

**The present work was submitted to the Faculty of Engineering**

**A GIS-BASED METHODOLOGY FOR GREEN ROOF DESIGN IN A DENSELY BUILT-UP  
AREA IN ULAANBAATAR, MONGOLIA**

**Bachelor Thesis**

by

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### Statutory Declaration

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## Acknowledgement

It has been a challenging project. This would not have been possible without my school, GMIT, and my teachers I would like to express my special gratitude to Mr.Uuganbaatar and Mrs.Gantuya for giving me better ideas and motivations and for closely supervising my thesis and encouraging me to complete this project. Last but not least, I am genuinely grateful for having such a caring family that always gives great advice and dear friends who are always willing to help me through tough times.

## Abstract

Ulaanbaatar has the highest population density in Mongolia. Consequently, for the past few decades, the massive movement of people to the city led to unplanned urbanization. Today, Ulaanbaatar is facing environmental problems in all seasons of the year. To resolve these issues, some measures have begun such as the “Green City Action Plan for the City of Ulaanbaatar”, and “Green building guidelines”, not to mention “A Billion Tree National Campaign”. These massive projects have made a little to nothing difference in the fight against deforestation, climate change and desertification due to a lack of green space and funding.[4] Thus, this work is to design green roofs on already existing buildings. The building footprint and potential rooftop areas for green roofs in 26<sup>th</sup> khoroo of Bayanzurkh district, Ulaanbaatar, Mongolia are analyzed using GIS software and Google Maps. Out of residential 358 buildings, 40% or 0.784 km<sup>2</sup> of roof spaces are available for installing greenery in the study area. Considering the design criteria and local conditions, extensive green roofs are recommended. The selection of vegetation differs depending on building height due to the biomimicry of mountain landscape into buildings. The cost of installation is higher than traditional roofs but once the green roofs are installed, they would be simple and long-lasting urban ecosystem improver with proper care and maintenance.

## Chapter 1

# INTRODUCTION

### 1.1 Problem

Global climate change has been affecting urban areas severely and the struggle to address the issue has been ongoing. Rapid urbanization initiated a series of weather events i.e., droughts and sandstorms near cities, resulting in capital losses and infrastructure damages. However, addressing such extreme weather events and their possible impacts is not the priority but rather the method to solve them. Thus, the race to find solutions, suited to urban conditions, has begun by conducting experiments and research all over the world. [4-6]

Likewise, Mongolian traditional nomadic lifestyles have been rapidly replaced by urban settlements since 1990. Originally, Ulaanbaatar city was planned for the living of 500,000 people at maximum. The migration to the city, however, has increased the urbanization about 4 times higher than planned. [1-2] This rapid population growth associated with intensive construction led to an increase in the number of buildings for housing, business centers and shopping malls. Investors, architects, and residents are interested in constructing profitable facilities, which, unfortunately, leaves residential areas with almost no green space. Lack of green space not only affects human health and lowers the life satisfaction of people, but also environmental problems such as noise and air pollution. [3]

### 1.2 Aim

The aim of this study is to design green roofs at the 26th khoroo of Bayanzurkh district, which mostly has mid-rise and high-rise residential areas. The district residential area has no green space, but, on the contrary, has many roofs and cemented roads. The roofs have the potential to provide green areas that the 26th khoroo desperately needs. The design is based on GIS-based remote sensing to calculate and measure the usable areas for greenery.

### 1.3 Brief History

Green roofs originated from Vikings about four thousand years ago to protect themselves from harsh conditions. However, the major development of the green roof design and implementation

started during the 19th century and has been constantly improving ever since. In the 80's, European countries started to turn housing roofs into green roofs. Moreover, European countries have done plenty of research on improving construction technologies, materials, drainage systems, growing media, and plants, inspiring North America and the rest of the world to refine the design.

The main objective of the green roof is to increase the standard of living as much as possible without negatively affecting the environment. Thus, it is of utmost important to utilize natural resources, such as rainwater detention, and preserve the habitats of indigenous animals. [4]

## 1.4 Introduction

The green roof design is an effective way of creating environmentally friendly roofs, on top of which vegetation can grow, while providing green habitats for the surrounding areas. The roofs, fundamentally, are made up of several covers that could be different depending on the roof types and climatic conditions. Green roofs may experience changes in the hydrological cycle, the transmission of energy, greenery, ecological recycling, and many other benefits generated by green roofs. [1-2]

A functional system of ecology consists of several types of infrastructures, concentrated populations, and apartment buildings. Construction and facilities occupy 42-47% of the city. Nowadays, cities and towns, however, are facing the urban heat island effect, air and water pollution, and flash flooding due to the lack of green zones. Luckily, green roofs save significant amounts of energy and decrease both the urban heat island effect and the temperature of the atmosphere while providing comfort for humans and managing stormwater. [5]

Green roofs are also grouped into three sections: extensive, intensive, and semi-intensive depending on their growing medium depths, accessibilities, vegetation diversities, saturated weights, maintenance, costs, and stormwater management. [4]

Over the past few years, researchers have developed a mixture-like design, a semi-intensive green roof, of extensive and intensive roofs, while keeping the advantages of both. This type of green roof has four basic layers for the sake of proper installation such as deck layer, waterproofing layer, insulation layer, and drainage system layer, but can be extended to many more such as root permeable filter fabric, growing media, leak detection layer, and plant cover. Every green roof has layers starting from the housetop and raising through its base layers. Regardless of the above classifications and vegetation, green roofs, most importantly, are utilized to be sustainable and environmentally friendly. [6]



*Figure 1. General green roof on a residential building*

### **Extensive green roofs**

Extensive roofs are aimed to increase the view. They are seen as public appealing green spaces rather than getting in touch with natural green spaces directly such as providing resting places for birds and controlling stormwater. Yet, they are lightweight and do not need regular irrigation and maintenance. The vegetation grows naturally without even irrigation. Their usual depth of substrate is between 8cm to 15cm. In terms of installation cost, an extensive roof is much cheaper than the other two types. Furthermore, they require little technical assessment and can cover a broad range with a roof slope of 0 to 30 degrees.

### **Intensive green roofs**

Intensive roofs demand regular care and weigh heavier than extensive roofs. They are directly accessible to both people and animals. The usual substrate depth is between 20 to 200cm. The longer the in-depth substrate becomes, the broader the selection of vegetation becomes. As a consequence, they have plenty of vegetation selections from herbs to shrubs to even big trees. The wildlife offers a wide range of vegetation.

Intensive roofs serve as an open space for their surroundings. They also use additional insulation for buildings. Because of their good stormwater management practice, they are often associated with additional initialization, raising the cost, the highest one yet, and maintenance frequency.

### Semi-intensive roofs

Intensive roofs are heavy and pressurize rooftops whereas extensive roofs have a limited choice of plants. Semi-intensive roofs are mixed with the benefits of both extensive and intensive roofs. Their substrate depth is estimated to be 10cm to 20cm. Like extensive roofs, they require almost no irrigation and maintenance and are lightweight. Like intensive roofs, they can have a broad range of plant selections. [8]

*Table 1. Types of green roof*

Criteria	Extensive	Intensive	Semi-intensive
Roof frame	Steel,concrete,wood	Concrete,max pitch 5%	Concrete
Plant mix	Sedums, moss, perennials	Shrubs, trees, lawn	Perennials, small shrubs, lawn
Substrate depth	8 to 15cm	20-200cm	10-20cm
Maximum loading	75-180 kg/m <sup>2</sup>	500-2000 kg/m <sup>2</sup>	200-500 kg/m <sup>2</sup>
Irrigation	Low	High	Medium
Maintenance (1-5)	1	4	3
Installation cost	Low	High	High
Accessibility	Often inaccessible	Highly accessible	Limited

### 1.5 Ecological benefits of green roof

Green roof presents a wide range of benefits in the fields of ecological, economic, spatial, and social. The earth's ecological systems are controlled by many cycles that are interrelated with each other. If only one changes, it affects all of them. To be more specific, urbanization massively disturbs the natural hydrological cycle and ecosystem. The green roof could positively influence the atmosphere and waters of regions; however, the expansion and interaction of green roofs together with the other approaches can only make an impact on the earth's changing climate.

In the following, only environmental benefits are mentioned. One of the green roof's contributions is the effective management of stormwater [38].

### 1. Stormwater best management practices

The hydrological cycle is a continuous water motion between the earth and the atmosphere. Stormwater is formed from the precipitation and melting of glaciers. Stormwater also supplies surface water and groundwater if not blocked. Vegetation can block the precipitation by dissipating droplets' energy and reducing erosion on the ground. Thus, plants cover healthy soil and then reduce water speed and infiltrate.

Stormwater runoff is rainfall that does not infiltrate and flow over the ground. Runoffs are divided into two types: surface and subsurface runoff. Subsurface runoffs are soaked into the soil and can move across horizontally and vertically. Surface runoffs move by gravitational force until they find a way to the water body. The speed and motion of stormwater runoff depend on the properties of the surface. Thus, the main objective of stormwater management is to reduce the surface runoff or increase subsurface runoff. If the subsurface runoff amount is sufficient enough it will be able to supply vegetation and groundwater.

In engineering practices, stormwater is collected at low points or in open channels which then discharges into the water body. However, if the surface is impenetrable, collected stormwater at low points will be higher than the actual capacity. Concentrated stormwater means its erosion force increases and adversely affects soil erosion such as banks, gully, and vegetation and loss of habitat. In urban cities, the grounds are made up of impervious materials, concrete and asphalt.

In recent years, stormwater collection in cities has shifted from centralized to decentralized practice, making the green roof one of the great ways of decentralized stormwater management practices. Green roofs block and hold runoff water 90% more effectively than centralized stormwater collection systems do. Green roofs do not work in downpours and large precipitation events as efficiently as capturing rainwater with the intensity of 2.54cm. They keep stormwater runoff to the central sewer system and mitigate the flood threat.[6]

### 2. Urban heat island effect and energy balance

Urban expansion and the development of man-made surfaces that do not allow water to seep into the ground are adversely affecting the air quality. As the indoor air temperature rises, the energy consumption climbs rapidly. In consequence, the emission of greenhouse gasses and other air pollutants contribute negatively to air quality. Urban heat island is one of such outcomes of urbanization. The natural grounds are taken over by roofs, roads, parking and other structures. So, when the dark surface materials are exposed to sunlight and absorb electromagnetic radiation,

these materials hold a large amount of energy and re-radiate it into the atmosphere, thus increasing the temperature of the surface environment and the ambient air temperature.

The rising temperature in urban areas (1.1° C in decades) affects local temperature as well as national and international. Air cooling and handling systems cool off indoor air and emit hot air to the outdoors triggering temperature rise in the surrounding area.

Green roofs help reduce the transferred heat of the buildings and re-emission it into the atmosphere. As indoor air cools down, there is no need to use air conditioning. Consequently, the energy consumption and waste heat are decreased by 10 to 30%.

In the wintertime, green roofs serve as insulating layers to lessen the heat demand. If the substrate has moisture, the insulation layer works less effectively. The green roof types, microclimate characteristics, and building qualities determine how much electricity could be saved. Green roofs can, furthermore, save the power use of a building. If there is a sufficient number of green roofs, they can decrease the aggregate demand in the power system. [9]

### 3. Air quality

Green roofs can be one of the more practical solutions that enhance air quality, mitigate climate change, and improve the well-being of people by reducing temperature and lessening the demand for energy consumption. Six primary air pollutants carbon – monoxide, tropospheric ozone (ground level), lead, nitrogen oxides, sulfur dioxide, and particulate matter – are released into the atmosphere, harming both humans and animals. Most of them are the results of generating electricity by burning fossil fuels. Once they are released into the atmosphere, they travel a fair distance. During their circulations, they interact and react with environmental constituents and form secondary pollutants such as ozone sulfuric acid and nitric acid, volatile organic compounds, nitrogen dioxide, etc.

Greenhouse gasses – carbon dioxide, methane, hydrofluorocarbons, and sulfur hexafluoride– keep the re-radiated heat without getting them out into space, which, as a result, causes climate change. Even though greenhouse gasses are vital for life on earth, rising emissions are adversely affecting human health, ecology, and economics. Thus, by installing and using green roofs, the air quality can improve in three ways: decreasing the urban heat island effect and decreasing regional temperature, avoiding further air pollution, and lastly removing existing air pollutants from the air.[10]

### 4. Noise reduction and electromagnetic pollution

As humans make more use of electronic devices, the electromagnetic fields they produce have swiftly expanded. However, following the technological advances, the uses of high-frequency electromagnetic waves, which are possibly carcinogenic, as also increased. Green roofs are

highly recommended for rooftops with telecommunication hardware because they reduce electromagnetic waves by up to 99.4%.

Construction sites, traffic, industries, and any other activities generate a noise level of 85dB. If the sound amplitude unit is over 180dB, it will be out of audible range. Luckily, green roofs are proven to minimize airborne noise levels by 60dB. [6], [10]

#### 5. Ecological diversity

The natural processes on earth are interrelated. A change in one system will have an impact on the whole ecological balance. Installing green roofs and adding up more green spaces in urban areas are satisfactory for a healthy local system. Any type of green roof provides a habitat for plants and animals. For example, plants that used to grow in the selected region, now destroyed, could be ideal vegetation of choice, meaning more efficiency for the green roof service. Following the plant diversity, some animals that lost their homes in nature due to development can find a safe heaven on green roofs. [5]

## 1.6 Challenges

Although green roofs may have many benefits in various fields, they also deliver a few problems. [37]

- Capital expenses

Green roofs have many layers compared to conventional roofs. They also include minor components. Minor components require connection nodes and knots in short distances i.e., the drainage system joint should be in every 3 meters. The cost of installation, and equipment price was more expensive than traditional roofs. This situation worsened due to coronavirus since the inflation increased in almost whole nations. Those factors, mostly the price limits the broadening of green roofs. Therefore, it might be hard to funding for initiation phase.

- External forces

Wind, snow and weight loads pressurize the buildings. Intensive roofs put pressure on the roofs 6 times more than external types do because they have deeper substrate than external type. Since extensive roofs require shallow substrate and their greeneries should also be short rooted perennials. They include many layers and regular maintenance might be needed depending on the roof type so that the additional external forces will apply in every time.

- Maintenance

As long as the green roofs have vegetation cover, they need proper care. For instance, if there is a weed among the plants, the weed should be removed because it decreases the growth of

inserted annual flowers and perennials. Also, the birds might be one of the destroyers of the green roof. However, there is not sufficient research about the green roof and the bird. This problem might arise if there is a plenty of species of vegetation but not appropriate substrate.

- Leakage

The green roof has a life expectancy of about 50 years. Although they are more durable than traditional roofs, once they have a problem with any of the layers they need to be replaced as fast as possible. Especially if the problem is in the filter membranes or drainage layers leak, they need to be replaced in an instant. If not, the leakages lead to structural damage to the buildings. Replacements, as a result, are expensive since they are replaced by whole new layers.

Slope and soil conditions cause problems for the green roof but in our case most of the roofs have a slope between 2° which will not cause slippery problems. Moreover, we are not using soil but an engineered medium. Thus, the soil condition and slope of the building will not be a challenge in our case.

Despite the fact, there are some technical problems. It is hard to measure how the green roofs are affecting in a good way to the above-mentioned benefits. Sometimes, finding the effective water controlling substrate becomes a problem but not in our case. Green roofs so called ecofriendly but some materials such as polymer filter layers should be converted to the more organic forms of material in order to prevent the solid waste whenever the replacement is done.

[5-6]

## Chapter 2

### STATE OF ART

Many research on green roof modeling in various fields has been conducted and many more researchers are on the move. Governmental and non-governmental organizations are encouraging the set-up of green roofs through policy, regulation, and financial incentives. Europe, North America, and Asia have started to promote and develop schemes. Supporting the green roofs is now the prime approach for green businesses. [5]

#### Sustainability goals

In February 2016, the Parliament approved and passed the “Concept of Sustainable Development of Mongolia-2030”. Out of 17 goals and 169 objectives of the “World Sustainable Development goals”, four chapters and forty-four objectives are matching with “the Mongolian Sustainable development” policy. Mongolian “Green development policy” provides legal information and guides green construction planning. In this policy, green building is written as “convenient and has proper technologies to handle heat loss, emissions to air, waste, energy efficiency, precipitation storage, and wastewater treatment”. [4]

Mongolia’s sustainable development vision, which was initiated in 2014, will come to finish by 2030. Regarding the aforementioned document, the share of urban green space will be 30 percent by the end of the project. Ulaanbaatar has the largest area of green space, 4.586 km<sup>2</sup>, in Mongolia. However, it is the least amount of green space per person, 0.4 m<sup>2</sup>, compared to the international standard, which is 24 m<sup>2</sup> for per capita green space. [3]

For the Mongolian sustainable development goal to be implemented successfully, the Mongolian green building design book was published by the UN Environment program. This book has 7 chapters, including sustainable development, architectural plan, life-cycle assessment, water-saving, energy-saving, material saving and model building. Unfortunately, a green roof is stated only once while other green building-saving efficiencies are written in detail. [4]

In Mongolia, several private companies offer the installation of green roofs. The biggest installment on a residential building has been executed by Nomin Construction or NCD group. The company is working on 16 building rooftops in the 4th khoroo of Bayanzurkh district. So, for now, NCD is doing further research on a green roof in Mongolia. [4]

## **Latest movement**

The President of Mongolia addressed the General Comment of the 76th Session of the UN General Assembly on September 22, 2021. He stated that, according to world trends and developments, to fight against climate change, Mongolia will plant a billion trees by 2030. A few days later the decree was issued to launch the “Billion Tree” national movement. The draft presidential decree stipulates that up to 1 percent of GDP should be spent on the environment. The billion-tree movement has 3 stages: preparation, intensification and sustainability. Currently, 76.9% of Mongolian land is severely affected by desertification and only 7.9% of the land is covered by forest. If the movement is deemed successful, desertification will decrease by 4% and forest land will be 9%. [13]

## **2.1 Literature review**

### **” Urban Integration of Green Roofs: Current Challenges and Perspectives”**

This study’s objective is to review 158 green-roof benefits and efficiency-related research papers. The documents are divided into categories based on the study areas such as city and neighborhood. Green roofs benefits are to increase biodiversity and stormwater management, reduce the urban heat island effect, to better air quality, and include public approval and the possibility of installation. As a result, conclusions are reached, that state

1. The lower-height buildings are suitable for biodiversity because of the rich selection of vegetation. However, mosquitoes’ numbers would increase due to abundant vegetation, meaning they could pose a threat to the public health. There are very few studies conducted on the matter, not to mention the whole biodiversity, so no other points to be highlighted.
2. As for stormwater management, it needs some modifications. Green roofs water retention can be efficient only if the rainfall is deemed moderate to high. Thus, stormwater management needs developments in the event of extreme rainfall and drought.
3. For the urban heat island effect, the advantages are present only in lowerheight buildings. Apart from it, those studies showed a direct positive influence on energy balance. Regardless, the roof manifested the effect on the top floors of the building and there was a little increase in temperatures during the night.
4. Air quality near the area of the green roofs had become better.

5. In the future, designation of green roofs in cities is difficult to choose, considering the given area and its features. The cost of installation is high and it should be further studied. Urban design for another assessment for green roofs is better if used with real urban features. Basically, more research is needed on the chosen 7 fields.[14]

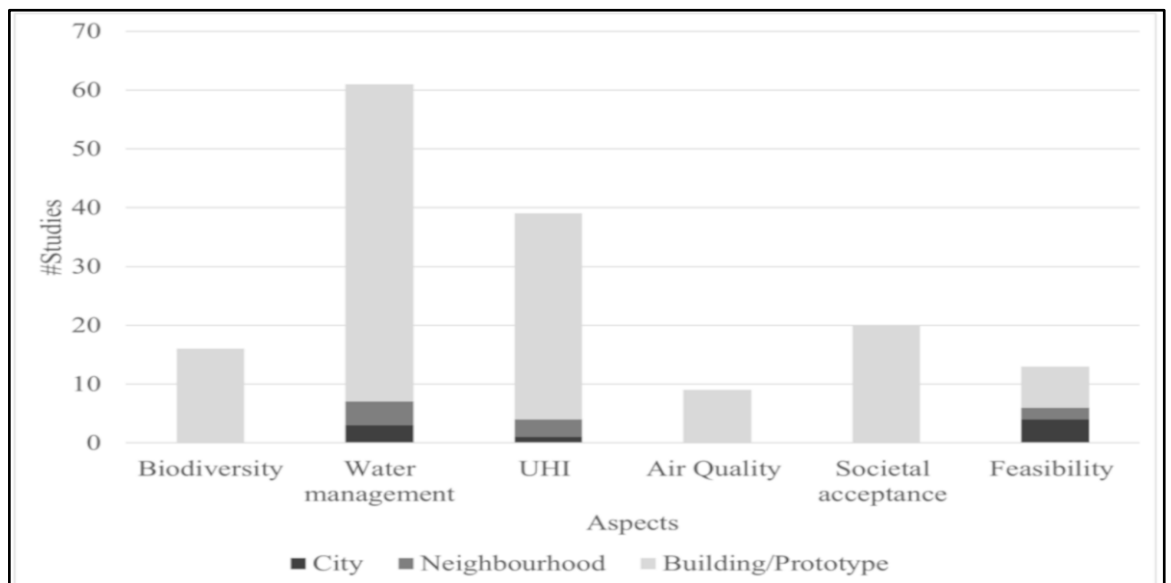
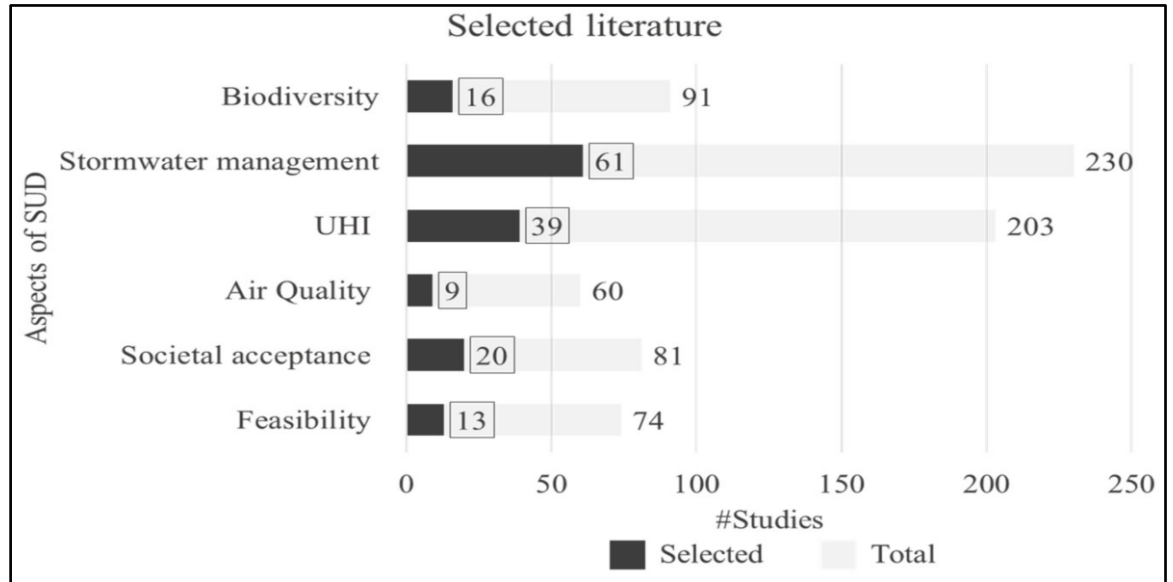


Figure 2. Selected literature for review

## **“A GIS-based mapping methodology of urban green roof ecosystem services applied to a Central European city”**

In this study, the target area is located in Braunschweig, northern Germany. The study area covers a 192km<sup>2</sup> area with a total population of more than 250 thousand people. There was also another ideal city with defined number of green roof areas for per inhabitant. Also, the further studies of usages of photovoltaics on green roof study was ongoing. This study is for assessing their local cities potential rooftops and defining the suitable area and some disturbing parameters relation.

Whole building traces is 7% of the city. This paper was done by defining the potential rooftop areas and doing the spatial analysis with provided measures of the building. The geodata of the location was provided by the local Environmental Agency and later processed with ArcMap 10, ESRI and ArcGIS. The data is accurate, so that the results are defined the suitable are effectively. Based on the roof inclination, the rooftops were divided into 3 sections A, B and C. A is below 1°, B is between 1 to 5° and C is above 5°. The problem with the study was either the rooftop area is too small or inclination degree is higher. Also, the rooftop materials, such as tiled roofs and their inclination angle is hard to install green roofs and for the engineering measurements.

The total suitable area for greening is determined by spatial variation. Of all rooftops, 5.7 km<sup>2</sup> area is usable with limited applications. This paper focuses on general green roof type, that the overall usable rooftop parts to be recommended extensive and intensive. This work has shown that the city has a plentiful of area and possibilities to install green roof on its existing buildings with the provided data of the whole city.

Based on the criteria, the buildings divided into three parts by their effective of usages, appropriate with high, moderate and low advantage. Likewise in other studies, the result showed that the center of the city has a high potential for green roofs. Even tough, the whole traces of the building were only 7% out of them the 14% the whole building had potential for potential area for green roofs. This study does not recommend any materials or vegetation and any other details. However, this study recommended the potential benefits in thermal regulation of buildings, air quality, stormwater managements and increase in biodiversity. Lastly, it shows the direct outline to plan which area is beneficial for further greenery. [15]

## Chapter 3

### DATA AND METHODS

#### 3.1 Data

All the data used in this work is collected from external sources. The land cover or land use data is downloaded from The European Space Agency's two dual-use satellites called Sentinel-2. This satellite system is made up of two similar satellites oriented at 180 degrees toward each other. Below map shows the land cover of 2020 with the highest resolution. The data was published by the Environmental Systems Research Institute on Jun 19, 2021. The accuracy of the map is 95% and higher.

The captured image of the surface is 290 km of width. The satellites will lower to the equator for 10 days and, if there is no cloud, the two are present and can evaluate for 5 days. The class prediction is 10m, meaning the algorithm dictates to take snapshots zooming in and out by 10m then observes and assesses new snapshots. The spatial resolution is also ten meters per pixel. Sentinel missions usually use 10 m resolution sensors to execute earth observations and capture in detail images from the height of 700 km. [16]

From ESRI's global cover map, the Ulaanbaatar land cover map of the year 2020 is shown below by clipping and merging layers in Figure 3. As representing in the map, most of the central part of the Ulaanbaatar city is in red color, indicating the built-up area is denser in the heart of Ulaanbaatar. Trees are located mostly in the outskirts of the city. In the urban area there are almost no vegetation is seen because of the scale of the map which indicates the greenery among the built-ups are not sufficient to be seen and they are divided into a very small amount. The Ulaanbaatar land cover map excludes 3 rural districts Nalaikh, Baganuur and Bagakhangai. Mongolian shapefile is collected from the free file of "Agency for Land Administration and Geodesy and Cartography». The boundaries of khoroo, country, city, and aimag are collected from an open source of National Geoportal of Mongolia. [45]

Since neither of the LIDAR technology nor its data is available in Mongolia, 3D visualizations of buildings in Ulaanbaatar city are obtained from Ulaanbaatar ARCGIS online platform in order to select the appropriate plants according to respective heights. These 3D models provide the length, height and surface area of certain buildings as well as their usage purposes. Based on these parameters, vegetation suited to the given conditions can be found.

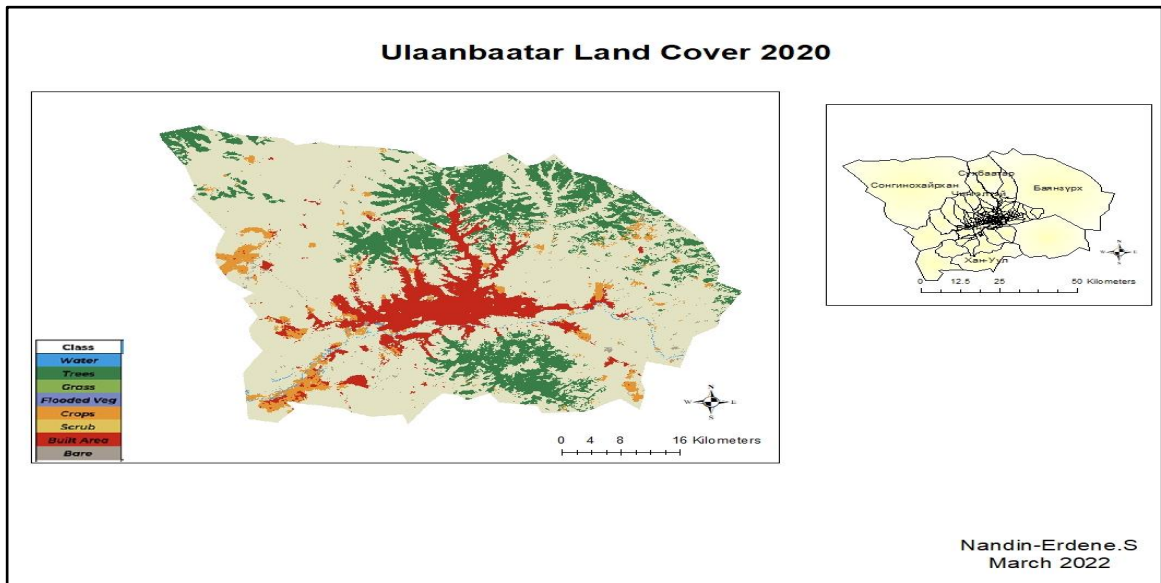


Figure 3. Ulaanbaatar Land Cover for the year of 2020

Google Maps are free and it's easy to find and collect data from it. This project deals with the mapping and spatial analysis so that the Open Street Map is used for building area analysis. At first, the rooftops of the targeted area are extracted then GIS analysis used. Later, rooftop areas and its unoccupied spaces quantity is found from using both OpenStreetMap data and GIS. Also, Google Street view 360 pictures are utilized to analyze rooftop slope. As shown in Fig4, study area buildings are dense in north-west part. [34]

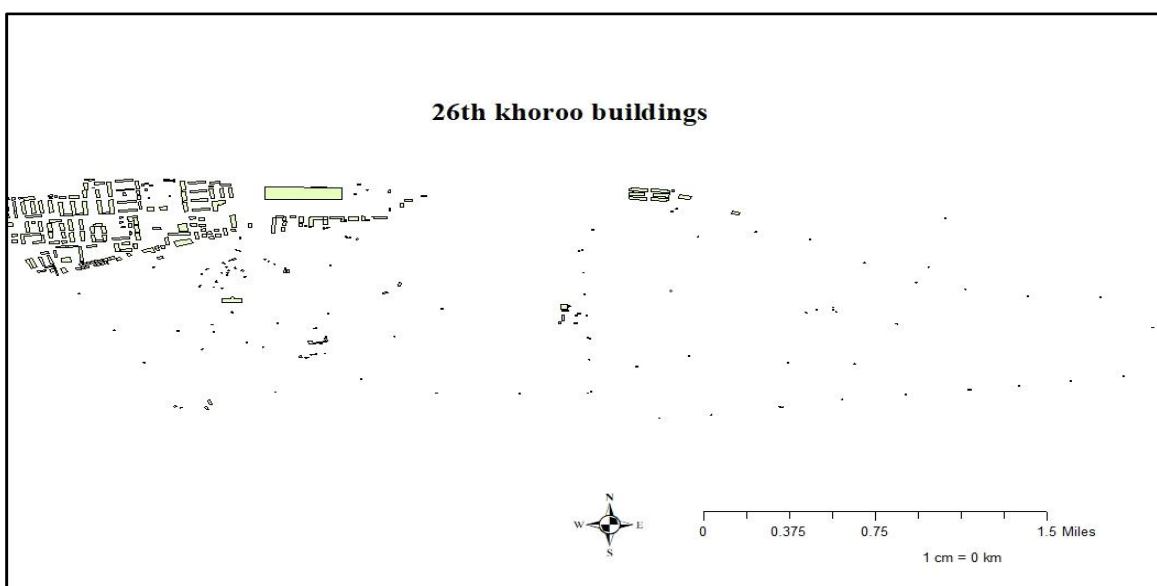


Figure 4. Footprint of Buildings from OpenStreetMap

## 3.2 Methods

### GIS

If this work was in thirty years ago, this spatial analysis of green roof would be simple map. Fortunately, the software which overlays, combines different graphics with many factors have developed.

Spatial analysis and determination of potential areas the GIS is used widely. GIS is the abbreviation for “Geographic Information System”. Inputting the primary sources of land references, the final product is executed step by step. It is a system that helps users to capture, analyze and present spatial information on a map. GIS is employed to predict the likely results on earth and has 6 key functions.

1. Data input
2. Data manipulation
3. Data management
4. Data information in specific format
5. Data analysis
6. Data visualization

GIS has many benefits in all sectors i.e., urban planning to earthquake, energy use etc. Trend of using GIS trend is getting increased year by year noting its advantages. Google earth is one of the simple GIS platforms in everyday activities. [44] Google earth is used for calculating potential rooftop space. On the other hand, ArcGIS is the more advanced analyzing and mapping software. In this work ArcGIS is used for analysis of the data. ArcGIS 10.8 is one of the most used services of ESRI. The software executes input, management, query, analysis and visualization. It is accessible both offline and online allowing to people make the maps whenever needed. Sharing and adding your perspectives to the map, working with and analyzing the data, designing the outputs are the main benefits of this software. ArcGIS have many extensions allowing users to work in many fields differing their purposes i.e., organizations, environmental agencies, etc.

This study is done with the execution of online and desktop ArcGIS platform. Online Google earth platform confirmed that the slope of the study area has only one classification 1-2°. As for the ArcGIS, it is used for different categories of work. Mapping the study area, bare land and densified area and for potential rooftop spaces. [17]

## Chapter 4

### MATERIALS AND FEATURES

#### 4.1 Design Criteria

Green roof designing guidelines, books and research papers have been included and employed as standard materials and features. The green roofs are influenced by the climate conditions of the chosen area. The targeted area's growing sedum is influenced by the designing components. Even a small-scale modification could leverage macro climate. Combined with all others, they make up the ecological niche in the city. [6] Considering the maintenance, irrigation, substrate depth, plants, cost and accessibility, extensive roofs are suitable for Ulaanbaatar city's conditions.[38]

##### 4.1.1 Roof slope

If the building satisfies the requirements for installing a green roof, the structural designing becomes the next key criteria. When installing the green roofs, water flow, growing plants saturation, nutrient cycle and vascular plant selection should be considered. The first criteria for installing green roof is the roof slope.

If the steep slope is not taken into account, the green roof becomes unstable and rainfall makes vegetation layers slide, making the plants unable to grow. Since the roof slope is higher than one



*Figure 5. Flat green roof*

or two percent more technical measurements and installment problems could occur. This poses even greater risks as the pitch of the roofs get higher. In general, green roof slopes are less than 35%. However, considering threats and making the drainage as effective as possible, most of the green roofs are installed with a steep slope of 1 to 2%.[12],[38]

In the targeted area, the majority of the roofs have no slope at all. Flat sloped roofs require less preservation against wind. However, waterproof and drainage systems on flat roofs are ineffective. Thus, the minimum installation should be 2% to protect vegetations and water-resistant layers. Intensive and extensive roofs are both common on flat roofs. Consequently, semi-intensive roofs have no special consideration when it comes to installing them on flat roofs.



Figure 6. Study area 360 view]

#### 4.1.2 Climate conditions

By the year of 2050 the population growth will be more than 65 billion and more than 60% of the citizens will live in urban area. This could arise more and more urbanization problems. Pollutions, not enough of green spaces, uncomfortable living condition, too much buildings in a small area, and environmental damage will be experienced. Moreover, the climate change will be continuing and the citizens will be living through those events because there will be not enough of green spaces to decrease the event.

As forementioned, the regular traditional rooftops absorb heat and do not reflect. As long as the rooftop and the paved roads are made of same material the increase in urban temperature will be the same. People will use air conditioner cool down as a result the urban heat island effect will increase. [36]

In the past century, green roofs were distributed all across the world, specifically extensive roofs expanding through Europe's colder regions. At that time, the purpose of green roofs was to keep constructions warm during the winter and cold in the summertime. Now, on the contrary, green roofs have become adaptation technology against climate change in developed countries. They are many empty roofs which has potential to decrease the urban heat island effect and to reduce the climate change phenomena in the cities.

The only challenge is in warm and hot climates, the amount of water is either too high or too low causing water and heat stress. The stresses are followed by increased temperatures below and underground, initiating ecological retort. Nevertheless, in the cities, it could be an advantage. Low precipitation makes the soil shallow and well-draining. The growing vegetation will filter excess rainfall, improving the runoff quality. Runoff maximum discharge or peak flow is reduced and the quality of stormwater runoff is increased. [6]

## Study Area

Ulaanbaatar is the coldest capital in the world. The city is influenced by the continental cold yet dry climate. The winter is long and extremely cold; the summer is warm and short. The average winter temperature is estimated between  $-15^{\circ}$  and  $-30^{\circ}\text{C}$  and in summer is estimated between  $10^{\circ}$  and  $26.7^{\circ}\text{C}$ , making the annual average temperature of the city  $-3^{\circ}\text{C}$ . The city is located in the forest-steppe zone, with low winds, at an altitude of 1950 m-2265 m above sea level. The sun shines in the city for 230-260 days a year or 2600-3300 hours. The average precipitation in UB is 233 mm annually. On average, the number of windless days is 100. Typical wind speed is between 4 m/s to 6 m/s from the north west direction.

The study area is chosen based on the number of tall buildings with no green areas surrounding and also on its potential green roof installations. 26<sup>th</sup> khoroo is one of the most densely populated areas in Ulaanbaatar and has the highest number of tall residential buildings. The khoroo covers a 16 km<sup>2</sup> area. [18-19]

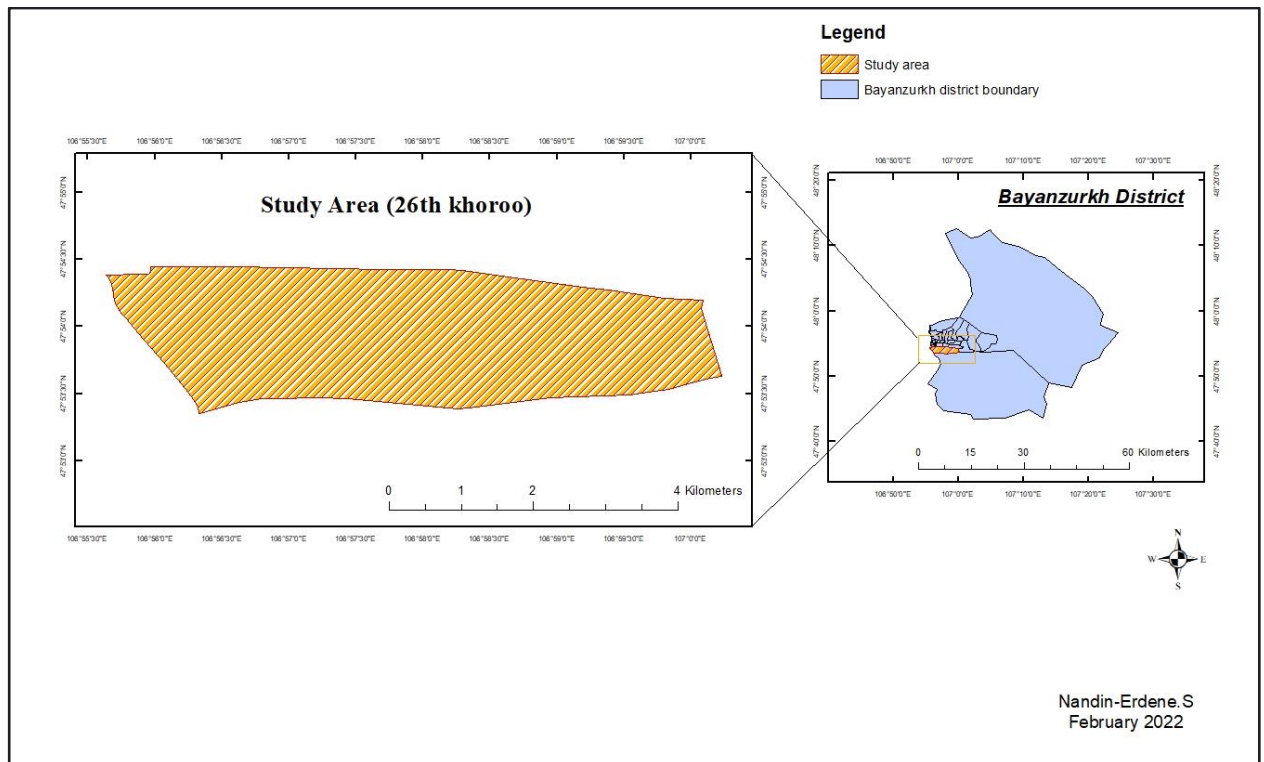


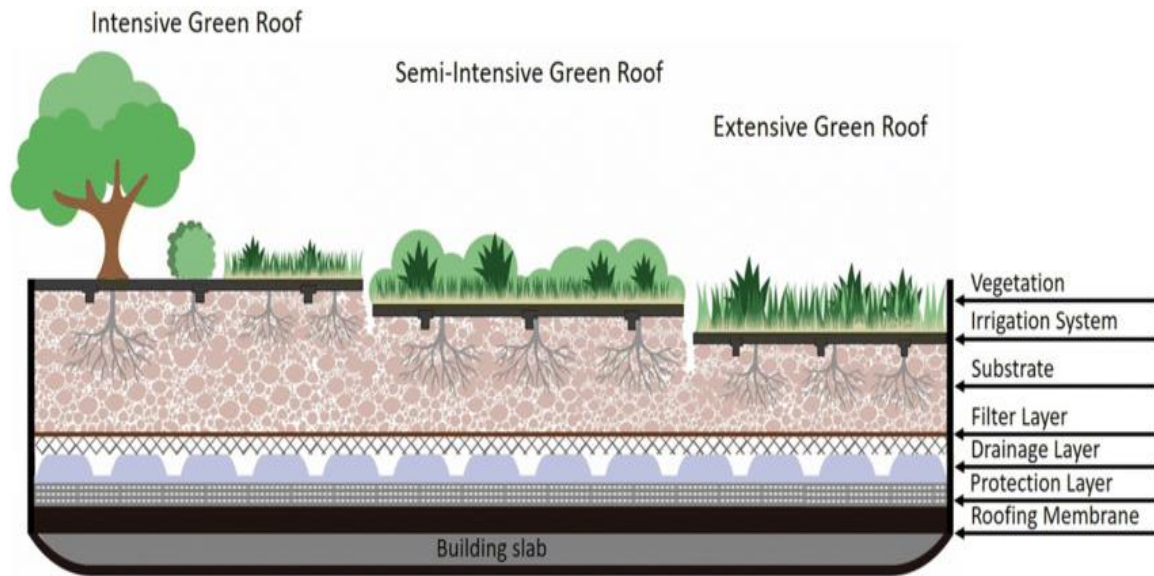
Figure 7. Study area: 26th khoroo, Bayanzurkh district

### **4.1.3 Load capacity**

Depending on the type of green roof, each type applies different loads into the building. Intensive roofs load the most to the roofs and extensive the least. Snow, stormwater, green roof layers, equipment, thermal are part of the carried loads. Carried loads on the roofs are divided into three sections: dead, alive and the synergy of the two. Usually, temporary shiftable layers are called alive load while dead loads, having the opposite characteristics of alive, are long-lasting. All the layers, plants and their soaked masses are the fundamental elements of green roof mass. According to some guidelines, load per area is between 18.64 N/mm<sup>2</sup> and 61.99 N/mm<sup>2</sup>. 18.64 N/mm<sup>2</sup> or 18.64MPa is a minimum requirement for extensive, which is still consider high quantity folding the atmosphere pressure 180 times. Therefore, when installing the green roofs some structural calculation of how much load does the building can hanle is needed. [21]

### **4.2 Component materials**

As previously stated in the introduction part, green roof consists of main 4 layers. Depending on the local condition and rooftop type, optional layer can be added. Intensive roofs have plenty of vegetation selection since they have high amount of subsubstrate. In contrast, extensive roofs have a few choices of plants due to their medium. Since they have many required and optional layers, each layer has plentiful of selection of materials. Their performance, life time expectance and life cycle are defined by material type. In recent years, recycled materials are used mostly in green roofs. For example, substrates can be made up of building waste such as bricks and glasses while filter, drainage, irrigation pipes, protection and roofing membrane are made of recycled polymers etc. [ 22]

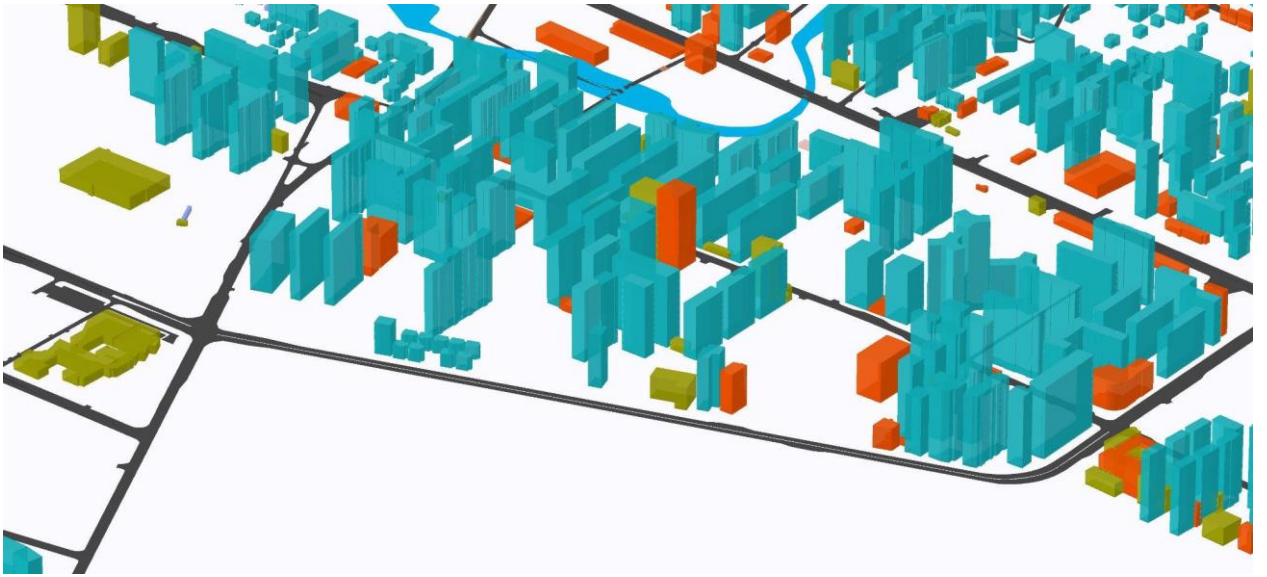


*Figure 8. Layers by different green roof type*

#### 4.2.1 Vegetation

Vegetation choice is one of the key factors that determine green roof's maintenance, irrigation and durability. Plant selection differs depending on the goal of the green roof plan i.e., artistic view and informative garden. Usually, native plants are recommended because they are more adaptable to the climate of that region. Selecting the native plants is the most efficient and water saving way. [4-6]

Model plant features include low maintenance, adaptability, low amount of water and nutrient use, light, and resistance to micro-climate conditions. In this work, the plant selections differ by the height of the buildings. As shown in the figure below, most of the buildings have floors of between 3 to 20, reaching 3 meters to 60 meters vertically. [24],

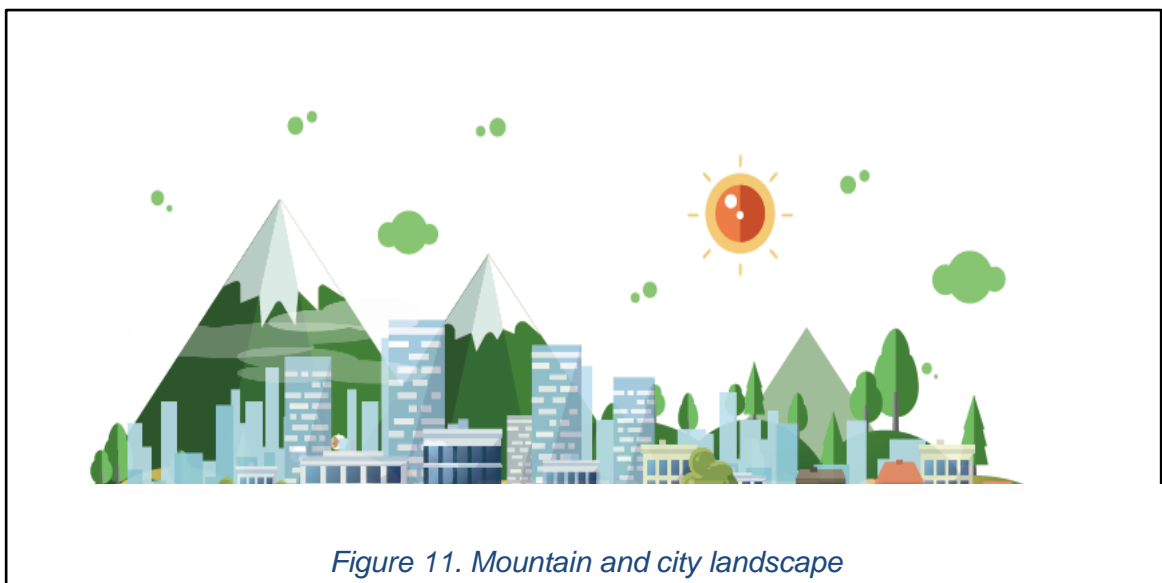


*Figure 9. 26th khoroo 3D visualization of buildings*

The figure above, the orange-colored buildings are referring to business centers. Likewise, green refers to retail stores and blue-green are resident buildings and apartments. The most of the buildings are apartments and a few business centers and malls. This confirms that the khoroo is suitable for potential greenery.

The selection of plants is focused on using the biomimicry of mountain landscape to city landscape. [27] Wild vegetation, depending on the altitude of the mountain, differs in sizes and species. Based on this notion, appropriate native plants are chosen.

Extensive roof can have a mixed variety of plants made of perennials such as sedums and mosses etc. Extensive roof's substrate depth is matching with perennials such as sedums and



*Figure 11. Mountain and city landscape*

mosses etc., since they grow mostly in thin soils. Thus, high elevation buildings are coupled with perennials.

However, for low-rise buildings, 1 to 4 floors, annual flowers are recommended. Annual flowers seed, grow, flower and senescence in one season. They add up beautiful views to the surroundings as well, but need immediate watering after plantation. Their growth continues even after cutting the above parts. [31]

For middle heighted multi-storey floor buildings, 4 to 6 floors, grasses and shrubs are suitable due to thin soil and frequent exposure to rainwater. They can adapt to mild to strong wind, sun and other climatic conditions. They can make up most of the natural vegetation because of low level maintenance.

Moss has many benefits. For instance, they protect permafrost and maintain the balance of heat and moisture of the forest. They are light, easy to care for, drought-resilient and economical & water absorption is high compared to their counterparts. On small-high-rise and high-rise flat roof buildings, mosses are an ideal choice because of high efficiency of water retention and management. [23-25]

*Table 2. Recommended vegetation types according to building heights*

<b>Floor range</b>	<b>Height, m</b>	<b>Vegetation</b>
<b>1-3 low-rise-building</b>	2.5-7.5	Annual flowers
<b>4-6 multi-storey building</b>	10-15	Grasses and shrubs
<b>7-16 small-high-rise-building</b>	17.5-40	Mosses and grasses
<b>17+ high-rise-building</b>	42.5+	Mosses and grasses

#### 4.2.2 Irrigation system

Mongolia is influenced by a continental climate in which rainfall is not consistent. It goes, rather often, without any rainfall for months and when it finally rains downpours begin. Thus, the closest climate classification that can be compared to Mongolia's conditions is Mediterranean climate, requiring irrigations regularly for greening.

Water enters into green roofs by precipitation and irrigation. Irrigation system helps plants to be healthy and strong, making them look colorful, and provides moisture when there is no rain to support. Abundant moisture then cools down the building. Irrigation is needed in arid or semi-arid

areas but should be taken in consideration when choosing plants, growing mediums and adding supplements.

Irrigation types such as drip, sprinkler, surface, shub etc. may experience changes depending on the building's characteristics and water resource of the area. With average precipitation between 300-400mm in our climate, irrigation and water retention elements have to be selected meticulously [28]. Water related challenges may occur such as water resources, conveys, pipes and watering methods. Fortunately, extensive roofs require low irrigation. Therefore, for dry periods, collection of rainwater in plant root form for later use and irrigation is the key solution in order to keep it from becoming runoff. The green roof will lose most of the water by evapotranspiration as retention and detention.[4]

Irrigation amount is directly related to the materials used for substrate. If the substrate is made up of materials that can keep moisture longer, irrigation does not play an important role. On the contrary, if substrate materials are less likely to keep moisture and save it for later use, irrigation system is necessary for greening.

As mentioned earlier, on high building rooftops, perennials are best candidates to plant. Although annual flowers are still a great choice, they need regular irrigation and maintenance from spring to late summer months. Since, the annual flowers are recommended on buildings of fourth level, their watering can be solved with the installed water taps on top of the rooftops. However, the shallow subsubstrate depth and native perennials doesn't need regular watering. [5]

#### **4.2.3 Substrate**

Green roof substrate is the source of nutrition to plants. The substrate is a mix of organic and inorganic materials. The percentage of the organic material should be 20% of the total substrate. Substrate mass should be in accordance with all other conditions, but heavy enough to resist wind but light enough to not pressurize the structure. Growing media is, too, a mix of light aggregate & peat, decomposed organics, and vermi-cast. Topsoil cannot be used for substrate since the regular soil has weigh more than engineered substrate. There are birds that lost their habitat due to urbanization. They seek food and shelter in the city. If the regular soil is used, they dig-up and the vegetation might be destroyed. Thus, for our condition, basalt wool or rockwool is a suitable choice for growing medium with its thermal insulating property [5],[14]

#### **4.2.4 Filter Layer**

Filter layer is made up of fabric and is lightweight, strong as well as long lasting. Filter layer's purpose is to block clogging' from entering into drainage. Filter layer is divided into many types: non-biodegradable, polyester (PET) & polypropylene (PP) and polyethylene (PE). Non-woven geotextile filter layer is often preferred for its high absorption capacity. The general books and literatures suggest that the further research and development on filter layer is needed. Besides mentioned geotextile kind of layers, generally filter layer should be non-clogging and cleans itself. [14],[39]

#### **4.2.5 Waterproof and Drainage system**

The waterproof membrane stands as the most important part of the green roof technology since it protects the building from any infiltration. Even though the waterproof membrane has many common features with conventional roofing, the membrane should be protected against UV rays and chemical elements that might come from vegetation. Bituminous is commonly used for such purposes.

While waterproof layers are installed to prevent any leakage into the building, drainage systems keep the necessary water and sink down the excess. Drainage layer width varies with the type of the roof. Both waterproof and drainage layers balance green roofs living. Waterproofing membranes are usually artificial synthetics, geotextiles, and rubber granulates. Out of aforementioned materials, geotextiles are suggested to use by the most of guidelines due to their lightweight and functionality.

Drainage system has many minor equipment such as a flat roof outlet made of PVC, tubing, drainage pipe, spout, and excess water control. Drainage system can be located either inside or outside of the garden. Usually, drainage zone is recommended to be located outside of vegetation zone. Drainage needs an additional filter in case of clogging caused by rocks from vegetation free zones. [5-6]

### **4.3 Vegetation free zone**

Water drainage points must be detached from the vegetation. Also, for the maintenance purpose, we should not be walking on out green area. Thus, at the edge of the vegetations there must be empty zone. These no plant zones are not just bare asphalt; they are covered with coarse

materials like gravels, sand, and stone to trap the sun and to shelter the vegetation. The width of the plant free zones is 50cm to 90cm from the ridge of the roof.[8]



*Figure 12. Vegetation free band*

## 4.4 Maintenance

Green roof's long-lasting life is directly related to the care taken throughout the year. Intensive roofs have deeper subsubstrate with varieties of plants; thus, they require more care than other two types. Extensive roofs have the shortest subsubstrate depth allowing people to enjoy greenery with affordable price and easy to care for. Layer materials have guarantees and warrants but some vegetation and growing media are dependent on microclimate conditions.

Thus, regular check-up or maintenance is needed several times a year.

### Spring

- After the long harsh winter, some of the vegetation is dead.
- Debris grasses should be collected then removed.
- Inspect the site and add the plants if needed
- Plant annual flowers
- Turn on the irrigation system if needed

### Summer

- Regularly check the membrane layer and irrigation
- Inspect the plants whether they have too many bugs or not and whether they are infected or not
- If the vegetation is destroyed by bugs or birds, re-plant.
- Dispose of the weeds

### Autumn

- Remove plants, if not possible do it in spring
- Dry up the irrigation system for winter

### Winter

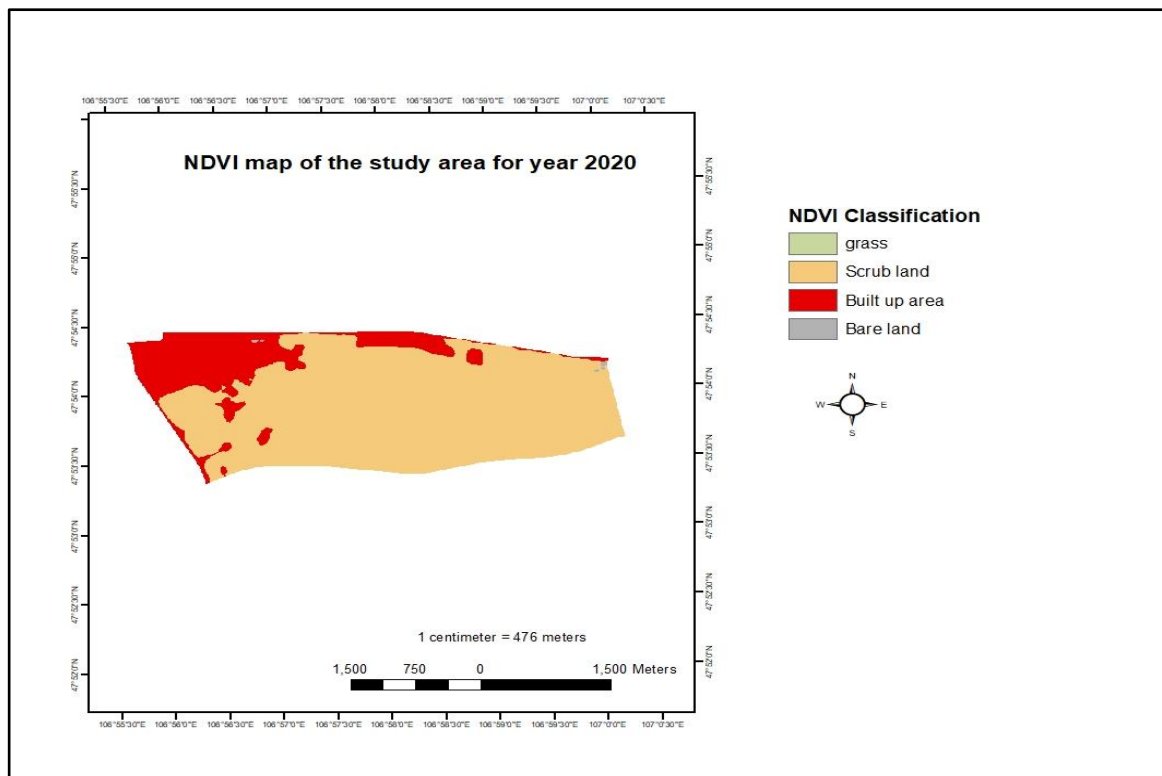
- Record the roof condition from November to March

From fall to spring, wind protection mats are extremely needed in case of wind erosion control. Mongolia has high wind resource therefore the protection mat should be included in spring.[8],[43]

## Chapter 5

### RESULTS

As of now, the green space of UB Ulaanbaatar is not sufficient for both those who live in the city center and those who live in the outskirts of the city. [35] Thus, utilizing the existing buildings' roofs was utmost important.



*Figure 13. Land cover of the study area*

Above figure shows the targeted khoroo's land use whose most parts belong to "National Garden Park", which has 148,000 trees and shrubs of 32 species with 98.5% survival rate. 19.32% or 1.73km<sup>2</sup> of 26<sup>th</sup> khoroo was occupied as of 2020. Red parts refer to built-up areas, in which green space takes up to almost zero percentage.

Below varieties of vegetation are indigenous to 26<sup>th</sup> khoroo and are expected to grow without much complications due to their long-time exposure to the extreme drought of the surrounding area. Furthermore, these plants have been present during the urbanization of the locale and

greatly increased their adaptability in cement-based areas. Selecting from those vegetations for the green roof is suitable for the initialization of the plantation stage. [37]

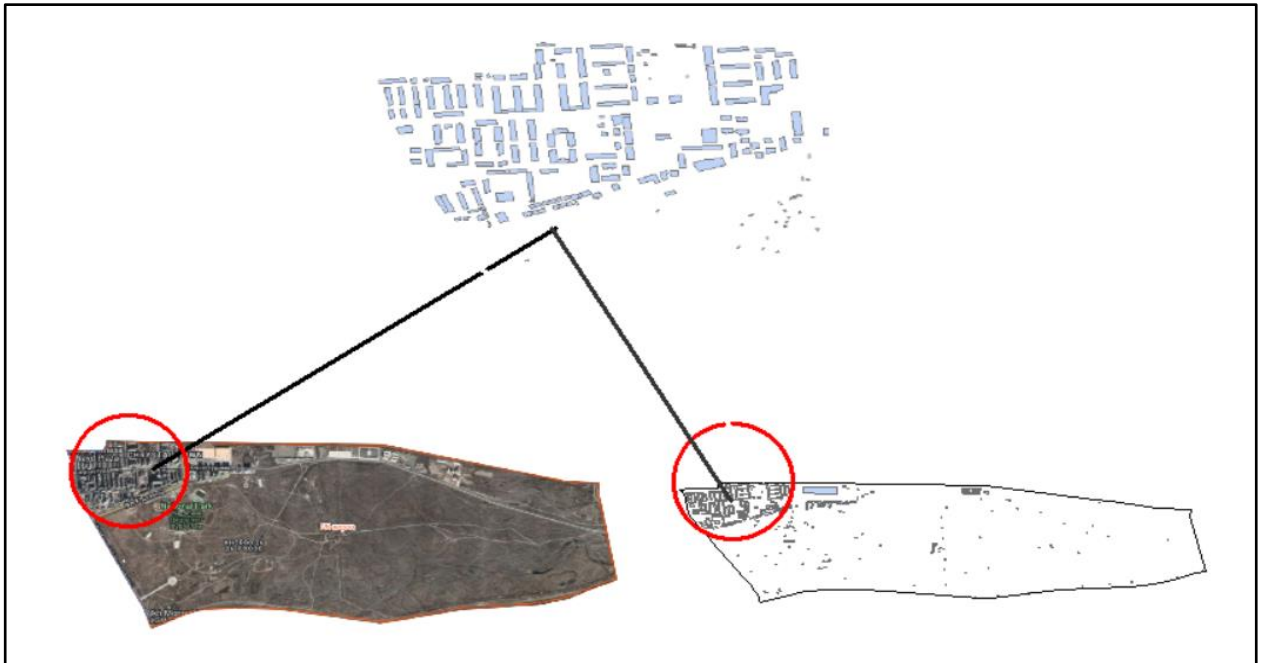
*Table 3. Native plants which grow in National Garden Park*

<b>Types of vegetation</b>	<b>Occupied percentage, %</b>
<b>Conifer</b>	3.5
<b>Deciduous</b>	22.3
<b>Ornamental shrubs and bushes</b>	9.5
<b>Shrubs and green fences</b>	64.6

*Table 4. Land use quantity of 26th khoroo in 2020*

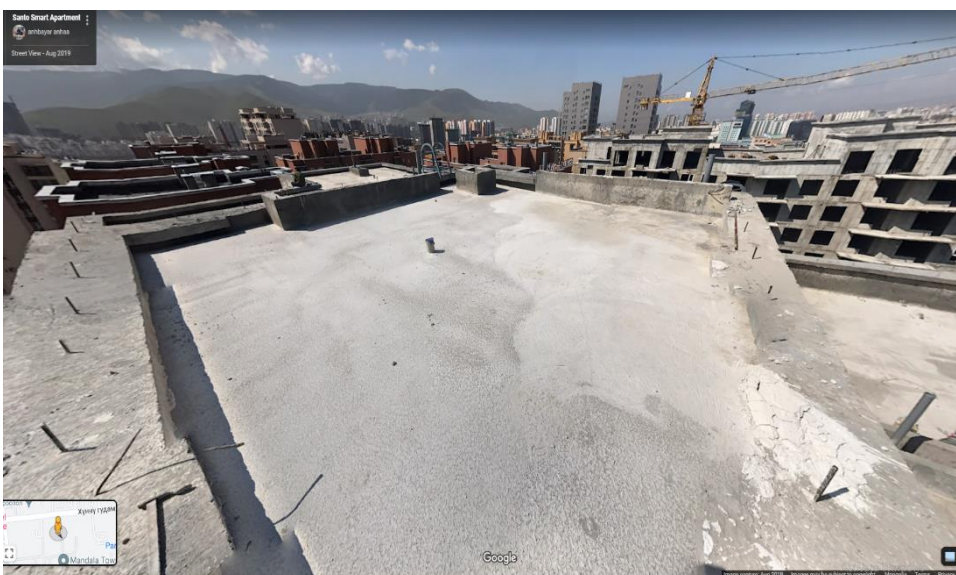
<b>Land Use</b>	<b>Length, km</b>	<b>Area, km<sup>2</sup></b>	<b>Area occupied, %</b>
<b>Scrubland</b>	19.381	7.180	80.53
<b>Built up</b>	965.989	1.722	19.32
<b>Bare land</b>	0.977	0.010	0.12
<b>Grass</b>	0.201	0.002	0.03
<b>Total</b>	986.549	8.915	100.00

## 5.2 Potential Rooftops



*Figure 14. Rooftop area extracted from open street map*

As of March 2022, the study area has a total of 358 buildings of residential, apartment, commercial, retail and in-construction, covering an area of 2.94 km<sup>2</sup>. There is a notable difference between the land cover map of 2020 and 2022. 26<sup>th</sup> khoroo's buildings have been on the rise, expanding the built-up area by 0.98 km<sup>2</sup> in just two years.



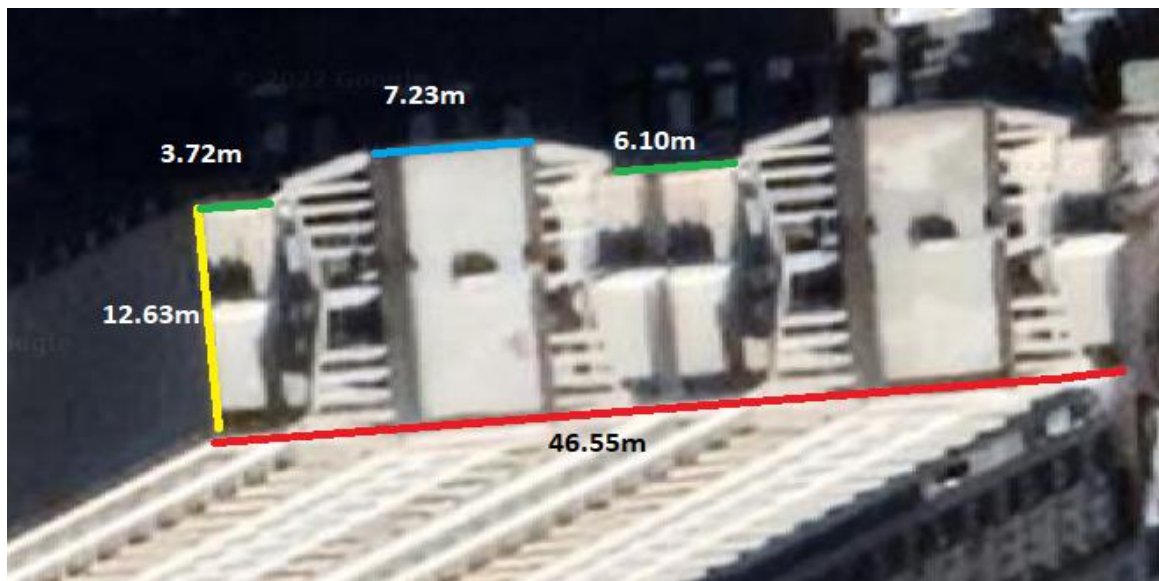
*Figure 15. General rooftop during construction*

As shown above, rooftops of the new buildings are neglected during the construction phase and left only to be used for emergency purposes. Also, the roof materials are cement or bitumen based meaning the rooftops in the target area has no problem with pre-installing measurement and construction challenges. Three different rooftops are chosen for determining the usable area. Those three can represent rest general roofs. The first and the third rooftop has a ventilation part which is quite covering quite big area. The second roof has a kind of terrace like parts on it.



*Figure 16. Olympic residence rooftop*

As shown in figure 17, most of the rooftops have facilities. Thus, usable area from figure.1 is calculated to be 305.60 m<sup>2</sup> (33%) out of total 924.71 m<sup>2</sup>.



*Figure 17. Time Tower rooftop*

Usable area for figure 18 measures up to 306.67 m<sup>2</sup> (52%), including the upper top of the building, out of 587.93 m<sup>2</sup>.



*Figure 18. Dunjingarav residence rooftop*

Usable area for figure 19 measures up to 226.50 m<sup>2</sup> (45%) out of total 498.15 m<sup>2</sup>.

It is apparent that each of the buildings has plenty of spaces with no special services and purposes attached, leaving the green roof design to be practiced with ease. Also, the selected buildings

could permit the green roofs to experience enough vegetation free zones, thus, allowing animals to mate and hide for their further enrichment.

*Table 5. Average usable area of rooftop*

No	Name	Total area of the roof	Usable area of the roof	Percentage of usable area	Average
<b>Building-1</b>	Olympic residence	924.71	305.6	33%	43.30%
<b>Building-2</b>	Time Tower	587.93	306.67	52%	
<b>Building-3</b>	Dunjingarav residence	498.15	226.5	45%	

The average of the three usable area percentage leads to 43.3%, which will be assumed 40% for the further calculations.

If all the buildings of 26<sup>th</sup> khoroo employ green roofs, green space of the built-up area will increase by 23.5%, making room for comfortable and harmonious living between locals and native animals. However, with an abundance of green space, one of the key concerns of the project becomes invasive species such as birds, insects, bugs and mosquitoes that might cause inconveniences to the public and the planted vegetation. To eliminate this threat, perennials and annual flowers that already grow in the National Green Park should be selected. These plants are well adapted and not prone to insects of the area. On top of that, a few varieties of perennials and annual flowers flourish in the park, hence, attracting a few types of insect species which could be handled easily.[41]

*Table 6. Total precipitation for the year of 2021*

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total, mm
2.6	1	6.4	26.4	44.1	83.5	45	33.6	52.8	2.9	3.9	0.5	<b>302.7</b>

## Storage calculation

Green roof as a tool of rain water harvesting is one of the best solutions since the Ulaanbaatar is located at flood risky area. If the total amount of precipitation in the year of 2021 is considered the detention and retention adds up to 593292 m<sup>3</sup>/year for all the buildings of the chosen area. Assuming that 40% of the roof area is utilized for green roof design, 237317 m<sup>3</sup>/year precipitation could be harvested. In 2020, Orgil soum of Khentii aimag received the highest precipitation of 81.9 mm/day from the rainfall during the recent years. If this is considered to be the maximum daily precipitation, 64210m<sup>3</sup>/d of water will be harvested and reused as irrigation for green roof. [28]

Average Mongolian tree has a diameter of 16.6 cm and takes up around 1 m<sup>2</sup> of spread area. [28] Thus, pinning down the usable rooftop area 40%, 784000m<sup>2</sup> of 26<sup>th</sup> khoroo could be summed up to 112000 trees ideally. However, in terms of CO<sub>2</sub> absorption, a suitable extensive green roof holds around 1.79 kg/m<sup>2</sup> annually, which then converts to a total of 1403360 kg of CO<sub>2</sub>. If a single tree consumes 25 kg of CO<sub>2</sub> annually, the number of trees of green roof projects drops to 56135. [42]

## 5.3 Construction Cost

Manna, a Mongolian construction company, has been heavily investing in green roofs since 2013 and has applied the concept to buildings for the first time. In terms of price, it is 40-55 thousand tugriks per square meter. However, the primary source materials at 100 ail show that construction cost, excluding vegetation, is 4 times higher than the fee the company offers.

*Table 7. Market price of components*

Material	Quantity	Cost
Medium, basalt wool,m2	0.6*1.2	90'000₮
Filter layer,m2	1*75	180'000₮
Drainage system,m2	3	150'000₮
Substrate,L	10	18'200₮

This could be due to several reasons. Firstly, the market price of installing the green roofs is higher than the quotation price because the current situation of the border remains undecided.

As a consequence, construction materials' cost has skyrocketed and left the market with scarce materials to be sold. Secondly, the installation company's materials such as its medium and substrate are cheaper and some of them do not match with the guidelines' recommended components.

Thirdly, the minor devices such as thermal regulation sensor, moisture sensor would add the cost. However, it should be noted that once the green roof is installed, it becomes sustainable, environmentally friendly and cost effective.

## Chapter 6

### DISCUSSION AND CONCLUSION

For the past 20 years, extreme weather events have increased in numbers and are expected to grow by 23% to 63% in the middle of this century. Destroying capital assets, infrastructures, housings, and communities, not to mention human lives, natural disasters will have a devastating impact on the population. In other words, the world is facing an imminent crisis. Thus, it is crucial to address underlying causes and to prevent such catastrophic events.

Employing green roofs is one of the most promising practices to fight against climate change. Green roofs have been in trend since late 80's [4] and proven to establish long-lasting bonds between humans and their environment. Therefore, the main objective of the study was to focus on green roof design, investigating suitable types of green roofs in accordance with Ulaanbaatar's regional climate, preferred vegetation selections, construction costs, and possible outcomes green roofs may bring.

Extensive green roofs are recommended in Ulaanbaatar because of its cold and dry conditions. 26<sup>th</sup> khoroo was selected as a study area for its rapid urbanization and lack of green spaces. Also, 26<sup>th</sup> khoroo showed promising aspects such as having plentiful buildings and bordering the "National Garden Park", which proved useful in determining suitable plants. The target area had a balanced ratio of high-rise and low-rise buildings, making it ideal to analyze plant species, and had rooftops almost free of supplemental facilities. Plant choices were inspired by nearby mountains, biomimicry, and varied depending on height of the buildings. Low-rise buildings were to use annual flowers while high-rise buildings were to use perennials and shrubs considering wind resistance, maintenance, and irrigation. Other features such as layers, drainage systems, and construction materials were all dependent on plant selection and, thus, would be susceptible to preferred choice.

The installation costs and maintenance rates are relatively high compared to other green projects; however, once they are installed, green roofs demonstrate various benefits like stormwater management, reducing urban heat island effect and cooling down buildings & surroundings.

With sufficient numbers, green roofs are able to drastically improve their respective microclimates, which then, in return, to combat global heating. Thus, even if creating green roofs requires meticulous details, expensive materials and combined works of government and private businesses, in the long term they will prove to be valuable. In comparison, "A GIS-based mapping methodology of urban green roof ecosystem services applied to a Central European city" has been chosen, a similar study focused on green roof designing, to bring out the advantages and

drawbacks of the target study. The aforementioned similar study was performed using GIS mapping, google 3D mapping, and geodata & LIDAR data from the Environmental Agency of the city administration of Braunschweig. It is safe to say that the comparison study has employed similar techniques, yet enjoyed a greater availability of data. In contrast, data on 26<sup>th</sup> khoroo was scarce. LIDAR data has been extracted manually rather than employed from an existing data bank. Furthermore, official geodata websites have not been updated and new constructions haven't been counted since 2016, making a total of 8.9km<sup>2</sup> instead of 16km<sup>2</sup>. The study area, thus, followed a total of 8.9km<sup>2</sup>.

The comparison study was also focused on installing green roofs on already existing rooftops but was able to classify rooftops based on their slopes using official data from the Environmental Agency of the City. However, the comparison study did not determine the usable area of rooftops while our study excelled at calculating the usable area. Furthermore, in Ulaanbaatar, especially in 26<sup>th</sup> khoroo, almost all of the existing buildings have flat roofs, rendering rooftop classification based on slopes useless.

The Braunschweig city's green roof study made substantial progress in determining ways green roofs may affect urban air quality but lacked CO<sub>2</sub> calculations. Moreover, Vegetation choice was only mentioned briefly. In 26<sup>th</sup> khoroo's green study, CO<sub>2</sub> was used to calculate vegetation amount and vegetation choice for greening was examined delicately.

## Suggestion

Due to Mongolia's harsh conditions, it is hard to resolve water related issues, when installing green roofs, such as finding sources for irrigation, placing the right drainage system, and managing stormwater correctly. These "hard works" can be simplified if rainfall is collected and reserved for later use. Because most of the buildings in Ulaanbaatar have steep slopes, it would be particularly easy to manage and collect rainwater. Buildings could station water tanks, which would be invaluable if intensive roofs or more accessible roofs were to be installed.[31]

Aside from only implementing green roofs, green walls could be introduced, which have taken a great momentum in popularity. Compared to green roofs, green walls are able to offer more green space, but harder to build and maintain. Green roofs' main goal is to widen green areas, thus transforming cemented areas on the ground could also work.

Mongolian has joined many environmental acts and publishing plans for the sustainable development. The public awareness of those actions and contribution of working together to make the city comfortable and green is currently not enough. However, the people are starting to realize it's not only the governments duty to make the city greener and but co-working is a solution. It is creative and affordable to install the green roofs by the "Association of the Homeowners" once they agree on whether they should install or not.

There are private companies who offers to install green roof, still the people who are interested in green roofs can't afford their services. There is existing Mongolian regulation (Construction Law, BBD, Building Regulation, Standard, and other related regulations) but besides the standards there should be also a guideline for the eco-friendly buildings. Thus, publishing Mongolian guideline for the people who are interested in green roofs for their private houses could be a small step for turning a apartment, residential and all-purpose buildings.

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