the environmental problems is urban flooding. Flash floods occur in many parts of city of Tashkent during periods of heavy rainfall, causing traffic jams, damage to city infrastructures, and reduce social life style. The occurrence of such floods is related to the following two reasons: firstly, existing problems of rational planning of the sewerage systems in the city of Tashkent, and secondly, it is related to the increase of impervious surfaces that limit the infiltration. The relief of the city, its geological structure and climate also play an important role in the occurrence of pluvial floods in Tashkent

Green spaces are extremely important in reducing urban flooding. Urban vegetation reduces the volume of surface rainwater by infiltration and slows down its movement. Despite the great benefits of green areas, unfortunately, in many cases, their degradation cannot be prevented. Green spaces in Tashkent have also decreased significantly in recent decades. Nowadays, the level of coverage of the city of Tashkent with green spaces is only 5.56%. Such areas include recreational parks, urban gardens, meadows, grasslands. Recreational parks, which are the largest green spaces in Tashkent, are located mainly in the centre of Tashkent (Figure 2). In the north-western and south-eastern parts of the city of Tashkent, there are very few green spaces.

The INVEST model, developed by Stanford University, is important in assessing urban ecosystem services. This model also includes an algorithm for urban flood mitigation. InVEST (Integrated Valuation of Ecosystem Services and Trade-Offs) models are positional, using maps as information sources and producing maps as outputs.

## 2. Materials and Methods

*Research object.* The city of Tashkent is the largest city in Uzbekistan with an area of 410 square kilometres and a population of 3 million people (in 2023). The city of Tashkent is located at the base of the Western Tianshan Mountains, between the Chirchik and Keles rivers. The main part of the city territory is situated on the I, II, II, IV and V terraces of the Chirchik River. The height of the city above the sea level is around 400-500 m. The highest parts of the city are in its northeast, and the lowest parts are in its southwest. The terrain of the I and II terraces of the Chirchik River in Tashkent is relatively flat, the gradient is not large, and it is mainly composed of alluvial rocks. The alluvial rocks of the III, IV, V terraces of the Chirchik River are covered with perennial loess. The thickness of loess reaches 40-80 m. Neotectonic processes caused the formation of convex, undulating plains on the III, IV, V terraces of the Chirchik River. The undulating plains accumulate water in low-lying areas during rainfall, increasing the risk of floods. The average annual temperature in Tashkent is 13.3°C, the average temperature in January is -1.1°C, and the average temperature in July is 27.5°C. The average annual rainfall is 360-490 mm and, which is uneven throughout the year (Figure 1). The most monthly rainfall falls on March and April. Therefore, most of the floods in the city occur in March and April.

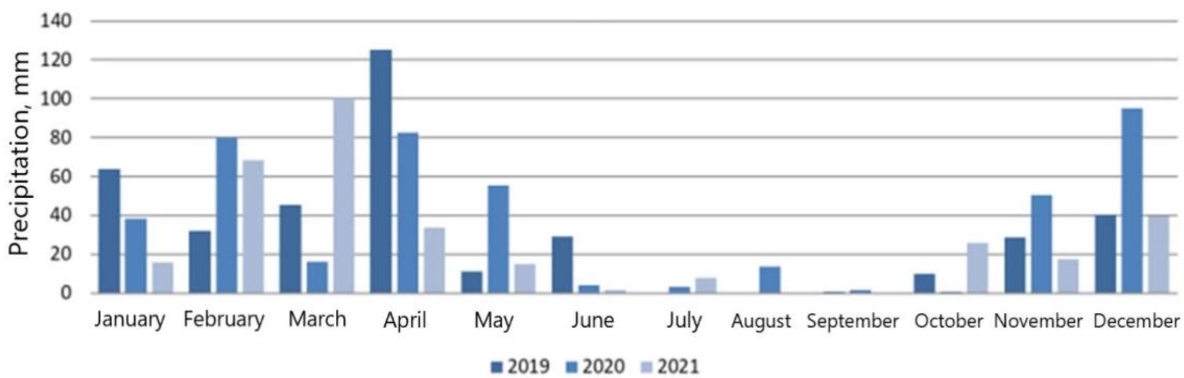



**Figure 1.** Average monthly distribution of the annual precipitation in Tashkent

The Invest model has been used to quantify urban flooding. The raster and vector data used as inputs in the Invest program have been created in ArcGIS 10.8 (Figures 2 and 4). The results of the field research method have been also used to input data into the InVEST model. The research work has been carried out in the following stages: 1) preparation of the database for the InVEST software; 2) input data into the InVEST software; 3) Processing the results obtained from the InVEST software.

*Preparing a database for the InVEST software.* The following are the main inputs for flood mitigation algorithm in the InVEST software: land use map of Tashkent city (in raster format), biophysical table, and map of hydrological soil groups of Tashkent city (in vector form).

Classification of Land use and land cover map of city of Tashkent has been created using from Sentinel-2 Imagery Using Supervised Classification in ArcGIS 10.8. In the city of Tashkent, 6 types of land use are distinguished: Urban trees, grasslands, open water, built up areas, impermeable roads, croplands with open spaces (Fig. 2).

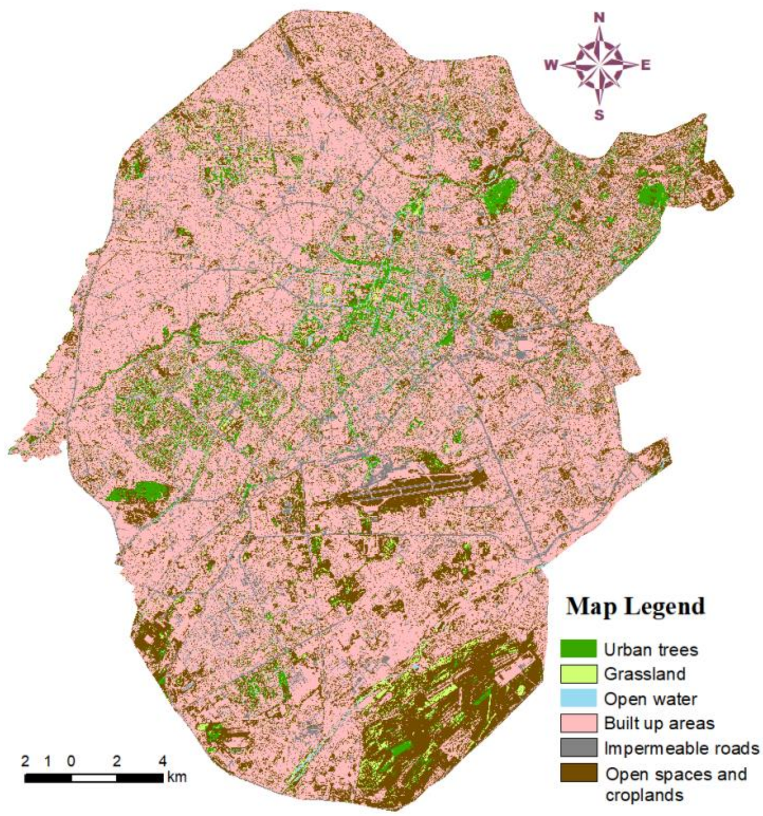
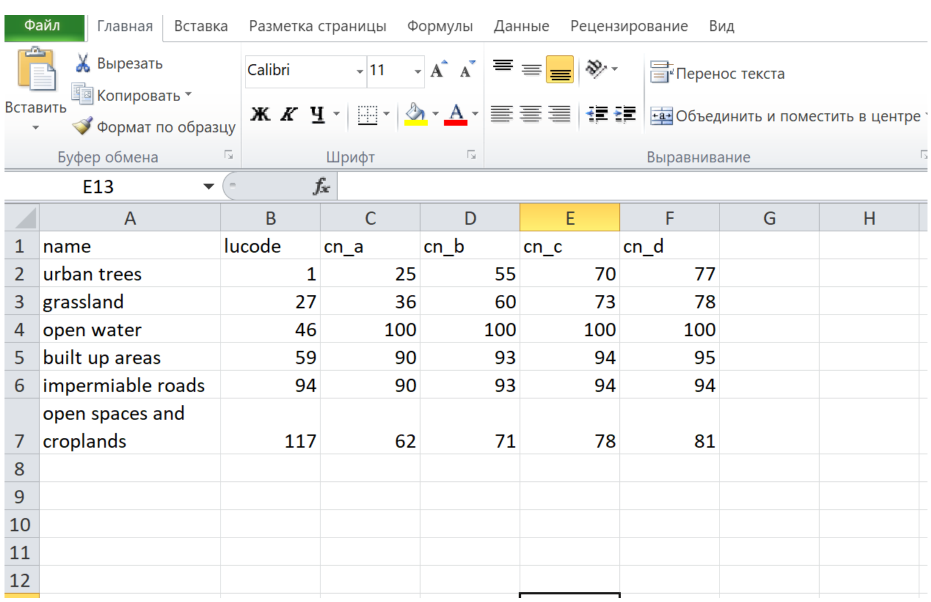



**Figure 2**. Land use and land cover map of city of Tashkent

Information corresponding to each land use type is included in the biophysical table. Curve numbers corresponding to types of land use are variable in four hydrological soil groups (a, b, c, d). Therefore, curve numbers are shown for each of the four soil groups. The biophysical table is saved in csv format in Excel.



| name | lucode | cn_a | cn_b | cn_c | cn_d |
|---|---|---|---|---|---|
| urban trees | 1 | 25 | 55 | 70 | 77 |
| grassland | 27 | 36 | 60 | 73 | 78 |
| open water | 46 | 100 | 100 | 100 | 100 |
| built up areas | 59 | 90 | 93 | 94 | 95 |
| impermiable roads | 94 | 90 | 93 | 94 | 94 |
| open spaces and croplands | 117 | 62 | 71 | 78 | 81 |

**Figure 3.** Biophysical table

The Digital Soil Map of the World (Geonetwork) map downloaded from the official site of FAO has been used to create a map of soil hydrological groups and processed in ArcGIS 10.8 software. There are 2 hydrological types of soils in Tashkent: C and D. Group C soils are sandy clay loam where Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. C and D soil groups have special features in the formation of urban floods due to the different level of infiltration.

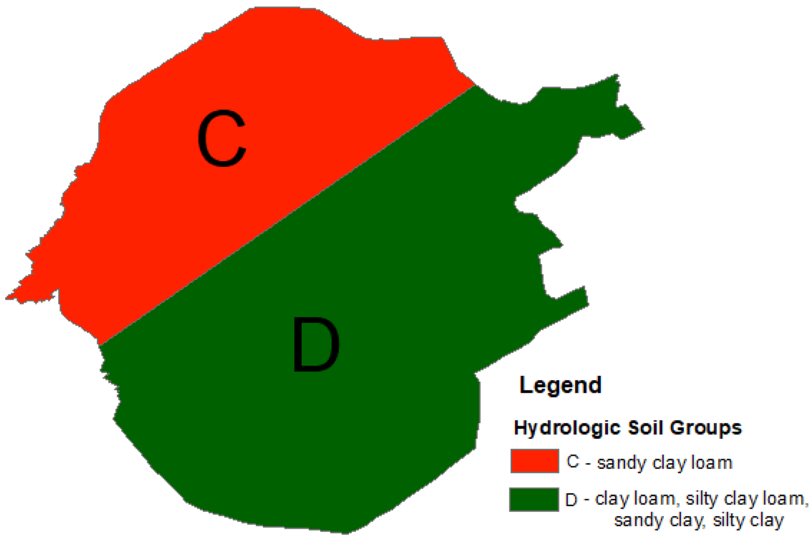



**Figure 4.** Map of hydrological soil groups of city of Tashkent

*At the stage of input data into the InVEST software*, vector and raster data prepared in the ArcGIS 10.8 software, and collected digital data have been entered into the InVEST software (Fig. 5).

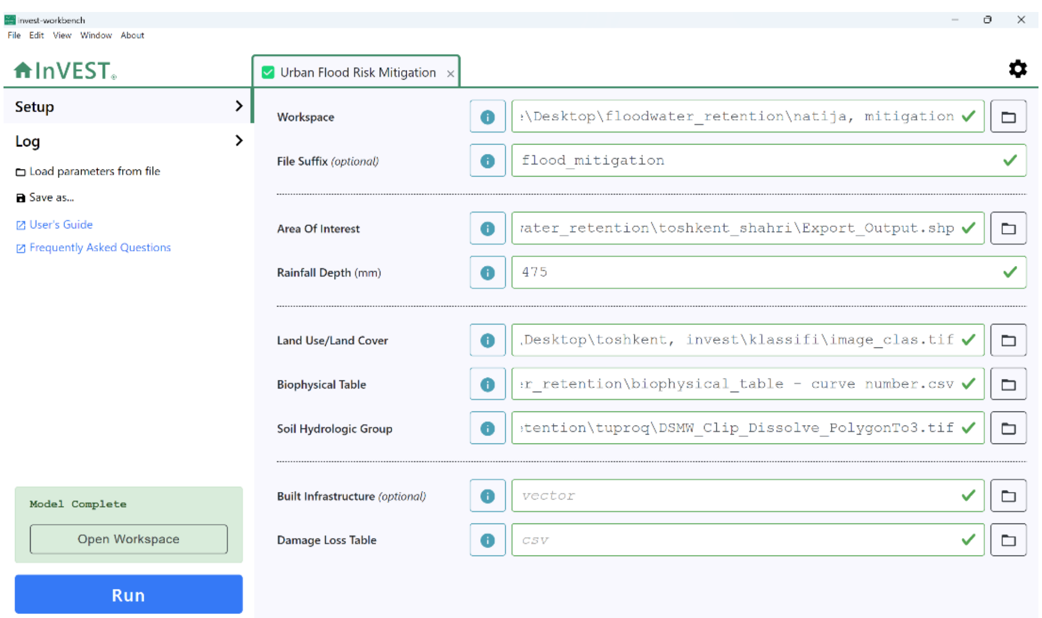



**Figure 5.** Inputting data into the flood mitigation algorithm in the InVest model

The results obtained in the InVEST software had been processed in the ArcGIS 10.8 software, and the legends of the map had been added.

## 3.Results

The retention of rainwater on surfaces in the city of Tashkent has been quantified. In the city of Tashkent, average runoff retention index, Average runoff retention ($m^3$/pixel), average surface runoff (Q, mm) has been determined and maps have made (pictures 6-8).

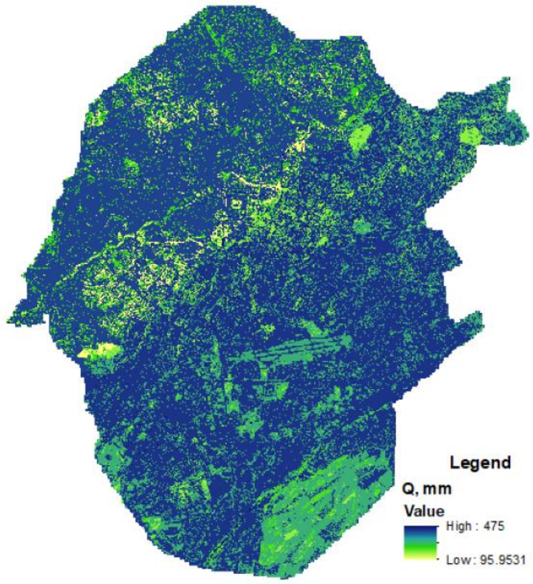



**Figure 6.** Potentianl runoff map of city of Tashkent

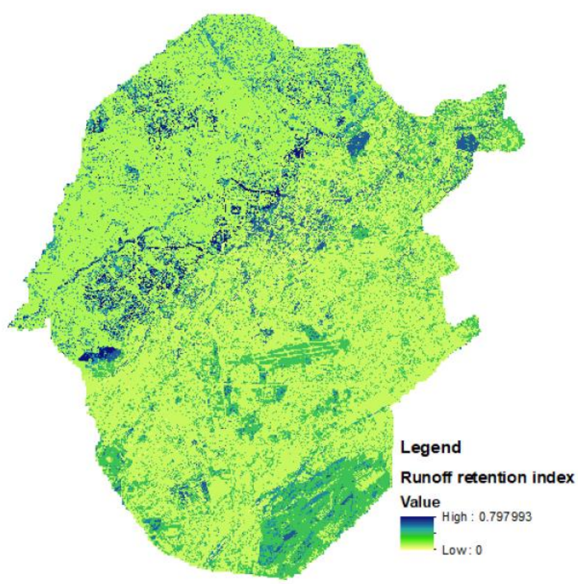



**Figure 7.** Map of runoff retention index of city of Tashkent

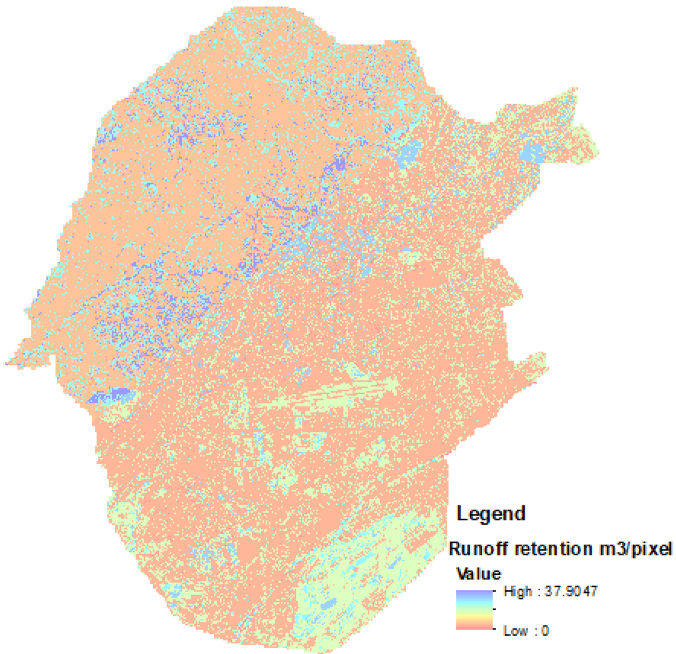



**Figure 8.** Runoff retention map of city of Tashkent

The results obtained in the InVEST program show that the ability of urban surfaces to retain flood water depends on the types of land use and land cover. According to the obtained results (figures 6-8) in the city of Tashkent, the ability to retain flood water is highest in the central parts where green areas occupy the largest areas; relatively low indicators are in the north-west and south-east of the city, where impermeable surfaces occupy large areas.

The flood mitigation potential of different land use and land cover types in Tashkent is shown in the table below.

**Table 1.** The flood mitigation potential of different land use and land cover types in Tashkent

| | Urban trees | Grassland | Croplands and open spaces | Impermeable surfaces |
|---|---|---|---|---|
| Average runoff retention index | 0.38 | 0.62 | 0.22 | 0.06 |
| Average runoff retention $m^3$/pixel | 18.2 | 37.9 | 10.52 | 2.7 |
| Average runoff(Q), mm | 293 | 95 | 369 | 445 |

**4. Discussions**

The soils of Tashkent city belong to C and D hydrological groups. The level of infiltration of rainwaters is not high in such soil groups. This increases the possibility of floods during the rainy season. Also, impermeable surfaces in Tashkent occupy about 80% of the city's area. Such surfaces produce full runoff during periods of rainfall, if wetting of dry surfaces and small amounts of evaporation not counting. As a result, the number and intensity of urban flooding will increase. The role of green spaces in the retention and infiltration of flood waters in the city of Tashkent is extremely high.

The flood retention abilities different land uses and land covers are shown in tabular form for comparison (Table 1). The flood water retention coefficient of grasslands is 0.62, that of urban trees is 0.38. Grasslands proved to be the most effective in reducing flood waters. The average runoff index of grasslands is 1.63 times higher than that of urban trees, and 10.33 times higher than that of impermeable surfaces. The amount of average runoff retention ($m^3$) is 2.1 times higher in grasslands than in urban trees, and 14 times higher in impermeable surfaces (Table 1). On the other hand, the formation of surface runoff water during the rainy season is the highest - 445 mm on paved surfaces. According to this indicator, such surfaces are 1.5 times ahead of areas covered with urban trees and 4.7 times ahead of grasslands.

Croplands and open spaces occupy large areas in the south-western parts of the city of Tashkent, near the city boundaries. Because these lands had been added to the city of Tashkent in recent years, and the city's infrastructure has not fully occupied these areas. Although the ability of flood water retention in such areas is higher than that of impervious surfaces, it is less than that of green areas. The amount of average runoff retention ($m^3$) is almost 2 times less in cropland compared to urban trees, and 3 times less compared to grasslands (Table 1). It is recommended to place more green spaces in such areas, which have not yet been fully occupied by city infrastructures. Increasing the number of green spaces in the south-western parts of Tashkent, where there are very few green spaces, will also help reduce the intensity of the summer urban heat island.

## 5.Conclusion

In city of Tashkent, the role of green spaces is extremely important in improving the social lifestyle of the population and urban microclimate, especially in reducing urban floods. Grasslands are the most effective in reducing urban flooding. It is necessary to take into account the increase of grasslands in decision-making and environmental projects. It is necessary to implement the following suggestions and recommendations aimed at improving the ecological situation and reducing the risk of flash floods in Tashkent:

*a)* Encouraging households in the city to grow natural grasslands near their homes, as the grassland is the most effective in reducing floods;

*b)* Creating more green spaces and grasslands in the south-western parts of the city, where have been added to the city of Tashkent in recent years;

*c)* It is necessary to scientifically research the issues of creating green roofs in the city of Tashkent. If the number of multi-story buildings with green roofs increases in the city, the possibility of rainwater falling down and forming a surface runoff will decrease;

*d)* Identify unused open spaces in the city of Tashkent, create a list of them and develop grasslands for such areas;

*e)* It is necessary to strengthen the protection of green areas in the city of Tashkent, to prevent their cutting for the construction of buildings.

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7/27/2024