ENHANCING STORMWATER REGULATORY ECOSYSTEM SERVICE OF RECREATIONAL GREEN SPACES WITHIN THE RESIDENTIAL AREAS OF ADDIS ABABA THROUGH SUSTAINABLE DRAINAGE SYSTEMS DESIGN:

THE CASE OF RECREATIONAL PARKS IN BOLE SUB-CITY

MSc THESIS IN ENVIRONMENTAL PLANNING AND LANDSCAPE DESIGN

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Declaration

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the Institute.

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Confirmation

The thesis can be submitted for examination with my approval as an Institute's advisor.

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Acronyms

AU	Africa Union
CIWEM	the Chartered Institution of Water and Environmental Management
CLUVA	CLimate Change and Urban Vulnerability in Africa
CSA	Central Statistics Authority
FAO	Food and Agricultural Organization
FDOT	Florida Department of Transportation
MEA	Millennium Ecosystem Assessment
MLIDT	Massachusetts Low Impact Development Toolkit
OAU	Organization of African Unity
PSP	Permeable Stone Pavement
SBMPS	Stormwater Best Management Practices Saanich
SuDS	Sustainable Drainage Systems
UK	United Kingdom
UNECA	United Nations Economic Commission for Africa

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Abstract

Recreation green spaces in urban areas, particularly those within the residential areas require proper design & planning consideration for two basic reasons. First, they provide a wide range of direct and indirect benefits (ecosystem services). Second, human activities within the green spaces have a great impact on the stability and continuity of the benefits generated. In the case of Addis Ababa, recreational green spaces, especially which are within the residential areas, have little attention with regards to landscape planning and design. Hence the benefits derived from the green spaces are less or not much more than recreational benefits (cultural ecosystem services). The aim of this research is therefore, to develop sustainable design solutions that can enhance multiple benefits such as regulatory ecosystem services without compromising the existing cultural services of green spaces. The study utilizes a case study research method by selecting two case areas of recreational green spaces from residential areas of bole sub-city Addis Ababa. Based on the result from the case study, the green spaces were actively used for recreation and amenity purposes, because they have well maintained landscapes, beautiful views and they are near to residential areas. In addition, the study has tried to look into a stormwater regulatory capacity of the green spaces and identified 37% to 59% potential runoff reduction. Hence, the study provided design interventions such as sustainable drainage systems to improve stormwater regulatory capacity of the study areas, and eventually enhance regulatory ecosystem services. In addition to existing well developed case areas, the study selected additional underdeveloped open green spaces as a third case area for testing the up scaling effect of the design strategy.

Keywords: Green spaces, multi-benefits, recreational activities, regulatory ecosystem services

CHAPTER ONE: INTRODUCTION

1.1. Background

Ecosystem services are provided at different spatial and service/functional scales. The local level is the basic unit for ecosystem services, especially when it comes to the human dimension of urban landscapes. These services are provided by green elements or basic complex ecosystems (green open spaces) which differ from their neighborhoods through their structures and functions (Breuste et al., 2013).

The presence of green open spaces in residential areas constitutes a major role in shaping life styles of people. They enhance the quality of life in most areas where they exist. They are the arena of both, neighbor's outdoor interactions consequently building the neighborhood's sense of community – and the micro ecological sphere – setting its parameters and configuring its fundamentals, (Kahalid Al-Hagla, 2008).

Green open spaces play an important role in the development of sustainability in a community by providing many ecosystem services. They help in neutralizing climate change, improves the local air quality, promotes biodiversity, enhances economic development, increases urban regeneration, reinforces social inclusion, serves as an environmental education platform, promotes individual and community health, a place for relaxation and children play area etc. (Campbell, 2001).

Addis Ababa, the capital city of Ethiopia is a fast developing city with a population of three million people and a growth rate of 2.9 percent per year. (CSA, 1999). The condensed part of the city is the major image and the overall face that characterizes the city. The disappearance of and extreme pressure on green spaces of Addis Ababa is another character which is destroying the scenic beauty of the cities' landscape and the ability of green space to perform their basic ecological, social and economic function; thereby enhancing unsustainable urban growth of the city (Mpofu, 2013).

Despite the challenges the city of Addis Ababa is facing on its green spaces today, some early established neighborhoods have recreational green spaces/parks integrated within, and this green spaces are functioning well in contributing to their neighborhood sustainability. Such examples of open space integration in neighborhoods are found in residential areas of Bole, located in woreda 23, Bole Subcity, Addis Ababa.

This paper aims to formulate a research on the elements and components of green spaces and analyze the roles they have in providing regulatory ecosystem services, specifically focusing on the stormwater retention capacity of the green spaces.

1.2. Problem statement

The lack of proper knowledge about the ecosystem services that green spaces provides in residential areas, both in the public and private sector, has resulted in the diminishing and wasting of existing green spaces. The priority given to the issues of green space in Addis Ababa is low. Typically, due to the benefits that green spaces provides in residential areas, and in overall in the city, it is expected that a reasonable amount of spaces will be reserved for such purposes and planned and designed carefully. However, this is not the case in Addis Ababa. A lot of the city's green spaces are converted to permanent structures. As the three year research project called CLlimate change and Urban Vulnerability in Africa (CLUVA, 2011) stated, an estimated 4,432 ha or 15% of the 'evapo-transpiring' (vegetation and water surfaces) present in 2006 were lost by 2011. Meaning, with such rate of green space loss in the city, there is a possibility of losing most of the evapo-transpiration surfaces if not all within only 30 to 35 years.

The problem of the city is not only in a loss of green spaces. There are some green spaces provided in different neighborhoods of the city with little attention for their landscape quality and amenities. Most of the green spaces are unplanned or left over spaces and the general attitude towards them by the public is not as one of important urban elements. As a result, it is common phenomenon to see open spaces that are being used as a garbage disposal site. As a consequence of the above facts, their function in urban ecosystem and the benefits that is derived from them is limited.

Currently, there are some researches focused on vegetation structure, management, and recreational services that are mainly focused on cultural and provisioning services of green spaces in Addis Ababa (Zebad, 2014; Samson, 2014; Anteneh, 2015). Less attention is given to the regulatory ecosystem services of green spaces by public sector and the community. Consequently, little research is conducted on this particular service in the academic arena as well.

This research aims to identify the potentials of urban green spaces in providing regulatory ecosystem services and tries to look into one of the important regulatory ecosystem services for urban residents, which is the stormwater regulation capability of green spaces. The research also tries to come up with sustainable drainage system designs to enhance stormwater runoff retentions of green spaces, eventually, to enhance other regulatory ecosystem provision capability of recreational green spaces.

1.3. Objectives of the study

The general objective of this research is to develop sustainable drainage system designs that can enhance stormwater regulating ecosystem services of recreational green spaces within the residential areas of Addis Ababa, without compromising the existing cultural services of green spaces.

And the specific objectives of this research are as follows

- To assess physical elements and human activities within the recreational green spaces (the study areas)
- To sort out major regulatory ecosystem services provided by the recreational green spaces by focusing on their stormwater regulation capacity
- To look into sustainable drainage system designs that can enhance stormwater regulating ecosystem service provided by green spaces
- To devise the up scaling strategy of design solution to other recreational green spaces of the sub city

1.4. Research questions

This research tries to answer the following questions.

- What are the physical elements and human activities within the recreational green spaces (the study areas)?
- What is the stormwater regulation capacity of the study areas?
- What are the sustainable drainage system designs that enhance the stormwater regulating ecosystem service provided by the green spaces?
- How to devise the up scaling strategy of design solution to other recreational green spaces of the sub-city?

1.5. Significance of the study

Green spaces that are located in residential areas of cities offer a great range ecosystem services for the society. There are services that easily recognized by city dwellers such as cultural ecosystem services which include as places for recreation, supporting development of children, promoting social interactions, and creating job opportunities. However, as usually it is beyond the knowledge of ordinary city dwellers, green spaces also provide regulatory ecosystem services which include, pollutant absorption and filtering, microclimate regulation, noise reduction, rainwater retention, and so on.

Studying the role that existing green spaces play in providing regulatory ecosystem services will give an additional insight in bringing the needed attention that are involved directly or indirectly with green space, such as the general public, urban planners and city Administrators. The research also helps in acquiring a comprehensive understanding of green spaces in residential areas and their contribution as a form of natural capital with a view for a better provision and design of recreational green spaces.

The final outputs of such a research can also be used as an input for further studies in the academia, as inputs for landscape designers and urban planners, and as inputs for future city planning and policy formulation.

CHAPTER TWO: RESEARCH METHODOLOGY

2.1. Introduction

This research has followed both qualitative and quantitative research methods to understand the potentials green spaces have in providing regulatory ecosystem services. A case area is selected based on appropriate criteria, and analyzed through the data collected and in regards to the literature reviews. This chapter discusses the methodology followed in conducting the research and the approaches applied in choosing the data collection techniques.

2.2. Selection of the case area

Urbanization changes a city’s environment, altering climate, water flow, water quality, and air quality. However, these attributes can be ameliorated or improved by green spaces through ecosystem services. Urban green spaces are also important in improving the quality of urban life for residents by providing several recreational services. To achieve a reasonable life and a higher possible quality of urban life for residents. Therefore, urban green spaces that are found within residential area's proximity, are very important (Jim et al., 2006).

Therefore the research focuses on urban green space typologies such as parks and other designated recreational green spaces in residential areas of Bole Subcity, Addis Ababa.

This area is chosen because of its unique characters listed below.

- The areas selected are recognized housing areas by the Addis Ababa city administration and consist of recognized neighborhood open spaces (green spaces) that are specifically planned and designed to serve the residents.
- The recreational green spaces surrounding residential areas are fully occupied by the inhabitants that help understand the experience.
- The areas constitute one of the earliest settlements and are located almost at the center of the city of Addis Ababa making it active and easily accessible to conduct the study.

2.3. Method of data collection

This research deploys a qualitative research method to gather information. Qualitative research is an effort to understand situations in their uniqueness as part of a particular context and interaction there. (Merriam, 2002) And this research also tries to understand the nature of green open spaces in residential areas of Bole Subcity and the role they play in providing different ecosystem services.

2.3.1. Developing a checklist

As its going to be discussed in depth in the literature review chapter (chapter 3), of these researches, The Millennium Ecosystem Assessment (2003) describes ecosystem services as benefits that people obtain from the ecosystem. These include

Provisioning services such as food and water;

Regulating services such as the control of climate, regulation of floods, drought, land degradation

Supporting services such as soil formation and nutrient cycling, crop pollination; and

Cultural services such as recreational, spiritual, religious and other non-material benefits.

Most of the ecosystem services consumed in cities are generated by ecosystems located outside of the cities themselves, often half a world away (Folke, 1997). It is estimated that for some of the largest cities of the world, taking into account only the most basic ecosystem services such as food production and assimilation of nitrogen and carbon (Provisioning and supporting ecosystem services), appropriate ecosystem areas equivalent to the size of a hundred times the area of the cities themselves is needed. Further, even though many people can benefit from ecosystem services that are from public green spaces because of their accessibility, quantitatively residential areas are the biggest ecosystem service provider with their larger green areas, (Loram, 2007).

Thus, this research has chosen as a case, recreational green spaces that are found within residential areas of Addis Ababa and focuses on direct and locally generated ecosystem services that are related to the study areas.

According to Loram (2007), the most important ecosystem services provided by urban recreational green spaces are, primarily cultural ecosystem services and secondly regulating ecosystems.

Therefore, using the following checklist of ecosystem services adapted from the Millennium Ecosystem assessment categorization (2003), the research tries to identify the ecosystem services provided the study areas and analyzes one of the important regulating services for urban residents.

Table 1. Checklist of ecosystem services (Millennium Ecosystem Assessment (2003) categorization)

Ecosystem services	Services to be identified	Service to be analyzed
Regulatory Services	Air Quality maintenance	
	Local climate regulation	
	Water regulation	Stormwater regulation
	Natural hazard regulation	
	Biological regulation	
	Disease regulation	
	Erosion control	
	Water purification and waste treatment	
	Pollination	
Cultural Services	Spiritual and religious	
	Recreation and ecotourism	
	Aesthetic value	
	Inspirational	
	Educational	
	Sense of place	
	Cultural heritage	
	Social Relation	

2.3.2. Primary sources of data

The research collects its primary information from systematic self-site observation, photographs taken from the sites and, from interviews and questionnaires conducted with 20 randomly selected and volunteer visitors, employees and administrative bodies in the recreational green space.

Self-site observation

As the Project for Public Space (PPS, 1999) advise: ‘When you observe a space you learn about how it is actually used, rather than how you think it is used”. One of the objective of the research is to identify the physical elements that are found within the green spaces and understand how they contribute to ecosystem services and how they are perceived by the users. Therefore a self-site observation technique is conducted and photographs are taken in identifying physical elements that constitute the green open spaces.

Interviews

Because city environments may be stressful for inhabitants, the recreational aspects of urban ecosystems are among the highest valued ecosystem service in cities (Kaplan, 1989). Parks, forests, lakes and rivers provide manifold possibilities for recreation, thereby enhancing human health and well-being (Konijnendijk, 2013). For example, a park experience may reduce stress, enhance contemplativeness, rejuvenate the city dweller, and provide a sense of peacefulness and tranquility (Kaplan 1983). Therefore the research deploys a qualitative systematic interview, especially to understand the role the green open spaces play in providing cultural ecosystem services, such as physical, social, spiritual and mental well-being.

The set of questions used in the case areas includes, participant general demographic variables (age, gender), what are the purposed for visiting the green spaces, where the recreational green spaces spent most of their time and the reasons why they choose the green spaces for their recreation. This helps in identifying ecosystem services that are being provided by the green spaces, whether with the visitor’s knowledge and knowhow or without even the visitor’s recognition.

2.3.3. Secondary sources of data

Secondary data, such as that are found from the internet, books and previous studies are used in preparing the literature reviews. For the precipitation data of the study areas, data gathered from the Bole airport station are used.

2.4. Data analysis and Presentation

To analyze the data collected a qualitative and quantitative analysis method is used. Data collected through self-site observations, and interview is analyzed and described through a qualitative method, since they are non-measurable qualities. However, software such as ENVI, AutoCAD, Geographic Information System (GIS) and Google images are used to make special analysis and quantify and measure surface areas in the green spaces.

The outputs of analyzed data and design proposals are presented with drawings, tables, graphs and maps using software such as Illustrator, Photoshop, Microsoft word and AutoCAD.

2.5. Scope and limitation of the study

There are many issues that can be discussed about while studying the ecosystem services provided by green spaces that exist in residential areas of Addis Ababa. Beside identification of ecosystem services, there are issues of valuing ecosystem services, measuring and quantifying ecosystem services, and others such as management issues related urban ecosystems. Thematically the focus of this study is in identifying the regulating and cultural ecosystem services related to green open spaces and analyzed stormwater retention abilities of the study areas. The research also tries to come up with multifunctional landscape design possibilities to enhance multiple ecosystem services. Spatially the study is limited to the geographical boundaries of Bole Subcity, Addis Ababa, focusing on recreational green spaces that are found within single unit residential areas.

The limitation of this study is mainly the lack of documented information on how these green open spaces meant to be used and how they are managed. The concern for open spaces and green areas in the city is very recent and there exists a lack of organized official body to get the needed information from.

2.6. Summary of Methodology

Table 2. Summary of research methodology

Research objectives	Data type	Data source	Data analysis	Outputs
Objectives 1 **Identifying physical elements & activities**	▪ physical elements & objects, & activities	▪ Satellite images ▪ Systematic self-site Observations ▪ Interviews	Data + remote sensing and GIS	▪ Descriptions and Table
Objectives 2 **Identifying the regulatory and cultural ecosystem services, and analyzing storm water retention**	▪ vegetation and built up cover (area ratio) ▪ types of plants, impervious surfaces & runoff, ▪ Visitor's interview	▪ Satellite images ▪ Systematic self-site Observations ▪ Interviews	Data + remote sensing and GIS	▪ Tables ▪ Descriptions
Objectives 3 **Looking for design possibilities**	▪ Reference to successful projects and case studies(local and international)	▪ Existing situation analysis ▪ Master plan & manuals ▪ Internet ▪ Books	▪ Literature review with data gathered	▪ Drawings ▪ Tables ▪ Descriptions
Objectives 4 **Replicability possibility of Design to other green spaces in the sub-city**	▪ Reference to successful projects and case studies(local and international) ▪ Reference to city master plan and neighborhood manuals	▪ Internet ▪ Books ▪ Master plan & manuals	▪ Literature review with data gathered	▪ Drawings ▪ Tables ▪ Descriptions

CHAPTER THREE: LITERATURE REVIEW

3.1. Definition of terms

Urban Green Spaces: urban green spaces are urban areas which are covered in natural or semi-natural ecosystems converted to urban spaces by human influence (Cemil and Gökyer, 2012). For Farrar (2009) a green space refers to recreational fields, urban agriculture, and natural play space for children, community, rooftop and balcony gardens, community compost sites, community orchards, and cycling routes. According to Mathias (2016) citing different sources an urban green space can be defined as formal and informal. Formal green areas include protected public parks, street gardens, playgrounds, sport fields, squares, private gardens, and vegetation cover in schools, hospitals, churches, mosques, embassies, cemeteries, parking lots, pedestrian lanes, etc. On the other hand, informal green areas include forest areas, river valleys, reserved expansion areas, agricultural lands, open leftover spaces, grazing lands, steeper degraded areas, shrub lands, etc. Urban green spaces are used to connect urban to nature.

Ecosystem – An ecosystem can be defined as ''a set of interacting species and their local, non-biological environment functioning together to sustain life'' (Moll and Petit, 1994). The living and non-living elements function together as an interdependent system – if one part is damaged it can have an impact on the whole system. Ecosystems can be terrestrial or marine, inland or coastal, rural or urban. They can also vary in scale from the global to the local. At the continental level examples include rainforests, deserts, and coral reefs. Closer to home, we might think more in terms of different types of habitats (e.g. Woodlands, grassland, marshes, heath land, rivers, peat bogs) though this can also extend to the urban environment (e.g. Parks and gardens, rivers and streams). In many cases, ecosystems overlap and interact (Price, 2007).

Ecosystem services - The Millennium Ecosystem Assessment (2003) describes ecosystem services as benefits that people obtain from the ecosystem. These include *provisioning services* such as food and water; *regulating services* such as the control of climate, regulation of floods, drought, land degradation and disease; *supporting services* such as soil formation and nutrient cycling, crop pollination; and cultural services such as recreational, spiritual, religious and other non-material benefits.

3.2. Urban Green Space Classifications

The urban green space has its own physical components, including urban forest, parks, riverine and street trees. Green space can become so many things like natural play spaces, community gardens, urban agriculture and rooftop gardens (Farrar, 2009; Rodhead, 2009). The following are some of the urban green space classifications (Kahalid, 2008)

Parks and gardens: areas of land, normally enclosed, designed, constructed, managed and maintained as a public park or garden. They can be either urban parks or country parks depending primarily on their location. They often incorporate other types of green space, such as children's play areas and sports facilities, but their primary function is for informal activity or relaxation, social and community purposes, and horticultural or arboricultural displays. Some parks and gardens may also be designed landscapes of historical importance, where they are of national significance.

Amenity green space: Managed and maintained landscaped areas with no designated specific use by people, but providing visual amenity or separating different buildings or land uses for environmental, visual or safety reasons. They may also be used, incidentally, as wildlife habitats.

Children's play areas: Designated and maintained areas providing safe and accessible opportunities for children's play, usually linked to housing areas and therefore normally set within a wider green environment of amenity open space. The primary function of these areas is to provide safe facilities for children to play, usually close to home and under informal supervision from nearby houses.

Sports facilities: Designed, constructed, managed and maintained large and generally (although not always) flat areas of grassland or specially-designed artificial surfaces, used primarily for designated sports. The primary function of these areas is to accommodate practice, training and competition for recognized outdoor sports.

Green corridors: Routes linking different areas within a town or city as part of a designated and managed network and used for walking, cycling or horse riding or linking towns and cities to their surrounding countryside or country parks. The primary function of green corridors is to allow safe, environment-friendly movement within urban areas. Moreover, they support wildlife colonization and therefore habitat creation.

Natural/semi-natural green spaces: undeveloped land with little or only limited maintenance which have been planted with wild flowers or colonized by vegetation and wildlife. They also include woodland, railway embankments, river and canal banks and derelict land, which may in some cases be thought of as temporary natural green space. The primary function of natural green spaces is to promote biodiversity and nature conservation.

Other functional green spaces: Essentially allotments, the yards of religious buildings and cemeteries.

3.3. Ecosystem services provided by urban green spaces

Urban green spaces, as the main provider of ecosystem services, in cities consists of different green elements, e.g. single trees in streets and gardens, tree covers of different layers, lawns and grass, bushes and shrubs, flower beds and ornamental plant arrangements etc. These 'basic units' are parts of multi-structural green areas, e.g. green corridors that follow transportation networks, parks and gardens, natural wild spaces, urban forest and community woodlands, cemeteries, allotments, playing fields and playgrounds, derelict and despoiled vacant land, or, to a lesser extent, of built-up urban structural units.

Many people can benefit from ecosystem services in public green spaces because of their accessibility. However, quantitatively residential areas are the biggest ecosystem service provider with their larger green areas. Loram et al. (2007) studied five British cities and concludes that private domestic gardens covered between 21.8 and 26.8% of the whole urban area.

The green patches of open spaces within urban areas range from vegetation remnants of the original natural landscape (mainly woods and wetlands), vegetation of the agricultural cultural landscapes (e.g. meadows and arable land), ornamental, horticultural and designed urban vegetation spaces (parks and gardens) to spontaneous urban vegetation (brownfields and derelict land). These four main groups of vegetation cover are results of different land uses and intensities of utilization and maintenance. They fulfil different ecosystem services and provide potential for even more (Pauleit, Breuste, 2011)

Table 3. A highlight of ecosystem services provided by urban green spaces (Breuste, 2011)

Vegetation group	Vegetation structure type	Main existing ecosystem services	Main potential ecosystem services
Vegetation remnants of the original natural landscape	Woods and forests Wetlands	Timber production, recreation, biodiversity, microclimate regulation, rainwater drainage, sewage treatment	Nature experience
Vegetation of the Cultural landscapes formed by agriculture	Meadows, pastures, drifts, dry grasslands, arable land	Food production, , microclimate regulation, rainwater drainage	Recreation, biodiversity, nature experience
Ornamental, and designed urban vegetation spaces	Decorative green (flower beds, small lawn patches, bushes, hedges etc.)	Decoration, cultural values	Biodiversity, rainwater Drainage
	Accompanied green along traffic lines or as addition to fill up the space between	Air filtering, microclimate regulation, rainwater drainage	Recreation, biodiversity
	Gardens/parks Allotment gardens Urban trees	Recreation, microclimate regulation, air filtering,	Biodiversity, nature experience, learning about nature
Spontaneous urban vegetation spaces	Spontaneous herbaceous bush and pre-forest vegetation	Biodiversity, microclimate regulation	Biodiversity, learning about nature, nature experience, recreation

3.3.1. Regulating Services of urban green spaces

Air Quality maintenance

Air pollution from transportation, industry, domestic heating, and solid urban waste incineration is a major problem for environmental quality and human health in the urban environment; it leads to increases in respiratory and cardiovascular diseases. Vegetation in urban systems can improve air quality by removing pollutants from the atmosphere, including ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter less than 10 µm (PM10) (Nowak, 1994).

While significant differences in performance have been found between plant species (e.g., between deciduous and evergreen species), urban trees have been shown to be especially important in intercepting air pollutants (Aylor et al., 2003). The distribution of different particle size fractions can differ both between and within species and also between leaf surfaces and in waxes (Dzierzanowski et al., 2011). Removal of pollution takes place as trees and shrubs filter out airborne particulates through their leaves (Nowak, 1996). Performance of pollution removal also follows daily variation because during the night the plant stomata are closed and do not absorb pollutants, and monthly variation because of the changes in light hours and because of the shedding of the leaves by deciduous forest during the winter.

Stormwater Regulation

Increasing the impermeable surface area in cities leads to increased volumes of surface water runoff, and thus increases the vulnerability to water flooding. Vegetation reduces surface runoff following precipitation events by intercepting water through the leaves and stems (Villarreal and Bengtsson, 2005). The underlying soil also reduces infiltration rates by acting as a sponge by storing water in the pore spaces until it percolates as through-flow and base-flow.

Urban landscapes with 50–90 % impervious cover can lose 40–83% of rainfall to surface runoff compared to 13 % in vegetated landscapes (Bonan, 2002). Interception of rainfall by tree canopies slows down flooding effects and green areas reduce the pressure on urban drainage systems by percolating water (Bolund and Hunhamm-ar, 1999). Street trees in New York, for instance, intercept 890 million gallons of storm water annually (Peper et al., 2007).

Other means of reducing urban storm water runoff include linear features (bioswales), green roofs, and rain gardens. For example, green roofs can retain 25–100 % of rainfall, depending on rooting depth, roof slope, and the amount of rainfall (Oberndorfer et al.,2007). Also, green roofs may delay the timing of peak runoff, thus lessening the stress on storm-sewer systems. Rain gardens and bio-retention filters can also reduce surface runoff (Clausen, 2007).

Local Temperature Regulation

Ecological infrastructure in cities regulates local temperatures and buffers the effects of urban heat islands. For example, water areas buffer temperature extremes by absorbing heat in summertime and by releasing it in wintertime. Likewise, vegetation reduces temperature in the hottest months through shading and through absorbing heat from the air by evapotranspiration, particularly when humidity is low (Bolund and Hunhammar, 1999).

Water from the plants absorbs heat as it evaporates, thus cooling the air in the process (Nowak and Crane, 2000). Trees can also regulate local surface and air temperatures by reflecting solar radiation and shading surfaces, such as streets and sidewalks that would otherwise absorb heat. Decreasing the heat loading of the city is among the most important regulating ecosystem services trees provide to cities (McPhearson, 2011).

Noise Reduction

Traffic, construction, and other human activities make noise a major pollution problem in cities, affecting health through stress. Urban soil and plants can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound waves (Aylor, 1972).

In row plantings of trees, sound waves are reflected and refracted, dispersing the sound energy through the branches and trees. It has also been shown that different plant species mitigate noise differently (Pathak et al., 2007).

Empirical research has found that vegetation factors important for noise reduction include density, width, height and length of the tree belts as well as leaf size and branching characteristics. For example, the wider the vegetation belt, the higher the density, and the more foliage and branches to reduce sound energy, the greater the noise reduction effect (Fang and Ling, 2003).

Noise reduction is also affected by factors beyond the characteristics of vegetation. For example, climate influences the velocity of sound propagation (Embleton, 1963) and noise attenuation increases with distance between the source point and the receiver due to friction between atmospheric molecules when sound progresses (Herrington, 1976).

Natural hazard regulation

Climate change is increasing the frequency and intensity of environmental extremes; this poses increasing adaptation challenges for cities, especially for those located in coastal areas (Zahran et al., 2008). In Europe, heat waves have been the most prominent hazard with regards to human fatalities in the last decade. The European 2003 heat wave, for example, accounted for more than 70,000 excess deaths (EEA, 2010). Ecological infrastructure formed by mangroves, deltas and coral reefs can act as natural barriers that buffer cities from extreme climate events and hazards, including storms, heat waves, floods, hurricanes, and tsunamis; this infrastructure can drastically reduce the damage caused to coastal cities (Danielsen et al., 2005).

Vegetation also stabilizes the ground and reduces the likelihood of landslides. Devastating effects caused by events like the Indian Ocean Tsunami in 2004 and Hurricane Katrina in 2005 have led a number of scientists to call for a new vision in risk management and vulnerability reduction in cities, based on wise combinations in the use of built infrastructure (e.g., levees) and ecological infrastructure (e.g., protective role of vegetation) (Danielsen et al., 2005).

Waste Treatment

Ecosystems filter out and decompose organic wastes from urban effluents by storing and recycling waste through dilution, assimilation and chemical re-composition (TEEB 2011). Wetlands and other aquatic systems, for example, filter wastes from human activities; this process reduces the level of nutrients and pollution in urban wastewater (Karathanasis et al. 2003). Likewise, plant communities in urban soils can play an important role in the decomposition of many labile and recalcitrant litter types. In urban streams, nutrient retention can be increased by adding coarse woody debris, constructing in-channel gravel beds, and increasing the width of vegetation buffer zones and tree cover (Booth, 2005).

3.3.2. Cultural Services of urban green spaces

Recreation

Because city environments may be stressful for inhabitants, the recreational aspects of urban ecosystems are among the highest valued ecosystem service in cities. Parks, forests, lakes and rivers provide manifold possibilities for recreation, thereby enhancing human health and well-being (Konijnendijk et al., 2013). For example, a park experience may reduce stress, enhance contemplativeness, rejuvenate the city dweller, and provide a sense of peacefulness and tranquility (Kaplan, 1983).

The recreational value of parks depends on ecological characteristics such as biological and structural diversity, but also on built infrastructure such as availability of benches and sport facilities. The recreational opportunities of urban ecosystems also vary with social criteria, including accessibility, penetrability, safety, privacy and comfort, as well as with factors that may cause sensory disturbance (i.e., recreational value decreases if green areas are perceived to be ugly, trashy or too loud) (Rall and Haase, 2011).

Urban ecosystems like community gardens also offer multiple opportunities for deco modified leisure and nowadays represent important remnants of the shrinking urban commons.

Aesthetic Benefits

Urban ecosystems play an important role as providers of aesthetic and psychological benefits that enrich human life with meanings and emotions (Kaplan 1983). Aesthetic benefits from urban green spaces have been associated with reduced stress and with increased physical and mental health (Van den Berg et al., 2010). Ulrich (1984) found that a view through a window looking out at green spaces could accelerate recovery from surgeries, and van den Berg et al. (2010) found that proximity of an individual's home to green spaces was correlated with fewer stress-related health problems and a higher general health perception. People often choose where to live in cities based in part on the characteristics of the natural landscapes. Several studies have shown an increased value of properties (as measured by hedonic pricing) with greater proximity to green areas (Cho et al. 2008)

Educational Values

Exposure to nature and green space provide multiple opportunities for cognitive development, which increases the potential for stewardship of the environment and for a stronger recognition of ecosystem services (Krasny and Tidball, 2009).As an example, urban forests and allotment gardens are often used for environmental education purposes and facilitate cognitive coupling to seasons and ecological dynamics in technological and urbanized landscapes. Likewise, urban allotments, community gardens, cemeteries and other green spaces have been found to retain important bodies of local ecological knowledge, and embed the potential to compensate observed losses of ecological knowledge in wealthier communities (Pilgrim et al., 2008).

The benefits of preserving local ecological knowledge have been highlighted in terms of increased resilience and adaptive capacities in urban systems, and the potential to sustain and increase other ecosystem services (Colding et al., 2006).

Sense of Place Values and Social Cohesion

Place values refer to the affectively charged attachments to places. Research conducted in Stockholm, for example, found sense of place to be a major driver for environmental stewardship, with interviewees showing strong emotional bonds to their plots and the surrounding garden areas (Andersson et al., 2007).

Attachment to green spaces in cities can also give rise to other important societal benefits, such as social cohesion, promotion of shared interests, and neighborhood participation. Examples include studies conducted in Chicago, Illinois, United States, and Cheffield, United Kingdom (Bennett, 1997).

Environmental authorities in the European Union have emphasized the role of urban green space in providing opportunities for interaction between individuals and groups that promote social cohesion and reduce criminality (European Environmental Agency, 2011). Likewise, urban ecosystems have been found to play a role in defining identity and sense of community (Gotham and Brumley, 2002).

Research on sense of community in the urban environment indicates that an understanding of how communities are formed enable us to design housing that will be better maintained and will provide for better use of surrounding green areas (Newman, 1981).

3.4. Optimizing Ecosystem Services Through Ecological Landscape Design

Every city and town is an ecosystem, containing both natural and built components. The biological, physical, built, and social components all interact with each other to determine the functions of the urban ecosystem (S. Danler and G. Langellotto, 2015). Every urban resident and business relies on ecosystem services such as clean air and potable water. These people and businesses also have a huge influence on the ecosystem on which they depend by consuming water and other resources, displacing natural systems, and emitting waste materials (ibid).

Designed landscapes often present neatly ordered versions of nature, but rarely take into account the sometimes messy natural functions and inter relationships of the plants and ecosystem. Most often the original landscape is removed to create a “clean slate,” upon which the built infrastructure is installed. Then often as an afterthought plants are squeezed into whatever space is left. The resulting landscape may be aesthetically pleasing, but too often consists of lawn and a limited palette of non-native trees and shrubs that provide only a fraction of the ecosystem services that an ecologically designed landscape could give (ibid).

The initial installation of a landscape is a significant expense, but ongoing maintenance to keep it looking the way it was designed can be even more expensive. By planning for and harnessing natural functions within a landscape, it is possible to minimize the toil and expense of weeding, fertilizing, mowing, pruning, watering, and replacing failed plants. Instead, a more self-sustaining landscape can be created, providing a greater level of ecosystem services. This ecological approach to landscape planning, design, and maintenance provides long-term ecosystem services in urban communities (ibid).

It is more challenging to design landscapes that filter storm water, clean the air, provide wildlife habitat, are pleasurable to look at and walk through, and require less maintenance. In the long term, though, they can be more beneficial and cost effective than conventional landscapes (S. Danler and G. Langellotto, 2015).

3.5. Multifunctional landscape design approach

Several definitions of multifunctional landscapes have been presented by different authors. The basic idea is that a given area can fulfil different functions and objectives regarding ecological, economic, cultural, historical and aesthetical concerns (Brandt, 2000).

Public green spaces may include parks, nature reserves, college campuses, public schools and cemeteries. As they currently exist, these features often serve multiple functions. For example, parks are specifically designed for recreation, but they are also known to provide a range of other ecosystem services including microclimate regulation, air quality control, stormwater management, and wildlife habitat (Jim et al., 2006). These spaces increase the quality of life for urban residents by providing both social and psychological services, including stress reduction, support for recovery from illness, and a location that fosters the development of social ties (Chiesura, 2004).

Public green spaces offer design opportunities because of the existing and potential functions they are able to provide. At the landscape scale, planners and designers consider opportunities to conserve existing public green spaces, protect and even expand these spaces with buffers or other green spaces on adjacent private lands, and connect these features with green public corridors. “Greenways” are a special type of corridor designed to accommodate multiple functions such as biodiversity conservation, stormwater management, recreation, and visual quality (Hellmund and Smith 2006). Greenways might also be designed to accommodate production functions, by incorporating plant materials that provide hay from grasses and legumes, timber sawn from hardwood trees, and nuts or berries from various fruiting species (Schoeneberger et al. 2001).

In addition to considering design at a landscape scale in terms of increasing multi-functionality, opportunities also exist at the site scale to improve conventional functions and incorporate unconventional functions into public spaces. Conventional cultural services such as recreation, human health, aesthetic quality, and education can be enhanced by supporting a variety of plant communities (Jackson, 2003). Examples include native forests and prairies for wildlife viewing and bird watching, open turf for team sports, and savanna settings for picnicking.

The visual quality of a landscape can be improved through planting designs that include preferred features such as trees and water (Kaplan, 1989) and screening of unpleasant views (i.e., highways or landfills). Landscapes containing areas of native plant communities, or historical collections, can provide a wide range of educational and research opportunities.

Unconventional ecological and production functions should also be considered for public green spaces. Stormwater infiltration, air pollution control, and waste treatment are functions that can be incorporated to improve the environment and provide educational opportunities. Figure 1 shows a multifunctional space located amidst the residential dormitory buildings at the University of Vermont, where stormwater treatment is integrated with a small outdoor amphitheater.

Other public sites such as schoolyards might be designed to support cultural functions specific to children, by providing adequate space and landscape diversity to encourage active play (Ozdemir and Yilmaz 2008), along with educational gardens to teach children about ecological functions or food production (McAleese and Rankin 2007).

Figure 1. Multifunctional stormwater treatment feature in the residential dormitory green space at the University of Vermont (S. Danler and G. Langellotto, 2015)

3.6. Sustainable Drainage Systems

The impervious surfaces that accompany most anthropogenic developments result in an increase in the stormwater runoff. Often, this stormwater runoff contains harmful pollutants (including heavy metals, suspended solids, nutrients, and bacteria) that contaminate nearby surface water.

Sustainable Drainage Systems (SuDS) are used to capture, infiltrate, and treat some portion of the runoff, reducing the negative impact of development on aquatic ecosystems. These features can be designed into the landscape to provide a wide range of additional ecological functions (such as microclimate control, wildlife habitat, and biodiversity), as well as cultural functions (including education and visual quality) (Dunnett and Clayden 2007). Most of the systems are developed as shallow trenches or basins containing a porous medium (such as sand, gravel, or organic matter) that allows infiltration.

3.6.1. Rain Garden system

Rain Gardens are excavated shallow surface depression planted with specially selected native vegetation to capture and treat stormwater runoff. Rain gardens can be applied with varieties of scales that range from domestic to public areas (Andy et al. 2012).

Figure 2.Rain garden approach in parks (Source. Texas AgriLife Extension Service County)

Multifunctional benefits

- **Regulating service -** Filters and cleans surface water runoff; reduces flooding; Mitigates urban heat island effect by increasing evapotranspiration.
- **Recreational -** Space for relaxation and quiet enjoyment; aesthetically pleasing; may also be used to grow vegetables.
- **Biodiversity -** flowers attract nectar-feeding insects; Invertebrate small animals can be added along with other habitat features.

Design Guidelines

- Rain gardens can be integrated with adjacent hard and permeable surfaces
- Overflow channels need to be integrated in case of overflows, which lead the water to existing drain or even to another rain garden
- Soil must be permeable, often engineered soils are added to the backfill. However even soils rich in clay may be mixed with other materials (sand, organic matter, rubble etc.) to improve permeability.

- Large rain gardens are better than small ones although most sizes will provide opportunities for controlling run-off, wildlife habitat and enjoyment

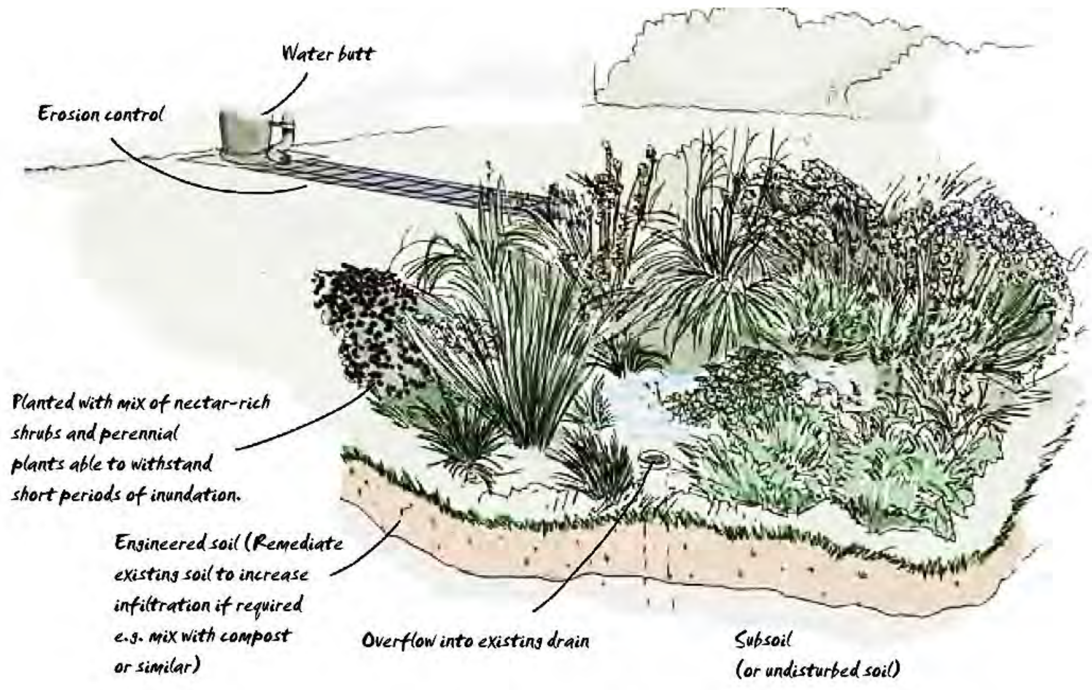


Figure 3. Illustration of Rain Garden (source, Andy et al. 2012)

3.6.2. Pervious Pavement

Pervious pavements consists of a permeable pavement (surface course) underlain by a uniformly-graded stone bed which provides temporary storage for stormwater runoff and promotes infiltration. The surface course may consist of porous asphalt, porous concrete or various porous structural pavers. Pervious pavement can be used in parking areas, on basketball and tennis courts, for trails and walkways, etc. (Andy et al. 2012)

Figure 4: Pervious pavement at parking areas (Andy et al. 2012)

Multifunctional benefits

- **Regulating service –** Allows runoff to percolate naturally into ground; reduce runoff from hard surfaces, first line retention of pollutants.
- **Recreational –** Firm and dry surfaces to park and walk on after heavy rain; visual aesthetics and landscape benefits
- **Biodiversity –** little direct benefits, however the treatment function generates cleaner water for receiving water body/collection pond.

Design Guidelines

- Minimum amount of space is required to maximize naturally-vegetated areas
- Permeable pavement is laid over approximately 100-200mm deep and voided stones
- Holes and gaps between blocks can be filled with gravel
- Lateral drainage from voided sub-base or through perforated pipes can be used to supply water to other features including ponds
- Where infiltration is not possible, collection chambers can be fitted to store and generate a clean supply of water for downstream water bodies.

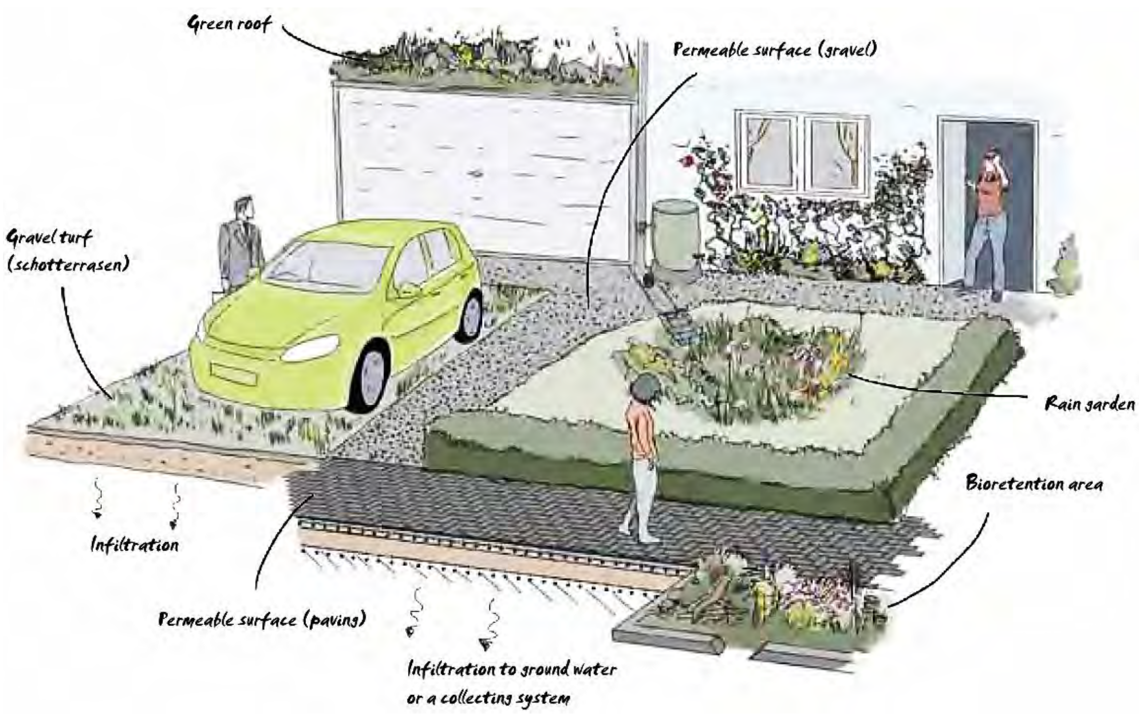


Figure 5. Variety of permeable surfaces together with other stormwater water management systems (source, Andy et al. 2012)

3.6.3. Vegetated Swale

Vegetated swales are linear, shallow channel that infiltrate water to the ground gradually or transport water from one part of the stormwater management areas to the next (collection area/pond). Vegetated swales can be densely planted with a variety of trees, shrubs, and/or grasses. Vegetative swales convey stormwater naturally, promoting infiltration, reducing runoff volume, and filtering pollutants. Vegetated swale are an economical alternative to storm piping and may be constructed between a street, parking lot or commercial areas, industrial areas and parks to provide a natural stormwater infiltration zone (Andy et al. 2012).

Figure 6: Vegetated swale alongside parking (Pennsylvania Stormwater Best Management Practices Manual, 2006).

Multifunctional benefits

- **Regulating service –** Slow runoff from hard surfaces; allow natural infiltration into soil; transport water to a specific collection area while filtering pollutants.
- **Recreational –** ideal for informal recreation and relaxation or formal with integration of seating benches; soft landscaped edge to hard surfaces can enhance aesthetic appeal; wildflower enhancement of grassland and ephemeral water increases visual appeal.
- **Biodiversity –** provide shelter and food for invertebrates, birds and animals; can be planted with native wetland plants, taking care not to impede stormwater passage and visibility; shallow pools upstream of check dams provide opportunities for wetland plants.

Design Guidelines

- In cross section, slopes need to be shallow, not greater than 1:3.
- Grass can be used to provide immediate water treatment function but to provide habitat, native wetland species pants need to be planted.
- Under-drain to create dry swale or exclude under-drains to create a wet feature
- Where check dams are used to minimize erosion, creating small wet areas can be considered
- Swales should not be connected until all bare soil has been turfed or until sown grass has developed a closed sward
- Curbs should be lowered or removed to allow free flow from hard surfaces into grass swales
- To enhance swale habitat, planting or sowing with native wetland species should be considered.

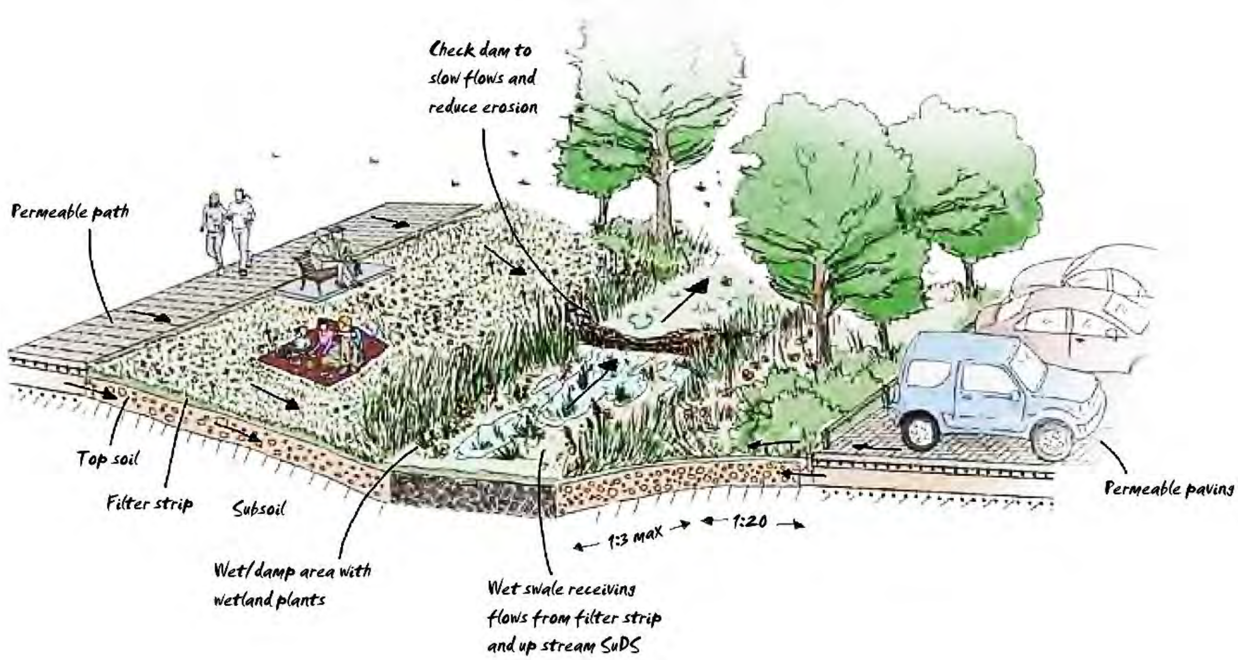


Figure 7. Wildlife-rich wet swale with check dam (linked to filter strip). (Source, Andy et al. 2012)

3.6.4. Green roofs

A green roof is a conventional rooftop that includes a covering of vegetation which allows it to act like a pervious surface instead of an impervious one. Green roofs provide runoff storage volume in the void space of both the growing medium layer and the drainage layer. There are two types of green roofs: intensive and extensive (Laura, 2010).

Extensive green roofs involve a shallow growing medium layer (typically less than 12 cm) and therefore support plants with shallow root systems, such as herbs, grasses, moss, and sedum.

Intensive green roofs include a deeper growing medium layer (typically between 12 cm and 35 cm) that can support plant species with deeper root zones, including trees and shrubs.

Intensive green roof systems are generally limited to flat roofs and require significantly more maintenance than extensive green roof systems.

Figure 8. Intensive green roof over a building (left) and extensive green roof over a bus stop sitting (right) (source: CIWEM, 2010)

Multifunctional benefits

- **Regulating service –** Slows and reduces runoff particularly during intense storms; generates supply of filtered water suitable for wildlife; reduction in the urban heat island effect through evaporative cooling; traps air borne pollutants; noise reduction; extensive roofs may not provide as much attenuation as that intensive green roofs.
- **Recreational –** increase visual and physical access to green spaces; can provide a community resource as an informal recreation and meeting space (especially intensive green roofs); educational opportunities especially in schools or public spaces (especially intensive green roofs)

- **Biodiversity –** bio diverse green roofs feature a variety of habitats both wet and dry; feeding and foraging areas for birds and invertebrates; habitat for breeding invertebrates; stepping stone habitat in urban areas; potential for water features to be included.

Design Guidelines

- Roofs with slopes greater than 45^{o} are typically not suitable for a green roof system.
- Careful attention and additional maintenance are necessary during the first two growing seasons to ensure establishment and proper function as a volume control system.
- Access should be considered for ease of inspection and maintenance.
- The load-bearing capacities of green roofs must be verified by a structural engineer and architect. Roof structure must be able to support green roof loading.
- Growth media should consist of 80% lightweight inorganic materials and 20% organic matter.
- Native plants should be selected
- If vegetation consists of drought-resistant plants, irrigation is usually only necessary during the plant establishment period. Otherwise, an irrigation system is a typical component of a green roof system (water reuse system may be used for irrigation).
- Pretreatment measures are not required for green roof systems.
- For extensive green roofs, a varied depth of substrate from 8cm to 12cm need to be ensured to increase water holding capacity and diversity of vegetation.
- For intensive green roofs, 70% of the roof area should be soil and vegetation (including water features if needed)

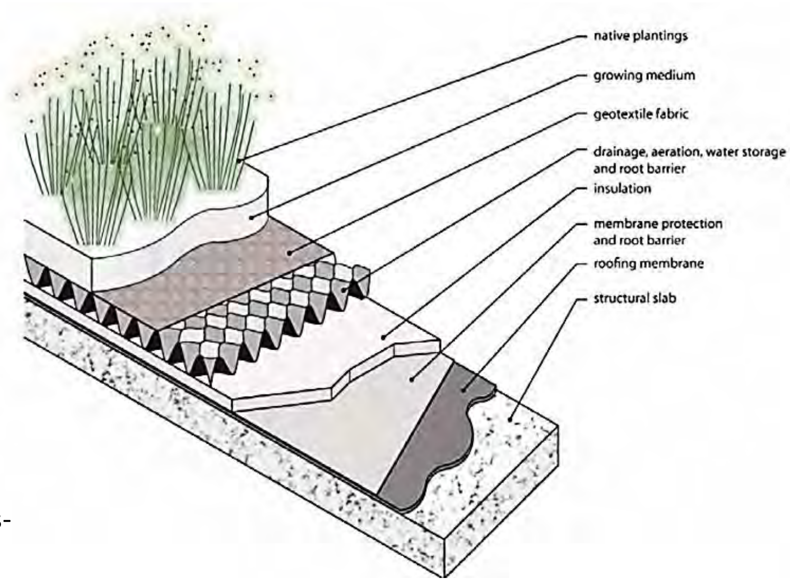


Figure 9. Typical Green Roof Cross-section (Source: City of Chicago, 2014)

3.6.5. Runoff Capture and Reuse

Runoff capture and reuse methods encompasses a wide variety of water storage techniques designed to "capture" precipitation, hold it for a period of time, and reuse it. These storage techniques may include cisterns, underground tanks, above-ground vertical storage tanks, rain barrels or other systems. Rain barrels and cisterns can be used in parks to capture roof runoff from pavilions, education centers or community recreation centers to then be used to irrigate gardens and water plants, flush toilets, storage for firefighting needs, etc.

Figure 10: Rain or large containers that collect stormwater and store (Pennsylvania Stormwater Best Management Practices Manual, 2006).

Multifunctional benefits

- **Regulating service –** reduces runoff discharge by collecting for reuse; generates supply of filtered water to water green areas back; pollutant removal may take place primarily through natural filtration by soil and vegetation.
- **Recreational –** generate supply of filtered water to be reused for recreational water bodes such as fountains or water play areas; can also be used to flash toilets in public recreational areas; stored water can be used for firefighting needs in public recreational or residential areas.
- **Biodiversity** – not directly but stored water can be used to meet the needs of landscaped areas and gardens, hence improving biodiversity.

Design Guidelines

- Water need for the intended uses should be calculated. For example, what will the collected water be used for and when will it be needed? If a 2,000 square meter area of lawn requires irrigation for 4 months in the summer at a rate of twice per week, how much will be needed and how often will the storage unit be refilled? The usage requirements and the expected rainfall volume and frequency should be determined.
- Designs should provide for use or release of the stored water between storm events in order for the necessary stormwater storage volume to be available.
- The Catchment Area on which the rain falls should be considered. The catchment area typically handles roof runoff.
- The first flush runoff may be diverted away from storage in order to minimize sediment and pollutant entry. However, rooftop runoff contains very low concentrations of pollutants.
- Screens may be used to filter debris from storage units.
- Cisterns should be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface, and capable of receiving water from rainwater harvesting system.
- The proximity to building foundations should be considered for overflow conditions.
- Covers (lids) should have a tight fit to keep out surface water, animals, dust and light.
- Positive outlet for overflow should be provided a few inches from the top of the cistern.

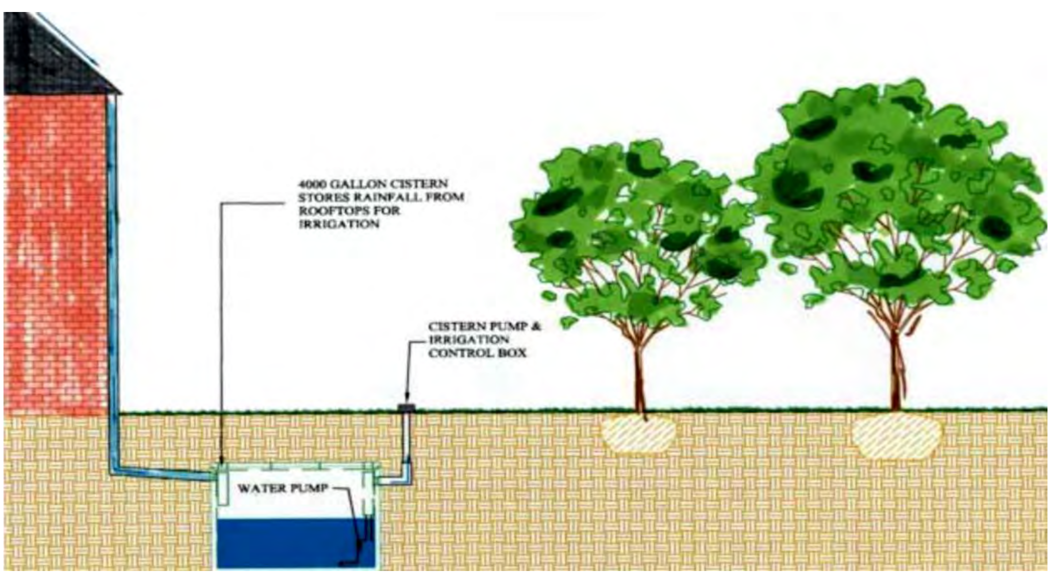


Figure 11. Typical underground rainwater capturing system (Pennsylvania Stormwater Best Management Practices Manual, 2006).

3.6.6. Estimating Surface Runoff

In order to propose and design sustainable drainage systems in a specific area, the amount of runoff should be calculated

The Rational Formula method – is the most commonly used method of determining peak surface runoff for small areas, due to its simplicity and ease of application. The rational method is a storm sewer evaluation method based on the rational formula (Maidment, 1993). The rational formula calculates the peak flow rate as a function of the rainfall intensity, the watershed area, and the runoff coefficient.

The Rational Formula is expressed as

$$\mathbf{Q = (C)\,(\mathit{i})\,(A)}$$

Where: Q = Peak rate of runoff (in m^3)

C = Runoff coefficient (dimensionless unit)

i = Average intensity of rainfall (converted to m)

A = Surface/catchment Area in m^2

Components of the rational formula

A – The area – draining to any point under consideration in a stormwater management system must be determined accurately. Drainage area information should include:

- Land use – present and predicted future as it affects degree of protection to be provided and percentage of imperviousness.
- Character of soil and ground cover as they may affect the runoff coefficient.
- General magnitude of ground slopes which, with previous items above and shape of drainage area, will affect the time of concentration. This includes information about individual lot grading and the flow pattern of runoff along swales, streets and gutters.

i – Rainfall Intensity – rain fall intensity is the average intensity rain fall. In case of calculating the total amount of runoff, the total amount of rainfall throughout the year should be used.

C – The runoff coefficient – The runoff coefficient of a surface will vary with surface material or soil type of the area. Infiltration rate is strongly influenced by the proportion of sand, silt, and clay (texture). Predominately clay soils have low infiltration rates, and a higher runoff coefficient. And sandy soils can infiltrate runoff rapidly and adversely impact groundwater, hence having a lower runoff coefficient.

The other factor that significantly influence surface runoff is the slope of land. Flat surfaces have lower surface runoff, while steep surface have a higher surface runoff. The following table is with summary of surface runoff coefficients with respect to slope, surface material and soil type.

Table 4. Runoff coefficient for different slope percentage and soil type (Source: FDOT, 1987)

Slope	Surface cover (material)	Runoff coefficient			
		Sandy soils		Clayey Soils	
		Min.	Max.	Min.	Max.
Flat (0-2%)	Grass, green covers	0.15	0.20	0.20	0.25
	Roof (corrugated sheet), Asphalt, concrete pavements	0.95	0.95	0.95	0.95
	Semi-pervious Pavements, compacted soils, cobble stones	0.75	0.95	0.90	0.95
	Vegetated swale	0.1	0.15	0.15	0.25
	Rain Garden	0.1	0.15	0.15	0.25
Rolling (2-7%)	Grass, green covers	0.20	0.25	0.25	0.30
	Roof (corrugated sheet), Asphalt, concrete pavements	0.95	0.95	0.95	0.95
	Semi-pervious Pavements, compacted soils, cobble stones	0.80	0.95	0.90	0.95
Steep (7%+)	Grass, green covers	0.25	0.35	0.30	0.40
	Roof (corrugated sheet), Asphalt, concrete pavements	0.95	0.95	0.95	0.95
	Semi-pervious Pavements, compacted soils, cobble stones	0.85	0.95	0.90	0.95

Run of coefficient for green roof vary depending on green roof depth. Generally the runoff coefficient for green roofs estimated from 0.10 (for deep intensive green roofs) to 0.5 (shallow extensive roofs).

3.7. Considering Vegetation Covers

Vegetative cover are important features that exist in many different configurations in urban green spaces. In urban areas, they may take the form of linear parks, planted areas along roads, or Greenways. Each of these habitats can provide different functions, but they can all be designed to facilitate or regulate microclimate, flows of water, resources, or certain organisms. For example, linear corridors can be important for their role in rebuilding connections that were available in the landscape before it was fragmented by development. Cultural connectivity is also important, as corridors can allow movement of people between neighborhoods of different social and economic levels (Shafer et al. 2000, Hellmund and Smith 2006).

In addition, vegetation covers can serve another important role in protecting sensitive areas through a variety of regulating services (Fischer et al. 2006). Extensive root systems of perennial plants hold soil in place, allow greater infiltration of water, and trap the sediment entering from adjacent areas (Lowrance et al. 2002, Lee et al. 2003). Vegetation covers can reduce the severity of flooding by slowing water flow and increasing the infiltration of water into soils (Schultz et al. 1997). And vegetation covers with trees can provide additional functions including filtering polluted air, mitigating unpleasant odors (Tyndall and Colletti 2001), reducing noise (Thompson and Sorvig 2000), and regulating the microclimate with their shade (Bolund and Hunhammar 1999).

3.8. Example of ecological landscape design

3.8.1. Village of Yorkville Park

The idea of this urban park dates back to the late 1950s, when a block of Victorian-era row houses was demolished along Cumberland Street to allow for the construction of the Bloor

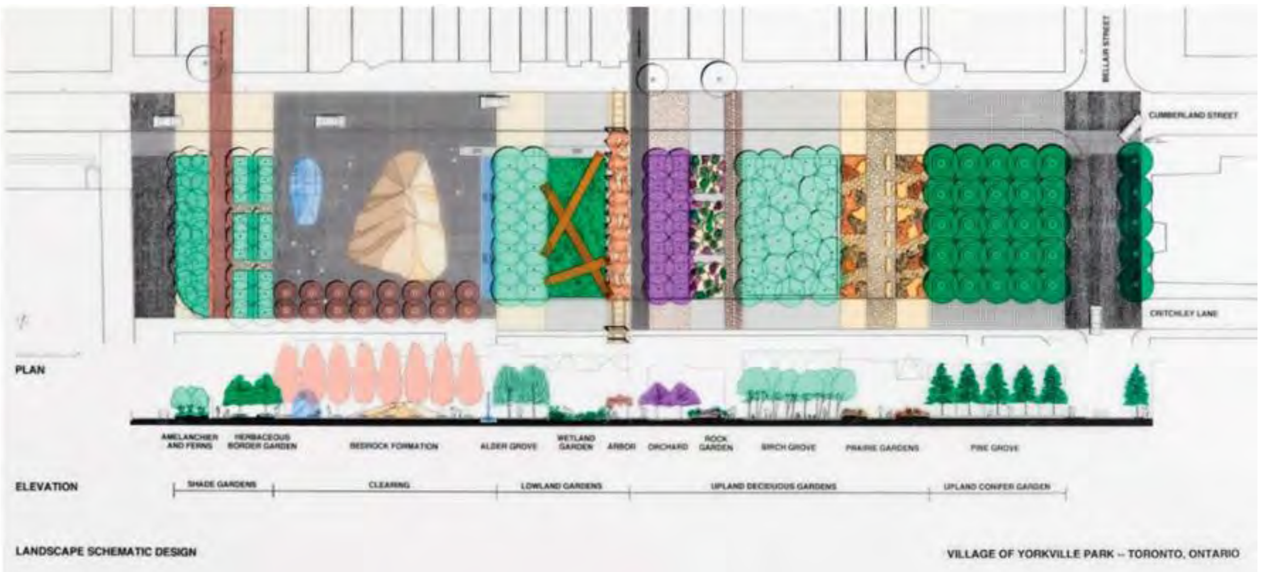


Figure 12 Village of Yorkville Park landscape schematic design (Anonymous, 2012)

Danforth subway line. The park sits on the cusp of two neighborhoods: the small-scale, old Yorkville neighborhood with its late 19th and early 20th century row houses, and the high- rise commercial core that has built up along the Bloor Street corridor since the subway opened. For years, this highly visible site remained a parking lot. Activist neighbors fought to build a public place to bring the neighborhood together rather than to divide it. Finally, in 1991, the City of Toronto Department of Parks, Forestry and Recreation announced an international design competition.

The community wanted a park that reflected the scale and context of the neighborhood, incorporated the native ecology of the surrounding region, and made connections with the circulation of local streets and a system of midblock passageways. The design strategy for the competition was to design the park to express the Victorian style of collecting. In this case, “collecting” landscapes of Ontario -pine groves, prairies, marshes, orchards, alder woods, rock outcroppings and so on -and arranging them in the pattern of the nineteenth century row houses.

The park design creates a series of linear subdivisions with contextual alignments to the building lot lines across the street and connections to mid-block passageways in the adjoining blocks. Each linear park segment is distinct in character, but related to the next, creating a park of diversity and unity. To anchor this space with an element of regional glacial geology, a large 700-ton bedrock outcrop of native Muskoka granite was taken apart along natural crevices, moved 150 miles south, and reconstructed on site. Immense yet inviting, the outcrop has a wonderful tactile surface for sitting and absorbs warmth on cool sunny days. Moveable tables and chairs next to the boulder offer a nice contrast of permanence and flexibility.

Figure 13; Village of Yorkville Park (Celik, 2013)

3.9. Summary of literatures

Recreational green spaces are landscape elements of the urban ecosystem, which are normally enclosed, designed, constructed, managed and maintained as public parks or amenity spaces. Usually when designed, they incorporate other types of green spaces such as children's playgrounds, sport facilities, parking areas, buildings or cemeteries. The primary functions of recreational green spaces are for provisioning of cultural ecosystem services such as relaxation, aesthetic benefits and social cohesions. In addition, recreational green spaces also provide regulatory ecosystem services, which include air quality maintenance, stormwater regulation, local temperature regulation and noise reduction.

Although it is challenging to design recreational green spaces for multi-benefits that filter stormwater, clean the air, provide wildlife habitat in addition to the primarily intended recreational services. In this regards there are several design possibilities exist at the site level to improve multi-functionality of open green spaces. An ecological landscape design approach such as Sustainable Drainage systems offer multiple functions. Primarily the systems are used to capture, infiltrate, and treat some portion of storm water runoff, reducing the negative impact on aquatic ecosystems. These features can also be designed into the landscape to provide a wide range of additional ecological functions (regulatory ecosystem services) such as microclimate control, wildlife habitat, and biodiversity, as well as cultural functions including education and visual quality. The following figure illustrates how ecological landscape design approaches to address one of the urban resident's problems (such as stormwater) eventually provide multiple benefits and enhance overall ecosystem services.

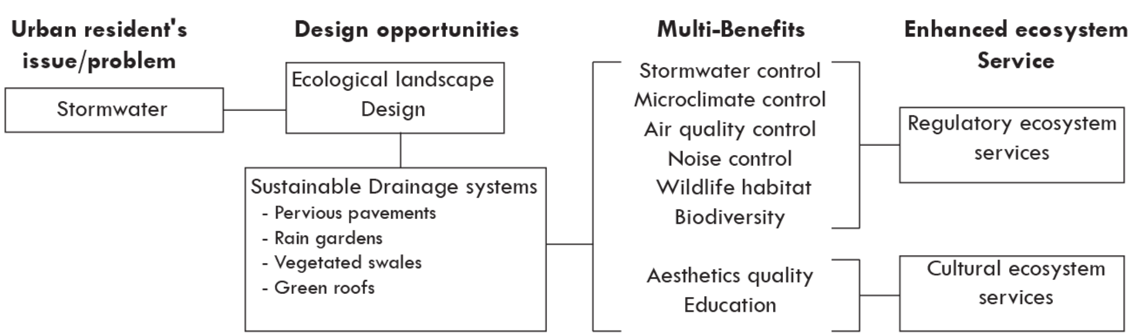


Figure 14. A summary of multi-benefits and ecosystem services that can be derived from ecological landscape design

CHAPTER FOUR: DESCRIPTION OF THE STUDY AREA

4.1. Introduction

There are some important points to be considered when studying the current condition of green spaces in the neighborhoods of Addis Ababa. The city's early urban development pattern, which is playing a fundamental role in guiding its urban development is one of the important factors. As a Consequence, discussing such factors in brief might help to have a general insight about the provision, growth and development of green spaces in Addis Ababa since the establishment of the city.

4.2. Historical Open Space Development in Addis Ababa

The establishment and growth of Addis Ababa is debatable as to whether it is a spontaneous settlement (Kumlachew, 2007) or the outcome of careful planning by Emperor Menelik II (Yirgalem, 2007). The initial area chosen for the establishment was on top of the Entoto Mountain in 1878, a mountain found on the northern part of today's city (Kumlachew, 2007). There Menelik II built two churches and a palace on top of Entoto. But due to the rugged topography and the extremely cold climate discourages the king to live and moves southwards to Finfine. This place of settlement was mainly chosen by Empress Taitu (wife of Menelik II). The emperor was very much attracted by the suitable climate and the hot spring of Finfine. Consequently the first house was constructed near to the hot spring water (Kumlachew, 2007; Yirgalem, 2007; Dirk and Elias, 2012).

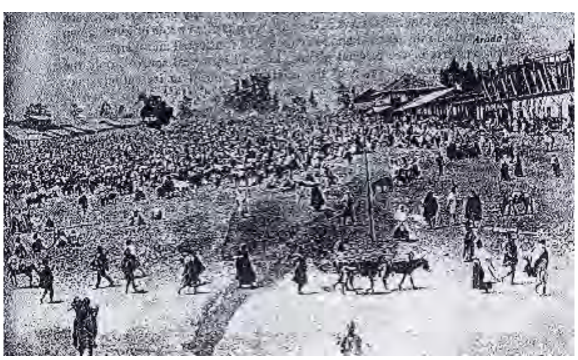


Figure 15: Early settlement of Addis Ababa; Left side Arada market and right side Gihibbi (Source: Kumlachew, 2007)

The general organization of the settlement was three institutional nodes and many 'sefers' (neighborhood like camp). The institutions were the castle of the King (Ghibbi), the church (Saint George Church), and the large open market called Arada. The 'sefers' were established by the allotted plots of lands to the king’s major chiefs. Between the 'sefers' there were considerable distances to avoid possible conflicts, which intern gives a chance for the residents to have their own open green spaces for their day to day activities (Yirgalem, 2007; Mikiyas, 2011).

The Kings castle (Ghibbi): - the grand palace has a very huge open space within its compound. This open space serves for different purposes, mainly for feeding all people weekly and occasionally (it is called Geeber).

The Saint George church: - the church had its own big open space outside. In this space the worshippers gather for different religious events like Meskel (the founding of the true cross).

Arada Market: - is a very big open market and used to serve people for different public activity. It can be said that it was the only public space in the era.

It is unarguable that these open public spaces played a fundamental role in the early development of Addis Ababa. However, the quality of their physical and spatial development in terms of urban space was very poor (Yirgalem, 2007).

4.3. Status of Green Spaces in Addis Ababa

In Ethiopia, the urbanization phenomenon has brought environmental problems in most urban centers, including Addis Ababa. Among the main environmental problems the degradation of open green areas is worth mentioning. The urban green areas are consumed by industrial, commercial, residential, infrastructural developments, and spontaneous and illegal settlements (Mpofu, 2013).

The disappearance and extreme pressure on green spaces of Addis Ababa is destroying the scenic beauty of its landscape; and decreases the ability of green areas to perform their basic ecological, social and economic function; thereby increasing unsustainable urban growth of the city (Mpofu, 2013).

Most of the social gatherings and children are forced to use the circulation roads; which intern disturbs the transportation system and the safety of children. Besides, it forces the youth to find a playing field out of their neighborhood, which is difficult for their parents to control.

Ethiopia after the Rio-Summit held in Brazil in 1992, have tried to address the environmental deterioration in many regards. The first and major decision is putting an article (Article 44) on the country's constitution in 1995. The article clearly states that the people of Ethiopia have the right to live in a healthy environment. Following the article the country establishes Environmental Protection Authority (EPA) in the same year. The environmental policy of the country was also developed after two years in 1997 (Mpofu, 2013).

In Addis Ababa, to improve the environmental degradation following the above decisional move a remarkable work was done on the master plan revision held on 2003. In the master plan out of the 54,000 hectares of the city 22,000 hectares or 41% was assigned for greenery purposes. And besides, Greening and Beautification office is established. But, the difficulties encountered in determining the ownership rights of several pieces of land by the city's land administration have brought problems for new Greening and Beautification Office in implementing the Development plan. This in turn obscures the implementation on the ground, the vivid intention seen on the Development plan on open spaces (Mpofu, 2013; Mikiyas, 2011).

4.4. Green space typologies in Addis Ababa

Different typologies of green spaces exist in a great variety of shapes and structures within the city and are classified in various ways based on vegetation type, size, intended function and landscape context. The following classification of existing green spaces in Addis Ababa is based on morphology and ecological function, adapted from a report conducted on green area typologies and mapping of green structures in Addis Ababa and Dares Salaam (Kumelachew et al, 2014).

The amount of green space in Addis Ababa in 2014 was 21,636 hectares, which is categorized into field crop, vegetable farm, public recreational parks, riparian vegetation, plantation forest, institutional forest (mixed forest), street plantation, and grassland.

Field crop: mostly grown on rainy seasons (June to September). After crop harvest (usually in November and December), the land remains bare and the land is used for livestock keeping. Tef (*Eragrostis tef*), Wheat (*Triticum aestivum*) and Barely (*Hordeum vulgare*) are the common field crops planted in Addis Ababa.

Vegetable farm: mostly planted along the river to make use the river for irrigation purposes. Cabbage (*Brassica oleravea*), tomato (*Lycopersicon esculentum),* potato (*Solanum tuberosum*), carrot (*Daucus carota*), onion (*Allium cepa*), garlic (*Allium sativum*), and lettuce (*Lactuca sativa*) are the major vegetable types grown on alongside the rivers.

Public Recreational Parks: enclosed, designed, constructed and managed green spaces constituting trees, shrubs, herbs and grasses. Parks in Addis Ababa provide recreational and social services such as public gathering, wedding receptions and birthday ceremony. At present there are 18 recreational parks in Addis Ababa, ranging in size from 647 to 142,796 ha.

Riparian Vegetation: plant types which grow along the riverside of Addis Ababa. Addis Ababa is drained by several rivers and stream which originate from the north, northwest and northeastern part of the city and flowing towards the south and finally drain into the Awash River.

Plantation forest*:* vegetation type found on the upper catchments of Addis Ababa, especially on Mt. Entoto. *Eucalyptus* is the dominant tree in plantation forest, although in some places pure stands of *Cupressus lusitanica* and *Pinus patula* could also be found.

Institutional forest (mixed forest): This category includes forests that are found within the compounds of governmental and non-governmental institutions. A mixture of both indigenous and exotic tree and shrub species constitute this forest. Due to this higher biodiversity is expected to exist in the institutional forest of the city.

Street plantation: Planted trees on pedestrian roads, road median and road corridors. Although the street trees of Addis Ababa having problems in establishing and growing well because of improper site management and follow up, their shading provision service is found to be more important as the climate of the city is increasing.

Grassland: green spaces largely covered with grasses. In Addis Ababa grasslands are found in military compounds, golf field, church compounds, and airports. During the rainy season, grasses develop on bare lands, changing the morphology of the landscape.

Bareland: a land which has never been occupied by any structures or a land which now isbare, butt used to be covered by built structure or vegetation. During the dry season the bare lands are devoid of vegetation and during the wet seasons bare lands are covered with grasses and other herbaceous vegetation.

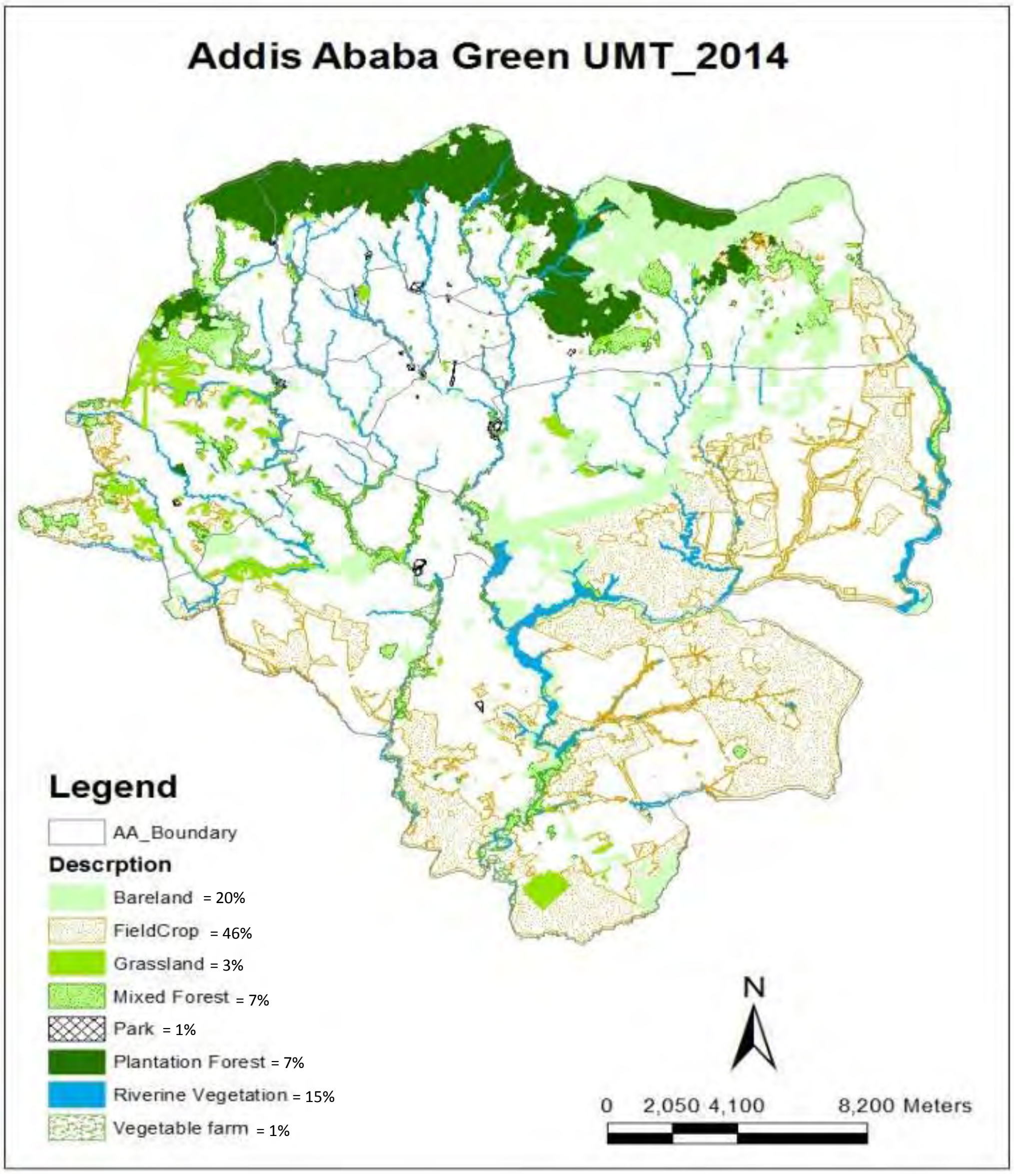


Figure 16. Green space map of Addis Ababa 2014 (Kumelachew et al., 2014)

4.4.1. Hierarchy of recreational parks in Addis Ababa

In order to ensure adequate provision of recreational facilities and dedicated park space cities usually provide a standard which is usually based on the park area, accessibility and population. Such park standard has never been in place in Ethiopia (Kumelachew et al, 2014). The master plan of Addis Ababa, which is under revision, proposed recreational park hierarchy based on park size. Accordingly, four hierarchies are recognized and the Ethiopian National Urban Green Infrastructure Standard (2015) describes the standard requirements for the recreational parks as follows:

Neighborhood Park: A size of around 0.5 hectares, which can serve up to 5,000 people in a radius of 500 m, with a carrying capacity of 0.1 ha/1,000 population and shall be located on local or collector streets, not arterial streets.

Woreda Park: A size of around 3 hectares, which can serve up to 40,000 people in a radius of 1,000 to 1,500 m, with a carrying capacity of 0.075 ha/1,000 population and shall be located on local or collector streets, not arterial streets.

Subcity Park: A size of around 8 hectares, which can serve up to 160,000 people in a radius of 4,000 m, with a carrying capacity of 0.05 ha/1,000 population and may be located on arterial streets.

City Park: A size of more than 15 hectares, which can serve up to 300,000 people in a radius of 6,000 m, with a carrying capacity of 0.05 ha/1,000 population and may be located on arterial streets.

Generally, all recreational park typologies are important in improving the quality of urban life for residents by providing several recreational services. But recreational parks that are found within residential area's proximity are the most important due to their accessibility (Jim et al., 2006). Hence, this study focused on neighborhood parks that are found within residential areas of Addis Ababa. Accordingly, three case neighborhood parks are selected from Bole Subcity.

4.5. Description of the case sub-city (study area)

The Bole sub city is one of the 10 sub cities in the Addis Ababa city administration. It lies 901’8’’N and 38049’29’’E. geographically; it is situated in the eastern part of the city. It shares boundary with Yeka Sub city in the north, Chirkos and Nifas silk lafto sub cities in the west and Akaki Kaliti sub cities in the south. In the East it also shares boundary with oromiya region. The sub city is divided in to woredas and covers an area of 122.8km^2.

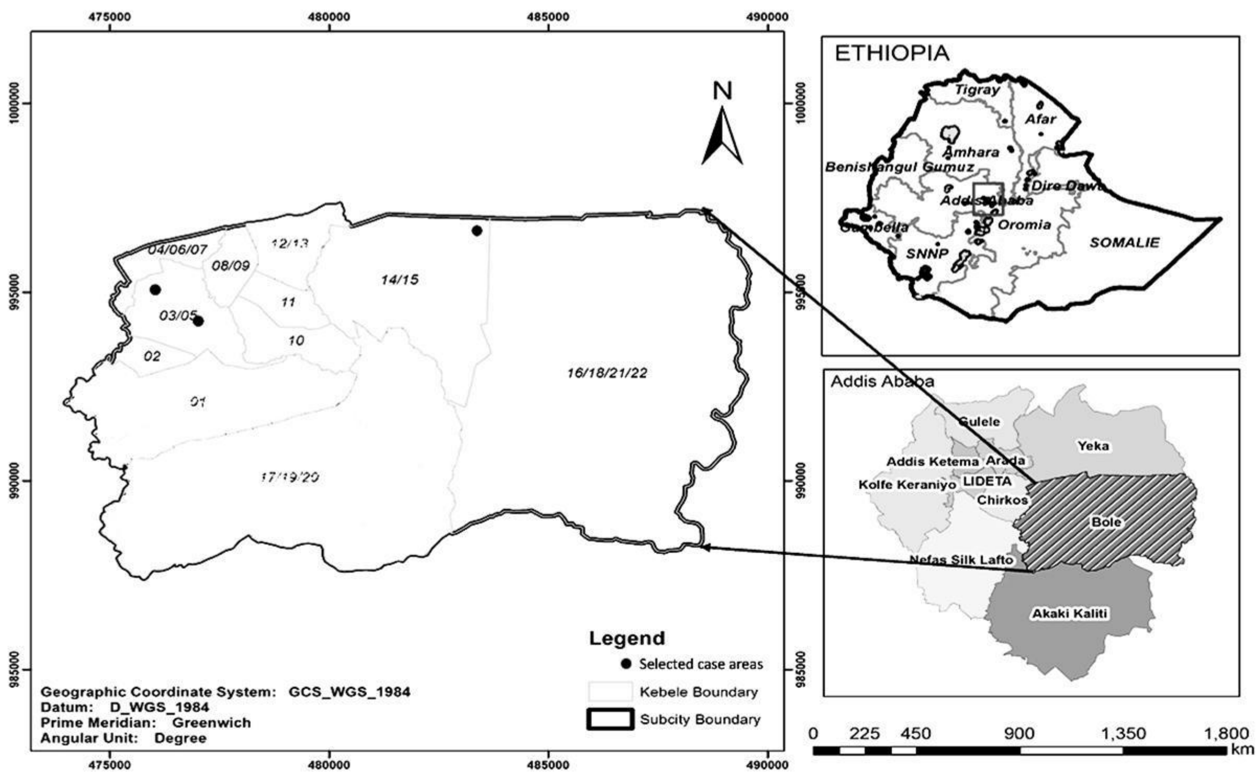


Figure 17 Geographical location of the study area. (Source: CSA 2014)

Three case areas of neighborhood parks are chosen for the study. Two of these case areas are from earlier single unit residential neighborhood (built before 1991 GC / in Derg regime) and the third case area is from new single unit residential neighborhood (Built after 2005 GC).

The research aims to learn positive experiences from case area one and case area two, which are developed, properly designed and being used by their neighborhood, and come up with a feasible design proposal for case area three which is currently under development.

4.6. Precipitation Data

The volume of water retention by urban green spaces was closely related to the amount of precipitation in the study area (Sanders, 1986). Rainfall data for Addis Ababa is obtained from Addis Ababa Observatory Station or Bole International Airport Station. Since Bole International Airport Station is within the case sub-city and closer to the case study areas, the data from this station were used. The data includes the record of daily rainfall precipitation throughout the year ranging from 1954 to 2014 GC for 61 consecutive years.

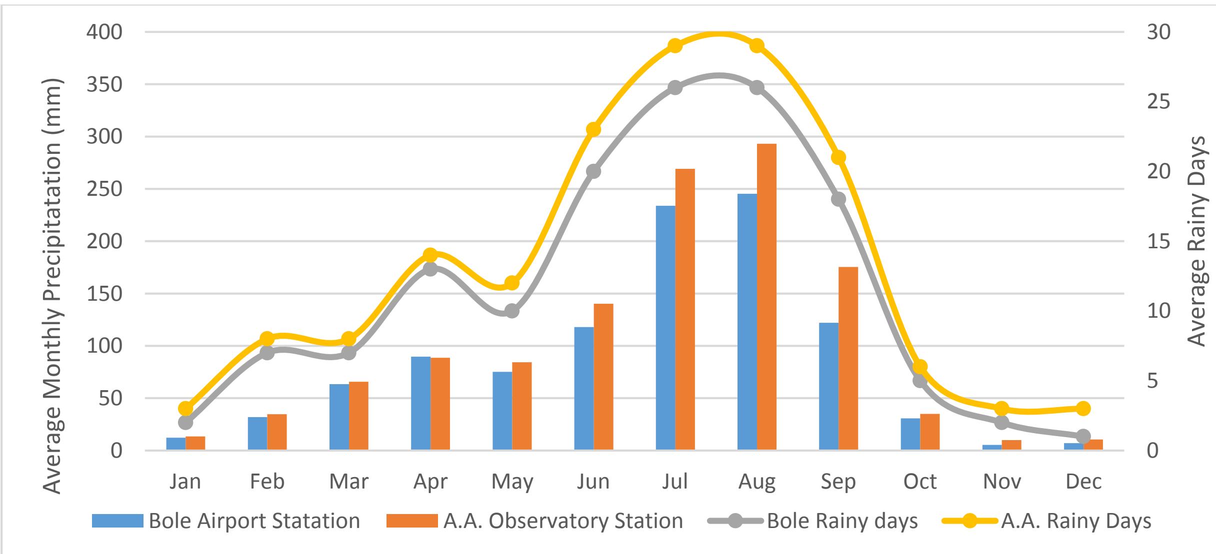


Figure 18. 24hr Rain fall data from both Bole airport station and Addis Ababa Observatory Station

Daily rainfall records of stations in Addis Ababa as obtained from National Metrological Agency depict that the rainfall distribution is bimodal in nature (Anteneh, 2015). Addis Ababa has a pronounced rainfall peak during the summer season locally known as Kiremt which is from June to September. It also exhibits a considerable amount of rainfall during February to May locally known as Belg.

Table 5. Precipitation data from Bole Airport Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall (mm)	12.3	31.9	63.4	89.7	75.2	117.9	233.9	245.4	122	30.7	5.3	7
Rainy Days	2	7	7	13	10	20	26	26	18	5	2	1

4.7. Study area 1: Shalla Public Park

Figure 19 Satellite image of Shalla Public Park in Addis Ababa (image source; Google maps)

Location – Addis Ababa, Bole subcity, woreda 23, old residential area

Housing type – Single unit housing typology

Ownership – Privately owned

Total area - ~ 13,200 square meters

Type of urban green spaces – Small Park

4.7.1. Slope analysis

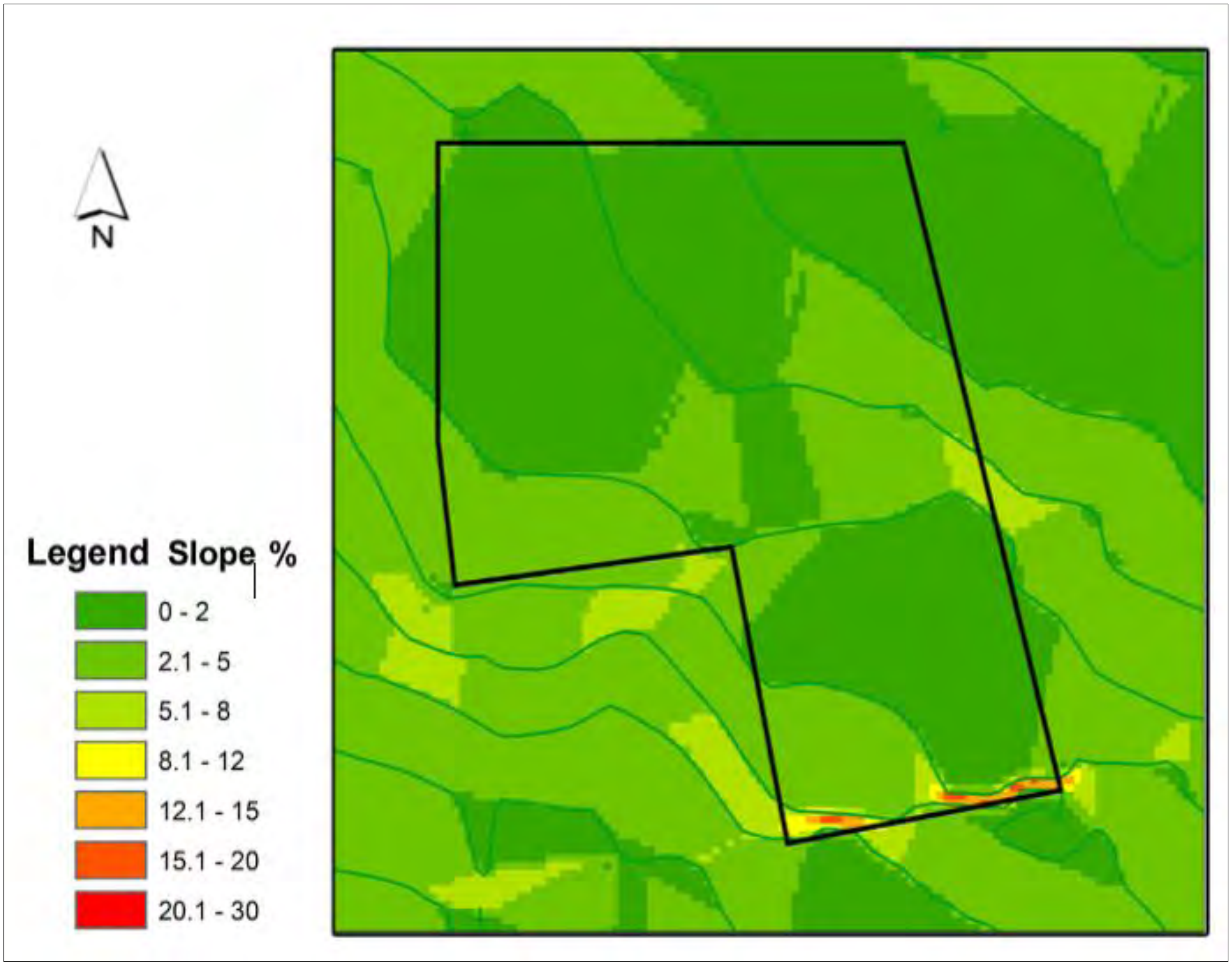


Figure 20. GIS slope analysis of Study area 1 (Shalla Public Park)

57% of the total area has relatively flat slope or below 2%. The Basketball court, the tennis courts and the majority of green courtyards of the park are located on the flat areas of the park or within the slope that is less than 2%. 40% of the total area has a gently rolling slope that is below 5%. The site also has steep slopes that range from 15% to 20%, which the research considered as negligible due to its small portion of the total area less than 1%.

4.7.2. Soil type Analysis

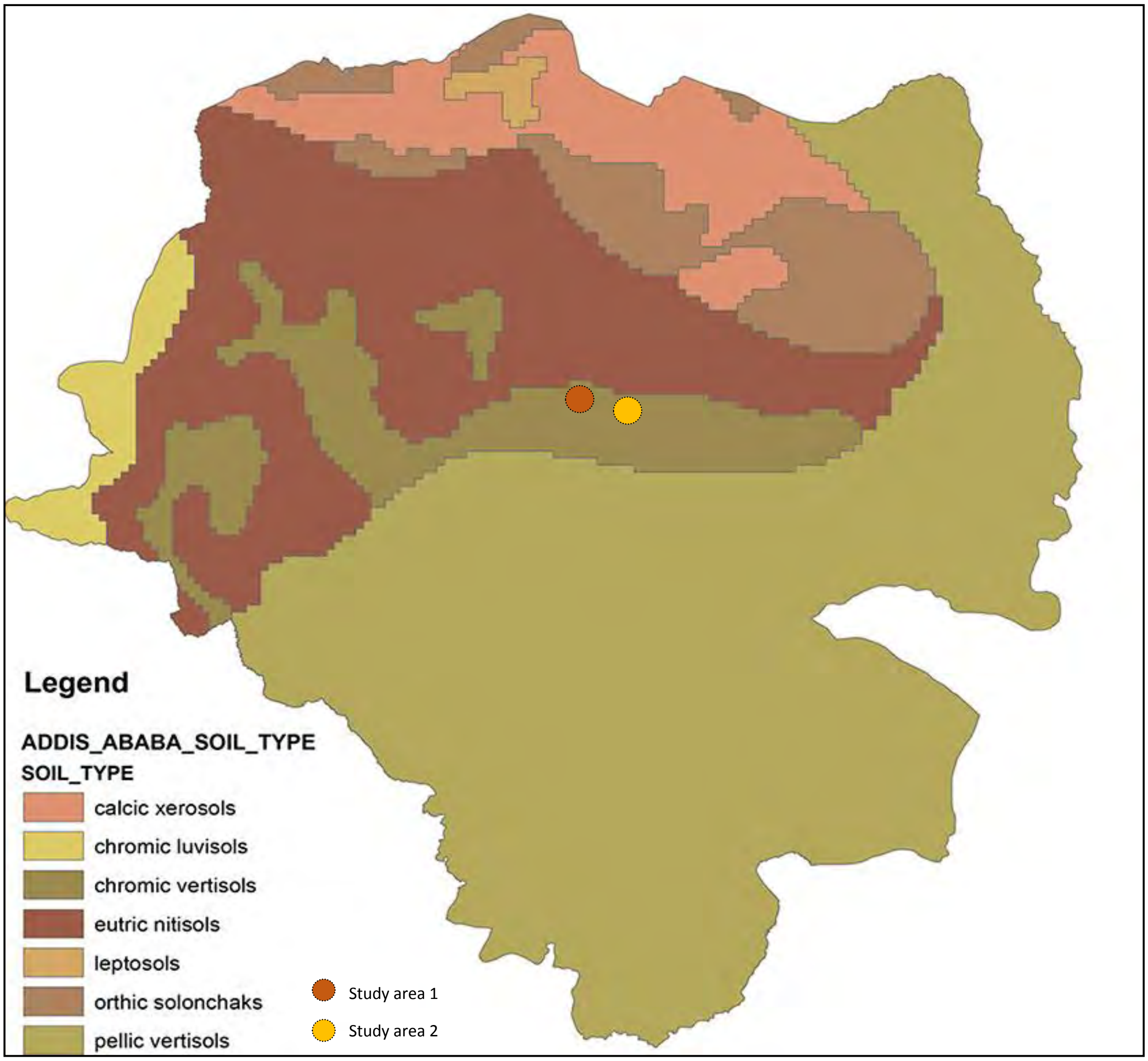


Figure 21. FAO soil classification of Addis Ababa 2004

Soils are the basic natural elements on which greeneries exist and upon which different infrastructures establish. Soil type of the case areas, therefore, is an important factor in studying public green spaces and their contribution in providing regulatory ecosystem services.

According to FAO soil classification OF Addis Ababa (2004) the soil type that exist within the case area is Chromic Vertisols. Vertisols are characterized by soils with 30% or more clay. Clays are usually active, cracking when dry and swell when wet Vertisols are extremely difficult to manage (hence easily degraded) but with very high natural chemical fertility.

4.8. Study area 2: Community recreational green space

Figure 22. Satellite image of case 2 (Image source, Google maps)

Location – Addis Ababa, Bole subcity, woreda 23, old residential area

Housing type – Single unit housing typology

Owner ship – Surrounding community

Total area - ~ 8,500 square meters

Type of urban green spaces – Amenity/recreational Green space

4.8.1. Slope Analysis

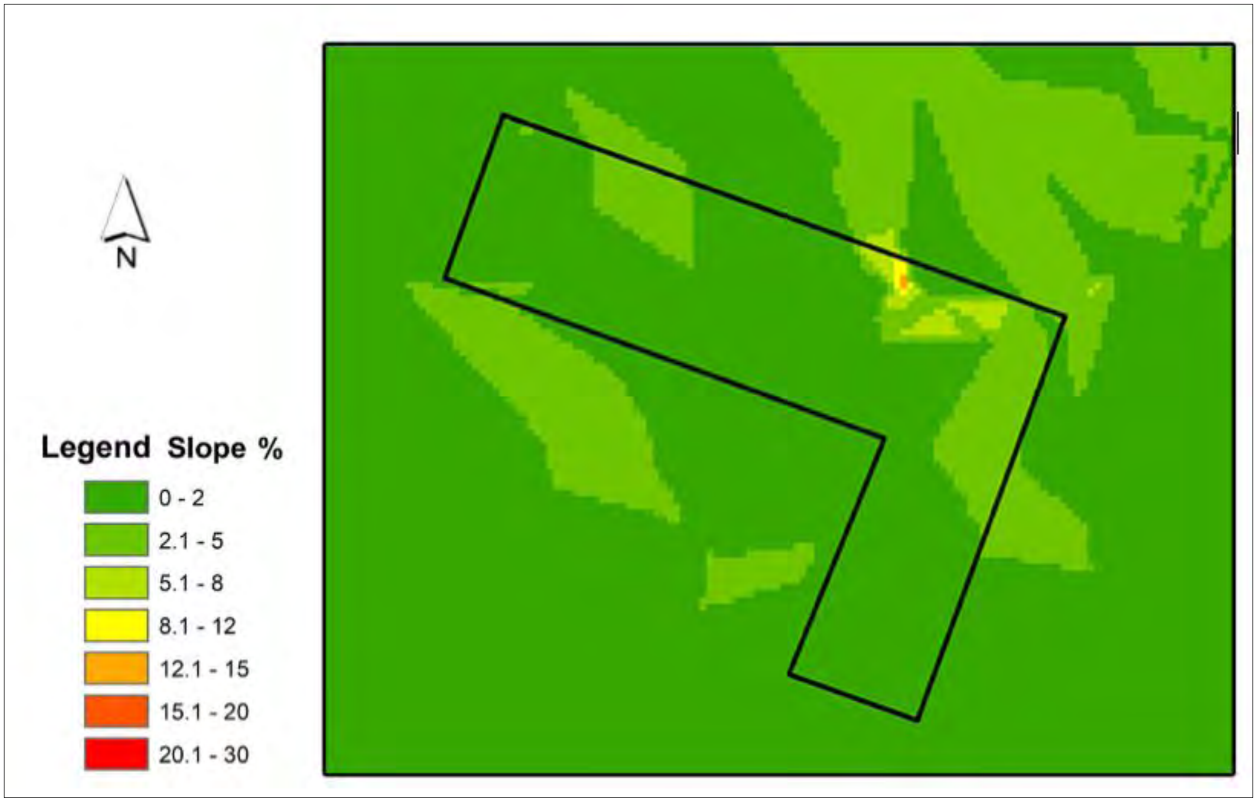


Figure 23. GIS slope analysis of Study area 2 (community recreational green space)

The majority of the study area which is 81% of the total area has a slope that is below 2%, which can be considered as a flat surface. About 18% of the total area has a slope that is above 2% and below 5%, which is a gently rolling slope. A negligible amount of area or less than 1% of the total area has a slope that a little bit above 5% and below 8%. All of recreational spaces such as the basketball court, the tennis courts, the playground and the majority of green courtyards of the park are located on the flat surfaces of the study area.

4.8.2. Soil type analysis

According to FAO soil classification of Addis Ababa (2004) the soil type that exist within the case area is Chromic Vertisols (the same soil type as study area one). Vertisols are characterized by soils with 30% or more clay. Clays are usually active, cracking when dry and swell when wet Vertisols are extremely difficult to manage (hence easily degraded) but with very high natural chemical fertility.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1. Data presentation of Study area 1

5.1.1. Vegetation Cover

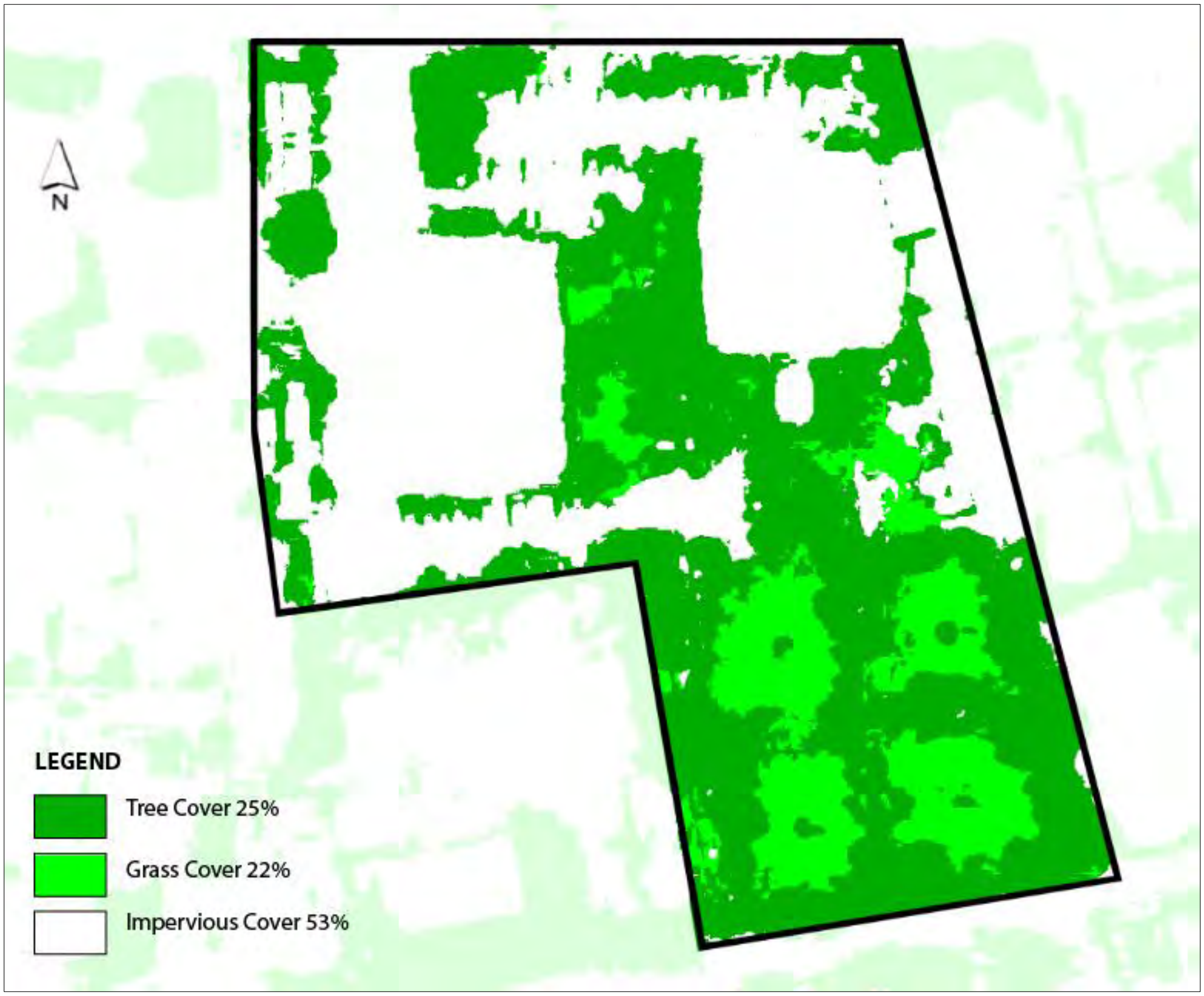


Figure 24. Vegetation covers percentage in the study area

Shalla Public Park has a total of 47% vegetation covered surface area. Though, the canopy size and shading characteristics of trees in the park covers a wider coverage, the total amount of pervious surface cover (Greeneries and trees) is smaller than the impervious surface cover, which is about 53%. The trees in the green spaces are planted by the green space's administration, and they consist a total number of 7 species. The total number of trees counted in the study area is about 113 trees.

From the total number of trees counted in the study area, 86% of the trees belong to exotic species while the remaining 14% belong to indigenous species. It can be established from this that indigenous trees are totally outnumbered by the exotic ones, while the benefits that is being derived from the exotic trees is also reasonable. *Casuarina Cunninghamiana* for instance, accounts about 29%, while it also provides multifunctional benefits such as shading, ornamental, nitrogen fixation, and soil conservation (Azene et al., 2007).

The condition of all trees in the study area can be considered as good. The reason might be because of the trees relatively young age (recently planted) and well landscape maintenance by the administrating body of the green space

Table 6. Species and number of trees found in the study area (reference for multifunctional benefits are adapted from Azene et al., 2007)

Tree Species (scientific name)	**Local Name** (Amharic)	**Origin** (Indigenous or Exotic)		**Total number of trees (**portion %)	**Multifunctional Benefits**					
					Ornamental	Shade	Nitrogen fixation	Soil conservatio	Wind Break	Food
Casuarina Cunninghamiana	*Shewshewe*	Exotic		31 (29%)	X	X	X	X	X	
Cupressus lusitanica	*Yeferenji -tid*	Exotic		15 (13%)	X	X			X	
Delonix regia	*Dire Dawa zaf*	Exotic		9 (7%)	X	X				
Jacaranda mimosifolia	*Yetebmenja zaf*	Exotic		17 (16%)	X	X				
Grevillea robusta	*Grevila*	Exotic		23 (21%)	X	X		X	X	
Juniperus procera	*Tid*	Indigenous		7 (5%)	X	X			X	
Phoenix reclinata	*Zembaba*	Indigenous		11 (9%)	X			X		
		Total		**113 (100%**						

5.1.2. Identified Physical elements of Shalla Public Park

Recreational green spaces, as the main provider of ecosystem services in residential areas, consists of different elements. The following table consists the elements identified and their conditions in the study area.

Table 7. Identified green space elements within the park (photos by author)

Elements	Description	Images
Green courtyards	Covered with well-maintained grass, and surrounded by trees and ornamental shrubs. The court serves as a recreational area and as a spot for photo shots during wedding ceremonies.	
Tree buffers	Located as space defining elements on the sides of streets, around courtyards, basketball and tennis courts and also as a buffer/fence around the park. Almost All the trees found in the study area are planted on this fusion.	
Car parking	Concrete paved (non-permeable) car parking space surrounded by mostly ornamental trees, such as *Phoenix reclinata*. Due to this most of the car parking area stays unshaded from direct sunlight throughout the day	

Sport courts (Basketball and Ground tennis courts)	Concrete paved basketball court (non-permeable) and compacted red soil paved tennis court (semi-permeable) with trees as surrounding and defining elments. There are two ground tennis courts and one basketball court in the study area	
Streets (Walkways, and Driveways)	Concrete asphalt paved streets (non-permeable) defined by shrubs and trees from the sides. The Drainage systems are found at the end of the streets and for this reason water stays on the surface for a while making walking uncomfortable during rainy days.	
Water body (Fountains)	Ornamental water fountain near by cafeteria entrance. The fountain works only on special ocassions such as for wedding cermonies or holidays. Water source four the fountain is from municipality water line.	

Water reservoir (Municipal and ground water source)	Plastic made water barrels that are used for the different recreational park's consumption. The water source to be kept in the barrels is from the munusipality water line. The barrels are located on the side of the green courtyards. Hence disturb visual aesthetics. Though its is not always relaiable, ground water source is used to water the greeneries in the compound.	
Cafeteria (With outdoor Sitting areas)	A recreational spot where, where a lot of visitors can be seen. The outdoor cafeteria is an extension of existing building that serves as a cafeteria, though people prefer the outdoor spaces, which is with sitting benches under tree sheds.	

5.1.3. Visitor's Experience in the study area

Data about the activities in the public park are mainly gathered from visual observation and informal interviews. Accordingly Social Ceremonies, Recreation, Sport activities, Children playing and Parking Services are the main activities identified.

General information about the visitors

Age – Shalla Public Park has visitors that are of a composition of different age groups. The following table summarizes the age composition of visitors counted on one of the busiest days of the park (Saturday).

Table 8. Age characteristics of visitors

Age group	Below 15	15-25	25-35	35-50	Above 50	Total
Number of Visitors	9	22	18	36	17	102

Among the counted 102 visitors, most of them were in the age group 35-50 counting about 35%, Teenagers (age group 15-25) counted about 21%, age groups 25-35 counted 18%, age groups that are above 50 counted about 18% and young visitors aged below 15 counted about 8% being the least.

Gender – Shalla public Park has visitors that are of a composition of both genders. The following table summarizes the gender composition of visitors counted on one of the busiest days of the park (Saturday).

Table 9. Gender composition of visitors

Gender	Male	Female	Total
Number of Number	67	35	102

Among the counted 102 visitors, most of them were males counting about 66% and females counting about 34%. While males can be seen in the park everywhere such as on sport courts, cafeteria and green court yards, females where only present at the cafeteria and a few on green courtyard areas.

5.1.4. Identified activities

Data about the activities in the public park are mainly gathered from visual observation and informal interviews. Accordingly Social Ceremonies, Recreation, Sport activities, Children playing and Parking Services are the main activities identified.

Social Ceremonies; Shalla Public Park has a building that has a multipurpose hall of about 750m^2 that it uses and rents off for several occasions and festivals, such as wedding receptions, holiday or religious ceremonies and organized festivals. Renting off of the hall is the one of the main income generating ways for the park. During the study a number of wedding ceremonies have been observed on weekends. And a festival such as the annual Japan festival held in the auditorium of the park is notable.

Figure 25; Left is outdoor view of the multipurpose hall and Right is the 5th annual Japan festival 2013 (source; Embassy of Japan website)

Recreation: Shalla Public Park serves as a place where people meet and spent time with friends, families or business partners. Visitors use the recreational amenities provided by the park such as a cafeteria and outdoor sitting areas for their meetings.

On Fridays and weekends the number of visitors increases up to 100 and above (102 Visitors counted in one of the Saturdays). Among this number of visitors most of them (66 visitors or about 67% of the visitors) spent their time at the outdoor sitting areas and cafeteria. And among these visitors 60 of them preferred and used the outdoor sitting areas and only 6 of the visitors stayed in the cafeteria.


Figure 26 Outdoor sitting area around cafeteria (Photos by author)

Sport Activities: Shalla Public Park is also a place for sport activities such as ground tennis and Basketball. The Park has two ground tennis courts and one Basketball court and visitors pay in order to use the courts. Among the 102 visitors counted on one of the busiest Saturdays 28% of them were engaged in sport activities and in these two sport courts (12 visitors were in the ground tennis courts and 17 visitors were in the basketball court).


Figure 27 Basketball and tennis courts of Shalla Public Park (Photos by author)

Children playing: although Shalla Public Park has no specifically allocated space forchildren, suchh as playground, some parents brought their kids to the park. Among the 102 visitors counted on one of the Saturdays, 5 kids (below age 7) were playing in the green courtyards.

Figure 28 Children playing in the courtyards (Photo by author)

Parking services: Shalla Public Park has dedicated parking spaces for visitors of the park or for people who just want the parking services for their cars. The park has about 110 parking spots and it is another income generating way for the park. During the busiest weekends or on some occasions such as wedding ceremonies, parking space shortages are common and people tend to use the basketball court as a parking space extension. 5 cars were seen parked on the basketball court during one of the busiest Saturdays.

Figure 29 Left parking spaces and right basketball court getting used as a parking space extension (Photos by author)

5.1.5. Where in the park, visitors spent most of their time

In identifying where in the park, visitors spent most of their time, a total counting of all visitors was conducted with respect to their place of stay in the park. The following table summarized the number of visitors and age groups found in each place in the park.

Table 10. Where in the park, visitors spent most of their time

Places in the park	Outdoor cafeteria	Basketball court	Ground Tennis court	Green courtyards	Total
Number of visitors counted (Age Group)	21 (25-35) 32 (35-50) 13 (above 50) Total = 66	8 (15-25) 9 (25-35) Total = 17	2 (below 15) 4 (35-50) 6 (above 50) Total = 12	5 (below 15) 2 (35-50) Total = 7	Total = 102

5.1.6. Respondents opinion regarding their understanding and cognition of green spaces in the case study areas

The interview has been conducted randomly with volunteer visitors to explore the visitor's awareness and cognitions of green spaces' services. The interview consisted of three sets of questions, the first question was the purpose for visiting the park and the second one was reasons for choosing the park for recreation, and the third question was the visitors' knowhow about green space's services. Accordingly, 20 volunteers were participated in the interview and their responses are summarized in the following tables and textual descriptions.

5.1.7. Purpose of visiting the park

The respondents were asked to rank the purposes for their presence in the park and most of them stated that their primary reasons were for relaxation, physical exercise, and aesthetic pleasure. This suggests that recreational services are primary ecosystem services that the visitors would like to derive.

Table 11. Visitor's purpose in visiting the park

Purposes	Very Important (%)	Important (%)	Least important (%)
Relaxation	55	35	10
Sport activities (tennis, football)	35	40	25
Social contact (friends, ceremony)	25	30	45
Aesthetic pleasure (visual appeal)	25	55	20
Nature appreciation (contact with nature)	40	40	20

5.1.8. Reasons for choosing the park for recreation

The respondents were also asked to rank their reasons in choosing the park for recreation purpose. It was found that comfortable local environment, well maintained landscape features, and recreational facilities, other than proximity to their residences, have been their reasons for choosing the park for recreation.

Table 12. Visitor's reasons in choosing the park for recreation

Reasons	Very Important (%)	Important (%)	Least important (%)
Proximity to residence	35	40	25
Recreational Facilities	40	35	25
Well maintained landscape	55	30	15
Comfortable local environment (temperature, air quality and Noise)	60	35	5

5.1.9. Visitors' knowhow about green space's services

To assess the visitor's knowledge and recognition about green space's ecosystem services, respondents were asked to read a list of regulatory ecosystem services and rate the importance relating to their experience in the green spaces. The ecosystem services (regulatory) ranked as the most important were the benefits relating to air maintenance (oxygen release and carbon-dioxide sequestration) and temperature. This might be due to the public's general knowledge about the benefits of vegetation in mitigating temperature and air quality.

Table 13. Visitor's knowhow about green space's regulatory ecosystem services

Regulatory Ecosystem Services	Very Important (%)	Important (%)	Least important (%)
Local climate regulation (Shading, temperature)	80	15	5
Air quality maintenance (oxygen release)	75	20	5
Noise reduction	55	35	10
Stormwater regulation (flood risk, ground water recharge)	35	35	30
Natural Hazard reduction (landslide, heat wave...)	20	55	25
Waste treatment (decomposition of organic wests)	35	35	30

Urban green spaces provide a wide range of direct and indirect benefits (ecosystem services), including carbon dioxide sequestration, microclimate regulation, pollution control, noise abatement, provision of recreational opportunities, stormwater retention, etc. (Grey and Deneke, 1986).

Although the primary services that recreational green spaces provide relates with cultural ecosystem services, a significant provision of regulatory ecosystem can also be derived. This study focuses on stormwater regulation of recreational green spaces to analyze the regulatory ecosystem services provided by urban recreational green spaces.

5.1.10. Stormwater management practice in the study area

Conventional method to manage rainwater has been engineering-oriented to move them out of an area or community spaces as quickly and efficiently as possible through a series of infrastructures. However, this approach has been found to bring some problems such as deterioration of water quality (Whitford et al., 2001) and other problems such as high costs in building these series of infrastructures.

The practice of stormwater management in the case area is based on conventional engineering-oriented method that focuses in discharging of storm water rather than harvesting to reuse it. However the park has its own ground water source and the interview conducted with the manager of the park states that, ground water is used to water the greeneries.

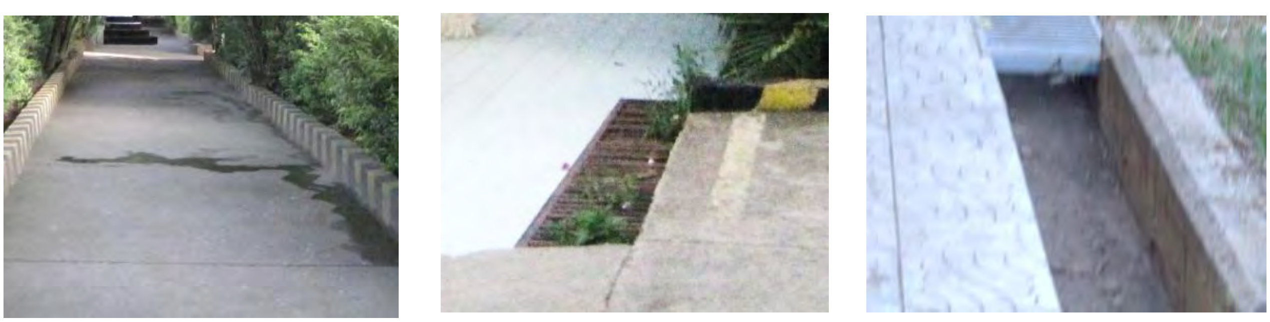


Figure 30. Existing drainage systems in the study area

5.1.11. Surface cover in the study area

Surface cover characteristics could affect water circulation significantly in urban area because surface is the primary site of mass transformation in urban ecosystems (Sanders, 1986; Grimmond et al., 1994) and the case includes surface covers within urban green spaces. Shalla Public Park has different surface finishes in different places. Based on satellite images and AutoCAD map of the study area, typical surfaces were calculated and are summarized below.

Table 14. Type of surface covers in the study area

Surface type	Location	Area (m^2)	Percentage
Building	Multipurpose Hall, Administration blocks, Cafeteria	1729	14%
Compacted red Soil	Tennis Court	1531	12%
Concrete pavement	Basket ball Car parking, pedestrian walkways	2922	22%
Asphalt	Street	841	6%
Grass & Trees	Green court yards	6177	47%

As it can be seen from the surface cover percentages, green areas cover most areas of the park, having about 47% total coverage and concrete paved surfaces following having a total coverage of 22%. Buildings with corrugated sheet covers, account about 14% coverage of the total area. Asphalt covers that are impermeable surfaces account about 6% from the total surface cover in the study area. It can be generalized from the above table that, 47% of Shalla Public Park is covered with pervious surface, and the remaining 53% is covered with impervious surfaces.

5.1.12. Runoff coefficient of surface covers in the study area

As stated previously on the slope analysis of the study area, 57% of the total area has a slope that is below 2%, hence runoff coefficients that are for flat slopes can be used with respect to surface cover materials. For the remaining 40% of the study area, runoff coefficients that are for rolling slopes can be used. Steep slope in the study area, covers about 3% which can be negligible due to its small part.

Soil type of the study area is also another factor that influence the runoff coefficient. Hence data from soil analysis of the study area is relevant and it is found that the soil type in the study area is Vertisol, which has a content of 30% clay. Clays are usually active, cracking when dry and swell when wet. The following table summarizes the runoff coefficients that should be used for the study area.

Table 15. Runoff coefficient for the study area

Slope	Surface cover (material)	Runoff Coefficient	
		Min.	Max.
Flat (0-2%)	Grass, green covers	0.20	0.25
	Roof (corrugated sheet), Asphalt, concrete pavements	0.95	0.95
	Semi-pervious Pavements, compacted soils, cobble stones	0.90	0.95
Rolling (2-7%)	Grass, green covers	0.25	0.30
	Roof (corrugated sheet), Asphalt, concrete pavements	0.95	0.95
	Semi-pervious Pavements, compacted soils, cobble stones	0.90	0.95

5.1.13. Stormwater retention capacity of the study area

The volume of potential runoff retention could be obtained when the precipitation and the surface runoff are known for the study area according to urban hydrological model proposed by American Soil Conservation Service (Whitford et al. 2001). According to the model to calculate the retention ability of green spaces, three scenarios of surface characteristics could be assessed (scenario A, scenario B and scenario C).

Scenario A means the current surface cover in the study area and

Scenario B is defined as that pervious surface (green courtyards in the case of the study area) was hypothetically removed and transformed into typical artificial impervious surface (same surface characteristics as current cover types except for green spaces). This is to calculate that a potential stormwater runoff of the study area, if green spaces were not present.

Scenario C – All recreational elements that have impervious surfaces (such as the buildings, sport courts and streets) in the study area were hypothetically removed and transformed into typical pervious surface (vegetation cover).

5.1.14. Estimated Surface Runoff

To estimate the surface runoff in the in the study area, the research used The Rational Formula method, which is the most commonly used method of determining peak surface runoff for small areas, due to its simplicity and ease of application. The rational method is a storm sewer evaluation method based on the rational formula (Maidment, 1993). The rational formula calculates the peak flow rate as a function of the rainfall intensity, the watershed area, and the runoff coefficient.

The Rational Formula is expressed as: **Q = (C) (*i*) (A)**

Where: Q = Peak rate of runoff (in m^3)

C = Runoff coefficient (dimensionless unit)

i = Average intensity of rainfall (converted to m)

A = Surface Area in m^2

5.1.15. Discussion on the results

Based on the gathered data of precipitation, slope, soil data, surface cover and related surface runoff coefficients, the following calculation is made for scenario A, scenario B and scenario C. From the difference of the results of the scenarios, stormwater retention of the study areas and the impacts of the physical elements on stormwater retention of the study areas are calculated.

Scenario A – Current surface cover in the study area

For the Rational Formula to be used, weighted average runoff coefficient of the study area need to be calculated

Table 16. Weighted average runoff coefficient of Shalla Public Park

Surface Cover	Area	Runoff coefficient (C)	Area x C
Asphalt and Concrete pavement (Sum)	3763	0.95	3574.85
Roof cover (Iron sheet)	1729	0.95	1642.55
Grass covers	6177	0.22	1358.94
Semi pervious (compacted soil)	1531	0.75	1148.25
Total	13200	Total	7724.59

Weighted average of C is the total of the "Area X C" column divided by the total of the "area" column, which is: C = 7724.59/13200

= 0.58

Therefore: Weighted average (C) of Shalla Public Park is **0.58**

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **13200 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

= $0.58 * 1.03m * 13200m^2$

= **$7885.68\ m^3$**

Scenario B – Green surfaces (pervious surfaces) in the study area were hypothetically removed and transformed into typical artificial impervious surface (Asphalt or concrete pavements)

Therefore: Weighted average (C) of Shalla Public Park would be **0.95** (since all surface covers are presumed to be the same, which are impervious)

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **13200 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

= 0.95*1.03m* 13200m^2

= **12916.2 m^3**

Difference = Scenario B – Scenario A

= 12916.2m^3 - 7885.68 m^3

= **5030.52m^3**

Scenario C – All recreational elements that have impervious surfaces (such as the buildings, sport courts and streets) in the study area were hypothetically removed and transformed into typical pervious surface (vegetation cover)

Therefore: Weighted average (C) of Shalla Public Park would be **0.2** (since all surface covers are presumed to be the same, which is pervious)

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **13200 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

= 0.2*1.03m* 13200m^2

= **2719.2 m^3**

Meaning, without the integrated recreational elements of the study area the runoff could get reduced to 2719m^3

Difference = Scenario A – Scenario C

= 7886m^3- 2719 m^3

= **5167m^3**

The estimated total rain water retention ability of Shalla Public Park annually is $5030m^3$, which is 37% of the total rainfall that the study area gets annually. Compering the result to other international studies conducted on subject, the retention capacity of the study areas is less. For example, the amount of stormwater retention by green spaces in Guangzhou city, China was 42% (Jim et al., 2006). The reason for the green space less retention capacity is due to the amount of impervious surfaces in the study areas which is 53%. Urban landscapes with 50-90% impervious cover can lose 40-83% of rainfall to surface runoff (Pataki et al., 2011).

Scenario C clearly shows that, the integration of recreational elements (such as the cafeterias, sport facilities, streets and car parking) to the study area (with their impervious surfaces) have resulted a higher weighted average runoff coefficient of the recreational green spaces. Meaning, unsuitable integration of recreational elements to green spaces could have an effect on the overall performances of the recreational green spaces and their provisioning of multiple benefits. The estimated total contribution (impact) of integrated recreational elements (having impervious surface) to stormwater runoff in the study area is $5167m^3$. This is 65% of total storm water contribution in the study area.

The Ethiopian National Urban Green Infrastructure Standard (2015) states that vegetation in recreational parks should at least cover 75% and other non-vegetation components at most 25% coverage. However, study area 1 (Shalla Public Park) have a vegetation cover of only 47%, which is below the standard. Hence it is difficult to consider the study area as a recreational park.

Finally, the role of green spaces in regulating stormwater retention is more effective for light rains than for intensive storms, especially in dry seasons (Sanders, 1986). This is due to the antecedent moisture of vegetation and soil is low during dry season which has a larger idle capacity to retain water (low runoff coefficient). On the contrary, continuous precipitation in rainy season would result in saturated condition of green spaces (higher runoff coefficient). Hence the role of green spaces in stormwater retention is more effective in dray seasons, where the amount of runoff could not exceed the maximum retention capacity of the study area.

5.2. Data presentation of study area 2

5.2.1. Vegetation cover

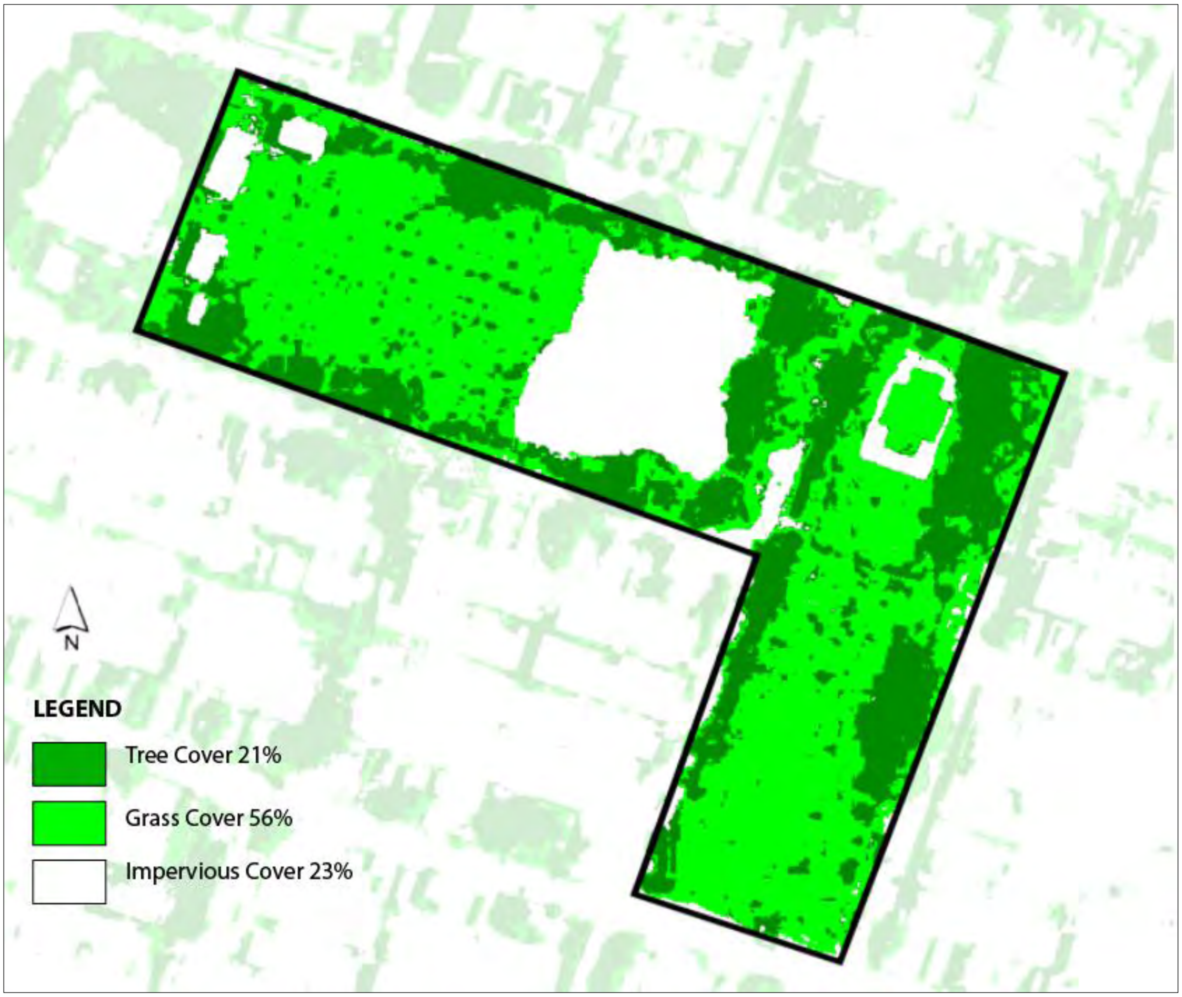


Figure 31. Vegetation covers percentage in the study area

The community recreational green space has a total of 77% vegetation cover and about 23% impervious surface cover. More than half of the study area is coved with grass, which accounted about 56% out of total surface cover.

The trees found in the green spaces are intentionally planted by the surrounding community and are consist of 7 species. The total number of trees counted in the study area is about 69 trees.

From the total number of trees counted in the study area, 91% of the trees are exotic species while only 9% are indigenous species. Even this 9% of indigenous trees consist only one species, which is *Acacia abyssinica*.

It can be established from this that tree diversity in study area is relatively low. This might be because of the fact that the trees are planted by the surrounding residents (except the *acacia abyssinica)*, the availability of divers3 trees to choose from on the market is low.

46% of the trees counted in study area are *Grevillea robusta,* a fast growing exotic tree that is being widely planted throughout the city, and out of this most of the trees are recently planted (2 or 3 years). The condition of all trees in study area can also be considered as good. The reason might be because of the trees relatively young age (recently planted).

Table 17. Species and number of trees found in the study area (reference for multifunctional benefits are adapted from Azene et al., 2007)

Tree Species (scientific name)	**Local Name** (Amharic)	**Origin** (Indigenous or Exotic)	**Total number of trees (**portion %)	**Multifunctional Benefits**					
				Ornamental	Shade	Nitrogen fixation	Soil conservation	Wind Break	Food
Acacia abyssinica	*Bazra girar*	Indigenous	6 (9%)		X	X	X		
Cupressus lusitanica	*Yeferenji -tid*	Exotic	15 (22%)	X	X			X	
Delonix regia	*Dire Dawa zaf*	Exotic	5 (7%)	X	X				
Jacaranda mimosifolia	*Yetebmenja zaf*	Exotic	11 (16%)	X	X				
Grevillea robusta	*Grevila*	Exotic	32 (46%)	X	X		X	X	
		Total	**69 (100%)**						

5.2.2. Identified physical elements of the recreational green space

Table 18. Identified green space elements, Study area 2 (photos by author)

Elements	Description	Images
Green courtyards	Covered with fairly maintained grass, and surrounded by trees and some shrubs. The court serves as a recreational and play area for kids and surrounding residents.	
Tree buffers	Located as space defining elements on the sides of streets, around courtyards, and as a buffer/fence around the overall green space. Almost All the trees found in the study area are planted on this fusion.	
Car parking	Although the recreational green space doesn't have its own parking spaces, the street that passes through the study area is being used as a parking spaces. The surface character of the street is asphalt and with surrounding trees beeing use as shadings.	

Sport courts (Basketball and Ground tennis courts)	Concrete paved basketball court (non-permeable) and compacted red soil paved tennis court (semi-permeable). There is one ground tennis court which serve also as Occasional gathering space, and one ground tennis court.	
Green Playground	Kids Playground with grass surface cover (permeable surface). The playgound is consist of the basic playing tools that well serve the kids under the age 10 from the surrounding ressidents.	
Sitting areas	Sitting areas in the study area are of sitting benches made of concrete material. The benchs are placed on the sides of courtyards and playground areas, and under tree shades.	

5.2.3. Identified Activities

Data about the activities in the public park are mainly gathered from visual observation and informal interviews. Accordingly Social Ceremonies, Sport activities, Children playing and Parking Services are the main activities identified.

Social Ceremonies: the neighborhood park serves as a space for different social occasions such as music festivals and wedding ceremonies. Usually the basketball court is the space which is used for the ceremonies due to its ground finish material that is concrete.

Figure 32. Multipurpose basketball courtyard (Photos by author)

Sport Activities; The neighborhood Park has one ground tennis court and one basketball court where visitors from the surrounding residents engage on sport activities on. The sport courts are mostly busy on weekends by visitors from the surrounding recidents.

Figure 33. The basketball court (left) Ground Tennis court (right) (Photos by author)

Children playing; The neighborhood Park has dedicated playground for kids and include basic equipment with grass surface coverage. Due to the grass surface cover, a cooler atmosphere can be noticed compered to basketball and tennis courts.

Figure 34. Playground with grass surface coverage (Photos by author)

Parking services: Although the neighborhood park doesn't have dedicated parking space for visitors, people tend to use the sides of the road as parking spaces. Parked cars can be seen on the side of the road taking the advantage of tree shades from the green space.

Figure 35 Road side parking taking the advantage of tree shade (Photos by author)

5.2.4. Stormwater management practice in the study area

The study area has the same stormwater management as in the case of study area 1, which is based on traditional engineering-oriented method that focuses in discharging of storm water out of the compound to municipality drainage lines. To discharge water, sewerage lines encircle the overall recreational green space.

Apart from stormwater that the study area gets from rainy seasons, the only water source that the green space use to water the greeneries is from municipality water line. And this could incur additional costs in running the green space.

Figure 36. Sewerage lines in the study area (Photos by author)

5.2.5. Surface cover in the study area

Based on satellite images and AutoCAD map of the study area, typical surfaces covers of the study area were measured and are summarized below.

As it can be read from the surface cover percentages of study area 2, green spaces (pervious surface) cover most areas of the study area, having about 77.6% of total coverage. Impervious surfaces such as Asphalt, concrete pavements and buildings, cover about 14.7% of the total area. Semi pervious surfaces (compacted soil), cover 7.7% of the total area.

5.2.6. Stormwater retention capacity of the study area

To estimate rainwater retention potential of study area 2, similar procedure as in the case of study area 1 is followed. That is three scenarios of surface characteristics could be assessed (scenario A, scenario B and scenario C).

Scenario A means the current surface cover in the study area and

Scenario B is defined as that pervious surfaces (green courtyards in the case of the study area) was hypothetically removed and transformed into typical artificial impervious surfaces (same surface characteristics as current cover types except for green spaces).

Scenario C is defined as that impervious surfaces (such as the buildings, sport courts and streets) in the study area were hypothetically removed and transformed into typical pervious surface (vegetation cover)

Calculating the runoff for the scenarios and knowing the difference between the scenarios could therefore be estimated as stormwater retention ability of the study area and the impacts of physical elements have on the green space stormwater retention ability.

Based on the gathered data of precipitation, slope analysis, soil data, surface cover and related surface runoff coefficients, the following calculation is made for scenario A and scenario B. The difference of the results of the scenarios, can therefore be considered as rain water retention ability of the study area.

Scenario A – Current surface cover in the study area

Table 19. Type of surface covers, study area 2

Surface type	Location	Area (m^2)	Percentage
Buildings	Store	154	2
Compacted Soil	Ground tennis Court	658	7.7
Concrete pavement	Basketball court	638	7.5
Asphalt	Street	450	5.2
Grass & Trees	Green yards, green playground	6600	77.6

For the Rational Formula to be used, weighted average runoff coefficient of the study area need to be calculated

Table 20. Weighted average runoff coefficient calculation, Study area 2

Surface Cover	Area	Runoff coefficient (C)	Area x C
Asphalt and Concrete pavement (Sum)	1088	0.95	1033.6
Roof cover (Iron sheet)	154	0.95	146.3
Grass covers	6600	0.22	1452
Semi pervious (compacted soil)	658	0.75	493.5
Total	8500	Total	3125.4

Weighted average of C is the total of the “Area X C” column divided by the total of the “area” column, which is:

$$C = 3125.4/8500$$

$$= 0.36$$

Therefore: Weighted average (C) of Shalla Public Park is **0.36**

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **8500 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

$= 0.36*1.03m* 8500m^2$

$=$ **$3150.8\ m^3$**

Scenario B – Green surfaces (pervious surfaces) in the study area were hypothetically removed and transformed into typical artificial impervious surface (Asphalt or concrete pavements)

Therefore: Weighted average (C) of Shalla Public Park is **0.95** (since all surface covers are the same, which are impervious)

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **8500 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

$= 0.95*1.03m* 8500m^2$

$= \mathbf{8317.25\ m^3}$

Difference = Scenario B – Scenario A

$= 8317.25\ m^3 - 3150.8\ m^3$

$= \mathbf{5166.45\ m^3}$

The estimated total rain water retention ability of the community recreational green space annually, is therefore 5166.45m^3. This is 59% of the total rainfall that the study area gets annually.

To analyze the impacts of recreational elements have on total stormwater retention;

Scenario C – All recreational elements that have impervious surfaces (such as the buildings, sport courts and streets) in the study area were hypothetically removed and transformed into typical pervious surface (vegetation cover)

Therefore: Weighted average (C) of the recreational green space would be **0.2** (since all surface covers are presumed to be the same, which is pervious)

Mean Annual Rainfall (*i*) (from precipitation data) is **1034.7 mm**

Total catchment area (A) (area of Shalla Public Park) is **8500 m^2**

Peak rate of runoff (Q) = (C) (*i*) (A)

$= 0.2*1.03m* 8500m^2$

$= \mathbf{1751\ m^3}$

Meaning, without the integrated recreational elements of the study area the runoff could get reduced to 1751m^3 annually.

Difference = Scenario A – Scenario C

$= 3151m^3 - 1751m^3$

$= \mathbf{1400m^3}$

The estimated total contribution (impact) of integrated recreational elements (having impervious surface) have to stormwater runoff in the study area is therefore 1400m^3 annually. This is 44% of total storm water runoff in the study area.

5.3. Analysis and Key findings

- The type of recreational green spaces studied are of two types. Study area 1 is a type of a Small Park, which has designed, constructed and managed landscape features whereas study area 2 is a type of amenity green spaces developed, which has designed and constructed landscape features but with a lesser management.
- The study areas incorporated several impervious recreational facilities such as, buildings, playgrounds and sport courts where different recreational and sport activities take place.
- People were actively using the study areas for reasons such as, incorporated recreational and sport facilities, well maintained landscapes, beautiful views, in addition to proximity to their residential areas.
- In addition to recreational services, the study areas also provided stormwater regulations services that reached 5031 m^3 annual retention capacity in study area 1 and 5166 m^3 in study area 2, reducing a potential runoff of 37% from study area 1, and 59% from study area 2.
- Stormwater retention capacity of the study areas were impacted by the impervious surfaces that reached 44% to 65% contribution to total stormwater runoff from the study areas.

Table 21. Summary of key findings

	Study area 1	Study area 2
Type of recreational green space	Small park	amenity green space
Total Area	13200 m^2	8500m^2
Total area of impervious surfaces (percentage)	53%	23%
Total area of pervious cover (percentage)	47%	77%
Weighted average runoff coefficient	0.57	0.36
Annual Stormwater retention capacity	5031 m^3	5166 m^3
Stormwater retained from potential runoff	37%	59%
Annual runoff	7886 m^3	3151 m^3
Contribution of impervious surfaces in the study areas to annual runoff	5167m^3 (65%)	1400 m^3 (44%)

5.4. Design Proposal

This section of the study focuses on illustrating how integrated ecological landscape design measures such as sustainable drainage systems enhance stormwater regulating ecosystem service of recreational green spaces. The design proposal have two parts (Part I and Part II). The first part of the design proposal focuses on integration measure that can be followed and implemented to improve existing conditions of the study areas (study area 1 and study area 2. Part II of the design proposal selects a third case area and adopts an ecological approach to public green spaces design development.

5.4.1. Design proposal Part I – Interventions for the study areas

The research found out that recreational green spaces with lower weighted average runoff coefficient (with less impervious surfaces) have a higher stormwater retention ability. Therefore to enhance stormwater abilities of green spaces means lowering weighted average runoff coefficient and this directly relates to the surface covers of the green spaces.

Therefore the proposal aims in improving the conditions of impervious surfaces in the green spaces. Namely in improving the surface covers of streets and parking lots, sport courts and building roofs.

5.4.1.1. Streets and Parking lot surfaces

Existing surfaces – Asphalt and Concrete paved

Figure 37. Existing Asphalt and concrete paved street surfaces (Photos by author)

5.4.1.2. Permeable Pavement

Permeable pavement incorporates the use of cobble stones, concrete, permeable asphalt, plastic grid systems, or pavers to form a durable and attractive surface that water can infiltrate. These applications are designed to allow water infiltration and minimize runoff (John Freeborn, 2015).

These permeable surfaces can be incorporated into existing Streets, parking lots and walkways. As water flows through the pavement, it is then filtered by bedding sand and stone gravel under the pavement and infiltrates into the ground.

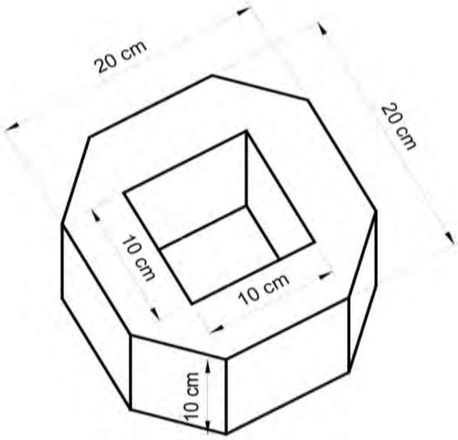


Figure 38. Permeable pavement patterns (source; Pinterest images)

Benefits and Effectiveness

(Adapted from Massachusetts Low Impact Development Toolkit (MLIDT))

- Permeable pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, permeable paving can infiltrate as much as 70% to 80% of annual rainfall.
- Permeable pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Grass pavers can improve site appearance (aesthetics) by providing vegetation where there would otherwise be only pavement.
- Permeable paving increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas, and the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures on a site.



Walk ways

Grass pavers (a.k.a. Grass blocks) – are a type of open-cell unit paver in which the cells are filled with soil and planted with grass. The pavers, made of concrete or synthetic, distribute the weight of traffic and prevent compression of the underlying soil. Runoff coefficients are similar to grass, 0.15 to 0.6 (MLIDT).

Grass pavers are proposed for pedestrian walk ways in the study areas, since activities are at low-speed and relatively low-weight, damage to plant materials is low.

Table 22. Surface area to be covered by Grass Pavers

	Study area 1	Study area 2
Surface area to be covered by Grass Pavers	651 m^2	280 m^2

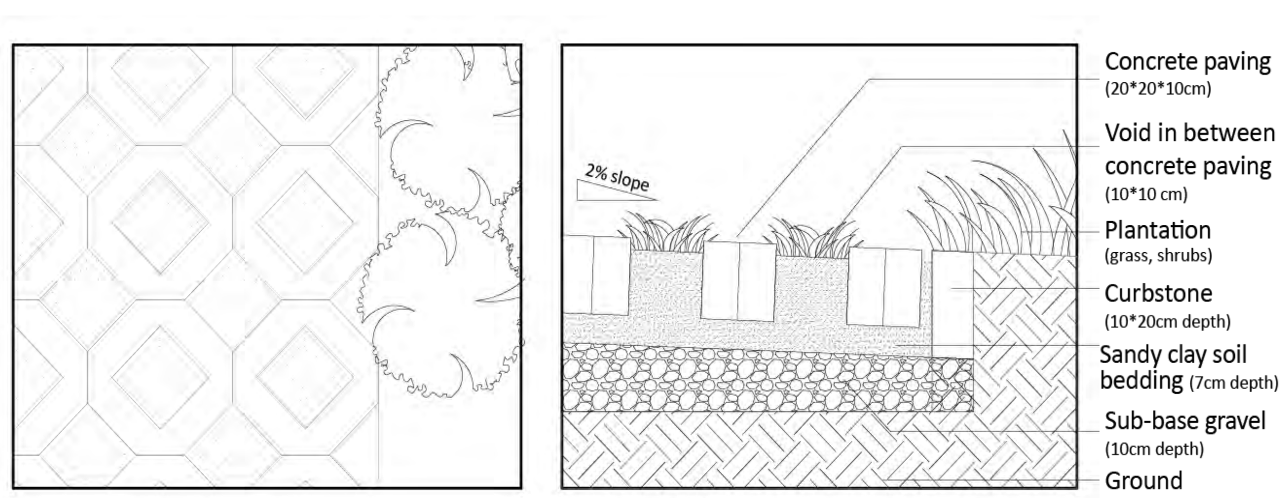
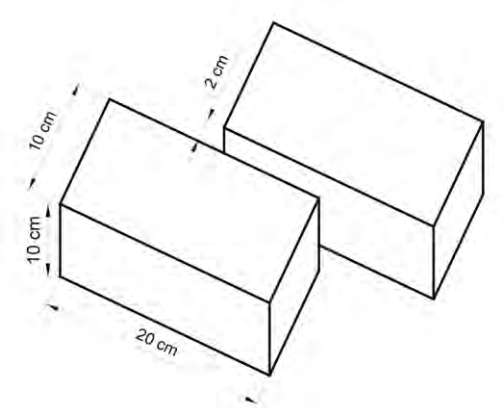


Figure 39. Walkway pavement Design (source: designed by author)

Driveways and parking area



Permeable Stone Pavement (PSP, a.k.a. unit pavers) – are blocks made of brick, stone, or concrete, set on a highly permeable bedding. The joints and opening voids within the pavers are also filled with sandy soils to allow water to percolate downward. The runoff coefficient range for PSP ranges from 0.3 to 0.75. The runoff coefficient of PSP will vary depending on rainfall intensity, joint width, and materials. Some concrete paving stones have an open cell design to increase permeability (MLIDT).

PSPs are proposed for driveways and parking area in the study areas, since the activities are at high-speed and relatively high-weight.

Table 23. Surface area to be covered by Grass Pavers

	Study area 1	Study area 2
Surface area to be covered by PSPs	2271 m^2	808 m^2

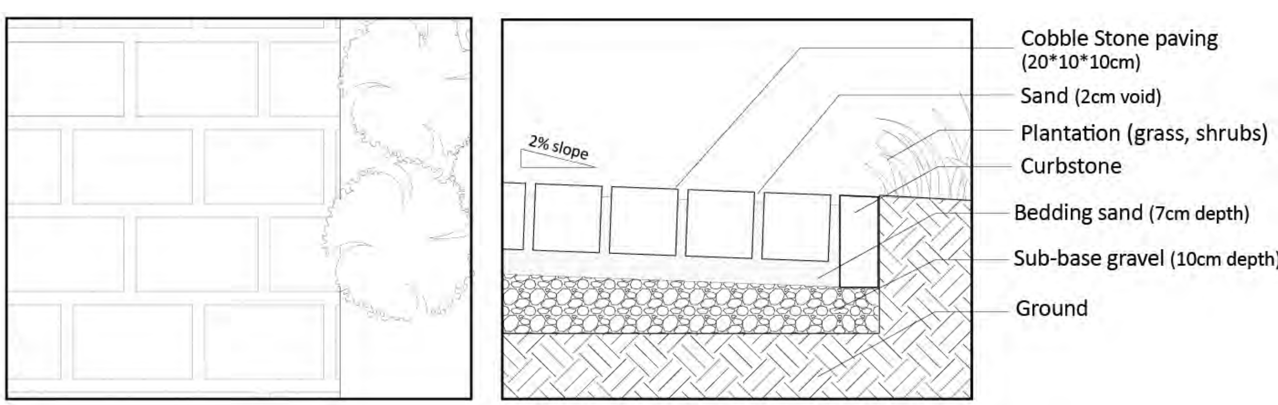


Figure 40. Drive ways and Parking lots design (source: designed by author)

5.4.1.3. Stormwater runoff reduction by permeable pavements

Table 24. Calculated estimation of runoff reduction by proposed permeable pavements

	Runoff Coefficient		Study area 1 Runoff from streets (annual)		Study area 2 runoff from streets (annual)	
	Existing	Proposal	Existing	Proposal	Exiting	Proposal
Walk Ways	0.95	0.3	667m^3	201m^3	274m^3	87m^3
Driveways and Parking areas	0.95	0.5	2222m^3	1169m^3	790m^3	416m^3
		Total	2889m^3	1370m^3	1064m^3	503m^3

As it can be observed from runoff calculation table using The Rational Formula, 53 % of the total runoff from existing streets (walkways and Driveways) can be minimized only by introducing permeable pavements. This is about 20% of total stormwater runoff reduction annually from study area 1 (Shalla Public Park) and about 18% of total storm water runoff reduction annually from study area 2 (Communality recreational green space).

5.4.1.4. Sport Court surfaces (Basketball and Ground Tennis courts)

Existing Surfaces – Concrete pavement for basketball courts and compacted soil for Tennis courts

Figure 41. Sport court surfaces of study area 1 and study area 2 (Photos by author)

5.4.1.5. Pervious sport courts

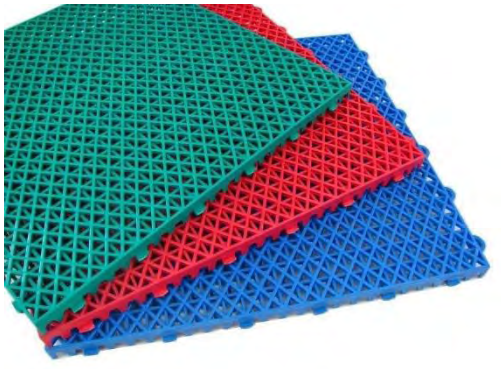
Pervious courts are interlocking modular sport tiles made of strong type of plastic, which are completely pervious that recharge water into the ground than an equal area of lawn (Deshayes, 2016). The technique is an important advancement in the sport courts construction that could replace the need for concrete and asphalt surfaces.

These permeable sport court surfaces can be incorporated into existing Basketball and Ground tennis courts to minimize stormwater runoff from the surfaces. As water flows through the surface tiles, it is then filtered by compacted bedding stone gravels and soils to infiltrate into the ground.

Figure 42. Permeable court surfaces (Source: Deshayes, 2016)

Benefits and Effectiveness (Adapted from MLIDT)

- Permeable sport courts provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, permeable courts can infiltrate as much as 70% to 80% of annual rainfall.
- Permeable pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Permeable courts can improve site appearance (aesthetics) by providing durable contrasting colors and they can be installed within short time.
- Permeable sport courts increases effective developable area on a site because portions of the stormwater management system are located underneath the courts, and the infiltration provided by permeable sport courts can significantly reduce the need for large stormwater management structures around the sport courts.



Pervious sport court tiles

Pervious sport court tiles are porous, interlocking panels installed on a permeable geotextile fabric and compacted earth and stone permeable sub base. The runoff coefficient for permeable courts ranges from 0.2 to 0.5 depending on the soil type used for sub base (MLIDT).

Table 25. Surface area to be covered by pervious sport court tiles

	Study area 1	Study area 2
Surface area to be covered by pervious sport court tiles	2171 m^2	1296 m^2

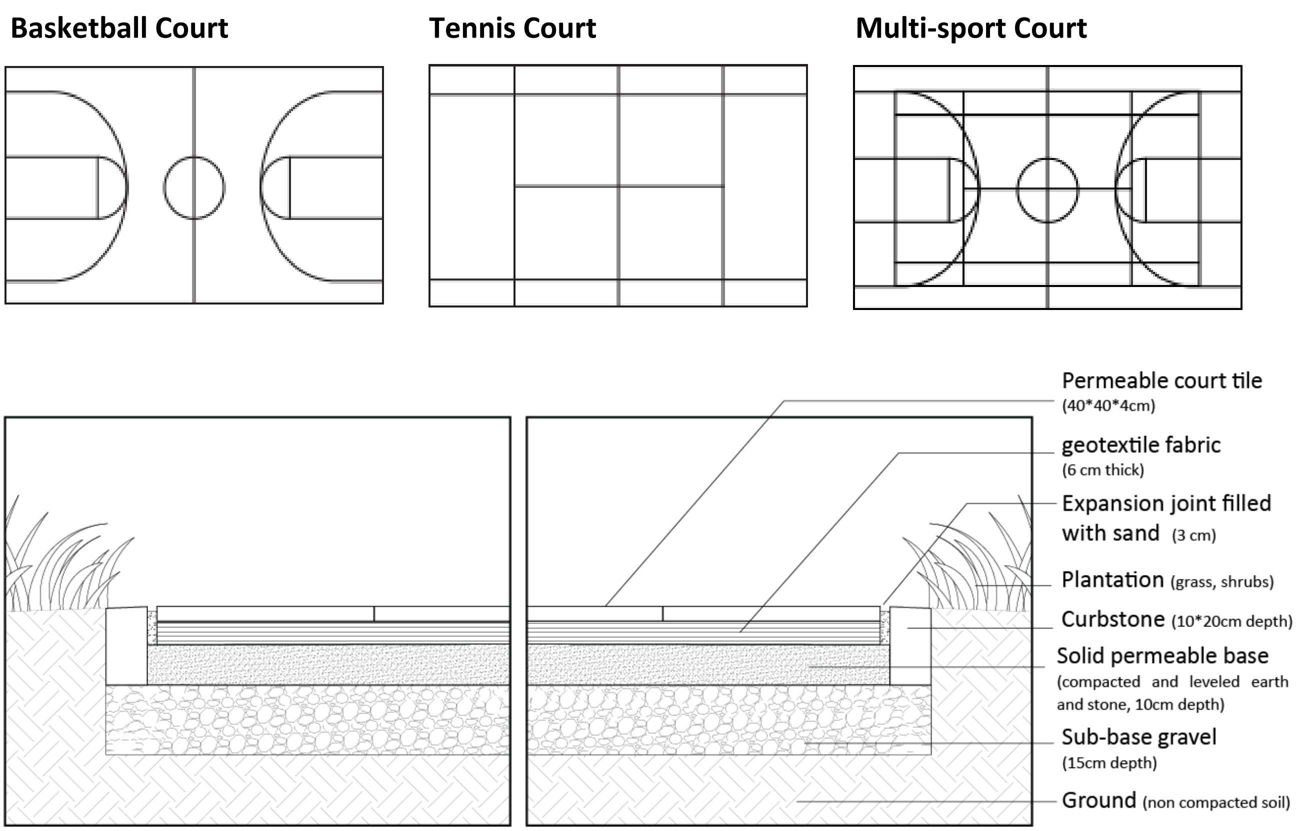


Figure 43 Sport courts design (source: designed by author)

5.4.1.6. Stormwater runoff reduction by permeable sport courts

Table 26. Calculated estimation of runoff reduction by proposed permeable pavements

	Runoff Coefficient		Study area 1 Runoff from sport courts (annual)		Study area 2 runoff from sport courts (annual)	
	Existing	Proposal	Existing	Proposal	Exiting	Proposal
Ground Tennis Court	0.75	0.35	1183m^3	552m^3	508m^3	237m^3
Basketball court	0.95	0.35	624m^3	238m^3	624m^3	238m^3
		Total	1807m^3	790m^3	1132m^3	475m^3

As it can be observed from runoff calculation table using The Rational Formula, 56 % (Study area 1) and 58% (Study area 2) of the total runoff from existing sport courts (Ground tennis and Basketball courts) can be minimized only by introducing permeable sport courts. This is about 13% of total stormwater runoff reduction annually from study area 1 (Shalla Public Park) and about 21% of total storm water runoff reduction annually from study area 2 (Communality recreational green space).

5.4.1.7. Roof Surfaces

Existing Surfaces – Corrugated iron sheet

Figure 44. Existing Roofs (Photos by author)

Extensive Green Roofs

Many research on the effectiveness of extensive green roofs to reduce stormwater runoff has shown that they intercept, retain, and evapo-transpire between 34% and 69% of precipitation with an average retention of 56% (Bruce, 2010). Hence extensive green roofs are proposed on the exiting roof structures

Existing building roof structure in the study area 1 are pitched roofs with a slope between 15% - 30% and are made of eucalyptus trusses of diameter 10-15 cm. Though the total area of roof cover in the study area 1 is 1729m^2, about 1550m^2 of these is suitable for extensive roof proposal (excluding temporary storage structures). Buildings in study area 2 are of light structures, constructed for temporary storage purposes. Hence the buildings are not suitable for extensive green roofs.

Table 27. Surface area to be covered by Extensive Green Roofs

	Study area 1	Study area 2
Surface area to be covered by Green roofs	1550 m^2	X

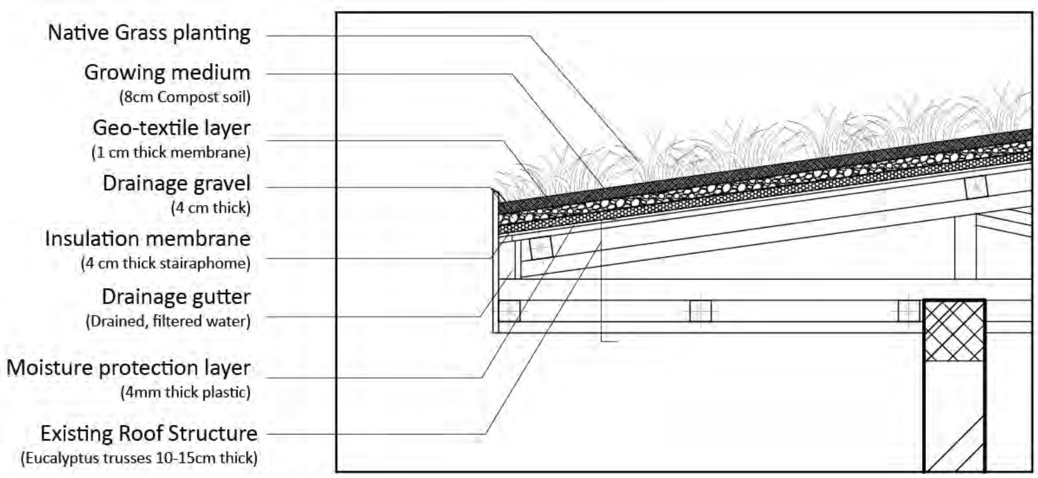


Figure 45. Proposed detail drawing for Extensive green roof

5.4.1.8. Stormwater runoff reduction by Extensive Green Roof covers

Table 28. Calculated estimation of runoff reduction by proposed Green Roof Covers

	Runoff Coefficient		Study area 1 Runoff from roof (annual)		Study area 2 runoff from roof (annual)	
	Existing	Proposal	Existing	Proposal	Exiting	Proposal
Roof Cover	0.95	0.3	1516m^3	478m^3	X	-
		Total	1516m^3	478m^3	X	X

As it can be seen from runoff calculation table using The Rational Formula, 68 % (1038m^3) of the total runoff from existing roof covers can be minimized only by introducing extensive green roofs. This is about 13% of total stormwater runoff reduction annually from study area 1 (Shalla Public Park).

5.4.1.9. Total Stormwater runoff reduction by proposed surface covers

Table 29. Calculated estimation of runoff reduction by proposed surface covers

	Study area 1 Runoff (annual)			Study area 2 runoff (annual)		
	Existing	Proposal	Difference	Exiting	Proposal	Difference
Streets (walkways and drive ways)	2889m^3	1370m^3	1519m^3	1064m^3	503m^3	561
Sport courts (Basketball and Ground Tennis)	1807m^3	796m^3	1011m^3	1132m^3	475m^3	657
Roof (Suitable for green roofs)	1516 m^3	478m^3	1038m^3	x	x	X
Total	6212m^3	2644 m^3	**3568 m^3**	2196 m^3	978 m^3	**1212 m^3**

The calculated total stormwater runoff with the existing surface covers of study area 1 (Shalla Public Park) and study area 2 (community recreational green space) annually is $7885m^3$ and $3151m^3$ respectively. Although the mentioned amount is still with contributions of green spaces, the runoff can further be improved or reduced by integrating permeable surfaces.

Therefore the design proposal of this research tried to integrate permeable surfaces in to the existing surfaces covers of the recreational green spaces. As a result of the proposed permeable surface covers, $3568m^3$ of stormwater runoff in study area 1, and $1212m^3$ of stormwater runoff in study area 2 can further be retained in the recreational green spaces.

To describe the enhanced stormwater regulation of the recreational green spaces in percentage, 45% of runoff in study area 1, and 38% of runoff in study area 2 is minimized by proposed permeable surface covers. To further enhance the storm water regulation of the recreational green spaces and retain the remaining stormwater runoff that is $4317m^3$ in study area 1 and $1939m^3$ in study area 2, sustainable drainage systems are proposed.

5.4.1.10. Proposed Sustainable Drainage Systems (SuDS)

It has been observed that the existing Street and parking areas are without proper drainage systems, and if there are in some areas, their function is poor due to maintenance issues.

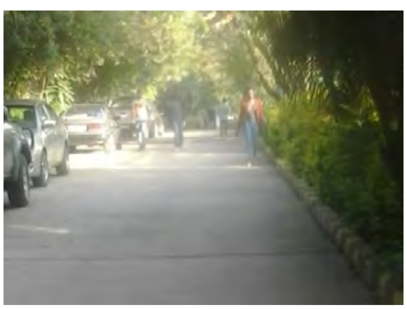


Figure 46. Existing streets and parking area

Existing streets are well vegetated with shrubs, but the 20 cm high curbstone that stand alongside the street, blocks stormwater runoff from draining to vegetation (permeable surface) and stormwater runoff travels long distance to reach drainage facilities.

Vegetated swales and Rain garden

Vegetated Swales are a type of bio-retention facility made of swales and Rain Gardens that are connected. Together they perform conveyance, infiltration and treatment functions. Vegetated Swales can be planted with evergreen and deciduous trees, shrubs, grasses, and ground cover species. To reduce the risk of erosion, check dams or weirs function to control flows and facilitate pooling of water in the Rain Garden areas.

The idea of integrating swales on the study areas is to minimize stormwater runoff through infiltration, evaporation and storage while filtering pollutants in conveyance to underground rain barrels.

Size Factor: The size factor for the Vegetated Swale is 0.19 or (19%) based on the bellow construction detail for depth. In other words, an impervious area of 100 m^2 would require a Vegetated Swale of 19 m^2 surface area with the following depth to manage the runoff. The width for conveyance swale is usually 600-900mm, with variable rain garden surface area depending on the impervious area it serves. (Source; Stormwater Best Management Practices: Saanich (SBMPS))

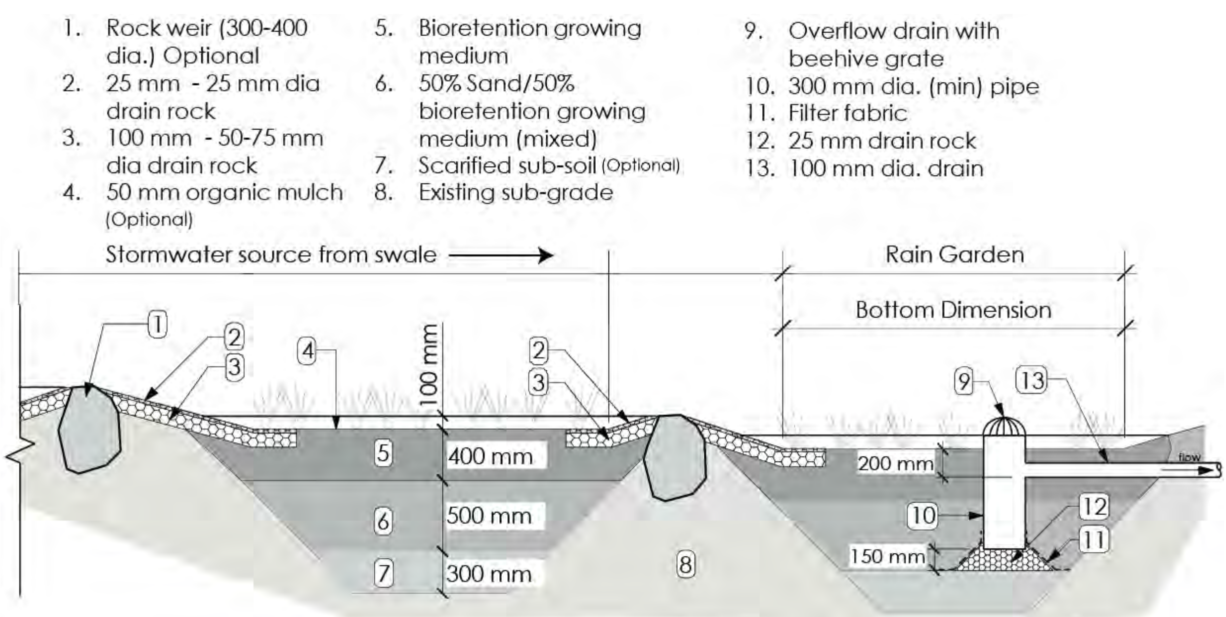


Figure 47. Vegetated Swale Profile (Source; SBMPS)

5.4.1.11. Required vegetated swale size for study area 1

The estimated reduced stormwater runoff after the proposed permeable surface covers in study area 1, is 4317m^3 annually. To calculate the required size of vegetated swale to manage the stated amount of runoff, the simplified size factor developed by SBMPS is used. But since impervious surfaces are no more available after the proposal, an equivalent amount of impervious surface for 4317m^3 annual runoff is calculated. Hence:

- Runoff equivalent impervious surface *(X)* for 4317m^3 annual runoff would be:
- Using the Rational Formula as: 0.95*1.03m* X = 4317m^3

  X = 4411m^2
- 19% of the equivalent impervious surface 4411m^2 = 0.19*4411m^2 = 838 m^2

Therefore the required surface are of vegetated swale is 838m^2, with treatment depth 1.2m.

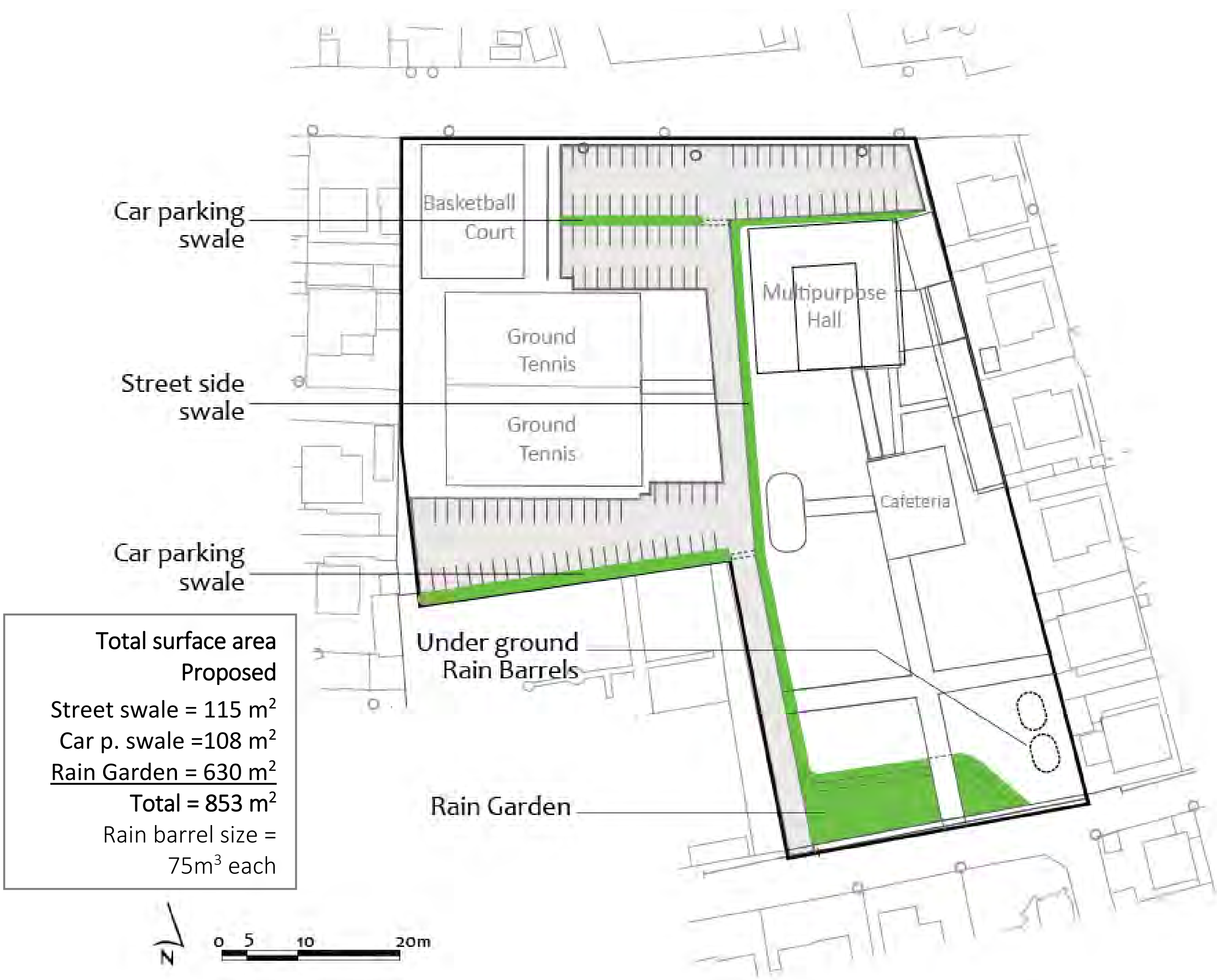


Figure 48. Proposed Sustainable Drainage Systems, Study area 1

5.4.1.12. Required vegetated swale size for study area 2

The estimated reduced stormwater runoff after the proposed permeable surface covers in study area 2, is 1939m^3 annually. To calculate the required size of vegetated swale to manage the stated amount of runoff, the simplified size factor developed by SBMPS can be used as in the case of study are 1.

- Runoff equivalent impervious surface *(Y)* for 1939m^3 annual runoff would be:
- Using the Rational Formula as: 0.95*1.03m* Y =1939m^3

  Y = 1982m^2
- 19% of the equivalent impervious surface 1982m^2 = 0.19*1982m^2 = 377 m^2

Therefore the required surface are of vegetated swale is 377m^2, with treatment depth 1.2m.

Figure 49. Proposed Sustainable Drainage Systems, Study area 2

5.4.1.13. Proposed vegetated swale's cross section details

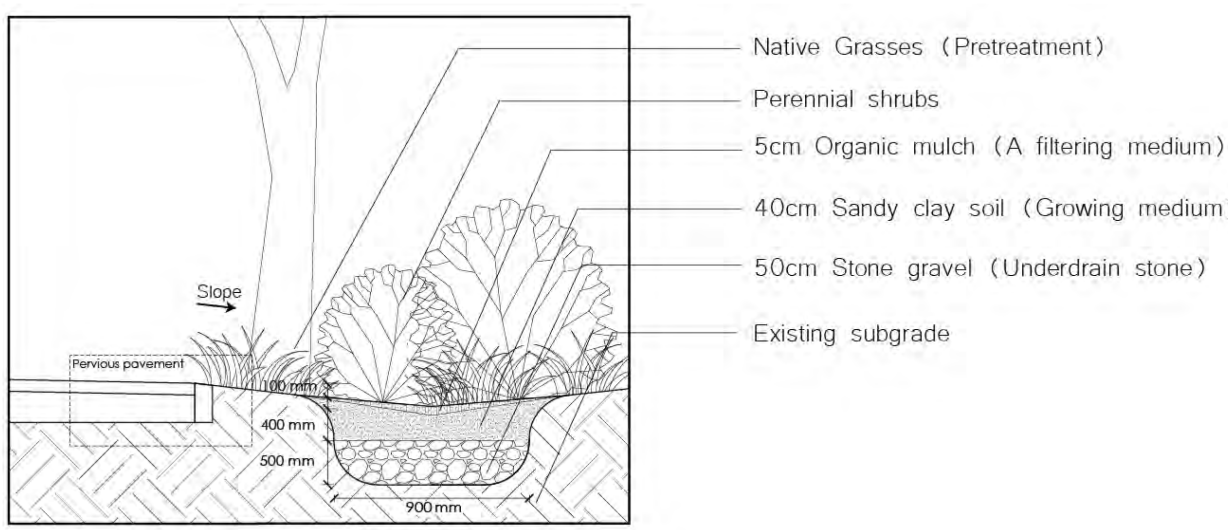


Figure 50. Street side Swale cross section detail

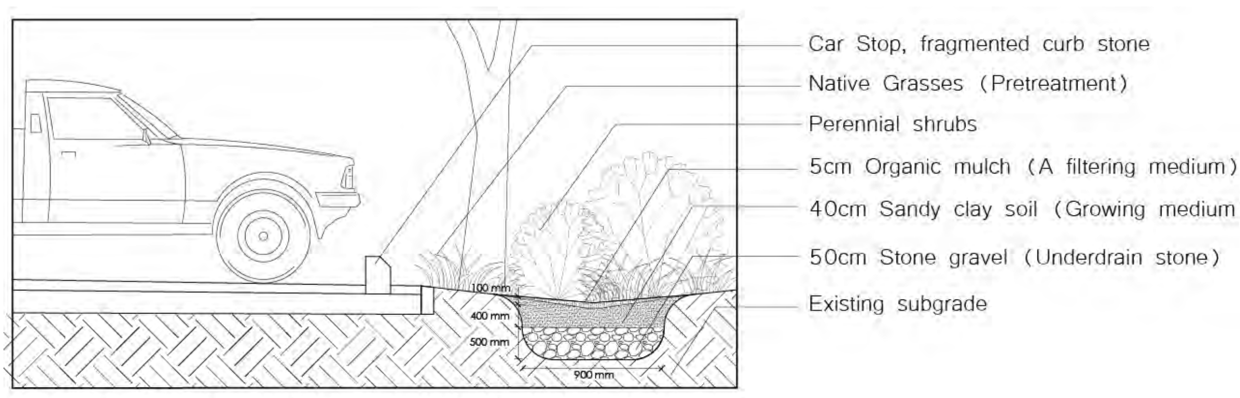


Figure 51. Car parking swale cross section detail

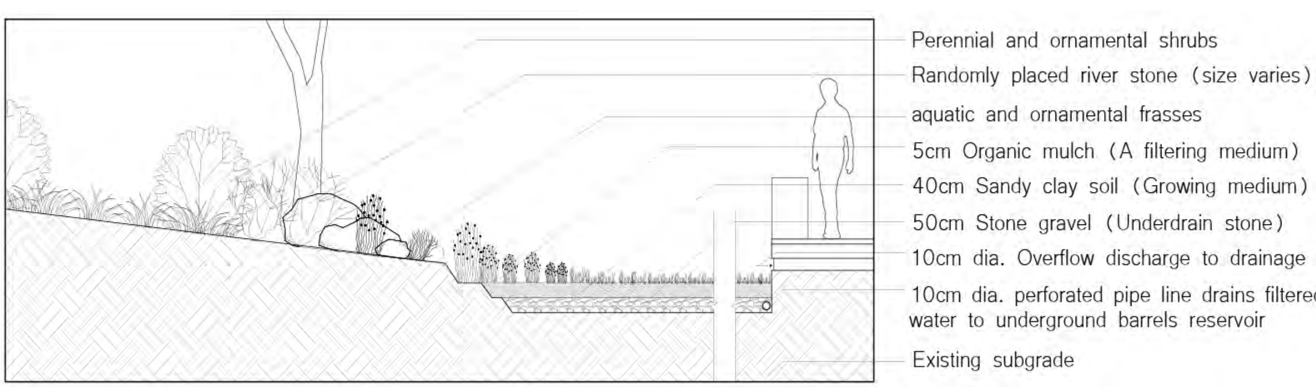


Figure 52. Rain Garden cross section detail

5.4.2. Design Proposal – Part II

Part two of the design proposal focuses on presenting a multifunctional design approach that can be followed while developing new recreational green spaces in residential areas. Accordingly the study selects a case area, and propose a schematic design. The case area located at the new residential development areas of bole sub-city woreda 10, often called with a name *CMC-MERI*). The case area is left for recreational green space development, and currently the resident's community is undertaking several steps to realize and develop a recreational green space project.

5.4.2.1. Study area 3 - Community Park

Figure 53 Satellite image of case 3 (Image source, Google maps)

Housing type – Mixed housing typologies (condominiums & single unit housings)

Owner ship – Surrounding community

Total area - ~ 8,700 square meters

5.4.2.2. Inventory and analysis of the case area

The first step in ecological approach to green space design is through inventory/ analysis of the site to be designed. This includes all information relative to steepness of slopes, soil type, solar orientation and existing vegetation.

5.4.2.3. Slope analysis

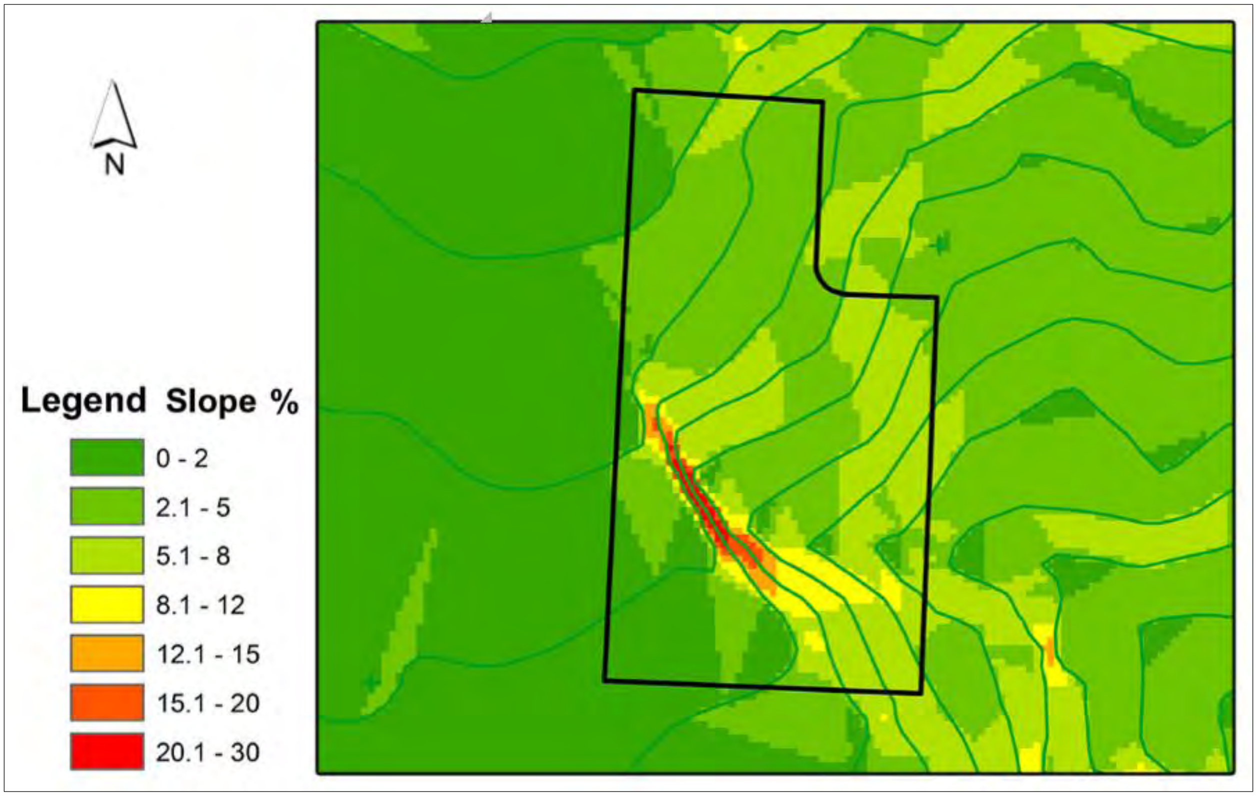


Figure 54. Slope analysis of the case area

The site has a sloppy characteristics, and about 7m difference in cross-section. About 18% of the total area has a slope that is below 2% and can be considered as flat surface. About 35% of the total area has a slope that range between 2%-5% and can be considered as gentle slope. About 33% of the total area has a slope that is above 5% and below 8% which can be considered as rolling slope, and the rest of the total area which is 14% has a slope that ranges between 8%-30% which can be considered as steep.

5.4.2.4. Soil Type Analysis

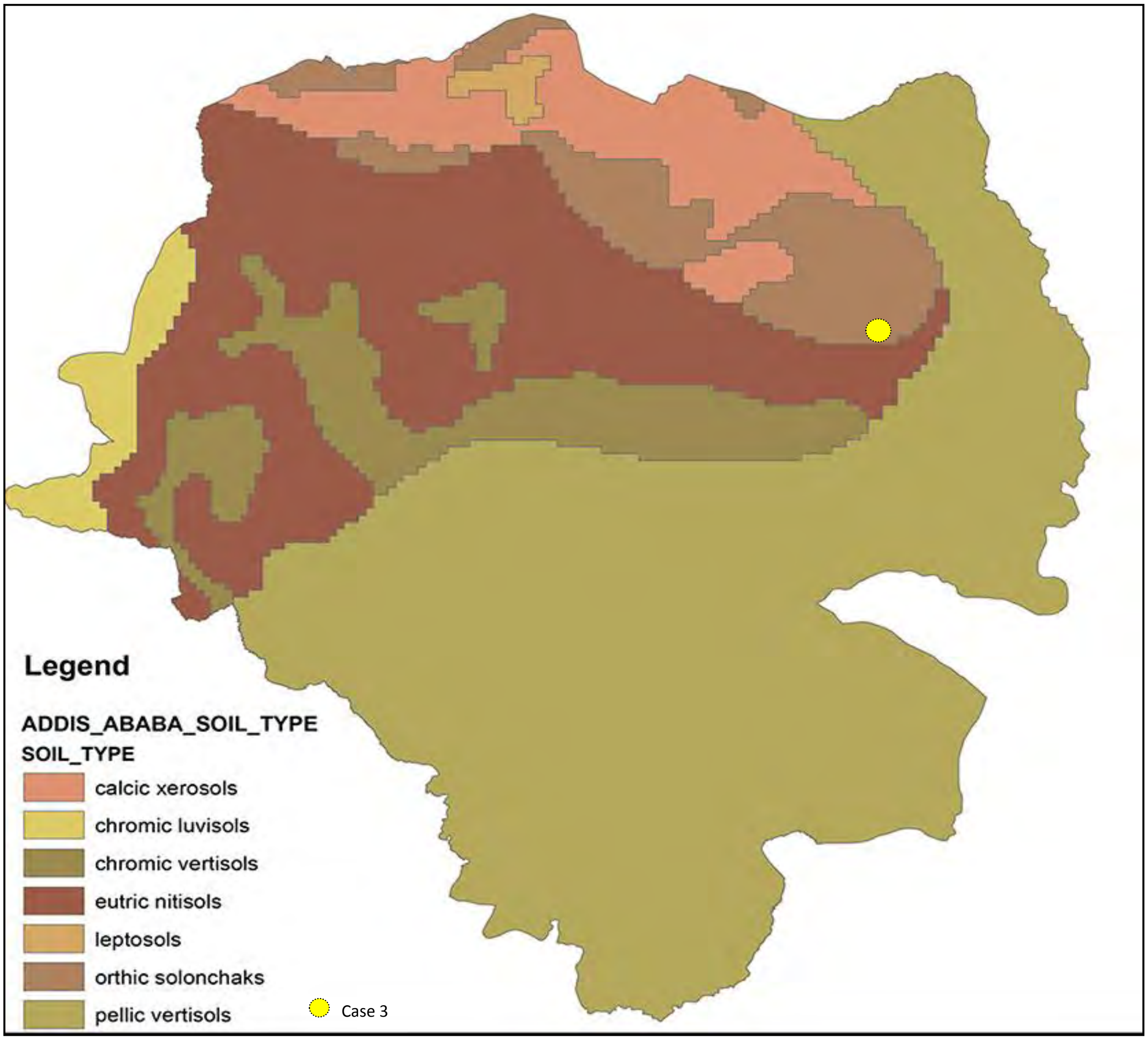


Figure 55. FAO soil classification of Addis Ababa 2004

According to FAO soil classification of Addis Ababa (2004) the soil type found on the case area is Orthic solonchaks. Solonchaks are characterized by having high content of salts and commonly confined in arid and semi-arid areas. Solonchaks have a stable soil structure that is brought about by the high salt content of the soil but typical structural expression of solonchaks does not exist. To properly support vegetation on solonchak soil types, salt tolerant plant types should be selected or flushing of salts from soil is necessary. A typical method to flush salt from the soil is by surplus irrigation or by natural methods during wet seasons.

5.4.2.5. Existing physical structures and vegetation covers

As it has been discussed earlier, the selected case area is located in the new residential development areas of the case sub-city. Hence the open space left for recreational green space development is also new without any infrastructures, or green development carried upon it.

Although the open space is not suitable for playground yet and there are no dedicated spaces for car parking, kids from the residents can be noticed playing football and residents also tend to use the spaces as a car parking spot.

Figure 56. Overview of the case area (photo by author)

5.4.2.6. Identified users' needs and functional requirements

As in any landscape design or planning process, it is important to overlay designer's understanding of the existing physical characteristics of the site, with an understanding of the spatial and experiential needs of the future users of the spaces. Accordingly the study has conducted an informal interview with the responsible community members for the development of the recreational green spaces. The followings are their vision for the green space.

Pedestrian circulation – for purposes such as walking and jogging (sport activities)

Sitting areas – for purposes such as chit chat and reading

Kids playground – that include multipurpose courts (basketball or tennis)

Parking area – with tree shades

Fountain – aesthetical pleasing water body

Vegetation covers – trees that have ornamental, shading and wind breaking characters

5.4.2.7. Concept development

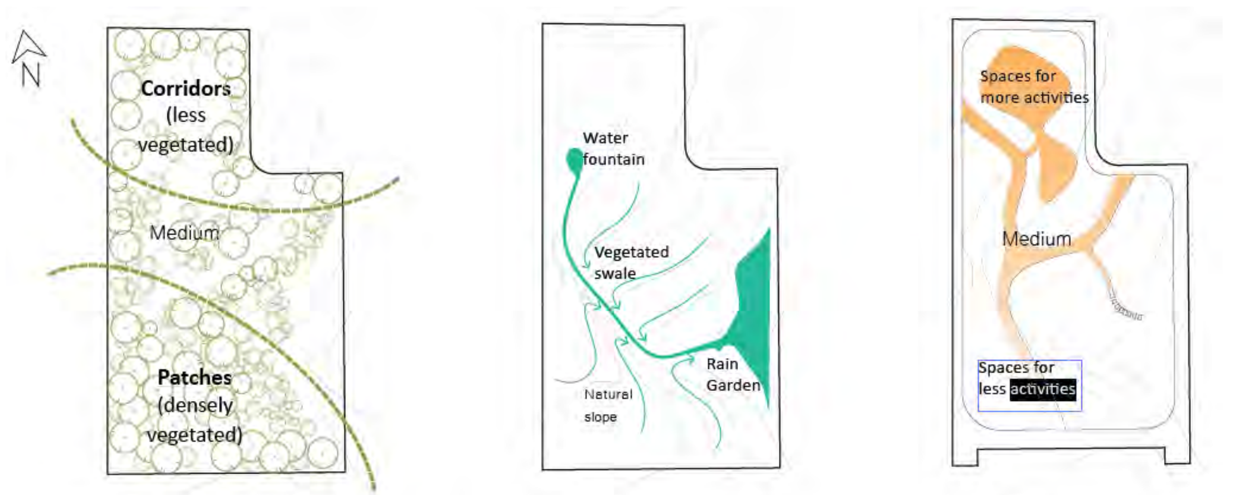
Recreational green spaces, as the main provider of ecosystem services in residential areas, consists of different elements, such as Vegetation, playgrounds, sport facilities, water bodies, access streets and so on. These 'elements' are basic for the recreational green space to be recognized, appreciated and be used/benefited by residents. But without coherent and unified organization, the elements may impact the services and benefits that could be derived from the green spaces.

The following concept is one way to approach organization of different elements in recreational green spaces for their best performances and multiple benefits. The elements in recreational green spaces can be categorized into three;

Vegetation covers – trees, shrubs and lawn

Water management – Drainages (vegetated swales), rain gardens, fountains

Active areas/spaces – Space for activities, sitting, walking, playgrounds, parking



VEGETATION COVERS

Creating hierarchical vegetation density, with plantation technique using patches, corridors, and a combination of both

Patches (densely vegetated) – covering steep slope areas as to prevent high speed water runoff and generally they are not suitable for intended activities

Corridors (less vegetated) – covering flat slope areas as to create space for activities (sport facilities)

WATER MANAGEMENT

Collecting stormwater runoff using curbs to vegetation swales and drain water to a rain garden, with the help of the site's natural slope.

Treated and filtered water from the rain garden will be stored in underground rain barrels and could be used for watering vegetations and ornamental fountain.

SPACES FOR ACTIVITIES

Spaces for different activities are created with respect to proposed vegetation cover and existing slope.

Steep sloped areas and densely vegetated patches with less spaces for activities, and flat sloped areas and less dense vegetated corridors with more spaces for different activities.

Figure 57. Concept Development

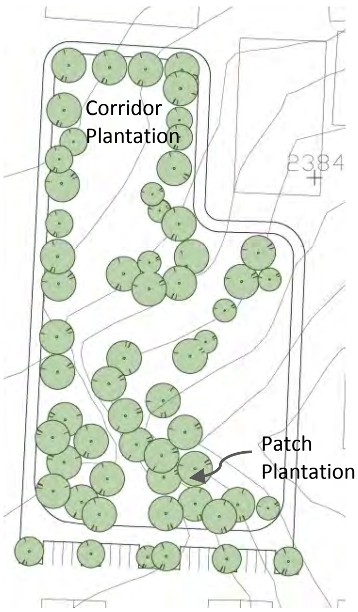
5.4.2.8. Master Plan development

The following master plan could therefore be developed based on the recreational green space elements organizational concept.

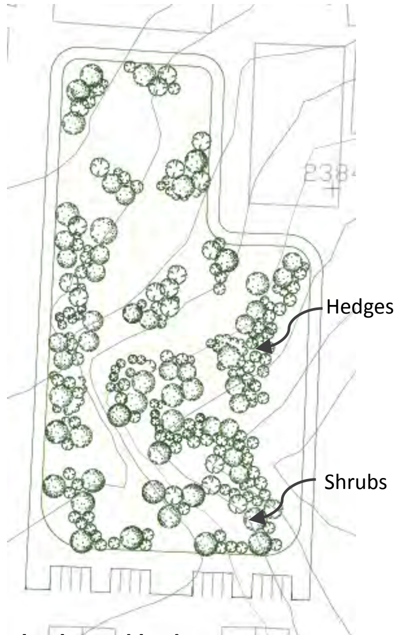
Figure 58. Master plan Development

5.4.2.9. Physical elements

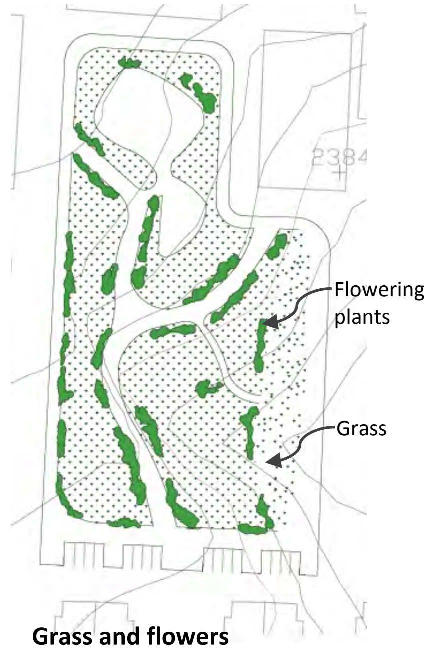
The following drawings are different layers for integration of physical elments into recreational green spaces.



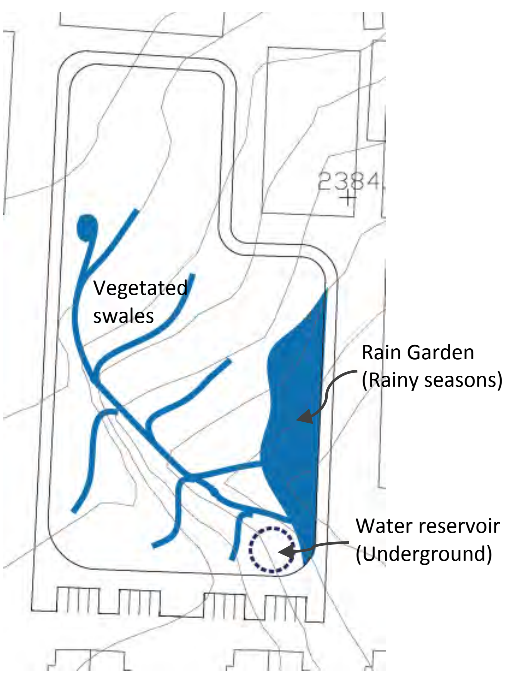
Tree plantation layer
(Based on patch, corridor, matrix)



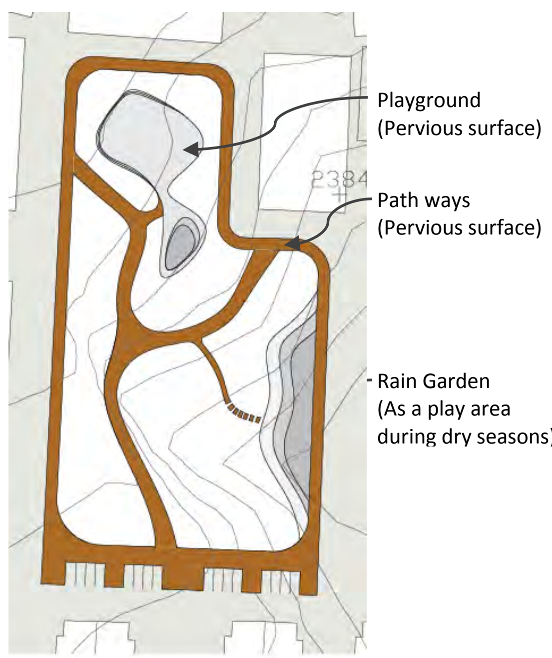
Shrubs and hedges plantation layer
(Based on patch, corridor, matrix)



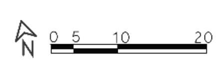
Grass and flowers plantation layer
(Based on patch, corridor, matrix)



Sustainable Drainage Systems
(Based on existing topography and natural slope)

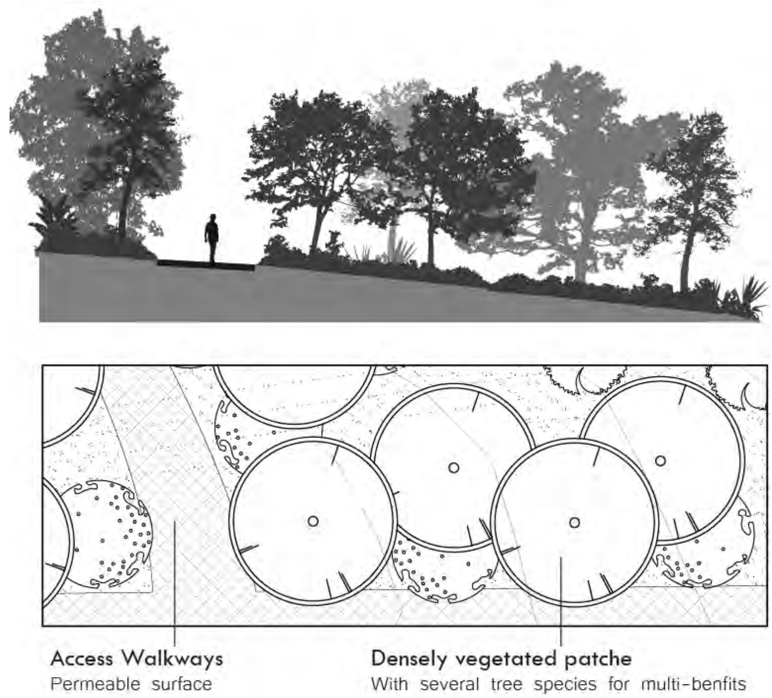


Access ways and space for activities
(Based on patch, corridor, matrix)



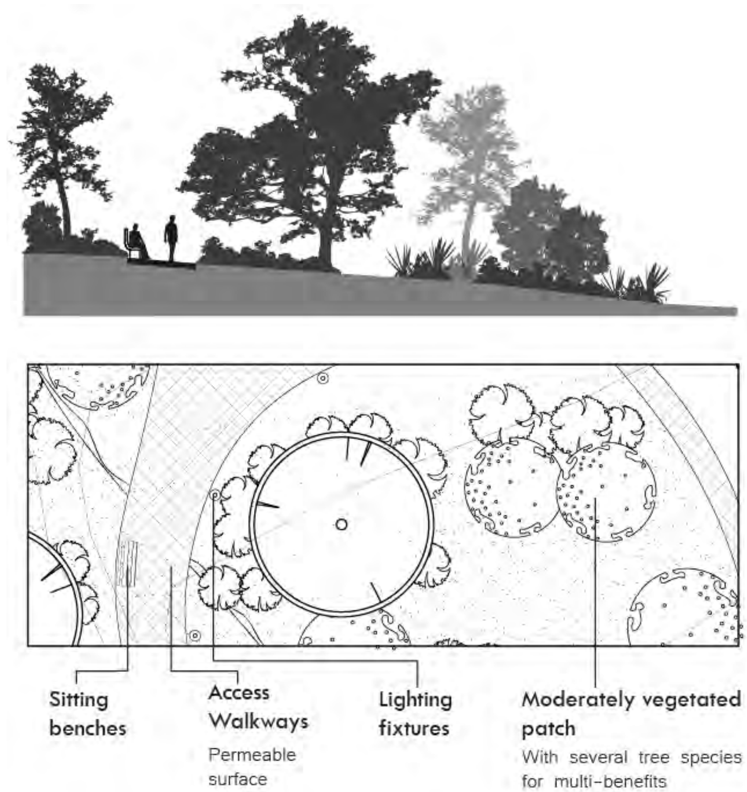
5.4.2.10. Detail considerations

Dense Vegetation zone



- Located at the steep slope areas to protect soil from erosion due to high speed water runoff
- With diverse trees and shrub species that provide multiple benefits such as ornamental, shading, or even fruits to attract birds and animals.
- Less human disturbance because of less activities i.e. by providing only a walking through pathway.

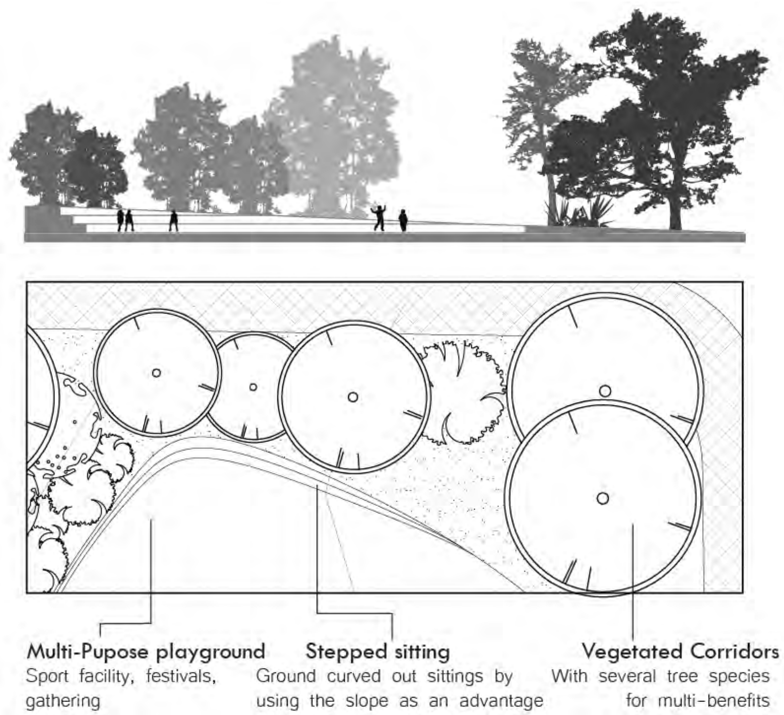
Moderately Vegetation zone



- Moderate vegetation of diverse trees and shrub species that provide multiple benefits with a combination of patch and corridor plantation techniques.
- Moderate activities by providing spaces for sitting benches in addition to walking through path ways.
- Moderately introducing objects that provide recreational services.

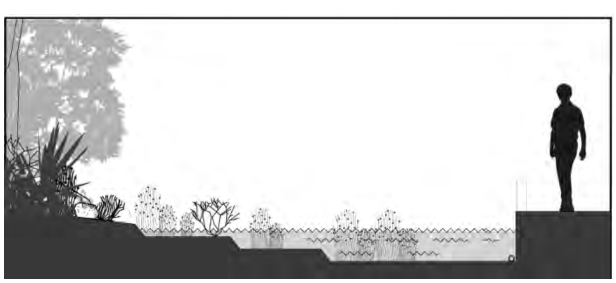
Scattered Vegetation zone

- Less dense plantation of diverse trees and shrub species that provide multiple benefits with a corridor plantation techniques.
- More spaces for recreational purposes such as sport activities, gatherings events or festivals
- Stepped sittings are proposed around multipurpose playground, curved out from the ground taking the natural slope as an advantage.

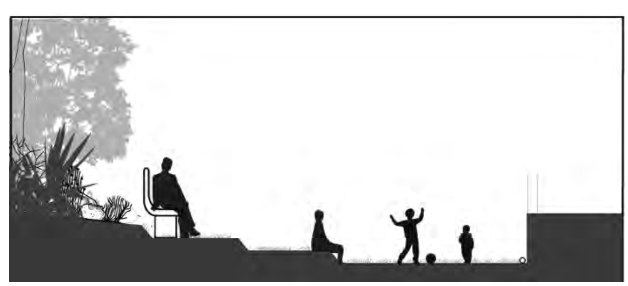


Multi-benefits of the space for the Rain garden

The space allocated for the rain garden have multifunctional benefits. During the rain seasons, it serves as a rain garden collecting storm water from the green space and filtering before storage. During dry seasons, the spaces serves as stepped sitting and play area for kids or a green gathering space for different occasions, hence providing additional spaces for activities.



Rainy seasons
Space serving as rain garden



Dry seasons
Space serving as a play and sitting area

5.4.2.11. Tree Recommendations for multifunctional benefits in the study areas

Table 30. Recommended tree species for multifunctional benefits of recreational green spaces (reference for multifunctional benefits are adapted from Azene et al., 2007)

Plant Species (scientific name)	Local Name (Amharic)	Origin (Indigenous or Exotic)	Multifunctional Benefits					
			Ornamental	Shade	Nitrogen fixation	Soil conservation	Wind Break	Food/Medicine
Acacia decurrens	*Yeferenj Tsatsi*	Exotic	X	X	X	X	X	
Acacia saligna	*Akacha saligna*	Exotic	X	X	X	X	X	
Casuarina equisetifolia	*Shewshewe*	Exotic	X	X	X	X	X	X
Celtis toka		Indigenous	X	X		X		X
Cordia africana	*Yeferenji -tid*	Indigenous	X	X		X		X
Dalbergia sissoo	*Sissoo*	Exotic	X	X	X	X	X	
Ekebergia capensis	*Lol, Somb,*	Indigenous	X	X		X	X	X
Erythrina abyssinica	*Korch, Gorgo*	Indigenous	X		X	X		X
Erythroxylum fischeri	*Moke*	Indigenous	X			X	X	X
Ficus sycomorus	*Bamba, Shola*	Indigenous	X	X		X		X
Gardenia ternifolia	*Dowa*	Indigenous	X	X		X	X	X
Grevillea robusta	*Grevila*	Exotic	X	X		X	X	
Mangifera indica	*Mango*	Exotic	X	X		X	X	X
Parkinsonia aculeata	*Filfile*	Exotic	X	X		X	X	
Piliostigma thonningii	*Yekolla wanza*	Indigenous	X		X	X		X
Pithecellobium dulce	*Temar*	Exotic	X	X		X	X	X
Schinus molle	*Qundo berbere*	Exotic	X	X		X	X	X
Senna siamea	*Yeferenji digita*	Exotic	X	X		X	X	X
Tamarindus indica	*Humer, Roka*	Indigenous	X	X	X		X	X
Vitellaria paradoxa	*Wedo*	Indigenous	X	X		X	X	X

5.4.2.12. Ground cover recommendations in the study areas

Table 31. Ground cover recommendations (reference for multifunctional benefits are adapted from Azene et al., 2007)

Plant Species (scientific name)	Local Name (Amharic)	Origin (Indigenous or Exotic)	Multifunctional Benefits					
			Ornamental	Mulch	Soil Improvement	Soil conservation	Wind Break	Food/ Medicinal
Aloe vera	*Eret*	Exotic	X		X	X		X
Annona senegalensis	*Yebere lib*	Indigenous	X				X	X
Cajanus cajan	*Yergib ater*	Exotic			X	X	X	X
Morus mesozygia	*Injori*	Indigenous	X			X	X	X
Phytolacca dodecandra	*Indod*	Indigenous				X		X
Vernonia amygdalina	*Khokhitsi*	Indigenous	X	X	X			X
-	Vertiver	Exotic			X	X		X
Carissa spinarum	*Agam*	Indigenous	X					X

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

Urban green spaces require public attention for several reasons. First, they provide a wide range of direct and indirect benefits (ecosystem services) (Grey and Deneke, 1986) Second, human activities have contributed to the change of green spaces in many ways in urban areas (Bassuk and Whitlow, 1988) which have a great impact on the stability and continuity of ecosystem services generated by urban green spaces. The result found from the research also indicates, while recreational green spaces can provide multiple benefits for residents, their designed landscape components intended for different activities of humans, may impact the maximum benefits (ecosystem services) that can be generated from the recreational green spaces.

The studied recreational green spaces have different physical components that are integrated to fulfill different activities of visitors. Apart from vegetation covers, the recreational green spaces also included a building for multipurpose services, cafeteria, sport courts (ground tennis and basketball courts) and parking areas. Based on the study the recreational green spaces were actively used for recreation and amenity purposes, because of incorporated recreational facilities, their well-maintained landscapes, beautiful views, provisioning of comfortable local environment (temperature, air quality and Noise), in addition to their proximity to residential areas.

Although the incorporated recreational and sport facilities satisfy the requirements of the green space users for theirs different activities, hence providing recreational services, the surface structure which they are made from, corrugated sheets in the case of buildings, asphalt covers in the case of streets, and concrete covers in the case of sport courts and parking areas, have a significant impact on the overall provisioning of regulatory ecosystem services. Based on the analysis of the study, which is stormwater regulation by the green spaces, the impervious surface integrated recreational and sport facilities contributed to an increase of a significant amount of stormwater runoff, which otherwise could be retained by the recreational green spaces. Accounting 65% contribution to total stormwater runoff from study area 1 and 44% from study area 2.

The estimated total stormwater runoff from study area 1 with current surface covers is 7886m^3 annually, and the estimated stormwater retention ability of the study area is about 5031m^3 annually. Hence the recreational green space's stormwater retention ability is 37% of the total rainfall that the study area gets annually, which is about 13905m^3, and which needs to be managed by urban flood water infrastructure if the existing recreational green spaces were to be removed.

With regards to the community recreational green space (study area 2), vegetation cover is relatively high, accounting 77% of the total area. Accordingly estimated total runoff from the study area is 3151m^3 annually, while the estimated annual stormwater retention ability of the study area is 5166m^3. The estimated annual stormwater retention ability is 59% of the total rainfall that the study area gets annually, which is about 8755m^3 and which needs to be managed by municipal infrastructures.

The design proposal of this research tried to integrate permeable surfaces and sustainable drainage systems in to study areas to enhance stormwater regulating services. As a result of the proposed permeable surface covers, 38% to 45% of stormwater runoff in the study areas are minimized. The proposed sustainable drainage systems also contribute in retaining the remaining stormwater runoff in the study areas.

The concluding remark of this study is therefore, recreational green spaces in the bole sub - city of Addis Ababa could provide substantial ecosystem services, not only as a recreational and aesthetic elements but also as a living component of the municipal infrastructure.

6.2. Recommendations

The overall findings of the research recommend several approaches to be followed to sustain recreational green spaces and thus maximize their provision of ecosystem services.

- Attention should be given to improve the surface characters of Physical elements that are found within recreational green spaces such as the surface character of streets, sport courts, and parking areas. Permeable surface need to be preferred over impermeable surfaces for their multiple benefits.
- The Ethiopian National Urban Green Infrastructure Standard (2015) suggests that green coverage in all types of parks should be in a ration of at least 75% green components and at most 25% other components. This recommendation should be followed as possible, for a better stormwater regulating service of recreational green spaces.
- Increasing density of vegetation covers in the recreational green spaces and improving the species diversity would help not only in providing various landscapes and multiple functions but also serve as a gene conservation approach.
- It is also important to adopt an ecological landscape design approach to green space design and management so that to drive multifunctional benefits (ecosystem services) out the green spaces.
- It is very important to increase the size and number of recreational green spaces within residential areas. As the Ethiopian National Urban Green Infrastructure Standard (ENUGIS) suggested at least a 5000m^2 area of green space need to be within a 500m radius of residential areas.
- Comprehensive management and maintenance of existing recreational green spaces could increase the benefit, including sustaining green spaces, planting of trees
- Public involvement in green space design projects could be a major driving force, far more than political support, for the management of urban green spaces. The public could be informed about the multiple benefits of green spaces beyond the recreational opportunities and amenities, which include flood protection, cleaner air, and nature conservation

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ANNEX

Semi-structured interview

General Information

- Name: ______________________________________
- Gender ________ Age ________

Functional usage

- Where in the park visitors spent most of their time.

Places in the park	Outdoor cafeteria	Basketball court	Ground Tennis court	Green courtyards	Total
Number of visitors counted (Age Group)					

- Purpose of visiting the park. (please thick as appropriate)

Purposes	Very Important (%)	Important (%)	Least important (%)
Relaxation			
Sport activities			
Social contact			
Aesthetic pleasure			
Nature appreciation			

- Reasons in choosing the park for recreation. (please thick as appropriate)

Reasons	Very Important (%)	Important (%)	Least important (%)
Proximity to residence			
Recreational Facilities			
Well maintained landscape			
Comfortable local environment (temperature, air quality and Noise)			
Any other (please write down)			

- Purpose of visiting the park. (please thick as appropriate)

Regulatory Ecosystem Services	Very Important (%)	Important (%)	Least important (%)
Local climate regulation (Shading, temperature)			
Air quality maintenance (oxygen release)			
Noise reduction			
Stormwater regulation (flood risk, ground water recharge)			
Natural Hazard reduction (landslide)			
Waste treatment (decomposition of organic wests)			