Czech University of Life Sciences Prague

Faculty of Forestry and Wood Sciences

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Diploma Thesis

Impact of Sustainable Urban Drainage System in Stormwater Management
A case study in Mat neighbourhood in Prishtina (Kosovo)

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DIPLOMA THESIS ASSIGNMENT

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Thesis title

Impact of Sustainable Urban Drainage System in Stormwater Management A case study in Mat neighbourhood in Prishtina (Kosovo)

Objectives of thesis

The main objective of this thesis is to present the Sustainable Urban Drainage System techniques in Kosovo and evaluate the impact of implementing some of these techniques in one of the neighbourhoods of Prishtina, which has proven that a conventional drainage system fails to meet the stormwater drainage requirements.

Methodology

This study is based on literature gathered from various books, journal papers, and credible online reports for 6 months. All the gained information from the chosen literature is important to understand the environmental, social and economic impact of implementing these practices toward a sustainable world. The data for the specific location chosen for this study are obtained from many state institutions, national reports and by investigation of the area.

The calculations have been realized, based on local condition, regulative plan of location and evaluation of obtained information. Most suitable Sustainable Urban Drainage System techniques are proposed for implementation according to the result of the calculations. The relevant approximation have been made derived from existing data and from the coefficients suggested by authors if the other data are known, in case of missing due to the problem of monitoring.

The proposed extent of the thesis

40 – 60 + tables + Figures

Keywords

Stormwater, Sustainable Urban Drainage System, Environment, Water Regime

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Recommended information sources

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Declaration

I declare that I have worked on my diploma thesis titled " The impact of Sustainable drainage system in stormwater management. A case study in Mat neighbourhood in Prishtina.(Kosovo)" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 09 April 2019 ______________________________

Acknowledgement

First and foremost, I would like to thank my supervisor, Doc.Ing, Jakub Štibinger for his continuing support and for all guiding and suggesting throughout all the process of work in this thesis.

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The Impact of Sustainable Urban Drainage System in Stormwater Management
A case study in Mat neighbourhood in Prishtina (Kosovo)

Abstract

Providing adequate urban stormwater management has been the most challenging issue throughout the world. The conventional drainage system used to drain the rainwater has shown its incapability to cope with surface runoff due to the ongoing process of urbanization, land use changes and the climate change impacts.

The Sustainable Urban Drainage System has been presented during the last century aiming to change the focus of stormwater management toward natural approaches which will help the efficiency of the conventional system, while, at the same time, improving water cycle and biodiversity, promoting green areas and mitigating floods and the impact of drought periods. Adapting SUDS approaches in the management of stormwater in many developed countries has resulted in multi-beneficial impacts in environment. Also, SUDS is appropriate due to its cost-effective benefits.

The aim of this thesis is to present SUDS approaches for the first time in Kosovo and to evaluate their impact in the stormwater management and in water resources in general.

Finding new solutions is crucial for a low-income state, which cannot afford to change existing pipe diameters and which did not realize proper stormwater management.

SUDS techniques are evaluated for an area of 21.8 ha which is planned to be constructed in the capital city of Kosovo. The chosen area has been threatened by over flowing sewerage system for many years. Construction based on conventional systems is outdated do to its insufficient capacity to cope with the situation in the city.

The results from the evaluation of SUDS techniques in this new area have shown that it can reduce the surface runoff and decrease the stress in the conventional sewerage system. Moreover, the implementation of these techniques will also improve water supply by reusing rainwater as the second source for irrigation and for toilet flush purposes in a city that has suffered for many years from water outage due to limited water resources.

Keywords: SUDS, stormwater, water resources, surface runoff, climate, environment, green roof, swales, RHW

Vliv udržitelného městského odvodňovacího systému na řízení dešťové vody
Případová studie v okolí Mat v Prishtině (Kosovo)

Abstract

Zajištění kvalitnýho managementu dešťové vody ve městech bylo velkým problémem po celém světě. Klasický drenážní systém, který je využíván pro odtok dešťové vody, není schopen se vyrovnat s povrchovým odtokem v důsledku probíhajícího procesu urbanizace, změn ve využívání půdy a dopadů změny klimatu.

Systém udržitelného městského odtoku začal být využíván již v průběhu minulého století s cílem zefektivnit a optimalizovat využití a odvod dešťové vody šetrně k přírodě, a zárovně zlepšit vodní cyklus a díky tomu také biologickou rozmanitost, taktéž zlepšení zavlažování zelených ploch a optimalizace povrchové vody, a tedy i dopad v době nízkého úhrnu srážek. Přizpůsobení přístupů SUDS v managementu dešťové vody v mnoha rozvinutých zemích vedlo k pozitivním dopadům na životní prostředí. SUDS je také vhodný díky vhodnému poměru ceny a efektivity.

Cílem diplomové práce je poprvé představit přístupy SUDS v Kosovu a zhodnotit jejich dopad na management dešťové vody a obecně na vodní zdroje.

Nalezení nových řešení je klíčové pro chudé státy s nízkými příjmy, a které si nemohou dovolit měnit stávající system odpadního potrubí a tudíž nemohou optimalizovat management dešťové vody.

V hlavním městě Kosova byla vybrána plocha o rozloze 21,8 ha na které byla využiita metoda SUDS. Vybraná oblast se již po mnoho let potýká s nedostatečnou kapacitou kanalizačního systému. Kanalizační system založen na konvenčních systémech je zastaralý a vzhledem k nedostatečné kapacitě, není schopn se vyrovnat s nynější situací.

Výsledky hodnocení metodou SUDS v této oblasti ukázaly, že je možné snížit povrchový odtok a snížit tak požadavky na stávjcí kanalizačním systém. Zavedení této technologie navíc zlepší opětovné využití dešťové vody, a to jako možný zdroj pro zavlažování, tak i jako šedá voda pro splachování toalet ve městě, které se po mnoho let potýká s výpadkem vody v důsledku omezených vodních zdrojů.

Klíčová slova: Klíčová slova: SUDS, dešťová voda, vodní zdroje, povrchový odtok, klima, životní prostředí

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List of abbreviations

SUDS – Sustainable Urban Drainage System

UN – United Nation

UK- United Kingdom

US- United State of America

WC- Water closet

WSUD- Water Sensitive Urban Design

SCMs- Green Storm Water Control Measures

BMPs- Best Management Practices

LID- Low Impact Development

BGI-Blue Green Infrastructure

EU- European Union

WFD- Water framework Directive

EPA- Environmental Protection Agency in United States

WWTP- Waste Water Treatment Plan

RWH- Rain Water Harvesting

UNMIK- United Nation Mission in Kosovo

FAO – Food and Agricultural Organisations

IHMK- Hydrometeorological Institute of Kosovo

USAID- United States Agency for International Development

MMPH -Ministry of Environmental and Spatial Planning in Kosovo

WB- World Bank

AKS- Kosovo Agency of Statistics

Introduction

The stormwater has been managed since early human civilizations, when people started to impact the water cycle. Its purpose is to drain the rainwater due to the impermeable surfaces that cause surface runoff, in order to protect the areas from flooding. The sewerage piped systems have been used to convey rainwater to the main recipients like rivers or other water bodies. Often, sewerage system affects the quality of the water bodies catchments due to the pollutants which flow along with rainwater. There are few countries in the world that can afford to treat these sewerage systems. Thus, due to high costs, many times, rainwater is released directly into waterbodies catchment.

The sewerage system can be served as a combined system which conveys the wastewater and rainwater into the same pipe and a separated system that conveys these two types of water in different pipes. The last practice is used by many countries nowadays, but in some low-income countries the combined sewerage system is still in use.

Water cycle has been deeply affected with population growth, use of land for human constructions, and impact of climate change.

The expansion of impermeable areas has prevented the infiltration while the water storage has been drastically decreased in many countries. The lack of coverage with green areas has decreased the evapotranspiration while climate change has impacted the dynamic of precipitations. These conditions trigger surface runoff, which leads to a situation where conventional systems are incapable to cope with runoff even during moderate rainfall intensity.

In an attempt to find the sustainable approach, management of stormwater system is being oriented towards natural solutions.

Sustainable drainage system (SUDS) has been presented in UK during the last century even though many other similar systems with the same purpose have been developed in different countries. Its main concept is to follow natural approaches in order to mitigate the runoff impact by increasing infiltration, evapotranspiration and promoting the green areas while at the same time improving water quality.

By showing their benefits, many of SUDS techniques have been applicated in many developed states in the world.

In Kosovo the SUDS term is completely new, while the focus of stormwater management is oriented toward the conventional piped system.

Since the war has finished the country has faced a transition period during which environmental conditions have been affected greatly. For a short period of time the country has underwent a rapid development, but the natural resources have been neglected in the process of ongoing urbanization. Kosovo has unevenly distributions of water resources which makes the situation more difficult to manage.

The main problem with urban stormwater management is evident in Prishtina, the capital of Kosovo, which is the most urbanised city with a very high population density. In last fifteen years, city has rapidly expanded with human constructions, but unfortunately, many of these constructions were not made in accordance with urban planning conditions. Meanwhile, water bodies have been polluted by the amount of sewerage discharge. The existing sewerage system overflows almost every time there is an increase in rainfall intensity.

The sewerage system in Prishtina is a combined system. It is not an appropriate system for different neighbourhoods such as Mat neighbourhood, which as one of the most constructed areas of the city has problems with overflowing sewerage system. The terrain of this neighbourhood has a gradient which allows all the upperpart construction to discharge into the sewerage by gravity in the main collector which is located in the lower part of the neighbourhood, that is, in main traffic road.

Hence, buildings in lower areas are affected by the incapability of sewerage system to cope with all the wastewater and rainwater coming from the buildings in upper areas. In this way inhabited buildings are flooded with a toxic sewage-runoff mixture due to the damage caused by the over flow sewerage system.

In addition to these problems, the trend of construction it still planned to expand in this neighbourhood. In 2015, regulative plan was approved by the Municipality of Prishtina for an area of 21.8 ha within this neighbourhood, which is planned to be constructed until 2025. Indeed, this is the last area that has remained empty from constructions within neighbourhood until this year. The stress in the main collector of the sewerage system will be highly increased and will cause severe consequences for inhabitants.

The SUDS techniques are aimed to be evaluated for the studied area, as an alternative approach which will help the conventional system to cope with extra wastewater and rainwater amount.

I. Objectives and Methodology

2.1. Objectives

The main objective of this thesis is to present the Sustainable Urban Drainage System techniques in Kosovo and evaluate the impact of implementing some of these techniques in one of the neighbourhoods of Prishtina, which has proven that a conventional drainage system fails to meet the stormwater drainage requirements. Furthermore, aims to reveal the environmental and social impact of SUDS in the city by using the appropriate techniques, in addition, to consider SUDS as one of the most sustainable solution for the future neighbourhood construction.

Key of this thesis contains:

- Highlighting the negative impacts of inappropriate stormwater management in Kosovo at many perspectives.
- According to literature/researches conclusions and current impact of SUDS implementation in in many other countries, introducing the SUDS techniques in one of the neighbourhoods of Prishtina.
- Analysing which SUDS techniques would be suitable for this neighbourhood and their benefits at comprehensive aspects of implementations
- Presenting a first study on this topic in Kosovo which open the way for further studies and considering the SUDS combining with conventional system as one the best and sustainable solution for future planning

2.2. Methodology

This study is based on literature gathered from various books, journal papers, and credible online reports for 6 months. All the gained information from the chosen literature made me able to understand the environmental, social and economic impact of implementing these practices toward a sustainable world. The data for the specific location chosen for this study are obtained from many state institutions, national reports and by investigation of the area.

Based on local condition, regulative plan of location and evaluation of obtained information the calculations have been realized. According to the results of these calculations the suitable Sustainable Urban Drainage System techniques are proposed for implementing. In case when some of the data were not available due to the problem of monitoring the relevant approximation by the scientific papers and books have been made.

II. Development of Sustainable Urban Drainage

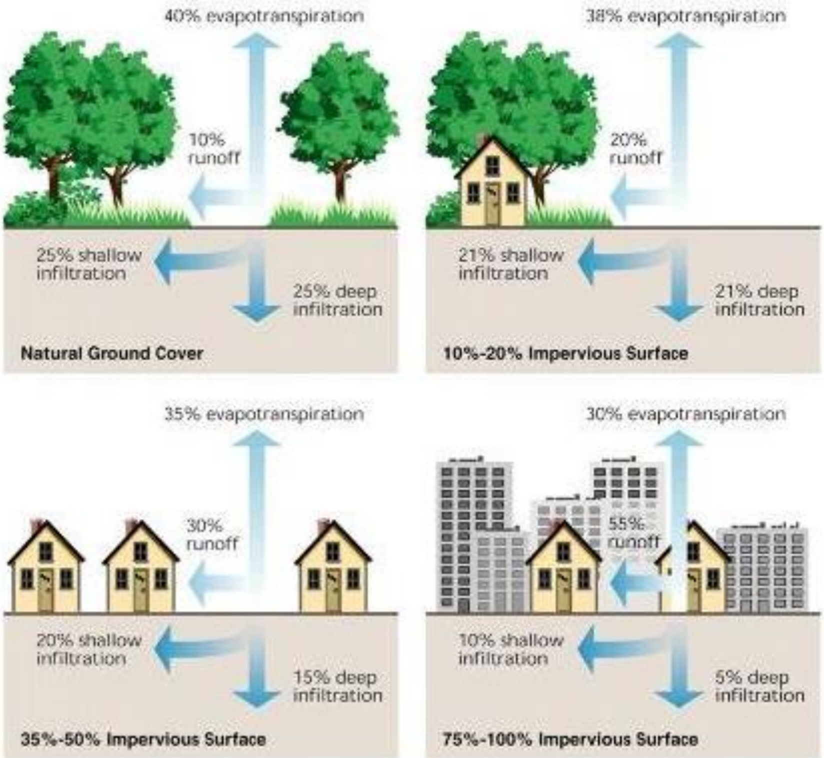
3.1. Urban Drainage

The drainage system has been introduced since the human activity has started to interact with water cycle. Since then water has been affected in many aspects. (BUTLER & DAVIES, 2004)

Human impact on water cycle has been manifold, but mainly due to exploitation of natural water resources which serves as a vital process for providing the water supply for human needs and activities. Another human impact can be observed in prevention of the surface water infiltration due to the impermeable land cover created by built-up areas. These activities are increasing every day due to population growth and concentration in cities. It's estimated that by the year 2030, the global urban population will reach 4.9 billion that represents a growth of 60% of the total population since 2000 (UN, 2000)

Rapid urbanization is a phenomenon that has seen exponential growth in the XXI century. Its impact in natural resources is the major threat for the environment while its consequences are the greatest challenges that the world is facing recently.

Figure.1. The impact of urbanization in the water cycle



Source: Introduction to the Stormwater Management Guidebook ((FISRWG, 1998).

Figure 2 shows the effect of urbanization in water cycle where evaporation has decreased 10% by increasing the impermeable surfaces from the built-up area, reducing evapotranspiration because of the low space of vegetation leading to a low capacity of the soil to infiltrate the runoff, causing around 15% reduction of infiltration capacity. The percent range of Impermeable coverage varies from 2% in rural areas, 10% in low density areas to 90 % in metropolitan areas (CWP, 20013)

Therefore, the runoff in high density areas has quickly discharged to a drainage system.

As a consequence, the flooding events are likely to happen around different urbanization zones of the world and this trend will continue if there is no implementation of an adequate drainage system. (KABISCH & KORN, 2017)

Urban drainage system can handle two forms of water, wastewater and storm water.

The wastewater can be defined as water that has been drained in order to maintain proper life conditions on Earth. Wastewater management is a necessity due to the fact that water contains dissolved material and larger solids originating from WC, washing, industries etc.

The storm water is rain water that can also be in every form of precipitations which has fallen on a built-up area. (BUTLER & DAVIES, 2004)

The main focus of this study is the proper management of urban stormwater drainage.

3.1.1 Historical overview of urban drainage

Much historical evidence shows that the concept of urban drainage has been introduced several thousand years ago. The essential demand for a healthy life by collecting waste from animals and people’s activities, but also for protection of their houses and their areas from high water levels made people think and seek for the solution.

The results of their work is proven by many of sewerage systems revealed by archaeological excavations in many cities. (BURIAN & EDWARDS, 2002)

"The sewer is the conscience of the city," stated Victor Hugo, Les MisÈrables

Ephesus, the city of Grece has shown us another example where archeologists have revealed and excavated the ceramic drainage pipes which supposed that are built 2000 thousand years ago. (Research) (EVANS. & ORMAN, 2013)

Figure 2. The drainage pipes excavated in Ephesus

Source: Urban Drainage and the Water environment a Sustainable Future

There is a lot of historical evidence that shows us that first urban drainage systems were constructed in a proper way which met all objectives of that time and remained successful for a long time although designing was limited due to lack of calculations and the other information.

The biggest revolution in adequate construction of the urban drainage system was made by the Roman Empire. This the time when huge masses of people moved to live in a city. Over the years, the urban drainage system has developed becoming an essential designed system for wastewater and stormwater removal.

In the XX century, the planning of the urban drainage system has progressed rapidly with inclusion of designed systems for preventing many diseases. The urban drainage systems were being designed and planned by engineers based in proper standards and calculations and using various integrated programming system that work with different set of data monitored for many years. (BURIAN & EDWARDS, 2002)

Whilst the engineering solutions are progressing and computation methods are getting more sophisticated, many places of the world are still facing challenges concerning water management. This drawback threatens the environment in these countries due to lack of wastewater and stormwater treatment.

Considering that nature works in the best way possible at protecting its natural resources, it is easy to conclude that if humans did not attempting to control the environment the chance of the occurrence of flood events would be much lower than it is now (BUTTLER & DAVIES, 2010)

3.1.2 Urban drainage system approaches

According to the history of urban drainage, it has been more than a century since the construction of separate and combined drainage system has started. As it can be inferred by its name, the separate system is used to collect separately wastewater and surface water within different pipes, while the combined system collects both types of water in the same pipe. These two systems are constructed by using the underground pipe system, named the conventional system. (HOYER & DICKHAUT, 2011)

In some cities, the hybrid system is introduced for applying, which is defined as a partially separated system which occurs when these two types of water are accidentally or intentionally combined. (BUTTLER & DAVIES, 2010)

Separated pipe system is the most applied system in developed countries while the combined system still remains applied in low-income countries.

The advantages of the separated drainage system are related to the differences in flow rates between the two types of wastewater (larger, more unpredictable and more variable flow rates for stormwater) and to the presumed difference in water quality. As stormwater was considered to be clean enough to be discharged directly into watercourses, this meant that stormwater networks were made shorter, more precisely dimensioned and, therefore, cheaper. (FOREST & PATOUILLARD, 2011)

Over the last two decades or so, the impact of urbanization and climate change on stormwater management has become the biggest challenge for designers.

The issue of whether the conventional stormwater drainage system would be sufficient to meet the requirements taking into consideration the environmental, social and economic changes resulting from external factors has been the most discussed topic between scientists. Overloaded infrastructure, expanding areas of impervious surfaces, increasing alteration of landscapes, shifting connections between human and natural systems, and increasing standards for ecological compliance exemplify the characteristics of human and social systems that contribute to challenges of stormwater management (TULER, 2016)

Hence, it was necessary to seek new solutions which will aid the urban drainage to adapt to future flood event scenarios.

In order to finding the balance between the rapid built up areas and the impact of climate change, the focus is oriented toward making resilient cities.

3.1.3 The impact of climate change on stormwater management

We are reminded constantly about the dangers of climate change that our planet is facing for a while now. Many reports state the earth’s climate is in a state of flux where the most important contributing factor are anthropogenic emission of greenhouse gases. (HULLEY & WATT, 2007)

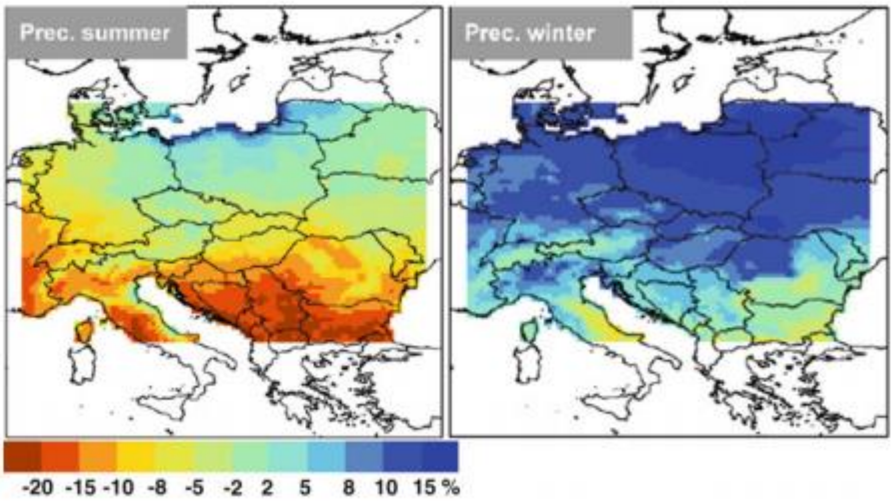
The questions that arise from these observations are crucial but also a source of persistent debates, questions such as what is the true scope of the consequences that will occur due to the human oriented climate change, but also would it be possible to improve the situation which has already occurred, even if the human impact would wane. (SANTATO, 2013)

According to NASA, the year 2016 has shown the highest measured temperatures since NASA has started monitoring temperature fluctuations. This situation has led to the point that several parts of Europe have already been exposed to extreme weather events like heat and cold waves, floods, wildfires (KABISCH & KORN, 2017)

Other research reveals the trends concerning future precipitation models which will become clearer at the end of the century, when shift of precipitation from summer to winter will become visible. A general assumption is that summer precipitation all over Central Europe (except along the coast of the Baltic Sea) will decrease, while in most cases Central Europe will most likely become wetter in the winter season. Despite these precipitation increases, the amount of snow and area covered by snow are expected to decline due to global warming.

In contrast, the projections for summer months shows tendencies for a decrease in precipitation especially in the southern parts of Central Europe. (ANDERS, et al., 2014)

Figure 3. Projected changes in mean precipitation patterns in Central and Eastern Europe in winter and summer



Source: Managing Protected Areas in Central and Eastern Europe Under Climate Change, Advances in Global Change Research

Figure 3 shows the predicted change of precipitations during seasons for years 2036-2065. The summer will be drier with less precipitation in Central and Southeastern Europe and with a high amount of precipitation in North of Europe. On the other hand, winter will be wet with a higher amount of rainfall in Central Europe. (ANDERS, et al., 2014)

Extreme rainfalls and droughts are increasing significantly as a result of climate change. The climate change is predicted to have various range of impacts in the management of water and drainage systems. In addition to these extreme conditions the urban drainage system will exceed its capacity, thus it is predicted that Europe will be exposed to many economic and social disturbances. (JENKINS, et al., 2017)

Changes in the dynamic of precipitation due to climate change but also due to the impact of urbanization will be the cause of floods and drought events within a single year.

As the urban heat island has shown, these events are likely to occur in urban areas because of the higher temperatures registered compared to rural areas. Urban areas are mostly affected by climate change due to the impermeable areas, less vegetation and from the heat released from human activity. (TAHA, 1997)

As mentioned in the previous chapter, the increase of urbanization has driven designers of stormwater management to apply the conventional pipe system and to quickly drain storm water runoff out from the cities.

Yet, based on climate change and the effects of human impact, the conventional piped system will not be able cope with exceeding stormwater in the current situation that we are continuously facing in the last decade. (ZHOU, 2014)

Increasing the pipe diameters would be the first approach that comes to mind if we want to aid the urban drainage system to cope with exceeding runoff. (WILDERER, 2004)

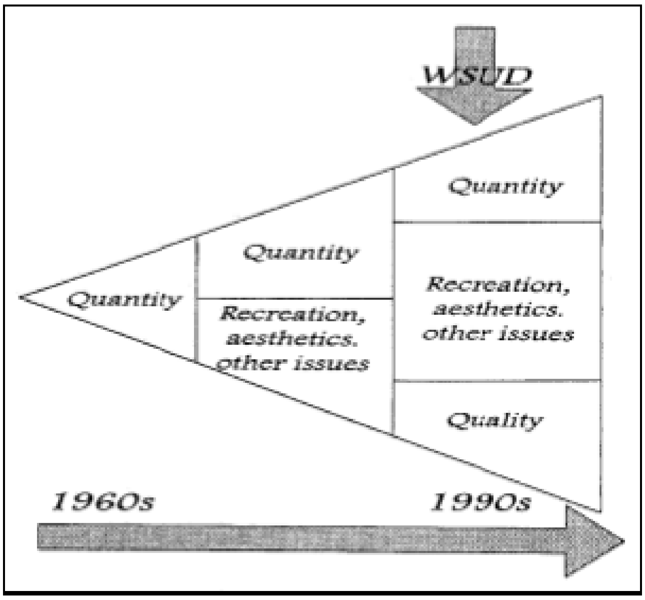
Still, besides the fact that a great investment is needed for implementing this approach (which cannot be afforded by a lot of cities), it will not be a sustainable solution taking into consideration the tendency of population overgrowth.

3.2. Sustainable Urban Drainage introduction

'The management of stormwater runoff in conventional urban developments has been driven by an attitude that reflects the view that stormwater runoff has no value as a useful resource, is environmentally benign and adds little to the amenity (aesthetic, recreation, education, etc) of an urban environment. Consequently, conventional urban stormwater management has focused on providing highly efficient drainage systems to rapidly collect and remove stormwater runoff [...]. These systems kept stormwater runoff "out of sight" and consequently "out of mind" Wong 2006 (HOYER & DICKHAUT, 2011)

It has been a while since stormwater management has been viewed as a part of civil engineering. In this paradigm stormwater management was conceptualised as the process of removal of the quantity of stormwater from cities in order to prevent flooding.
Nowadays, an integrated system of experts including urban planners, environmentalists, engineers, architects and ecologists are working together with the aim to achieve a sustainable solution for stormwater management, taking into account other aspects, such as runoff quality, visual amenity, recreational value, environment protection, and multiple water uses. (CIRIA, 2015)

Figure 4. Changing focus in Stormwater Management



Source: Water Sensitive Urban Design- A paradigm Shift in Urban Designs. (Whelan et al., 1994)

Fig 4. Figure shows the evolution of changes in the focus of stormwater management during the last part of 20 century. The focus has shifted towards addressing the quality of water as an integrated part of storm management.

The multidisciplinary system management of stormwater has integrated into urban planning where ensuring the quantity of stormwater must be accompanied by the protection of water sources and environmental health. (WONG & BROWN, 2009)

Sustainable Urban Drainage System (SUDS) is a term introduced in UK when stormwater started to be viewed as a resource which can be infiltrated, retained and conveyed to water bodies for future use. It can be also referred as Water Sensitive Urban Design (WSUD), Green Stormwater Infrastructure, Stormwater Control Measures (SCMs), Best Management Practices (BMPs) etc. However, regardless of the terms that could be used, the objectives remain the same. (CHARLESWORTH & BOOTH, 2017)

There is no strict definition of SUDS, but it can be understood as a 'green' technique, part of civil engineering that mimics the natural process of management the stormwater. (ESTONIA-LATIVIA, 2013)

By understanding the water cycle in the environment, SUDS can be designed to decrease the runoff volume by infiltration at places where soil condition allow and by catching the runoff from stormwater which will delay the runoff peak flow in order to help the reduction of pressure on conventional pipe system. It must be said that this is only one of the objectives of SUDS for treating the quantity of runoff.

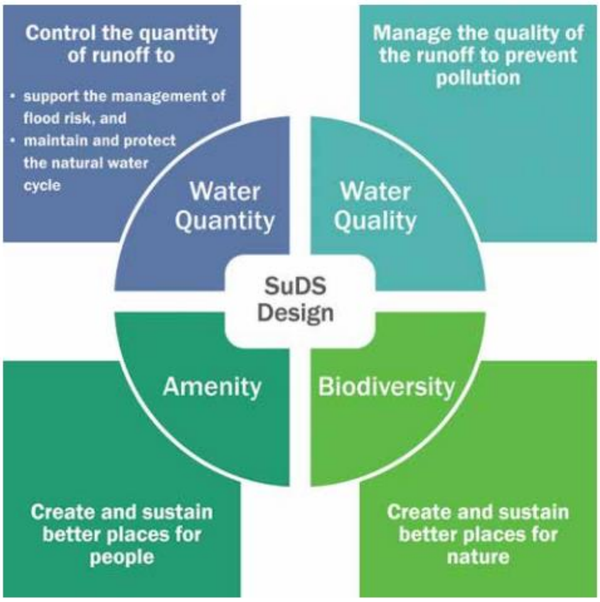
The concept of SUDS in catching the runoff peak means not only to prevent flooding but by using different techniques it could be used to allow stormwater to return back into the water cycle.

This can happen by increasing the evaporation, infiltration and by discharging stormwater in watercourse as close as possible. In addition to this, by using the SUDS treating techniques, we can improve the impact of stormwater in the environment. This will be done by increasing the quality of watercourse which will also affect biodiversity in a positive manner. Increased emphasis on improving stormwater quality for the protection of urban aquatic ecosystems has led to the re-examination of current stormwater management practices which is also defined by the EU Water Framework Directive (WFD) (WONG & BROWN, 2009)

According to (CIRIA, 2015), SUDS has four objectives. These objectives are: minimization of the impact of urbanization and climate change in the quantity and quality of runoff by managing the flood risk and maintaining the quality of runoff and water cycle while at the same time maximising amenity and biodiversity (Fig. 5)

The balance between these four objectives is the main concept of SUDS, while results of its implementation depend on site characteristics. These objectives are referred to as the four pillars of SUDS design

Figure 5. The main objectives of SUDS



Source: CIRIA, 2015

Another significant component that allows SUDS to be evaluated as the most sustainable solution its lower cost compared to conventional systems. This approach which has its main focus the preservation of the ecosystem will be beneficial in the financial aspect as well. The natural approaches always tend to reduce the cost of maintenance due to the capability to work by themselves. (MIGUEZ & VER, 2012)

SUDS is also known as Low Impact Development (Lid) in the United States and New Zealand. The implementation of SUDS techniques has shown a tendency which is predominantly based on the use of natural approaches and on moderate engineering techniques to preserve the environment and to reduce the impact of urbanization. (DIETZ, 2007)

The impact of SUDS implemented in UK accompanied by blue-green infrastructure (BGI) has resulted in many benefits. The effect of BGI is to enhance the quality of the urban environment by carbon sequestration, air pollutant absorption and improvement of the biodiversity. (MOLLA, 2015)

Implementation of both of these natural approaches to manage the surface water in Killingworth and Longbenton has resulted in wide array of benefits, such as reduction of damages caused by flooding by up to £50 million over a 100-year period, followed by water quality improvement, reduction of air pollution, increase in biodiversity and increase in the price of property. (O'DONNELL, et al., 2018)

The Waterloo urban catchment in London has been studied in order to assess SUDS adaptation measures during flooding and in conditions of pronounced climate change. The authors aimed to compare real option measures and fixed adaption approaches using a model which simulates flooding and rainfall intensity alteration. Real options are flexible measures that take into consideration investment changes under different circumstances. Authors conclude that real options approach achieves a bigger advantage than fixed adaptation approach. This occurs due to higher costs of adaptation measures, though benefits of real options approach is reduced when the drainage capacity of SUDS measures decreases. The results obtained from the case study indicate that real options approach is able to handle the uncertainty of climate change during assessments made by SUDS measures for surface water flood risk management (LIU & WANG, 2018)

A study from Scandinavia has shown that Norway is a country with low flood prevention compared to other Scandinavian countries. This conclusion was made due to the observation that the focus of the Norwegian authorities was oriented on Waste Water Treatment Plant (WWTP) while other countries were taking into consideration the implementation of SUDS. (TORGERSEN, et al., 2014)

Orientation of surface water management towards a natural solution has resulted in major changes in the UK, which has resulted in inclusion of SUDS in development policies of different national institutions. (CIRIA, 2015)

"IBA Emscher Park" in Germany was one of the first places where SUDS objectives were introduced as stormwater management measures. Implementation of SUDS objectives has been successful, especially when using infiltration measures. (HOYER & DICKHAUT, 2011)

Implementation of SUDS techniques depends on site condition. These techniques can be divided in following groups:

- Prevention- applying the individual site approaches to prevent flood and pollution.
- Source Control- treating and controlling runoff by catching the rainfall as close as possible. The measures which contribute here are rain harvesting, green roof, green areas, permeable pavements.
- Site Control- providing measures for catchment and manage stormwater. This group includes measures obtained during rainwater harvesting and infiltration, after which stormwater is released in water bodies.
- Regional Control- providing measures that manage runoff from several sites in order to catch, treat and reuse stormwater. (ESTONIA-LATIVIA, 2013)

The SUDS components are rainwater harvesting systems, green roofs, infiltration systems, filter strips, filter drains, swales, bioretention systems, trees, pervious pavements, attenuation storage tanks, detention basins, ponds and wetlands. In the next chapter, each of them will be treated in a comprehensive way.

One of the main objectives of SUDS is to reduce the pressure of flow into existing sewerage drainage. Therefore, during the SUDS designing process, it is essential to understand the process of sewerage and the site condition.

The designing process is challenging because site characteristics are not always identical. The proposal for designing SUDS at any inappropriate situation can be found below:

Floodplains sites cannot be managed by SUDS. However, management of routine rainfall in these sites can be effective in designing SUDS if grading and creation of surface features are limited and the discharge will disappear in different directions. Areas with high groundwater

level must determine the depth of the water table in order to protect it from contamination. In cases when results show high levels of groundwater, the infiltration should be avoided by using above surface SUDS measures. Also, if groundwater resources are protected, then discussion with Environmental Agencies will lead to the selection of the technique.
In areas with poor permeability in which there is no chance for infiltration to occur even at greater depth, the focus of SUDS designing must be oriented in treating runoff above ground. (KKC, n.d.) The SUDS design should not be considered in the contaminated area.
When SUDS requires designing in places that are already constructed and developed, it’s important to understand the existing drainage system, its capacity and the topography of the location where the techniques are allowed to be implemented.

3.2.1 Legal framework and national policy for SUDS

The legal framework comprising the different government institutions and municipality management office that are in charge of the environment, water, sewerage flooding must be arranged working together toward sustainability. (MIGUEZ & VER, 2012) The lack of cooperation between responsible institutions for each component of SUDS has resulted in many problems during designing and implementing the techniques according to Stahre. (CHARLESWORTH & BOOTH, 2017)
The SUDS designing, it’s a multidisciplinary system which seeks for a detailed development plan to address the environmental, social, economic, technical condition including the participation of policymakers, technical experts, stakeholders.
The main important driver that affects the SUDS in order to be practiced and accepted it can achieve by including the techniques of SUDS in urban developing plan of the cities. This plan must define every component and required data that are necessary for the techniques of SUDS in order to be designed and implemented. Also, it is important to include this approach in the flooding preventing plans, environmental protection plans, and water resources management plans. The responsibility of maintained after implementing the techniques it is crucial to be defined, due to the fact that the gap between responsibilities has resulted many times in decreasing the benefits of SUDS.

III. The SUDS Techniques -Designing and Implementing

4.1 Rainwater Harvesting Systems

Rainwater harvesting system (RWH) is a technique of SUDS which as a part of source control plays an important role in catching the stormwater mainly from the roof during heavy rainfall events. This system can have a twofold function. Besides providing a measure to reduce runoff peak, it can serve as rainwater storage to ensure water for domestic use, mainly for laundry and toilet. (OBC, 2010)

RWH implementing has resulted successfully in cases when there is no separated stormwater system, by reducing runoff and pressure in the sewerage system and preventing the sewerage outflow. (ESTONIA-LATIVIA, 2013) It is important to mention that RW cannot help solo in stormwater management due to the limited capacity in storage.

According to CIRIA, RWH benefits are:

- RWH can meet some of the building water demand for domestic use
- It can reduce the volume of runoff from a site
- It helps to reduce the volume of attenuation storage required on the site. (CIRIA, 2015)

The RWH is considered to view as a sustainable solution especially in developing countries where the water access is low also the fewer groundwater sources fail to meet the water demands. RWH can contribute to mitigate the city’s water demands and serve as a secondary solution until the main water supply will be ensured. Many studies have shown that the continuous usage of rainwater in order to meet the daily demands increase the rainfall capture by creating space in the storage tank for future events. (DOMENECH & SAURI, 201) Thereby, a balance between runoff and water exploitation would be reached.

The rainwater storage with minimum treatment can have a wide range of domestic usage as for wash machines, toilets, irrigation, car washing. Regarding the usage, the particular treatment system of RWH will be chosen. The storage tank can place on the roof or underground.

The design and use of RWH depend on the local precipitations amount and their distribution during the year. The storage capacity its mainly influenced by the roof surface dimensions that serve for rainfall capture.

The RWH system are divided in three types: gravity system, pumped system and composite system. (CIRIA, 2015) The gravity system provides a water supply for domestic use from rainwater storage tank located on the roof from where the rain water is captured. In low elevations buildings, the storage tank can be located on the ground and serve as water supplier for the first floor and other demands like irrigation or for other washing purposes.
The pumped system its commonly used when rainwater storage tank its situated underground. Composite system uses the advantages of gravity and pumped system. It takes the rainwater by gravity in storage tank while in case of the excessive runoff the rainwater its stored in underground tank.

The harvesting system has shown a high range of usage in many states that face water scarcity which by using the treated rain water that is stored in the system have reuse for further domestic purposes as a main source of water supply.

This practice has been used in the developing countries also where the drought period was affecting their water resources. (CAMPISANO, et al., 2017) In Canada the rainwater usage is determined according to the building law which allow the rainwater to be used for toilet and urinal flushing. (OBC, 2010) The ability to reduce the runoff, peak discharge rate downstream by storing the water has been some of the benefits of this practice. There are difference range of values of runoff reduction that many authors have revealed. According to (FARAHBAKHSH & DESPINS, 2009) the harvesting system has shown a decreasing runoff of 89% in Ontario

It is also important where is located the cistern and what is the dynamic of precipitation at the place that will be used.

The benefit of using the stored rain water for irrigation purposes especially during the summer, this practice had also showed the economic benefit of the system. (TRCA, 2010)

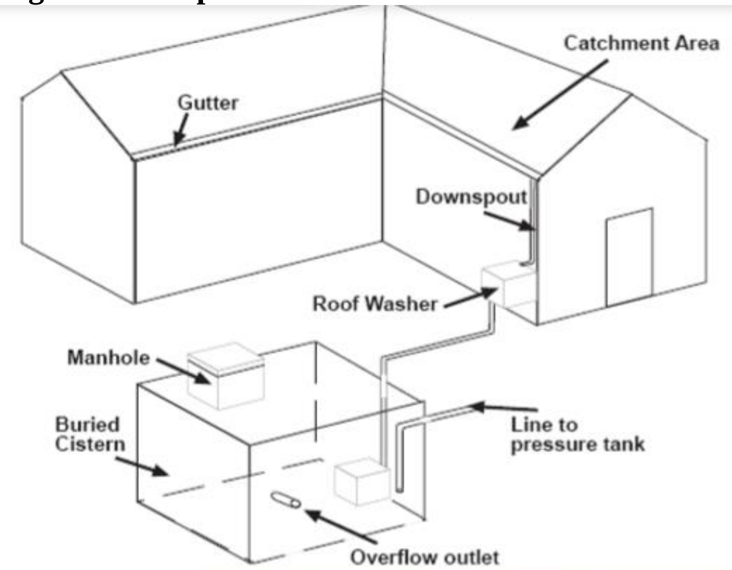
RWH implementing may has not a direct impact in biodiversity but by reducing the flow in downstream areas can help them to increase the biodiversity.

4.1.1 Design and Components

According to (OBC, 2010)here are six components taking part on RWH designing:

- Catchment area;
- Collection and conveyance system;
- Pre-treatment system;
- Storage tank;
- Distribution system;
- Overflow system.

Figure 6. Components of a residential rainwater harvesting cistern system



Source: Low Impact Development Stormwater Management Planning and Design Guide

The catchment area it's the place where the rain falls and captured. It usually reefers to roof but can also be other sources like parking lots and walkways.

4.1.2 Limitations

The SUDS guidance and different papers have listed some of the limitations of RWH usage. One of the main concerns is about the cost of maintenance and installation

The maintenance of the system in order to ensure the quality of water is crucial for RWH. A study made in a school has revealed that the water quality was deteriorating by contamination due to the absence of maintenance. (LEE, et al., 2016) Also due to the lack of maintenance condition the mosquitos can affect the system, by using as their favourite place during the summer. The study that has compared and evaluated the RWH for 4 countries has come in the conclusion that the further studies should be more focused on studying the maintenance aspects in order to define and provide more detailed information how can affect the quality of collected rainwater. Due to the fact that many people are sceptic about its benefits the support of social-political can impact that this system to be accepted. (CAMPISANO, et al., 2017)

The seasonal condition is the main factor that defines the location of RWH, due to the fact that winter season will affect the system causing the problem like freezing. The underground located system has the benefit to not be affected by the session and many of the other external factors.

4.2 Green Roof

Green roofs are natural practices that promote vegetated surface layers installed in the top of the buildings providing multi-beneficial functions. (CIRIA, 2015) The design of the green roof mimics the natural processes in order to ensure a sustainable stormwater management approach. By using the vegetation layers, the runoff peaks are delayed, reduced and retained. Additionally, the green roofs provide an energy use reduction, increase in evapotranspiration, reduction of urban heat and also, represent a new niche for biodiversity. (TRCA, 2010) It is one of the best practices of SUDS, especially in high-density areas where soil condition cannot support infiltration or where contamination sites do not allow infiltration. Green roofs are divided into two categories: extensive roofs and intensives roofs.

- Extensive roofs found a wide spread of using because of their low requirements of maintaining. They consist of a thin layer, maximum 15 centimetres, lightweight and suitable to be implemented at any kind of building roofs with wide range of slope compare to intensive roofs. (except the ones with a slope more than 20 degrees should provide protective measures). (EDMONTON, 2014)The designing of extensive roof aims to support biodiversity of plants with low demands that can grow and survive in many disturbances like grasses, mosses and some tolerant other species. The low maintenance cost has made this category to find implementing on a large scale at roofs of many cities. In particular, in highly urbanized cities where climate and soil condition cannot support the water cycle and vegetation, the intensive green roofs have shown a significant impact in a sustainable approach. Also due to the lightweight layer, the extensive roofs can find implemented as retrofitting.
- Intensive roofs are used to create a recreational space for people, but also to offer the appropriate conditions for the growth of different plants. In other words, it can be referred to as a roof garden where many species are able to grow including trees, grass, and different plants. Due to high biodiversity and large habitats, this practice demands a deeper soil, higher than 15 cm which must be consistently maintained. (GRO, 2014) The use of the deep soil layer induces the capability of intensive roofs to retain a high amount of rainwater and contributes in runoff decrease. The intensive green roof are more appropriate in flat roofs.

(EDMONTON, 2014)The high cost of irrigation and maintenance means that this practice can be implemented mainly in commercial buildings. The heavy soil layer prevents intensive roofs to be implemented as retrofitting, while at the same time intensive roofs offer high thermal protection (STOVIN & SWAN, 2007). For many years, the intensive roofs have continued to be implemented as the best sustainable approach which provides recreation and amenity benefits in many cities that are seeking an adaptation techniques in response to the impact of high urbanization. impact. (CIRIA, 2015)

4.2.1 Design and Components

Green roof can be installed in many types of the roofs of new buildings, including those built in different site conditions. It is one of the SUDS components that can be incorporated almost in any urbanized area, where there is an intention to implement natural approaches. Green roofs may be limited in their application for rainwater retention in cases characterized with high slope and big weight of installations. Some studies have shown that an increase in slope can cause an expansion in the amount of green roof runoff whilst other studies do not show any relationship between slope and water retention in green roofs. The best results are achieved when slope of the roof is between 5 and 20 degrees. (BERNDTRSSON, 2009)
This is a moderate slope that allows rainwater to be drained by gravity and at the same time the capacity of runoff reduction will remain rational. (HINNMAN, 2005)
Large roofs are the main focus of stormwater management due to the amount of runoff reduction and retention from large storage capacity. Green roofs are considered also to be installed as retrofitting in an existing building where its structure capacity and slope allows (STOVIN & SWAN, 2007) A study that has evaluated the benefits in using the SUDS practices in combination with conventional system that cannot cope with expansion needs has resulted more cost effective and less disruptive during construction. (ASHLEY & BLACKWOOD, 2000)

The rainwater retention and runoff reduction in mitigating the impact of urbanization has been shown to be successful by implementing green roofs in many cities. During the storm event, the water will be intercepted by the plant layer, then it will infiltrate and get retained in the soil and stored in the drainage layer while the moister will lose by evapotranspiration. (STOVIN, 2010) Thus, the significant factors resulting in effective application of green roofs are the thickness of the growing medium, type of drainage, storage capacity, vegetation layer cover, the volume of rain events, dry events and slope. (VIJAYARAGHAVAN, 2016)

Fig 6. Shows the components of the green roof which are used during installation. These components are dependent on the location and by environmental demands. Each of its components plays an important role in the effect of the green roof, notably the appropriate relation between these components and external factors indicate a higher result of successful implementation. Many studies have shown that the combination of reduced slope and deeper media clearly reduced the total quantity of runoff.

The vegetation plays a significant role which does not only reduce the amount of stormwater runoff but also extends its duration over a period of time beyond the actual rain event.

Figure 7. Schematics of different green roof components.

Source: Green roofs: A critical review on the role of components, benefits, limitations and trends

Many studies have shown that the combination of reduced slope and deeper media clearly reduced the total quantity of runoff. The vegetation plays a significant role which does not only reduce the amount of stormwater runoff but also extends its duration over a period of time beyond the actual rain event. (VANWOERT, et al., 2005)

The substantial role of vegetation in hydrological processes, by means of evapotranspiration, has been known for many years. The amount of evapotranspiration depends from climatic conditions and vegetation type. During the winter period that is accompanied by wet medium condition, the evaporation will significantly decrease resulting in lower retention capacity of green roof, thus is important to plant less demanded species. (NAGASE & DUNETT, 2012)

Various studies have shown the importance of using native plants. Environmental Protection Agency (EPA) in the United States (2012) has claimed that native plants adapt to local conditions; once they are established, they do not need watering, fertilizers or pesticides. Also, they restore the ecosystem while providing beneficial conditions in ecology. There are also other studies claiming that planting and maintaining native species can be challenging due to the invasive species (LI & YEUNG, 2014). The most important condition is choosing the tolerant species that are adaptive and remain successful even after many local disturbances. Hence, Sedum species is often regarded as an ideal choice for planting on green roofs because of its properties to survive a long period without water. (VANWOERT, 2005)Yet, it is also important to plant species that are adaptive to variations of solar radiation.

The rainwater retention and runoff reduction its highly influenced by climatic condition, rainfall events, and soil depth. Values of the reduction of stormwater differ between studies with various conditions. Kolb (2004) reported that green roofs reduced annual runoff by 45–70%, Moran et al. (2004) report 60% total rainfall retention and an 85% reduction in peak flow rate. (STOVIN, 2010) Also, Bengtsson(2005) cited at (BERNDTRSSON, 2009) have defined the roof water storage capacity is the filed capacity minus wilting point, while according to observations has shown that a field capacity 45% and wilting point 15% corresponds with great retention There are many different studies that have agree with Bengtsson.

Another study has shown he relationship between depth of rainfall and percentage of rainwater retention which results in 88% retention of storm amount smaller than 25.4mm, 54% retention for storms 25.4-76.2 mm and 48% for large storms. (CARTER & RASMUSSEN, 2005) The amount of storm 10 mm or lower is completely retained by the green roof. (SIMMONS & GARDINER, 2008) Many studies unanimously state that the green roof influences the runoff peak by reduction and retention, while their influence in rainfall peak is more modest. However, retention is dependent upon antecedent moisture conditions. If there would be repeated rain events, the retention capability will decrease almost zero. (STOVIN, 2010) Thereby, green roofs may result in more effective management of moderate storms with long dry periods in highly developed areas where other techniques are limited in scope. Otherwise, these techniques should be seen as an aid to conventional stormwater system

The beneficial effects in mitigating the impact of heavy urbanization has resulted in rapid spread of green roof installations in many cities around the world. Germany was the first country to take the initiative for considering this practice as a sustainable approach. Recently, in Germany, the green roof coverage has increased continuously by approximately 13.5 million m2 per year (SAADATIAN & K.SOPIAN, 2013). Basel green roof coverage has reached 15%, while in Toronto, the law states that all new building with roof surface ≥2000m2 are obligates to install green roof on 20-60% of their area. (CHEN, 2013)

Regarding the quality of runoff water, many studies conclude that the difference in water quality from different green roof installations persists due to the installation process and maintenance. Even though rainwater is considered as a generally clean water, studies claim that except for nitrates, a lot of other pollutants like heavy metal and pesticides are found in different green roof runoffs. The main factors influencing green runoff purity are: type of the material being used, soil thickness, type of drainage, maintenance, type of vegetation, dynamic of precipitations, wind direction. (BERNDTRSSON, 2009) A study in Toronto has compared the amount of runoff contamination between the green roof and conventional roof within the same area which resulted in less load of contaminants in the green roof. (SETERS, et al., 2009)The first flush runoff effect should also be considered in evaluating green roof performance. The first flush runoff will always be considered more polluted due to the long period of dryness. The roof surface can be contained by atmospheric particles and vegetations debris. (BERNDTRSSON, 2009)

The fact that green roof has proven its capability to reduce runoff means that the potential for reduction of runoff contamination is to be expected. There are no hard-proof data in relation to the exact amount of pollution that can be reduced by green roofs. Hence, it's expected that future studies should focus more on the quality of green runoff in different circumstances, and not just in the amount of reduction of runoff.

Another beneficial effect of green roofs is the improvement of thermal effect in buildings especially during winter period. However, in the summer season, a lot of studies have shown reduction of the energy utilized for cooling, whereas during winter, the debate whether consumption effects are higher than the reduction energy are still present among (VIJAYARAGHAVAN, 2016).

4.2.2 Limitations

For many decades green roof installations have been used extensively as one of the most sustainable practice in order to mitigate the impact of urbanization and climate change. Still, limitations regarding future perspectives allow room for debate and improvement.

Due to its positive effects in rainwater retention, the use of green roof has been listed a successful practice in this respect, but if one takes into consideration that the stored water adds extra weight to the roof structure, it is imperative to find materials relevant to the appropriate requirements. (BIANCHINI & KasunHEWAGE, 2012)

According to (TRCA, 2010) guidelines, it is evaluated that maintained cost of vegetation, and water damage to roof should be seen as the mainly limitations. Considering that extensive roof offers a low maintained coast due to the vegetation demands, selectin them for implementation can attenuate this limitation. Whilst, for the failure of waterproofing elements a warranty it is always need in order to ensure that damage of water proof can be damage because otherwise can cause higher damages to the roof structure.

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4.3 Swales

Swales are the best practice of SUDS that by using the vegetated shallow canals may help to reduce the peak flow, improve the quality of water and increase the groundwater recharge. The usage of this practice also contributes to biodiversity and amenity of the area where is implemented when the flow of deep water is designed in order to preserve the quality of stormwater. Swales can replace the conventional pipes work by using the vegetation, mainly grass to slow the water flow, facilitating the sedimentation and enhancing the infiltration through the root zone.

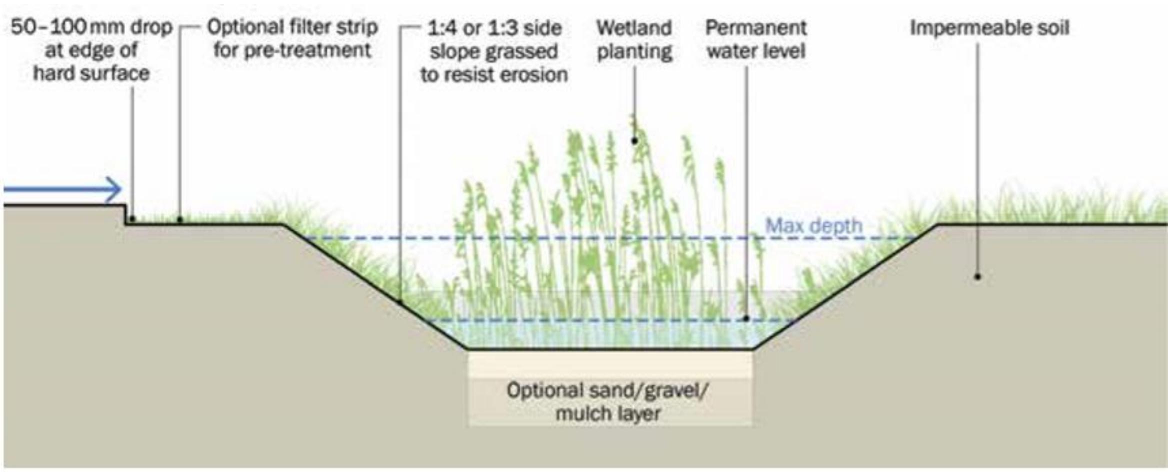
In cases where infiltration is limited due to the high level of groundwater or to prevent groundwater pollution, the impermeable layer of geotextile can be used under the bed system. In the zones with higher slopes, the dam can be used to decrease the velocity and increase pollution retention through sedimentation and maximize the infiltration where it is allowed. Low cost of installation compared to the conventional pipes, the easy maintenance, the practice approach of integration in spaces, and their effectiveness to remove the pollutants has shown some of the best advantages of this practice. (CIRIA, 2015)

According to (EDMONTON, 2014)the evaluation of runoff reduction efficiencies by using the practice of SUDS in Canada and the USA has resulted in 40-80% of reduction and has shown the good range to remove the pollution components and the total removal of bacteria. While another study in California after evaluating the runoff reduction by using swales have concluded that 27-41% is the total runoff reduction in their studied areas. Another recent study about runoff pollution in China has resulted in high effectiveness in reducing the thermal impact of urban stormwater runoff by using swale. (LI, et al., 2018)

Many authors claim that their effects in the stormwater management may be derived by the soil components, the terrain topography and the hydrological conditions designs, and maintenance. The swales can be dived as wet swales, dry swales and small vegetated swales that convey and treat a moderate rainfall event. (CIRIA, 2015)

4.3.1 Design and Components

Figure 8. The components of swales body



Source: CIRIA, 2015.

The design of vegetated swales is the main driver that affect their effectiveness. They usually have a trapezoidal shape with a shallow deep and a moderate slope.

According to (CIRIA, 2015) guidelines for swale designing, it is defined as the limitation for bottom width of 0.5-2m. The wider or narrow swale can be used but always the shallow flows must be provided in order to preserve the quality of water treatment and to prevent flows that cause erosion. The (TRCA, 2010) guidelines for swale designing suggest the bottom width of grass swales must be 0.75-3m while the treatment of water quality by allowing the shallow flows is also mentioned.

The (ESTONIA-LATIVIA, 2013) suggests that for swale that is built with a higher gradient, the bottom and the sides need to be reinforced. While the side slopes must be strengthened 0.1-0.2 m above the water level. Longitudinal slopes should be between 0.5% and 4% and if the slope exceeds 3%, the dam must be included (TRCA, 2010). The (CIRIA, 2015)defines a longitudinal slope for designing the swales which must be 0.5-6% and it is also mentioned that the dam must be incorporated if the slopes are bigger than 3%. If the swales are built with slope bigger than 5%, they are called chutes and their bottom should be made by concrete. All the guidelines agree that the side slopes should be as flat as possible with maximum slope of 1:3 -1:4 in order to prevent the erosion.

The maximum swale depth must be 0.4-0.6 m (CIRIA, 2015)or 0.3-0.4m or (ESTONIA-LATIVIA, 2013)The higher deep requires more advanced design and result in a higher cost. But within limitation values, the depth can be chosen according to the space and the purpose of implementation.

According to the hydraulic components design, it is the part of the swales implementation where takes the main focus. Due to the fact that swales should be able to convey the excessive runoff according to space at which is constructed is based in the rainfall events of those areas. SIDS suggests that the designed runoff volume should be empty within 24 h in order to ensure storage and treatment for further rainfall events.

The vegetation consists mainly of grasses which play the main role in infiltration during the peak rainfall must be designed and maintained to 0.075-0.15m height. (all)

The depth of flow should be maintained below vegetation with a maximum 0.1m (CIRIA, 2015) while the (TRCA, 2010)defines a maximum depth 0.15m. The maximum velocity limits altering about 0.3-0.5 m/s, which is strongly depended by the slope and soil conditions. Thereby, the maximum time for runoff conveyed along the swale must be at least 9 minutes. The reduction of peak flow can be strongly related to the slope of the swales, thus if designing it is made for this purpose the slope must be smaller than 1.5% (CIRIA, 2015)

The design of swales according to the runoff events volume it is defined from 4 hours to 6 hours.

Regarding biodiversity, swales can provide a range of variate plants of using which will improve the biodiversity of the plant in the area of implementation. The usage of native plants is always proposed due to the capability of them to adapt to the climate condition of places that are intended to implement.

It is crucial to determine the level of underground water where swales are intended to implement because the infiltration is not allowed if the water level below the base it smaller than 1m. (CIRIA, 2015)

According to (TRCA, 2010)after 10 years monitoring resulted that swales do not contaminate the undersoil even after this time period.

It also should avoid the places where are dense with trees due to the shade created which prevents the vegetation of swales to growth. The swales are mainly used to convey runoff along the roads and from the parking place.

4.3.2 Limitations

As every practice of SUDS also the swales show some limitation conditions in designing, implementation, and maintenance.

The risk of contamination it always exists if the treatment of runoff is not made according to hydraulic design for water quality. Even in cases where the hydraulic design limitations are taking into consideration, the swales implementation must be avoided in places that have resulted contaminated in groundwater and near the roads with high traffic.

It is important to use the send imitation pre-treatment to avoid the runoff pollution.

The risk for mosquitos it always exists in the natural practices, but if the design of swales it's made according to standards and the swale will be empty after 24h this risk will be avoided. (TRCA, 2010)

The other SUDS practices like the pond, wetlands, canals, bioretention systems, infiltration systems, filter strips, filter drains will not be evaluated in this thesis due to the missing data about groundwater level and their quality in the studied area. Also, the data about the rainfall maximum intensity for the long period of time it is one of limitation for the some of not evaluated techniques.

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IV. The analysis of environment in Kosovo

5.1 Introduction

Kosovo is a small and young country located in south-eastern part of Europe covering an area of 10 870 km². The estimated total population number in 2017 was 1 798 506 resident inhabitants with 80% of albanian ethnicity followed by serbs as the largest minority. (KWS, 2017) The range of distribution in rural areas is around 60%, with others living in urban areas. (ASK, 2017)
Nature in Kosovo is mainly dominated by mountains, which make 44% of its total area. The highest point is 2656m while the lowest point is 297m. The climate is mid-continental, characterised with cold/wet winters and hot/dry summers. The annual average rainfall is 596mm which occurs mainly during the winter and is characterized with an uneven range of distribution within the country. (AKS, 2017)
Since 1999, after the war period, Kosovo was under the protectorate of UNMIK (United Nation Mission in Kosovo) while in 2008 it has declared independence.

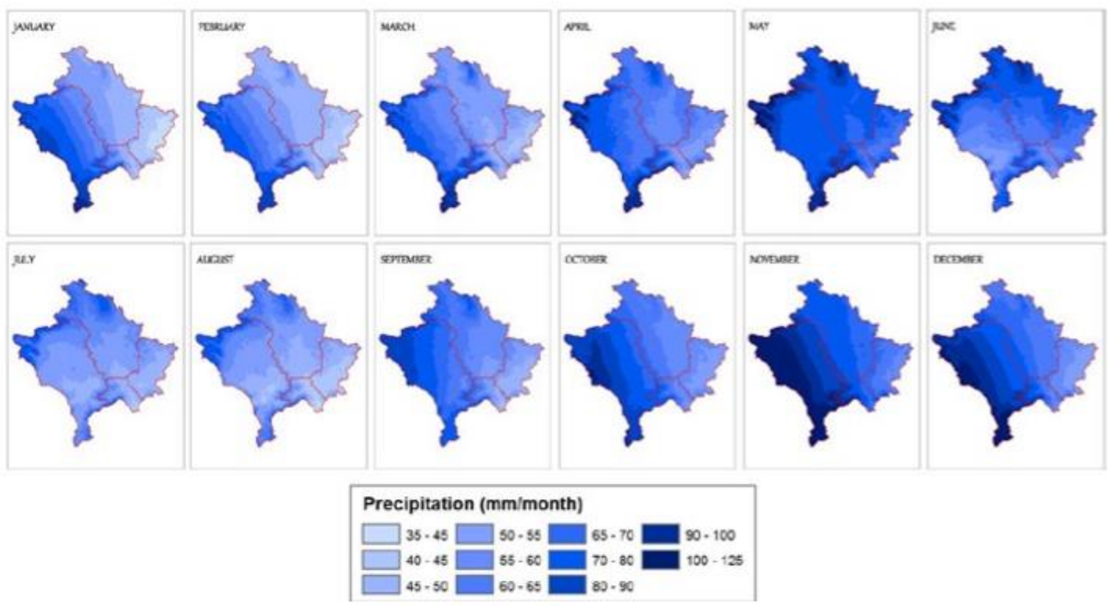
In the period of time until 1999, when the state was under the serbian regime, investment in infrastructure was sparse, mainly in rural areas.

The post-war period transition lead the country to enter in a very difficult economic, political and social situation while their consequences have affected mostly the natural resources. Considering the fact that during the war most parts of the country were destructed, the trend of construction has rapidly expanded, becoming one of the most profitable business. The lack of law construction enforcement was used by the business community to expand their activity in disrespect of the law and planned standards. Many buildings have failed to meet essential requirements regarding the environmental protection. On the other side, due to the social and economic pressure (until 2007, the 47% of the population has been living in poverty), the government priorities were focused more in finding fast solutions without planning a long-term strategy (KORCA, 2007). Since construction was becoming the most profitable business employing many citizens, responsible institutions did not find it suitable to prevent the rate of constructions for many years. Consequently, natural resources have been threatened by uncontrolled exploitation followed by a lack of proper management and lack of investments. The water scarcity has created a situation in which there is limited access to potable and domestic water for many inhabitants of Kosovo. In recent years the focus of institutions has begun to shift towards a sustainable solution for management of natural resources. Yet, the long-term period of negligence in protecting natural resources has created a need for inclusion of many sectors in creating a detailed strategic plan for sustainable management for the future.

5.1.1 Water resources management

Kosovo has limited water resources compared to its neighbouring countries. The FAO Aqustat report states that Kosovo has about 1600 m³ total renewable water resources per year, which comprise only 16% of the regional average. (WB, 2018). The uneven range of distribution of rainfall in Kosovo has resulted in drought and flood events occurring within one year.

Figure 9. The distribution of monthly average precipitations in Kosovo



Source: Kosovo Water Security Outlook Report, 2018

The water resources are divided into four main river basins, with a total surface of 10 907km² flowing toward the Adriatic Sea, Black Sea, and the Aegean Sea. (KWS, 2017) They are characterized with moderate flow range while many of reports have unveiled many components that contribute to river pollution. (WB, 2018)

This condition is triggered by the lack of wastewater treatment and by the lack of wastewater collection from villages in the sewerage system.

There are 5 artificial lakes in Kosovo which are the main suppliers of potable and domestic water through the water system pipes along the country. Total accumulation of these rivers is 565 million cubic meters. (AMMK, 2015) Water level in these rivers alters during the year, while the lowest level of water is experienced during the summer causing major stress in the water supply. Considering that these basins are the only water suppliers in Kosovo, the damage caused by decreasing the water level is crucial. Since 2004, 80% of municipalities in Kosovo have suffered from water outages due to the decrease in water levels in water reservoirs. (EARLY, 2014)

For many kosovar citizens, water outages during the summer have become normal. Their daily activities are continually affected in different ways. Additionally, many of business activities in cities have been affected by water outages, resulting in profit losses

As previously mentioned, more than half of the population lives in the village, where agriculture is the main activity. Many crops have already been damaged and failed to produce high harvest due to the reduction of irrigation during peak of germination time. This situation has caused high income losses, contributing to poverty and orienting the country towards increase in import of many yields even though they could be produced in Kosovo.

The expansion of the water supply system has significantly increased last years. This shows a developing step in order to offer clean water to many villages. (AKS, 2017) On the other hand, efforts to create another water source or to manage existing water sources properly in order to meet the actual water demand have been negligible.

It is very logical that expansion of water supply network is not the appropriate decision, since it has failed to meet actual water demands.

Table 1. Percentage of households connected to water supply system

Year	Population[2]	Number of inhabitants connected to the public water supply systemk[3]	Number of inhabitants not connected to the public water supply system[3]	Connected to water supply %	Not connected to water supply %
2011[1]	1,780,021[1]	1,138,549[1]	641,472	63.96	36.20
2012	1,815,606	1,300,918	514,688	71.65	28.35
2013	1,820,631	1,362,967	457,664	74.86	25.14
2014	1,804,944	1,424,766	380,178	78.94	21.06
2015	1,771,604	1,550,558	221,046	87.52	12.48
2016	1,783,531	1,597,849	185,682	89.59	10.41

Source: Kosovo Agency of Statistics, 2017

The other important contributor to improperly management of water supply occurs due to head losses in pipe flow.
The water scarcity in Kosovo has had a crucial impact on ecosystem degradation as well. Regarding groundwater, there is no monitoring system for groundwater resources levels and quality in Kosovo. According to the Ministry of Environment, they are mainly located in the western part of the country. (AMMK, 2015). Villages in Kosovo that are supplied with water from their private underground wells have no information concerning the quality of water.

5.1.2 Waste water and stormwater management

The situation of wastewater management in Kosovo is even worse than water resources management, considering the fact that it is one of the major drivers with substantial impact on the water cycle throughout the country. Since the time that Kosovo was under the serbian regime, there was not a wastewater treatment plant for the sewerage system. The sewerage system and the individual wastewater (more than half of the country does not have access to sewerage systems) was conveyed directly to the river. (KWS, 2017) This practice has remained in place even after that period, which has led the country to face many problems like pollution and flow changes in the rivers, surface water pollutions, flooding, and ecosystem degradation. The sewerage system in Kosovo is a combined system that collects wastewater and rainwater through the same pipe. In many cases, the system is not constructed to cope with these two forms of water. As a consequence, the period with high intensity of rainfall in a short period of time causes many damages in infrastructure and increases the risk for the spread of many diseases.
According to the water report from the Institute of Statistics of Kosovo, in 2016 the sewerage system has expanded to collect 70% of the total wastewater discharge in the whole country. It is an evident difference compared to ten years ago when only 38% of the country discharged the wastewater into the sewerage system. (AKS, 2017)

Table 2. Percentage of wasterater collected in sewerage system in Kosovo

Year	Population[1)]	Number of residents in household connected in the network 2[)]	Number of residents in household not connected in the wastewater network	Connected in the network %	Not connected in the network %
2013	1,820,631	1,004,377	816,254	55.17	44.83
2014	1,804,944	1,057,144	747,800	58.57	41.43
2015	1,771,604	1,178,350	593,254	66.51	33.49
2016	1,783,531	1,233,298	550,233	69.15	30.85

Source: WSRA - Water Services Regulatory Authority, 2016

The Hydrometeorological Institute of Kosovo (IHMK) has not been functional for many years, thus it is not able to provide essential data for rainfall events for a period of time more than 10 years. Also, in the mountains, there is a lack of monitoring stations with snowpack gauges and this is important because most of the precipitations that cause flooding originate from high altitudes. Many foreign agencies have provided help in creating a program for prediction and detection of flood events, but IHMK is still not able to provide calculations for every part of the country due to the lack of professional staff (GIZ, 2001) On the other hand, government investments are prioritized towards expansion of infrastructure rather than monitoring and protecting water resources.

The design of sewerage system and other wastewater structures has been made according to collected data before the year 1990. This practice of designing is continuing even though many reports and foreign institutions claim that the dynamic of precipitations has changed due to the effect of climate change. In November 2016, many of municipalities of Kosovo were flooded as a result of heavy rain where many of families were evacuated from their houses. (BULLIQI & KASTRATI, 2014)

The illegal logging issue in the forest, which is another environmental threat for Kosovo has resulted in increased erosion and sedimentations. The decrease of the riverbed capacity to convey floods has been triggered due to sedimentation. (WB, 2018)

According to measurements, all rivers in Kosovo are polluted. The difference in the rate of pollution found in the rivers changes according to the quantity of wastewater discharge. Rivers that serve as the recipient of industrial wastewater have shown critical rates of pollution.

In recent years, four Kosovo villages have constructed wastewater treatment plants which treat a small amount of wastewater volume.

5.1.3 Impacts of climate change

Kosovo has been affected by drought periods many times during last years. Understanding the trend of improper management of natural resources, is crucial in predicting how will Kosovo experience the impact of climate change. According to United States Agency for International Development (USAID) report on climate change in Kosovo has projected that the main affected sectors will be: water resources, forests, agriculture, energy and infrastructure, human health. (USAID, 2017) The UNEP report has declared that according to their estimation snow days in Kosovo will decline to 50 days until 2015. Due to the increasing temperature, especially in the mountain, the fire disturbance in the forest has also been predicted. (WB, 2018)

5.1.4 Water management framework

The first environmental law in Kosovo after the war period was approved in 2003 while the Water Law was approved in 2004. This was the time when the country was under the protectorate of UNMIK. Over time, many strategies, developing plans and regulation plans were developed toward law enforcement. The responsible authorities for water management in Kosovo are the government, ministries, The Kosovo Inter-Ministerial Water Council, other governmental institutions and municipalities. Kosovo's laws are adapted in accordance with European Union laws. (KORCA, 2007)

The main concern about law enforcement through the years was the lack of defined responsibilities within institutions which has created a gap in law interpretations. This situation has been utilized mainly by business communities.

Considering that Kosovo is not a member of the world and European institutions of water, the detailed reports of monitoring data are not required, thus efforts for investing in these sectors are avoided.

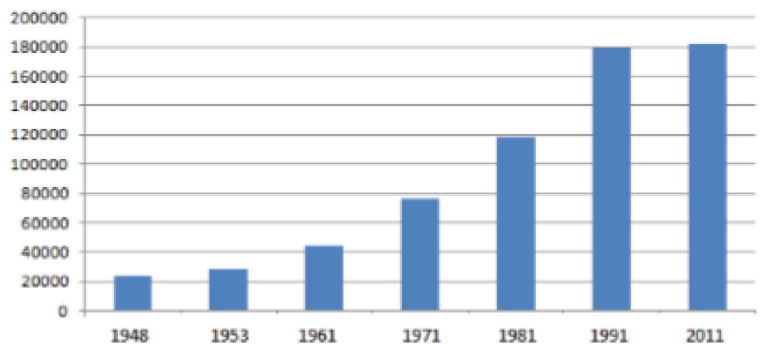
In recent years, the awareness of institutions towards law enforcement has resulted in increase of the monitoring and inspection capacity. The Kosovo Water Strategy 2017-2036 has shown a significant development in providing water policies, activities, and plans that can likely influence the improvement of natural resource management. For the first time strategies are being oriented toward SUDS measures as one of the best efforts in combating the impact of land use change during the years, the increase in trend of urbanizations and climate change impacts. But there is no specific detailed plan for using and developing SUDS techniques and their benefits for water resources management. This water strategy was drafted according to EU directives. If the actions and investments included in this draft will be implemented, the future of water resources in Kosovo will change in many dimensions.

5.2. Case study - Mat neighbourhood in Prishtina (Kosovo)

5.2.1 Introduction

Prishtina is the capital city of Kosovo, located in north-eastern part of country and covered an area of 7768.ha. It has a relief with an altitude from 535-730m. (Prishtina, 2012)
It is one of the most populated cities in Kosovo with a high population density compared to other cites in Kosovo. Considering that it is one of the most developed cities in Kosovo, the tendency of population to move to Prishtina has increased after year 2000. According to the statistical agency of Kosovo, it is estimated that 200 000 inhabitants live in the capital in 2017. (ASK, 2017) Yet, this number is not accurate when taking in consideration that around half of the population in Kosovo are working and studying in Prishtina. Thus, even though they are registered as inhabitants in their hometowns, during working days they mainly live in the capital, only to return back to their towns in weekends. This makes Prishtina a city with 400000 people living in the capital most of their time. (BIRN, 2014)
The diagram below shows the increasing trend of population in the city over the years.

Figure 10. The growth of population in Prishtina during the years 1948-2011



Source: The Urban Development Plan in Prishtina for years 2012-2022

The infrastructure planning of the city was designed in 1950. In early calculations, engineers did not consider that the trend of population would increase by 100% so fast. Even though the planning was designed for 40 years, after 1990 Prishtina was in a very difficult situation under the serbian regime. After 2000 the development of the city has increased significantly. This is especially the case after the year 2007, when it occurred a succession of rapid constructions, where almost all the public buildings were under construction or were built as new ones. Residential buildings also had a rapid trend of construction leading Prishtina to be named as a construction zone. (BOUSSAUW, 2012) On the other hand, infrastructure has expanded along with buildings, without a preparatory plan. The construction business was considered as the main market in the city with the highest number of employments. Due to lack of investments in the other cities, the concentration of population was directed toward the capital.

In 2004 the Law of Spatial Planning was approved, followed by the Urban Planning Law and Regulatory Plan of Construction. Even though these laws are in place formally, illegal construction has been expanding rapidly. In a very short time Prishtina has become the worst nightmare for urban planners. (KONDIRNOLLI, 2017) The problem of urban planning has worsened in other aspects as well, such as corruption and business mafia, which were the main problems that Prishtina was trying to combat.

For many years the struggle against the corruption and uncontrolled construction has resulted unsuccessful. Until 2014, there were an estimated 46 000 illegal constructions in Prishtina. (KONDIRNOLLI, 2017). The same year, with the change of mayor of Prishtina, the trend of illegal construction has stopped, and the Law of Legalization for previous constructions was approved.

Now, Prishtina is suffering the consequences of all these law infringements for so many years. Water shortages, periods of flooding due to the incapacity of the sewerage system to convey the wastewater, air pollution, lack of green area, degradation of biodiversity, are some of the challenges that citizens in Prishtina are facing daily. This situation will become worse if new sustainable approaches are not taken into consideration in order to help the recovery of environment.

5.3 Mat neighbourhood

The area that will be studied in this thesis is located in Mat neighbourhood, the east part of Prishtina. It is the only area in this neighbourhood that has remained empty from illegal and legal constructions. The Mat neighbourhood is the most populated and built zone within Prishtina. The regulative plan of this zone approved in 2006 (Prishtina, 2006) was on the most horrible plans ever that Prishtina has experienced. Almost all of the constructions are destined as residential building. Due to the lack of urban planning there is a lack of public buildings like school, ambulance, and kindergarten which were not planned to be constructed in order to meet the resident demands.

The illegal constructions in this area are around 30%, while the permitted constructions do not respect the distance between buildings. As explained in the previous chapter, owners of construction companies were part of the corrupt system in Kosovo, thus the main purpose of constructions were to exploit every corner of the area in order to reach great profits. The permeable surface is almost absent in every part of this area by preventing infiltration and creating the condition in which total rainfall is being treated as a runoff. In addition, the situation is worsened by the lack of green areas, which affects the process of hydrological cycle by decreasing evapotranspiration and increasing the runoff even during rainfall events with moderate intensity.

Figure 11. Mat 1 neighbourhood 2006

Source: The Urban Regulatory Plan, Mati

Figure 12. Mat 1 neighbourhood 2015

Source: Google Maps (Recording in 2015)

The figure 11. shows the photo map of Mat neighborhood in 2006 while the Fig 12. shows the same photo map, taken in 2015. The highlighted red part in the second photo is the area that will be studied. The difference between photos shows the trend of construction during 9 years. As can be seen the second photo has more constructions nowadays.
The developing plan of the studied area was approved in 2015 and it is expected that it will finish by. (Prishtina, 2017) The procedure of bidding has finished with an agreement in place which states that this will be an investment between the municipality and a private company.

5.3.1 The water supply system

Water resources are considered limited in Prishtina. The main supplier for potable and domestic water in the city are basins of artificial lakes of Badovac and Batllava. The capacity of these two reservoirs has failed to meet the daily requirements of populations.(WB, 2018)

Table 3. Main Water Storage Reservoirs in Prishtina

Reservior	**Water flow (River)**	**Catchment**		**Total Volume**
		m^2	Live Storage	m^3
Batllave	Batllave	226.0	25.1	30
Badovac	Gracanke	103.0	20	26.4

Source: National Water Strategy 2017-2036

During the period 2007-2016, Prishtina has experienced water shortage every day. During the summer of 2014, which was registered as the driest season in history, the water level of the reservoirs drastically declined, which triggered an outage of water supply for16 hours per day(BIRN, 2014). The water company in Prishtina has claimed that the outage of water was the only solution in order to continue supplying water due to the fact that there was no other option for securing water. Illegal connections and excessive water consumption was the main justification of the responsible company for the unplanned situation that was affecting the quality of life in the city.
Indeed, the inappropriate management of water resources accompanied by rapid growth of the population were the main drivers that tuned this problem into a daily occurrence for Prishtina.
The Mat neighborhood is supplied with water from Badovac reservoirs.

In 2016, the project of third water treatment plant was constructed in Shkabaj, donated from the German Development Bank which has improved the situation and reduced water outage. The newest water treatment plant has the capacity to process 700 l/s of water. Currently, the situation with water supply system is stable but in case that water levels in reservoir will start to decline as a consequence of a drought period, then water shortages will return. The likelihood of this scenario is greater if one takes into consideration the trend of drought periods that are predicted to affect Kosovo in future years. If there will be no implentation of new sustainable solutions then consequences of water shortage will be worrisome.
The studied area in Mat neighbourhood has the potential to start applying SUDS practices, in order to catching the water and reuse it either for domestic purposes or irrigation facilities. Even though the HWS can be viewed as a great investment, still, preventive measures always result in lower cost, especially in cities such as Prishtina, where water resources should be treated with very careful consideration.

5.3.2 The sewerage system

The sewerage system in Mat neighbourhood serves for conveying the wastewater and rainwater into a combined system. The topographic terrain of the location has made possible for discharge of sewerage system to flow by gravity. The mixed water and rainwater are discharged into the main collector from where they are released directly in the river Prishtina. Once upon a time, this river was flowing through the city creating an aesthetic pleasure. But this can be mentioned only as a historical fact because now the river has turned into the main sewerage system collector. Nowadays, Prishtina river is flowing underneath, collecting the wastewater and rainwater from every objects and the road nearby. The river then continues flowing out of the city toward two villages and gets discharged in Sitnica river as its final destination. In other words, the wastewater of Prishtina is becoming the groundwater of these two villages. (SWENEEY, 2017) . The lack of investment in construction of wastewater treatment plant has made the Sitnica river to be ranked as the most polluted river in Kosovo. Additionally, the river pollution is not the only concern, but also the likelihood that the groundwater will get polluted. According to the Ministry of Environmental and Spatial Planning (MMPH) the groundwater in Prishtina is not polluted (AMMK, 2015). Considering the fact that in Kosovo there is no existing groundwater monitoring system that measures every change in the groundwater, MMPH conclusions seem doubtful in their reliability.

The problem of overflowing sewerage manholes during the period of heavy rains is the main concern of Mat neighbourhood inhabitants. This condition results in flooding of inhabited buildings with toxic sewage-runoff mixture, causing minor flooding to parking, obstruction to traffic and creates an unpleasant situation. According to rain intensity data Prishtina does not sufffer from high rain intensity events that might be the cause of this situation. Inadequate dimension of pipes make it impossible for this neghbourhood to cope with all the wastewater and rainwater. Also, the impermeable surface that prevents rain infiltration and delays runoff, is an important driver of this condition.

The presented photo below is one of the events that is repeated during heavy rain days.

Figure 13. The over flowing sewereage system manhole in Mat neighborhood.

Source: Metro newspaper, Prishtina, 2018.

As mentioned previously, the discharge of sewerage system is oriented by flow of gravity. Therefore, buildings situated in lower altitude and the main road that connects the neighbourhood with the city centre are affected by the sewer overflow because the main collector is located there.

The studied area that is planned to be built is located at the upper part of the neighbourhood, which means that will be an extra factor loading the sewerage system and precipitating conditions for overflow.

The planner's argument that pipes will be dimensioned separately for wastewater and rainwater is meaningless due to the fact the two-sewerage system will release in the main collector which is already under pressure. The highest registered values of precipitation in Prishtina for 24 hours is 71mm and 25mm for 3 hours. (IFRC, 2017) The drought condition related with rain accumulation was measured by the standardised precipitation index (SPI). In order to evaluate the situation for a long period of time, data for the period 1926/1949-

2016 were used. The SPI values in 2016 have shown that, during November, Prishtina exceeds the limited values which are in the levels considered as sufficient wet conditions, while in December, Prishtina suffers from a deficit in rain conditions.
Hence, the effort in seeking other solutions that will reduce and delay the runoff, and increase the permeable surfaces is crucial for the new construction area. If the practice of discharging the sewerage system will remain the same even for another 21ha covered area that is planned to be build, then severe consequences will occur.

5.3.3 The Sitnica river conditions

According to the EU standards for heavy metals, metals found in Sitnica river have not exceeded these standards, except for nickel, lead and cadmium (Kosovo water strategy report. (KWS, 2017)
On the other hand, another published paper that has measured and evaluated pollution components in Sitnica river has shown that the concentration of heavy metals found in the river exceeds maximum values. Based on these results, authors claim that the need to construct the wastewater treatment plant and seeking other environmental approaches must be undertaken as soon as possible. (SHALA & SALLAKU, 2014)
The table below shows the levels of biological and physical components found in the Sitnica river.

Table 4. Results of physical and chemical parameters in Sitnica River.

Parameters	Units	Station														
		Devetak (S1)			Gracka (S2)			Plemetin (S3)			Pestova (S4)			Mitrovica (S5)		
		Sp	Su	A	Sp	Su	A	Sp	Su	A	Sp	Su	A	Sp	Su	A
Temperature	°C	6.4	14.9	10.2	12.7	21.2	14.7	13.2	19.9	15.5	12.4	21.6	14.6	12.6	22.2	15.0
Turbidity	NTU	9.5	61	9.2	3.3	14.4	9.7	7.7	17.2	9.1	3.5	5.2	16.5	4.0	5.4	17.0
Conductivity	µScm-1	262	280	270	645	560	680	831	660	610	612	680	570	616	640	610
pH	0-14	7.99	7.85	8.20	7.75	7.25	7.514	7.80	8.27	7.58	7.78	7.66	7.76	7.76	7.48	7.56
Dissolved oxygen	mg/L	10.51	7.40	9.37	5.48	1.60	3.03	0.53	2.40	2.84	4.82	1.70	3.21	6.76	3.50	4.17
Chemical oxygen demand (COD)	mg/L	18.0	4.2	nd	30.0	57.0	65.5	26.4	56.0	58.2	11.3	72.5	76.9	12.8	93.0	105.4
Bio-chemical oxygen demand (BOD)	mg/L	8.5	1.9	<0.1	17.0	34.5	22.6	13.9	31.0	24.3	5.40	29.4	32.9	5.5	43.6	42.3
Total phosphor	mg/L	nd	0.053	<0.1	0.580	0.799	0.465	0.770	0.504	0.369	0.330	0.657	0.435	0.410	0.441	0.542
Nitrates	mg/L	nd	nd	nd	4.3	nd	0.3	nd	2.4	nd	6.5	5.9	6.3	6.7	9.9	11.2
Sulphate ion	mg/L	9.103	39.8	18.6	27.29	26.06	39.88	98.15	70.45	92.86	40.82	72.78	59.92	54.51	70.73	72.90

Source: The effect of Industrial and Agricultural activity on the water quality of Sitnica river

Furthermore, the vegetation crowds the river bank? while the flora and fauna have gone extincted in Sitnica river.

The construction of the wastewater treatment plant in Prishtina with a cost of about 66 million euros has started last year and is expected to finish until the end of 2019. The project is co-financed between Kosovo government and French government.

The Czech Development Agency of the International Development Cooperation Program has also invested in construction of a biological wastewater treatment plant near Badovac, that treats the sewerage system of three villages near the lake. The projected has finished in 2017 and its implementation has had a significant impact in improving the quality of water in the lake.

5.3.4 The regulative plan of the studied area in Mat neighbourhood

The studied area that is planned to be constructed until 2027 covers a surface of 21.68ha. It is planned to be constructed according to the development plan of Prishtina (Prishtina, 2012)It has a terrain slope of 5.8% which provides that sewerage system to be discharged by gravity. According to the Geological Institute in Kosovo, the soil is classified as loamy due to the fact that the zone was used as agricultural land in the past.

The construction is destined mainly for residential buildings. The classification of surface regarding the index of surface distribution is presented below:

Table 5. Percentage of planned surface coverage in the Mat neighbourhood.

Residential buildings	Public Buildings	Infrastructure	Free space
34%	**3.2%**	**15%**	**47.8%**

Source: Detailed Regulatory Plan for Urban Blocks "B17", "B18", B19" and "B20" of Mati 1 Neighbourhood Pristina 2007-2025.

Regarding public buildings, it is planned the construction of an ambulance, school, kindergarten, and cultural center. The main area destined for residential facilities will contain eleven buildings with a maximum of sixteen floors. A park that covers 1 ha surface is planned to be placed in the centre of the area in order to offer access for every building.

The distribution of surface according to construction space per square meter is presented below.

Table 6. Calculations of construction surfaces in square meters.

Classification Number	Surface designation	Surface m^2	Constructed surface m^2
R1	Residential Building	11333.77	56621.55
R2	Residential Building	12173.4	47784.56
R3	Residential Building	11627.93	78591.33
R4	Residential Building	9394.09	45176.09
R5	Residential Building	9614.25	40233.5
R6	Residential Building	8507.09	38653.8
R7	Residential Building	15898.52	79952.62
R8	Residential Building	11305	56427.54
R9	Residential Building	9860.53	40341.28
R10	Residential Building	8756.45	35959.93
R11	Residential Building	7976.58	28507.39
C1	Commercial Building	20448.28	69757.23
P1	Kindergarten	5043.22	1315.24
P2	School	9467.8	1919.65
P3	Ambulance	10673.69	2813.99
P4	Cultural Centre	10077.09	4518.9
G	Park	10121.88	0

Source: Detailed Regulatory Plan for Urban Blocks "B17", "B18", B19" and "B20" of Mati 1 Neighbourhood Pristina 2007-2025.

The total surface for the buildings is 182279 m^2. The distance between objects is planned to be 10 m as determined by the development plan. This new neighbourhood will be the first case in Prishtina that will be constructed according to standards and that will contain every facility that a neighbourhood must have.

The sewerage system in this project is planned to be constructed separately, but, as mentioned previously, the final collector that conveys the sewerage system of this area will gather the rainwater and wastewater together. Furthermore, the separately planned system will not have any impact in decreasing the pressure in the main collector, which has already shown problems with overflowing. Only if the municipality will invest in constructing the new system that will separate the wastewater and rainwater, then we might expect positive results.

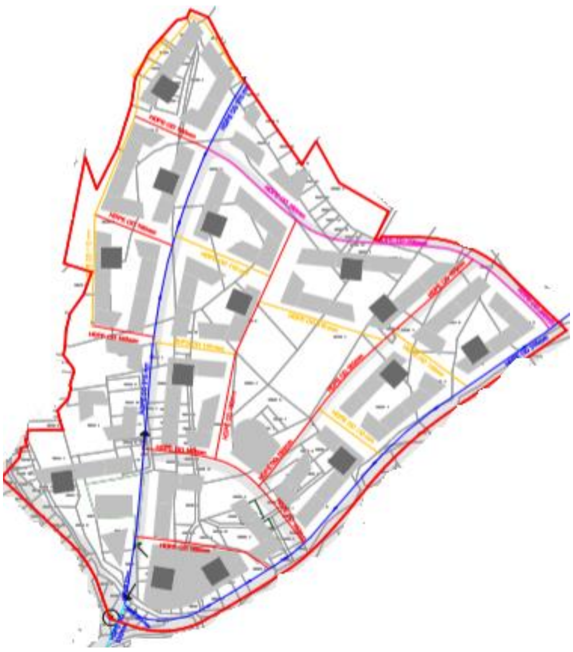
The designed sewerage system contains 4 types of dimension pipes: PESN8 Ø250, PESN8 Ø315, PESN8 Ø500, PESN8 Ø630. Topography of terrain enables the realization of discharge through gravity towards the main collector with dimension Ø1000.

The designed rainwater system is dimensioned with pipes PESN8 Ø315 and PESN8 Ø400. For the dimension of pipes, rain intensity data between years 1926 – 1988 with a rainfall range of 29 years are used. Surely, this practice for designing the rainwater system is inappropriate taking into consideration changes in the dynamic of precipitation events over time. But due to lack of data for maximum rainfall intensity for the last 20 years period, the engineers in Kosovo do not have another solution to design the rainwater sewerage system. Hence, this is another reason why heavy rain events in Kosovo cause overflowing of sewerage system and minor flooding.

This chapter provides many reasons why SUDS should be seen as the best practice to be used in this area. The implementation of SUDS techniques will have multiple benefits in ensuring sustainability not only for stormwater management but also for water supply and wastewater management.

The figure below shows the design of rainwater sewerage system in the studied area.

Figure 14. The rainwater piped system discharge in the studied area



Source: Detailed Regulatory Plan for Urban Blocks "B17", "B18", B19" and "B20" of Mati 1 Neighbourhood Pristina 2007-2025

V. Evaluation of SUDS techniques in the studied area.

6.1 Statistical analysis of the total amount of monthly rainfall through the years 2001-2018

Many national reports state that, in recent years, Prishtina has experienced changes in the values of rainfall during the years, which has triggered the driest and wettest months within one year. But, there is no report that confirms these claims with proper statistical analysis of the data.

We used the Mann-Kendall test to evaluate the trend in the total amount of monthly rainfall for seventeen years. The purpose of using this test was to assess the change in rainfall amount for every month during the years 2001-2018. The value for p was considered significant when less than 0.05.

The trend of changes in the amount of rainfall during the months for years 2001-2018 did not yield a statistical significance. But, if one takes into account data up to 2017 than changes become significant in months of October and July.:

Figure 15. The trend of October rainfall during the years 2001-2018

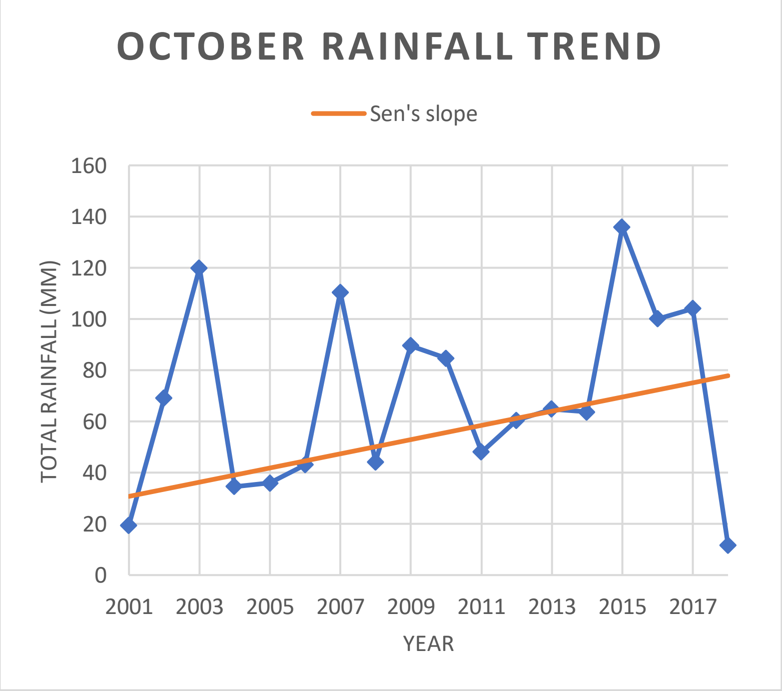


Table 7. Statistical results for October rainfall trend for two periods of time.

October **2001-2018**		October **2001-2016**	
p-value	Sen's slope	**p-value**	Sen's slope
0.198	2.771	**0.036**	3.238

The results in the table show the difference between two time periods for the trend of rainfall amount for October.

The chart below presents results for July, in which there is a significant trend of rainfall during the years 2001-2017.

Figure 16. The trend of July rainfall during the years 2001-2018

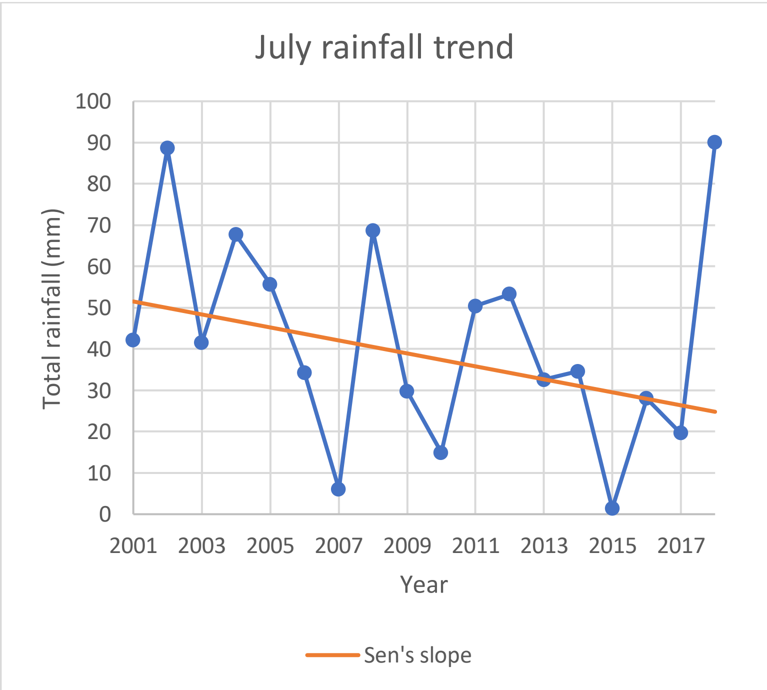


Table 8. Statistical results for July rainfall trend for two periods of time.

July **2001-2018**		July **2001-2016**	
p-value	Sen's slope	**p-value**	Sen's slope
0.150	-1.571	**0.023**	-2.794

The results for the other months can be found in appendix.

6.2 Green Roof`

Green roof installation has been consistently shown to have many beneficial impacts, which is why it has been used widely in developed countries throughout the world. Calculations below show how can green roof affect the surface runoff reduction in the studied area that is planned to be constructed.

As mentioned in the previous chapter, green roofs can be divided as extensive and intensive. For the extensive roof, I have chosen the soil layer of soil to be installed 8 cm which is within limits (maximum of 15 cm), while for the intensive roof I chose the soil layer 20cm. (CIRIA, 2015) According to (BERNDTRSSON, 2009)the soil layer with the filed capacity of the green roof in the range 45% and with the wilting point 11% have shown the good potential of retention. For calculations, I have used these proposed values. By knowing these two values it was easy to calculate the water content in the green roof soil layer which is the change between the field capacity and wilting point which in this case will be 30 % maximum. The same source defined that runoff from the green roof can be considered when the volume of rainfall exceeds its field capacity.

The slope it assumed to be within limits 5º-20º. The evapotranspiration's values are important in this calculation because of the capability to reduce the water content and to help the soil layer to increase the field capacity for the next rainfall event. Due to the fact that evapotranspiration's values are not measured in Kosovo, I have calculated the potential evapotranspiration by using the formula of Thornthwaite. The scientists that had used this formula have studied the climate data in the South-eastern part of Europe where Kosovo it is located as well. Formula used for calculations is presented below: (NISTOR, et al., 2017)

$$E_{t0} = 16\left(\frac{L}{12}\right) \times \left(\frac{N}{30}\right) \times \left(\frac{10T_i}{1}\right)^{\alpha} \tag{1}$$

where, E_{t0} is the potential evapotranspiration [mm/month], L is the total amount of monthly sunny hours that are being calculated [h], N is number of days in the month being calculated, Ti is the average monthly temperature of month [Cº], α is the complex function of heat index that is calculated with empirical formula presented below:

$$\alpha = 6.75 * 10^{-7} * I^3 - 7.71 * 10^{-5} * I^2 + 1.7912 * 10^{-2} * I + 0.49239 \tag{2}$$

where I is the annual heat index calculated with formula:

$$I = \left(\frac{\overline{Ti}}{5}\right)^{1.5} \qquad (3)$$

Data concerning average temperature, total monthly hours of solar irradiation were taken from IHMK in Pristina and they can be found in the appendix.

Other calculations for green roof include values of actual evapotranspiration. But, since potential evapotranspiration values were found, the actual evapotranspiration can then be calculated by using the formula according to Bergström, 1992:

$$\theta \geq \theta_{fc} \quad \text{if} \quad E_t = E_p$$

$$\theta_{wP} < \theta < \theta_{fc} \quad \text{if} \quad E_t = E_{p0} * \frac{\theta - \theta_{wP}}{\theta_{fc} - \theta_{wP}}$$

$$\theta \leq \theta_{wP} \quad \text{if} \quad E_t = 0 \qquad (4)$$

Where, θ is the water content in the soil [%], θ_{fc} is field capacity of soil [%] and θ_{wP} is the wilting point [%]. (KARLSSON & POMADE, 2017)

For the runoff rate from green roof are used the calculations below, derived from the soil water balanced equations. (HILTEN, et al., 2008)

GR Runoff = I + P - ET ± ΔSW, (5)

where I is infiltration (in this case by the green roof layer) [mm/24h], P is dimensioned precipitation value per day [mm], ET is actual evapotranspiration for day [mm] and ΔSW is the difference in water content per day [mm]

$\theta current$ = $\theta_{watercontent}$ - Et per day +P (6)

$\theta retention\ capacity$ = θ_{fc} - (θ_{will} + $\theta current$) (7)

Groof/runoff= $\theta retention\ capacity$ < 0 (8)

According to the chosen soil layer of 80 mm for the extensive roof, I calculated the maximum field capacity 36mm, maximum water content 24mm and wilting point 12mm based on selected percentages of water contents in the layer. For the intensive roof layer of 200mm I calculated the values 90mm for field capacity, 60mm for maximum water content and 30mm for wilting point.

The actual water content is the previous rainfall amount minus evapotranspiration. The runoff from green roof can be considered when the field capacity is saturated, which in this case occurs when field capacity has reached 36mm for extensive roof and 90mm for intensive roof.

Using daily data from IHMK in relation to monthly amount of rainfall was helpful in reaching final calculations. For the actual evapotranspiration, the monthly amount is divided with the number of days within the month. The water content at the beginning of the month was assumed as 30% of field capacity.

Many authors have proposed that the driest and wettest month of the year should be chosen for evaluation of rainwater retention amount by the green roof and for surface runoff reduction.

By using the formulas above, I calculated the daily evapotranspiration and the amount of rainwater retention for chosen months.

The percent of retention by green roof was defined by formula: (SIMS, et al., 2016)

$$\text{Retention } (\%) = \frac{\text{Rainfall (mm)} - \text{Runof(mm)}}{\text{Rainfall (mm)}} \tag{9}$$

To present the real situation which explains how green roof affect surface runoff can, I have chosen the year 2014, which as I explained in the previous chapter was considered the month with the highest amount of monthly precipitation since 2001. In this year, April was considered the month with the highest precipitation (218.8 mm) and August was the driest month with 9mm of the total precipitation through the month. Due to the extreme difference between these two months, I have included September as well, which has an average value of precipitation that is usually registered by the IHMK system, and also October, to strengthen the results. Also, these latter months show how antecedent driest event affects the capacity of the green roof in water retention the next month. The results of these calculations are presented below while tables with rainfall data for 2014 and tables with calculations can be found in the appendix

Table 9. The reduction of the total amount of rainfall by green roofs for four months in 2014.

	APRIL		**AUGUST**		**SEPTEMBER**		**OCTOBER**	
	Ext	Int	Ext	Int	Ext	Int	Ext	Int
Total Rainfall [mm]	218.8*	218.8*	9.0*	9.0*	152.8*	152.8*	63.7*	63.7*
Green Roof W Retention [mm]	23.0	30.8	9.0	9.0	33.9	56.6	25.2	29.8
Percentage of Total Retention	11%	14%	100%	100%	23%	37.%	39%	47%

*The total amount of precipitation for selected months (IHMK, Rainfall data 2014)

The calculations show how green roof installations can affect the runoff reduction in the studied area by rainwater retention. The difference between the intensive and extensive roof is not a strong indicator in runoff reduction for the chosen months.

6.3 Rainwater Harvesting System

RWH is a technique included in SUDS approaches as one of the best practices for runoff reduction, while at the same time it provides for collected water to be used for different purposes.

Due to the problems with water scarcity in Prishtina, this system must be seen as the best solution in ensuring the water for irrigation, toilet flushing, road cleaning, car washing.

As mentioned previously, there is no other water supply source in Prishtina besides the water company, thus the same drinkable water is used also for irrigation. The stress in the water supply system will be higher after the studied area of 21.8ha will be constructed.

Since the buildings are planned to be constructed up to sixteen floors, the rainwater caught from the roof will show low rate of pollution compared to lower roof catchments. This is another reason that makes harvesting systems a feasible solution for this area.

The first flush rain shows a high rate of pollution or as the (BERNDTRSSON, 2009) explained as the initial runoff from the impermeable surfaces after the dry periods which contains the atmospheric particles that should be removed. It is estimated that this first flush or roof runoff coefficient is 0.95. (FARRENY & PINZON, 2010) The irrigation coefficients can be calculated as 0.95m³/m² per year, according to Zhou et al., cited in one master thesis. (OLSSON, 2011) For the rainwater collection volume, I used the formula below: (FARRENY & PINZON, 2010)

$$Vcoll = Proof * \varphi * A * I \qquad (10)$$

where ,V is the collected volume for month [m³/month], Proof is the percent of roof in the studied area, φ roof runoff coefficient or first flush, A is the total studied area [m²] and I is dimensioned precipitation [m]

$$Virrig = kirrig * Agreen \qquad (11)$$

where, V is the irrigation volume needed for the studied area [m³] , Kirrig is the irrigation coefficient for square meter [m³/m²] and A is the total area of irrigation [m2]

The total studied area is 21.68 ha or 216800m². The attached table in the previous chapter of the regulative plan of the studied area shows the classification according to surface use. The roofs are planned to cover 34 % of the area while the green area is planned to cover 40% of the area. The runoff roof coefficient is calculated 0.95. The precipitation values are taken from calculations of the monthly average of the total amount of rain for 10 years, 2009-2018. The calculations for collected rainwater volume are made for every month, and the irrigation coefficient 0.95 m^3/m^2 is divided per twelve months.

By using the formulas above, the coefficients and the monthly average of the total amount of rain for 10 years, the calculation results are presented below:

Table 10. Monthly rainwater volume collected from RWH

Months	Total amount of rainfall [mm]	Total collected volume [m^3]	Volume for irrigation [m^3]	Percent of irrigation fulfillment [%]
January	54.42	3429.75	6865.33	49.96
February	44.08	2778.09	6865.33	40.47
March	55.58	3502.86	6865.33	51.02
April	55.58	3502.86	6865.33	51.02
May	74.35	4685.82	6865.33	68.25
June	59.99	3780.80	6865.33	55.07
July	50.52	3183.96	6865.33	46.38
August	33.79	2129.57	6865.33	31.02
September	41.68	2626.83	6865.33	38.26
October	76.32	4809.97	6865.33	70.06
November	56.28	3546.98	6865.33	51.67
December	61.00	3844.45	6865.33	56.00

**The average of the total monthly rainfall for ten years, 2009-2018 (IHMK)*

The results in this table show the amount of rain volume that can be collected every month, the volume of water needed for irrigation, and the percentage of rainwater collection that fulfils irrigation needs. All the collected water can be used for irrigation, but this amount of rainwater is not enough to meet irrigation demands. This shows how much water would be needed to irrigate the green area that is planned to cover the studied area, and how much percentage of water would be saved by the water supply system.

As the (Prishtina, 2017) states that 3.4% of buildings are destined as commercial and public buildings like school, ambulance, kinder garden and historical centre, I have also calculated the collected volume from the roof of these buildings in order to reuse the rainwater for toilet flushing. New toilets that are being installed need 6 l of water per flush. I calculated the collected volume from the commercial and public roofs for every month. I have converted volumes into litres. These monthly volumes are divided per days of the calculated month. Daily collected volume is divided per 6 litres (which is the amount needed for one toilet flush) to reveal how many toilet flushes can be done by using the collected rainwater.

For volume collection, I used the same formula as above (9) with different percentages of the roof, because only 3.4% of the roofs are destined for commercial and public buildings. The calculation results are presented below:

Table 11. Monthly rainwater volume collected from RWH in commercial buildings

Month	Total Rainfall [m]*	V collected [m³]	V collect per day [m³]	Vcollect litter [l]	Total toilet flush per day
January	54.42	414.71	13.38	13377.70	2229.62
February	44.08	335.91	12.00	11996.88	1999.48
March	55.58	423.55	13.66	13662.85	2277.14
April	55.58	423.55	14.12	14118.28	2353.05
May	74.35	566.59	18.28	18276.96	3046.16
June	59.99	457.15	15.24	15238.50	2539.75
July	50.52	384.99	12.42	12418.99	2069.83
August	33.79	257.50	8.31	8306.37	1384.39
Septembr	41.68	317.62	10.59	10587.44	1764.57
October	76.32	581.60	18.76	18761.23	3126.87
November	56.28	428.88	14.30	14296.10	2382.68
December	61.00	464.85	15.00	14995.22	2499.20

**The average of the total monthly rainfall for ten years, 2009-2018 (IHMK)*

The results show high number of toilets flushes per day that can use the collected rainwater volume. It is hard to predict how many people will be on these public and commercial buildings, but I think that these values can cover a high amount of water used for the toilet flushes.

These calculations show the benefits of using RWH installations in the studied area.

6.4 Swales

Swales have been used for many years in order to convey the runoff through vegetated shallow channels, which promotes green space and improves biodiversity. In many places, swales do not have a high rate of distribution because it is hard to integrate this technique in high urbanized areas due to limited space. Also, in Mat neighbourhood where the studied area is located, green space has the minimum coverage, or it can be said that it is almost extinct there. Regulative plan of the area that will be constructed states that 46% of 21.86ha will be covered by green spaces. I have evaluated that swales can be suited well for this area. The swales calculations are mainly based in guidelines by (CIRIA, 2015) and (TRCA, 2010) guidelines.

According to these guidelines, vegetated swales can drain an area with a maximum of 2 ha. For the studied area are chosen 5000 m² to be drained by swales. The trapezoid shape is common for the design of swales; thus, this shape has been chosen for calculation.

According to (CIRIA, 2015) the limitations for the bottom width are from 0.6-2m thus, for the calculations I used a 0.8m bottom width and a longitudinal slope of 0.7 %. For water quality the maximum depth of water flow was defined 1m. In this calculation the depth of flow is defined 0.12 and 0.15m for each case. The height from the maximum height of water flow to the top of swales is selected 0.1m, which is within limits. The total height of swales is defined 0.22 and 0.25m. The longitudinal slope value is calculated 1:3.

The velocity is calculated by Manning's equation while the roughness coefficient for the grass swales is defined 0.035. The width/length ratio is calculated 1:7.

Swales are planned to be constructed along the main road of the studied area with same direction as conventional pipes that are designed to convey the runoff from the rain.

The runoff coefficient values needed to calculate the runoff peak flow are estimated in relation to green and impermeable surfaces. By knowing that studied area contains 40% of green area and 34% of the impermeable surfaces, the runoff coefficient for the total area was found by calculating the relation between green area coefficient 0.1 and the impermeable coefficient 0.8. The runoff coefficient value for swales calculations in the studied area was evaluated as 0.46.

According to (TRCA, 2010) the swales should be dimensioned to drain the 4-hour storm with a maximum intensity. (CIRIA, 2015) define that swales can be dimensioned for two years storm with a maximum intensity for 15 min duration in order to ensure the water quality. Also, it is proposed the swales can be dimensioned for the maximum intensity for 15 min with a recurrence 10 years.

Due to the limited data for the maximum intensity per 24 hours for 10 years I only had the data of the maximum intensity for 24 hours with a recurrence time of 8 years.

Thus, for the calculations I chose two different events, the maximum rain intensity with 15 minutes duration with recurrence time of 2 years, and the maximum rain intensity with 15 minutes duration with a recurrence time 8 years. The maximum rain intensity for 24 hours is found in the appendix.

The runoff peak flow was calculated by the rational formula of runoff: (BUTTLER & DAVIES, 2010)

$$Q = I * A * \varphi \tag{12}$$

where the Q is the runoff peak flow [m^3/s], A is the area catchment area [m^2], φ is the runoff coficient and I is the dimensioned precepitations intensity [m/s].

The Manning's equaiton is used for finding the velocity in the swales and Chezy equation for finding the maximum flow: (BUTTLER & DAVIES, 2010)

$$Q = A * v \tag{13}$$

Where Q- is the maximum flow in swale [m^3/s], A is cross-section area of swale [m^2] and v is velcoity determined by Chezy equation [m/s]

$$v = C\sqrt{R * I} \tag{14}$$

Where v is the velocity in swales [m/s], C is Manning coefficient, and R is the hydraulic radius [m] and I is the slope [%] The Manning's coefficient is calculated by the formula:

$$C = \frac{1}{n} \times R^{\frac{1}{6}} \tag{15}$$

Where n is the roughness coefficient, estimated 0.035 for swale. The hydraulic radius is calculated by formula:

$$R = \frac{A}{P} \tag{16}$$

Where A is the cross-section area of swale [m^2] and P is the wetted perimeter [m]. The cross-section area and the wetted perimeter are calculated based in the depth flow.

$$A = h_w(b + mh_w) \tag{17}$$

Where h_w is the water flow deepth [m], b is botom width [m], m is the longitudianl slope ratio.

$$P = b + 2h_w\sqrt{1+m^2} \quad (18)$$

Based on the total length/wide ratio, the length of swale was easily calculated, also the top of swale is derived when is defined the total depth and bottom width of swale.

The total area of swale was calculated by formula:

$$As = B + L \quad (19)$$

Where B is the top width of swale [m] and L is the length of swale [m]. Also is calculated the time of travel of runoff along the swales that is defined as Length divided by velocity. (CIRIA, 2015)

$$T = \frac{L}{v} \quad (20)$$

Using the formulas, coefficients and defined values above the results are presented below:

Table 12. Maximum flow of swales calculated for two rainfall events

	Maxmimum rain intensity for 15 min durutation with recurece time 8 year	**Maxmimum rain Intensityfor 15 min durutation with recurece time 2 year**
Rain intensity [mm/h]	**47.05***	**27.78***
Total rainfall amount for 15 min [mm]	11.75	6.95
Runoff coficinet	0.42	0.42
Drined Area [m²]	5000	5000
Flow deepth [m]	0.15	0.12
Hydraulic Radius [m]	0.1	0.08
Manning cofficient	19.69	18.91
Velocity [m/s]	0.5	0.5
Maximum flow [m³/s]	0.1	0.06
Lengh of swale [m]	158	158
Totl Swale Area [m²]	363	344
Residence time [min]	5	6

**Maximum rain intensity calculated for 15 min storm with return period 8years and 2 year*

The results from the calculations are within the limits that have been defined by guidelines. The results for velocity are 0.5 m/s, which is below 1 m/s in order to prevent the erosion.

The percent of drained area covered by the swale resulted in 11.1% which is a good value according to (TRCA, 2010)

The infiltration values are neglected here because of the lack of information about the level of groundwater. Regarding the missing data, the infiltration cannot be allowed until it is ensured that the level of groundwater must be below 1 m of the swale.

VI. Results and Discussion

- **Results of the statistical analysis**

According to the statistical analysis, we can conclude that changes in the monthly amount of rainfall during 17 years were significant for two months only until 2017.

The declined trend of rainfall until July 2017 provides the evidence for the difficult situation that Prishtina has faced with water supply outage during these years. Due to the decline of water levels during July in the water supplier basins in Prishtina, the citizens continued to suffer the consequences even in the months to come.

Lack of balance in the water supply management related to demands for water has created a situation that only one month of stress on reservoirs can trigger a significant impact for water supply. This is evidence of improper management of water supplies system in Prishtina which has not been based in sustainable solutions. This is one case that has proven that waiting for rainfall events to happen every month in order to fill the reservoirs with water by not creating secondary alternatives, results in serve consequences in water supply.

On the other hand, October rainfall data have resulted in a statistical difference through the years, which shows an increase in the total amount of rainwater. Meanwhile, it is another evidence for overflowing sewerage events due to the impermeable areas and the inability of the conventional sewerage system to cope with stormwater during the ongoing process of constructions.

The implementation of SUDS techniques in Prishtina will not only decrease the surface runoff and prevent overflowing sewerage system but at the same time will improve the water supplies system by creating another source of water usage for irrigation and other purposes.

The SUDS techniques implementation in Prishtina, will not only decrease the surface runoff and prevent overflowing sewerage system but at the same time will improve the water supplies system by creating another source for water usage for irrigation and different purposes.

- **The green roofs**

The results for the green roof installations in the studied area has shown a good impact on runoff reduction by rainwater retention. Even though in the month with a high amount of rainfall it has resulted in scant effects in water retention, the ability to delay the runoff compared to the conventional roof has to be appreciated. Considering the fact that April does not represent the model for the common amount of monthly rainfall in Prishtina, the calculations from September and November total rainfall amount can be taken into consideration in evaluating the impact of runoff reduction by green roofs in the studied area. The table below shows the percentage of surface runoff reduction by the green roof in the studied area calculated for four months:

Table 13. Total amount of runoff reduction by extensive green roof during four months in 2014.

	Total Rainfall [mm]*	Rainfall Retention [mm]	Percentage of Total Retention [%]	Runoff Reduction [%]
April	218.0	23.0	11%	4%
August	9.0	9.0	100%	34%
September	152.8	33.9	23%	8%
October	63.7	25.2	39%	14%

**The total monthly rainfall in 2014 (IHMK)*

There is a small difference between extensive and intensive green roof in surface runoff reduction, especially for the month with the highest amount of rainfall. Hence, this goes in favour of proposing extensive green roof to be implemented in the studied area. Furthermore, extensive greens roof provides less cost for maintenance. They are also more practical to execute and do not require special roof construction due to the light layer depth. Extensive green roofs can cover whole roof surface and the most important condition is that they support less demand plant species like grass, mosses which can be adapted in many disturbances.

Considering that intensive green roof can provide recreational facility it can be appropriate to install it in commercial buildings which can also afford the maintenance cost.

It is important to mention that these calculations must be considered only for representing an idea about the green roof impact in the studied area. For the real design, more detailed calculations should be considered. The evapotranspiration value should be measured; the detailed daily calculations for water retention in the soil according to the plants that are being used; and drainage layer should be carefully taken into consideration in order to prevent the roof waterproof layer failure. The particular care in plant selection demands must be considered in order to prevent their withering, and the precise maintenance cost analysis should be calculated to ensure a long-term impact on efficiency.

- **Rainwater harvesting system (RWH)**

The RWH calculations results have shown a great potential so that the collected volume can be used for irrigation. Even though the total collected volume every month will be spent on irrigation, still, it could not meet total demands for irrigation in the studied area. Hence this presents strong evidence for the importance of using this system where irrigation is much needed. The results have also shown that it is not needed to construct an extra system for conveying the unnecessary collected rainwater out from the reservoir to open space for further rain events because all collected volume will be spent for irrigation within a month.
Also, results of collected volume of rainwater from commercial and public buildings roofs have shown that a considerable number of toilet flushes can use this kind of water.
Additionally, the RWH will not only collect the rainwater and serve as another source for supplying water but will also help in reducing the surface runoff and decreasing the stress in the conventional pipe system.
The table below represents the percentage of runoff reduction calculated for the total amount of rainfall in years 2009-2018 by using the RWH in the studied area. The percent of runoff reduction by RWH in the studied area.

Table 14. Total amount of runoff reduction by RWH for the whole year.

Total runoff volume [m³]*	Total volume of rainwater collected [m³]	Percentage of runoff reduction [%]
114990.72	41821.94	36.36%

**Calculated runoff from average monthly rainfall data for 2009-2018* (IHMK)

The focus of calculations is to evaluate the surface runoff reduction within the studied area. In order to implement the technique, one must take into consideration the detailed analysis for RHS cistern. The designing phase of RHS cistern must take precautions and should include professional experts. The design for rainwater catchments, infiltration process and the chosen location for cistern placing should be carefully analysed according to site characteristics and climate conditions.

According to proposals from respectable literature, the underground cisterns have been highly assessed and provide the best performance. The maintenance of cistern is crucial for this system in order to prevent water pollution.

- **Swales**

The results of calculations for swale in this thesis were evaluated in order to provide initial informations about the role of swales in delaying runoff peak flow, which can decrease the stress in conventional pipe systems. The calculations are made according to guidelines for dimensioning of swales, though infiltration rate and conditions of groundwater level were limited in these calculations.

When the real design process will be planned the groundwater level and quality must be the first condition that should be taken into consideration.

Missing informations regarding these conditions in the studied area were the major limitation for exact evaluation of swales. While neglecting infiltration, the maximum flow parameters of swales regarding to the rainfall intensity of the studied area are found. The results represent how swales can treat the runoff with a natural approach while at the same time the plant biodiversity is being promoted.

Good maintenance conditions for swales are much important to ensure a good quality of water.

VII. Conclusion and Recommendations

The main scope of this thesis is to create an initial idea about the way that SUDS techniques can affect stormwater management by reducing the surface runoff and improving the water quality by promoting green space in the studied area that is planned to be built in Prishtina.
By analysing the recent literature about the benefits of SUDS approaches implemented in many developed countries, and by analysing the situation of water resources management in Prishtina and Kosovo in general, this work tries to create an initial evaluation which can be used by Kosovar institutions so that natural approaches will be considered as the best solutions especially for low-income countries where the expansion of the conventional system is impossible and the natural resources are limited.
By evaluating the impacts of the three techniques in the area with 21.8 ha I would highly recommend that the focus of responsible institutions in Prishtina should be oriented towards SUDS approaches for every new construction in further years.
To create a detailed guideline of SUDS techniques in Kosovo, one must include many professional experts like policy makers, engineers, urban planners, environmentalist, stakeholders. Also, it is necessary to take into consideration detailed informations and monitoring data for all the natural conditions in the state.
The implementations of SUDS techniques in Kosovo will not affect only stormwater management but all the ecosystem in general.
In the beginning, SUDS takes much commitment to be designed, but there is no other solution in protecting the environment and managing the water resources that have been neglected for many years in Kosovo.
I would finish this thesis with a sentence cited in the World Water Day Conference in England, 2019: ‘We need water wastage to be as socially unacceptable as blowing the smoke in face of a baby’.

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IX. Appendix

Climate data for Prishtina, 2001-2018

2001					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	-	76.8	2.7	96	2.3
February	-	41.1	2.8	95	1.3
March	-	15.1	10.3	87	2.6
April	-	127.5	9.3	91	1.5
May	-	48.4	16.5	88	1.6
June	-	49.1	18.2	82	0.9
July	-	42.2	21.9	80	1.2
August	-	33.9	22.6	79	1.5
September	-	91	8.1	88	1.6
October	-	19.5	13.2	95	0.8
November	-	24.8	4.4	92	1.9
Decemeber	-	55.3	-5.7	77	2.2

2002					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	-	3	2.7	89	1.6
February	-	11.6	2.8	93	1.2
March	-	50.3	10.3	85	3
April	-	51.4	9.3	92	1.8
May	-	97.8	16.5	89	1.3
June	-	37.1	18.2	84	1.6
July	-	88.6	21.9	84	1.5
August	-	184.3	22.6	46	1.7
September	-	137.4	8.1	89	1.6
October	-	69.2	13.2	74	1.4
November	-	47	4.4	87	1.6
Decemeber	-	65.6	-5.7	93	1.4

2003					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	15	116.1	0.5	91	1.3
February	8	13.5	-3	80	1
March	10	0.9	4.6	66	1
April	20	42.3	8.8	75	47
May	13	41.5	19	68	1.6

June	11	20.3	22.1	63	0.7
July	8	41.6	22.4	57	1
August	3	23.2	23.8	53	1.4
September	8	54	15.1	70	2.1
October	15	119.9	10.6	75	1.8
November	16	49.6	6.9	84	2.3
Decemeber	20	19.1	0.6	81	1.7

2004

Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	21	72.7	-1	79	1.8
February	16	52.9	2.6	73	1.7
March	16	55.6	6.3	69	1.9
April	21	51.1	11.8	65	1.5
May	18	46.4	13.1	69	1.5
June	14	4.3	19.3	69	1.1
July	8	67.7	22.5	64	1.0
August	6	56.3	20.7	67	1.2
September	10	53.8	1.1	67	1.2
October	10	34.6	14.2	73	1
November	16	110.1	5.3	80	1.3
Decemeber	16	33.3	1.6	87	1.5

2005

Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	14	30.7	0.0	78	0.8
February	17	34.7	-2.6	79	1.4
March	19	51.3	5.0	76	1.4
April	13	54.1	10.1	65	1.8
May	15	98.2	15.8	67	1.6
June	11	55.4	17.0	66	1.2
July	14	55.7	21.1	66	1.0
August	14	76.8	19.6	71	1.2
September	12	21.1	16.8	74	1.0
October	6	35.9	11.0	73	1.1
November	11	41.3	4.2	78	1.3
Decemeber	21	87.6	1.8	82	1.4

2006					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	12	35.5	-3.5	79	1.2
February	16	67.6	-0.9	82	1.2
March	15	96.5	5.1	74	2.0
April	18	75.5	11.7	69	1.2
May	10	42.5	15.2	64	1.5
June	13	55.5	18.8	67	0.9
July	8	34.3	21.5	62	1.4
August	13	90.4	20.2	64	1.0
September	9	30	16.8	67	1.0
October	7	43.1	12.4	69	1.3
November	6	27.3	5.3	75	0.9
Decemeber	8	32.1	7.2	85	2.2

2007					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	10	49.6	3.9	76	10.6
February	12	19.7	4.8	75	1.7
March	8	53.3	8.2	68	2.4
April	9	25.2	1.0	60	1.6
May	18	72	16.2	73	1.5
June	8	21.2	21.0	63	1.3
July	3	6.1	24.0	50	1.4
August	8	24.2	22.9	56	1.3
September	11	56.8	14.8	63	1.9
October	18	110.4	10.5	81	1.2
November	19	151.9	2.4	89	1.2
Decemeber	13	30.2	-1.0	85	1.1

2008					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	13	19	0.0	76	1.6
February	6	4.5	3.4	75	1.7
March	1	93.5	70.0	68	2.4
April	12	16.4	11.3	60	1.3
May	9	64.9	15.3	73	1.5
June	11	113.4	20.0	63	1.3
July	10	68.6	21.1	50	1.4
August	5	20.4	22.5	56	1.3
September	13	44	15.3	63	1.9
October	5	44.2	12.5	81	1.2
November		46.9	7.3	89	1.2
Decemeber	19	105.8	3.2	85	1.1

2009					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	16	58.8	-0.6	84	1.3
February	14	44.5	1.1	73	2.2
March	17	76	5.3	75	2.5
April	11	26.7	12.9	65	1.5
May	10	58.6	16.8	67	1.0
June	13	90.4	19.1	69	1.0
July	7	29.7	21.6	63	1.2
August	7	46.8	22.1	63	1.1
September	11	14.1	17.1	69	0.9
October	14	89.6	10.7	78	1.5
November	11	72.5	7.7	80	0.8
Decemeber	18	79.6	3.6	85	2.2

2010					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	17	70.7	0.5	83	2.0
February	19	86	3.0	83	1.8
March	17	50.1	6.6	71	2.0
April	17	78.5	11.5	74	1.1
May	15	77.2	16.0	70	1.6
June	7	67.8	19.5	71	1.0
July	7	14.9	21.7	69	1.2
August	5	27.6	23.0	63	1.3
September	9	26.2	17.0	69	1.3
October	17	84.7	9.5	83	13.0
November	15	95.6	10.4	79	2.1
Decemeber	20	111.1	2.1	82	2.0

2011					
Month	Rain Days	TotaRaiall (mm)	Tmes C	Humidity %	Wind m/s
January	8	19.5	-0.3	84	0.6
February	10	20.3	0.2	79	1.6
March	8	25.1	6.4	71	2.2
April	10	33.8	11.1	64	1.9
May	9	66	15.1	72	1.6
June	17	23.9	19.6	67	1.4
July	9	50.4	22.3	61	1.0
August	7	3.1	22.7	58	1.1
September	3	34.1	20.2	62	1.3
October	5	48.1	9.9	74	1.8
November	7	4.5	3.4	75	1.0
Decemeber	3	73.7	1.6	86	1.5

2012						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	16	105.7	43.1	78.5	-1.7	83
February	14	36.1	11.8	70.4	3.7	81
March	4	12.8	6.4	215.9	7.1	62
April	17	51.5	12	173.6	11.1	68
May	12	102	24.5	203.9	15.5	66
June	5	6.2	2.5	309.6	22.2	57
July	5	53.3	21.5	347	24.9	54
August	1	3.9	3.9	317.3	24.2	47
September	7	13.7	2.3	254.9	20.2	58
October	7	60.4	11.5	208.7	13.8	68
November	8	29.6	6.8	90.1	8.6	79
Decemeber	17	65.9	13.2	55.5	-0.6	86

2013						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	15	21.4	5.5	58.2	1.6	82
February	14	31.3	2.3	52.8	3.9	78
March	17	25.7	2.7	112.4	6.6	72
April	11	18.9	1.3	154.1	12.8	62
May	16	56.2	7.4	169.3	16.7	65
June	14	37.5	9.2	130.5	19.0	68
July	4	32.6	18.5	232.8	21.6	57
August	3	5.6	2.3	232.9	23.4	53
September	9	56.6	21.6	140.3	16.8	63
October	7	64.8	33.9	149.3	12.6	70
November	9	42.6	16.5	58.6	7.4	81
Decemeber	4	15.9	4.8	97.8	0.7	83

2014						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	10	10.9	3.9	21.9	2.9	84
February	5	2.2	0.8	98.7	6.6	68
March	15	50.1	12.2	129.4	8.3	70
April	19	218.8	61	78.8	10.5	78
May	15	71	23.1	164.5	14.5	74
June	10	88.7	20.1	161	18.6	72
July	15	76.8	34.6	213.3	20.7	71
August	5	9	3.7	213	21.9	68
September	18	152.8	37.6	127.6	15.5	82
October	11	63.7	34.2	107	10.9	80
November	12	82.4	49.1	60	8.1	83
Decemeber	13	58.6	12.3	41.2	1.8	86

2015						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	19	63.7	14	66.3	-0.8	81
February	12	78.5	24.5	103	2.5	75
March	14	90.3	19.5	76.6	4.6	76
April	6	38.3	8.5		10.4	78
May	10	63.2	16.8			
June	12	45.9	10.8	169.4	16.9	73
July	3	3.1	1.4	291.4	24.4	57
August	5	56.2	39.5	290	23.8	58
September	11	42.1	16.7	207.1	19.1	67
October	14	136	46.9	147.9	11.9	81
November	8	41.4	16.4	170.4	7.6	7
Decemeber	2	0.8	0.6	78.2	1.6	88

2016						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	17	93.8	26.2	67.9	0.0	83
February	14	38.1	10.9	113.1	8.0	76
March	14	101.5	31.9	130	7.1	75
April	7	24.3	8.1	199	13.7	62
May	17	100	22.2	214.4	14.6	71
June	12	46.5	24.3	227.1	20.8	67
July	8	106.9	28	259.1	21.9	67
August	10	115.2	71	223.8	20.5	69
September	8	40.9	19.9	171.9	16.7	72
October	18	100.1	10.3	90.5	11.0	80
November	10	120.4	65.7	107.1	5.6	79
Decemeber	1	2.3	2.3	101.2	-0.5	79

2017						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	10	57.6	26	32.6	-4.9	90
February	6	41.8	16.9	116.6	4.7	74
March	7	12.8	5.4	172.7	9.5	61
April	10	48.4	12.9	167.1	10.9	61
May	15	81.4	19.1	200.3	15.7	69
June	8	42.8	11.9	234.9	21.4	67
July	9	47.5	19.6	250.1	23.4	58
August	4	48.5	21.7	254.2	22.2	57
September	11	33.4	11.7	153.7	18.7	65
October	8	104.1	32	189	11.1	76
November	14	40.9	9.5	100.6	6.0	83
Decemeber	12	144.3	57.1	71.5	2.8	81

2018						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Insolation h	Tmes C	Humidity %
January	10	42.1	16.8	81.2	1.2	87
February	6	62	15.7	63.5	2.0	81
March	7	111.4	15.7	101	6.1	77
April	10	16.6	8.2	185.1	15.4	60
May	15	67.9	24	163.5	18.1	68
June	8	150.2	33.8	192.3	19.5	74
July	9	90	21.3	236.7	20.8	76
August	4	22	7.7	210.1	21.7	71
September	11	2.9	1.7	192.8	17.0	66
October	8	11.7	4.2	93.9	13.0	71
November	14	32.9	9.9	60	6.6	81
Decemeber	12	57.8	12.4	71.5	-0.1	89

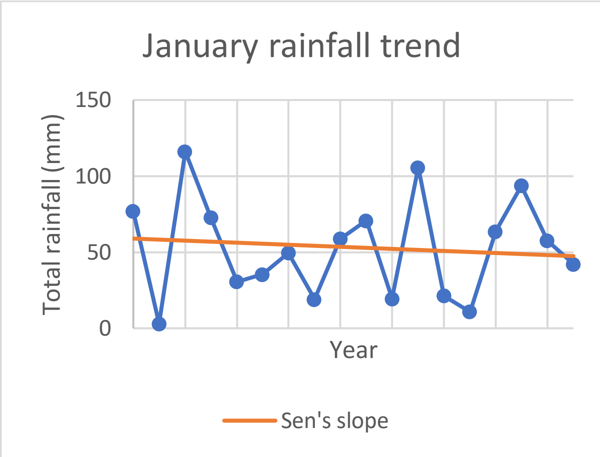
Source: IHMK-Institute of Hydrometeorological in Kosovo

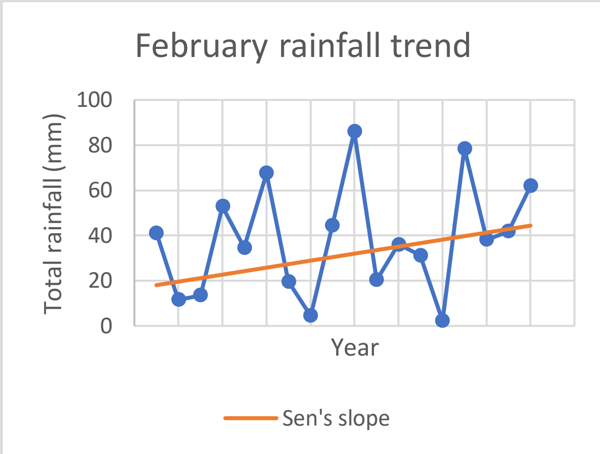
http://www.ammk-rks.net/?page=1,90

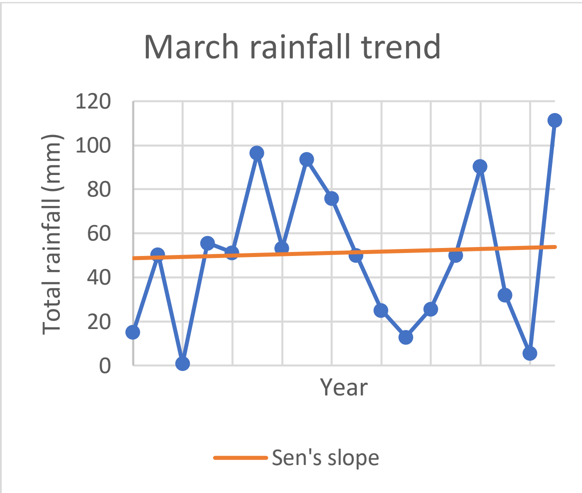
The results of statistical analysis for the other months.

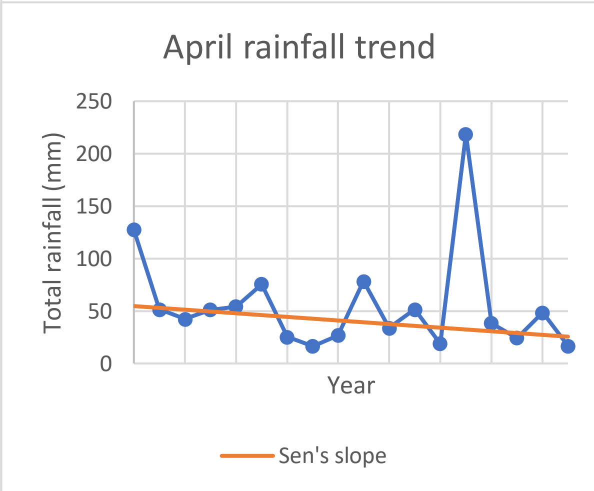
The Man Kendell test is realised in XLSTAT.

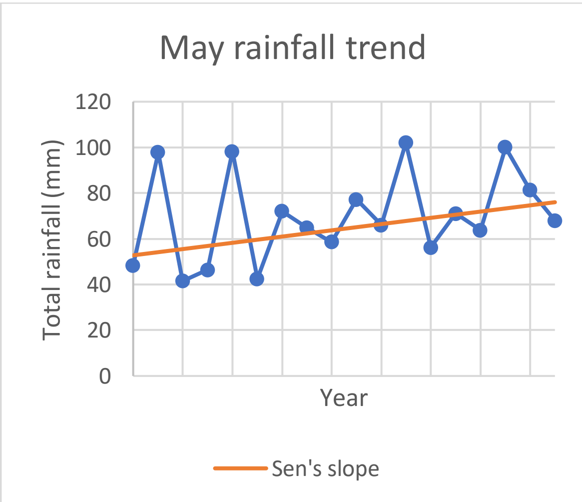
Trend of monthly total rainfall for years 2001-2018		
Month	P- value	Sen slope
January	0.88	-0.678
February	0.325	1.55
March	0.970	0.300
April	0.173	-1.713
May	0.150	1.367
June	0.256	2.015
August	0.325	-1.915
September	0.081	-2.258
November	0.940	-.0.33
December	0.820	-0.583

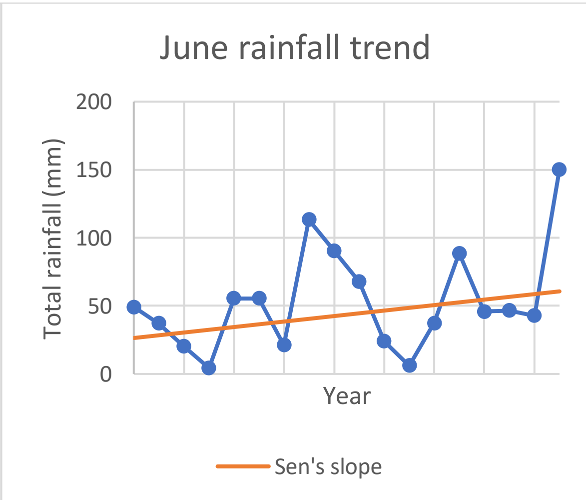

January rainfall trend
150
100
50
0
Total rainfall (mm)
Year
Sen's slope

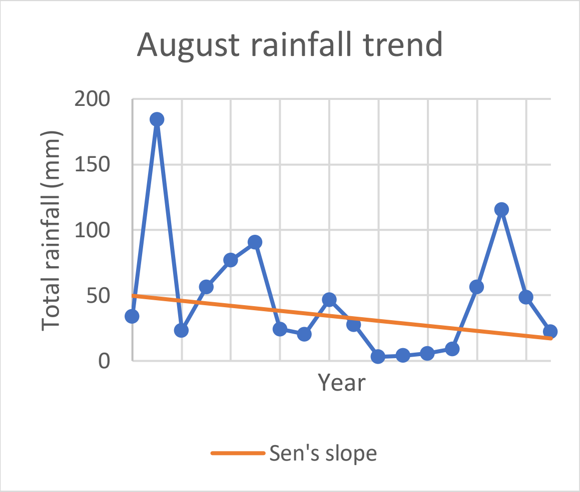

February rainfall trend
100
80
60
40
20
0
Total rainfall (mm)
Year
Sen's slope

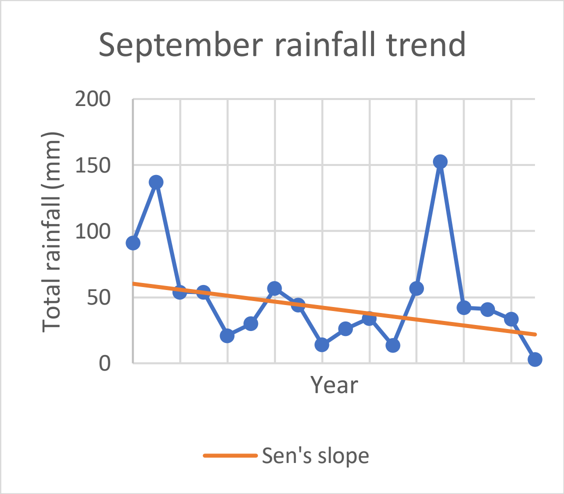

March rainfall trend
120
100
80
60
40
20
0
Total rainfall (mm)
Year
Sen's slope

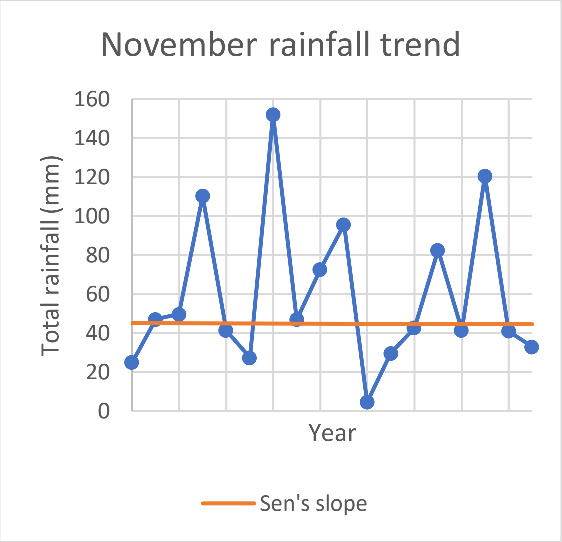

April rainfall trend
250
200
150
100
50
0
Total rainfall (mm)
Year
Sen's slope

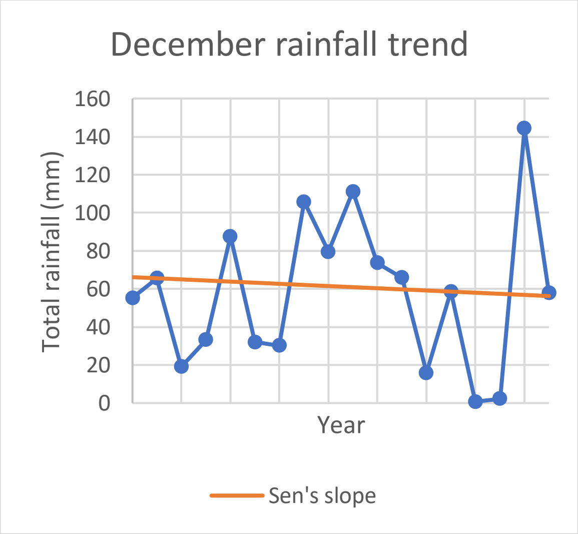

May rainfall trend
120
100
80
60
40
20
0
Total rainfall (mm)
Year
Sen's slope


June rainfall trend
200
150
100
50
0
Total rainfall (mm)
Year
Sen's slope









The calculations of protentional evapotranspiration by Thornthwaite formula, in 2014 (Used for Green Roof calculations)

2014						
Month	TotaRaifall (mm)	Insolation	Tmes C°	Annual Heat Index	Function of heat index	Potential Evapotranspiration
January	10.9	21.9	2.9	0.44	0.50	10.7
February	2.2	98.7	6.6	1.52	0.52	26.27
March	50.1	129.4	8.3	2.14	0.53	38.09
April	218.8	78.8	10.5	3.04	0.54	36.62
May	71	164.5	14.5	4.94	0.58	58.13
June	88.7	161	18.6	7.17	0.62	59.31
July	76.8	213.3	20.7	8.42	0.64	81.64
August	9	213	21.9	9.17	0.65	73.21
September	152.8	127.6	15.5	5.46	0.59	47.38
October	63.7	107	10.9	3.22	0.55	36.64
November	82.4	60	8.1	2.06	0.53	27.66
December	58.6	41.2	1.8	0.22	0.49	23.69

The example of Green Roof Calculations for April.

Calculations are made in excel tables. This is an example of calculations in April. for an extensive green roof with choose soil layer 80mm. As I mentioned above, I chose the field capacity of the soil layer to be 45%, wilting point 15% and the water content in soil in the first day is assumed to be 15mm field capacity. The maximum water retained in the soil is the maximum field capacity of soil that in this example was 45% of 80mm which is 36mm. The potential evapotranspiration is found with Thornthwaite formula (1) for the month is divided with days of the month, assumed that is equal for each day.

The actual evapotranspiration in April 36.62mm divided with days of the month is 1.22mm/day.

Actual evapotranspiration is found with the Bergström, 1992 (4) formula.

The calculations are made for each day of the month, while the distribution of the rainfall within days was found in IHMK data.

By using the formula of soil water balanced equations (5) and knowing the percent of water content to be, the calculations were made.

Apr-14										
Days	**Rainfall**	Potential Evapota mm	Max Field capacity ϴofc	Willing Point ϴwill (%)	Water content ϴ	Actual Evapot mm	ϴcurrent	Total water	**ϴretention capacity**	**Q roof run oof**
1	0	1.22	36.00	12	15.00	0.15	14.85	26.85	9.15	/
2	0	1.22	36.00	12	14.85	0.14	14.70	26.70	9.30	/
3	0	1.22	36.00	12	14.70	0.14	14.57	26.57	9.43	/
4	0	1.22	36.00	12	14.57	0.13	14.43	26.43	9.57	/
5	0	1.22	36.00	12	14.43	0.12	14.31	26.31	9.69	/
6	4.2	1.22	36.00	12	14.31	0.12	18.39	30.39	5.61	/
7	0.8	1.22	36.00	12	18.39	0.33	18.87	30.87	5.13	/
8	0	1.22	36.00	12	18.87	0.35	18.52	30.52	5.48	/
9	0	1.22	36.00	12	18.52	0.33	18.19	30.19	5.81	/
10	**7.2**	1.22	36.00	12	18.19	0.31	25.07	37.07	**-1.07**	1.07
11	**5**	1.22	36.00	12	24.00	0.61	28.39	40.39	**-4.39**	4.39
12	**2.8**	1.22	36.00	12	24.00	0.61	26.19	38.19	**-2.19**	2.19
13	0	1.22	36.00	12	24.00	0.61	23.39	35.39	0.61	/
14	0	1.22	36.00	12	23.39	0.58	22.81	34.81	1.19	/
15	0	1.22	36.00	12	22.81	0.55	22.26	34.26	1.74	/
16	**37.2**	1.22	36.00	12	22.26	0.52	58.94	70.94	**-34.94**	34.94
17	**12.9**	1.22	36.00	12	24.00	0.61	36.29	48.29	**-12.29**	12.29
18	**12.4**	1.22	36.00	12	24.00	0.61	35.79	47.79	**-11.79**	11.79

19	**61**	1.22	36.00	12	24.00	0.61	84.39	96.39	**-60.39**	60.39
20	**25.4**	1.22	36.00	12	24.00	0.61	48.79	60.79	**-24.79**	24.79
21	**1.4**	1.22	36.00	12	24.00	0.61	24.79	36.79	**-0.79**	0.79
22	**1**	1.22	36.00	12	24.00	0.61	24.39	36.39	**-0.39**	0.39
23	0	1.22	36.00	12	24.00	0.61	23.39	35.39	0.61	/
24	**9.7**	1.22	36.00	12	23.39	0.58	32.51	44.51	**-8.51**	8.51
25	0	1.22	36.00	12	24.00	0.61	23.39	35.39	0.61	
26	**1.6**	1.22	36.00	12	23.39	0.58	24.41	36.41	**-0.41**	0.41
27	**6.3**	1.22	36.00	12	24.00	0.61	29.69	41.69	**-5.69**	5.69
28	**2.5**	1.22	36.00	12	24.00	0.61	25.89	37.89	**-1.89**	1.89
29	**16.1**	1.22	36.00	12	24.00	0.61	39.49	51.49	**-15.49**	15.49
30	**11.3**	1.22	36.00	12	24.00	0.61	34.69	46.69	**-10.69**	10.69
TOTAL	**218.8**									195.71

Qroof runoof is when the watercont execds the field capacity of soil layer

Total Rainfall 218.8mm
Total Green Roof Runnoff 198.23mm
____
Retetention = 23.09 mm
Rainfall reduction =11%

The average of total rainfall for ten years, 2009-2018 (Used for RWS calculations)

2009-2018						
Month	Rain Days	TotaRaiall (mm)	MaximuRainfall (mm)	Hours with sun	Tmes C	Humidity %
January	13.8	54.42	17.38	61.21	-0.2	84
February	11.4	44.08	13.76	83.97	3.6	77
March	12.0	55.58	16.94	133.30	6.8	71
April	11.8	55.58	19.74	161.57	12.0	67
May	13.4	74.35	21.04	194.04	14.3	69
June	10.6	59.99	20.18	208.36	19.7	69
July	7.6	50.52	20.98	266.35	22.3	63
August	5.1	33.79	28.72	263.17	22.6	61
September	9.8	41.68	17.52	187.75	17.8	67
October	10.9	76.32	25.52	138.82	11.4	76
November	10.8	56.28	30.12	100.19	7.1	73
Decemeber	10.2	61.00	16.94	70.13	1.3	85