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Green Infrastructure Technique of Rainwater Harvesting for Sustainable Educational Institute Campus Design

by

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This research work is dedicated to my parents, respected teachers and all those friends who have supported me since the beginning of the research.

CERTIFICATE OF APPROVAL

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Abstract

In the current situation of global warming, the availability of fresh water is a blessing. Due to uncontrolled extraction of groundwater, water table is decreasing with a rapid pace. This reduction and water scarcity dilemma could be resolved through better management of available water resources. Rainwater harvesting is the most applicable and demanding way for conservation of water, which includes localized storage of rainwater for different future use. In this thesis, a case study of Capital University of Science and Technology (CUST) Islamabad Pakistan has been taken to assess the potential of rainwater harvesting. Google Earth Pro (GEP) was used for marking out boundaries of the study area. Digitization of the campus was worked out by using ArcGIS. Overall demand for water in the campus was calculated by considering the total population. Selection of suitable sites for the storage of rainwater harvesting (RWH) was identified. Quantity of rainwater was calculated by using Gold and Nissen. Storage tank size and location was suggested on three different places on the basis of natural ground slope. The result of this study shows that 100% of the water can be saved by rainwater harvesting. The saved water can be used in effective way like land scape irrigation by reducing the usage of groundwater resources.

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Abbreviations

GC	Green Campus
GEP	Google Earth Pro
GI	Green Infrastructure
LIC	Low Impact Construction
RWH	Rainwater Harvesting

Chapter 1

Introduction

1.1 Overview

Sustainability is becoming a critical problem in growth of campuses. Sustainability is a general concept derived from the word “sustainable” meaning “capable of sustaining at a certain level.” [1]. Campus sustainability has become a global concern and the 1972 Stockhom Declaration was the first to refer to sustainability in higher education, acknowledging the interdependence between humanity and the environment.A variety of ways are proposed to achieve environmental sustainability [2]. Universities can now be perceived as ’small cities’ that occupy a wide area of land, growing populations and traffic, and various complex activities that are not confined to purely educational and research activities. These actions can directly or indirectly effects the environment and sustainability.

Sustainable development on this earth has become an important guiding concept for human life. Sustainable linked to the standard of life in a society, how the cultural, social, and environmental structures that make up the community of ensuring for present and future need with stable, significant and successful existence. The universities are therefore one of the instruments which can be particularly useful for sustainable growth [3].

Green Infrastructure (GI) have the ability to minimize electricity consumption, water use and storm water runoff, and to provide other advantages, such as better indoor air quality and the use of local resources. The green infrastructure & buildings focuses on initiatives that can reduce the environmental impacts associated with building and infrastructure construction and operations. This encourages more energy and water usage [4]. The term 'sustainable campus' refers to the strategy or initiative that has been selected to achieve the ideal future. This is a means one of for improving sustainable achievement within a university campus and raising visibility among university workers and students [5].

If the current request is met without compromising the potential of future generations to meet their needs, sustainability can be achieved. Based on these statements, it can be deduced that sustainable campus architecture involves the construction of a campus that meets present needs and increase quality of life with a focus on environmental, social and economic equilibrium without diminishing the needs of current and future [6].

In the last 30 years, imperiosity has remained the most important indicator of urban planning, with many studies suggesting a clear connection between imperceptible areas and waterway safety [7].

GI concept usually covers open field, gardens, green roofs, biological preservation, manufactured wetlands and localized water storage (e.g. rain water collection), river conservation and multiple peripheral surface combinations [8].

(GI) is a general definition and strategy that originated from other terms including "ecosystem infrastructure", "ecological infrastructure", "natural infrastructure" and "sustainable infrastructure." The term is often used interchangeably in planning and engineering research with Low Impact Construction (LID), but "sustainable development" has developed to include LID and is now with the dominance concept used in North American and European policy [9].

With new students enrolled each year, campuses are growing; more rooms are required for hostels, road signs for traffic flows management, more classrooms and parking space are required [10].

GI is a solution, where people have the option to protect safe wetlands, have certain conservation advantages and promote community sustainability. In contrast to an ecosystem of single-use grey storm water that utilizes rainwater drains, green infrastructure uses plants and grounds for management of the rainwater in which it falls. Green infrastructure offers not only rain water management but also water treatment, air quality assurance and much more by incorporating natural procedures are the constructed environment [11].

As centers of knowledge, universities have an important and strategic role in exploiting the social and economic benefits of revolutionary ideas. The aims of this analysis is to analyze the green campus core sustainability technologies and adopt recommendations for the introduction of sustainability techniques in the capital University Science and Technology, Islamabad.

1.2 Research Motivation

- Sustainability of the university is a major concern today. Sustainable campus calls on the university to encourage green buildings that reduce energy and water use while maintaining a low carbon footprint. Now a days, 5000 students are enrolled in the Capital University of Science and Technology (CUST). Thus, CUST wants to follow green building strategies for smart campus architecture.
- Water scarcity for Pakistan is a major and rising problem. Pakistan is now faced with relative (per person) water shortages, and both population and water demands are expected to increase for several decades [12].
- Water shortages limit agricultural production. As a result, the problem of food security is growing with increasing population growth. The motive of this research is to protect the water shortage which produces drought, ensuring food availability and improving the community's wellbeing.

1.3 Problem Statement

Sustainability concept arise with the climate changes and increasing environmental problems such as climate change, pollution growth and uncontrolled developments *cause water scarcity and degrade water quality. Increasing water scarcity requires efficient water management to meet the future demands. To provide efficient water management with sustainable storm water management, rainwater harvesting, renewable energy reuse of greywater systems and decrease in use of the potable water is essential.*

1.4 Overall and Specific Research Objective

The aim of this research is to study the effectiveness of campus physical development planning in Pakistan in creating a sustainable living on campus by assessing the problems that exist. The research is conducted in Islamabad. The limitation of this study is to provide sustainable campus in terms of:

- Review of campus master plan.
- Rainwater harvesting for potable water saving.
- Rainwater collected from roof tops of different blocks of an institute is an adequate source of sustainable water supply that could be harvested by constructing RWH tanks at appropriate location. Greening in campus is needed to ensure healthy life of a conducive research environment.

In this research work, a sustainable campus is analyzed for by analyzing different green infrastructure techniques, such as green campus, and rainwater harvesting. Therefore, the specific goal of this research is as under:

"Green Infrastructure Technique of Rainwater Harvesting for Sustainable Educational Institute Campus Design".

1.5 Thesis layout

The layout of research comprises of main five chapters. These are:

Chapter 1: It is titled as introduction. It explains the overview of sustainable development, research motivation, problem statement, overall and specific research objective, brief research methodology and thesis layout.

Chapter 2: It explains the literature review related to previous researches on techniques for sustainable campus. It consists of background, research history on sustainability and green infrastructure, rainwater harvesting and summary of this chapter.

Chapter 3: It is named as study area, methodology and data. It consists of background, study area, review of campus master plan, pervious and impervious area, rainwater harvesting, Gould and Nissen formula (1999) is used for potable water saving and summary of this chapter.

Chapter 4: It is named as results and discussions which covers calculation of impervious and pervious area, review of campus master plan, calculation of rainwater harvesting potential of campus and summary of chapter 4.

Chapter 5: It consists of conclusion, results from the study and future recommendations.

Chapter 2

Literature Review

2.1 Background

The idea of sustainability develops with the growing world and rising environmental concerns. Sustainability approach is being adopted for most of the campuses and project across the world. Global warming and rising scarcity of water supplies, water management is a big challenge.The Stockholm Declaration of 1972 was the first to request sustainability in higher education and acknowledged the interdependence between humans and the atmosphere and suggest some strategies for achieving environmental sustainability. Sustainability has become an issue of global significance [2]. In the past two decades, several organizations (campuses) have been engaged in their education frameworks to include sustainable growth [13]. Campuses are big user of energy and resource which produce toxic waste [14]. Our activities like the usage of classrooms, labs, offices and facilities have a strong effect on the environment [15]. The sustainable campus provides a superior environment for campus students, in particular, in terms of their environmental, social and economic quality of life for the public, by comparing physical development planning of universities now research campuses. Preparing for population expansion on a campus has a significant influence on the life and decision-making of students. These findings demonstrate the perfect way to create a balance to build a compact campus [16]. Green Campus (GC) is a tool for university sustainable development activities. These are opportunities that allow the university to change its processes to avoid harmful impacts on the populations and to establish a healthy environment of social progress that is focused toward sustainable development and disruptive practices. In this chapter techniques for sustainable campuses have been briefly discussed.

2.2 Research History on Sustainability and Green Infrastructure

When existing requirements are met without sacrificing on the potential of future generations to fulfil their needs, sustainability can be accomplished. On the basis of these assertions, we can infer that developing a sustainable campus requires such solutions that meets current needs and improves life quality, while being consistent with the needs of future generations, based on natural, social and economic balance [6].

Utilized a multi-criteria system and identified several indicators, and developed an evaluation model to act as a tool for effective universities to promote decision taking. The authors said GC is a well-established university culture that encourages awareness of local and global climate change. The initiatives planned for GC systems involved the conservation of energy, recycling, water safety, transport efficiency, waste management and environmental protection [17].

Through the integration of the three economic, social and environmental facets the true benefits of sustainable development can be achieved [18].

Nifa et al [19]. That the integrated project delivery system for sustainability in architecture for campus growth notes that sustainability on campus enables the university to promote green buildings that have a low carbon footprint and consume less electricity and water. By reducing the risk of air pollution in campus buildings causing respiratory problems to a healthier climate, energy-efficient green buildings strive to improve illumination, air, ventilation, and indoor air quality.

Lau et al [20] "Healthy campus by open space design: Approaches and guidelines." Two campuses were contrasted with different urban landscapes, so that challenges and possibilities are identified for the implementation of rural architecture, spatial architecture and green design. They saw that a stable campus can protect many places to accomplish various objectives. Finally, a system incorporating the three approaches is combined to create a sustainable definition.

Measure the key performance indicators (KPI) for a sustainable campus design. They calculate 35 indicators composed of 6 groups including building and services, electricity and climate change, pollution, water, transport and education. They reveal that education with a weight of 0.2665 is the most significant category for sustainable campus assessment, whereas resources and climate change with a weight of 0.1156 are perceived to be the least effective category for sustainable campus assessment [21].

Open areas between buildings and acting as connections to locations offer a sense of orientation on the campus through the integration and organization of various sites and elements; they also provide an aesthetic sense of appealing environments and visual surprises. In outdoor settings, apart from the formal class and discussions, many new and novel concepts arise. The nature and calming feeling in the open space promote impromptu gatherings and conversations and give exhausted scientists fresh air [22].

Definition means that sustainable campus is not only a reflection of green and environmental-friendly systems, but also the whole social landscape nearby. The ecological campus of universities must therefore be a healthy campus environment, encouraging fair rights and exports and social justice in all its fields through electricity, resource conservation, disposing of waste and constructive management [23].

When natural sources of water such as streams, wells, rivers fail and harvested rainwater can be used for a variety of purposes in arid and semi-arid regions. Rainwater is only recently being used in private residences, public buildings and heavy industry through pipeline systems. For water supply, rainwater is used in schools, car washing centers and factories [24]. Investigated that rainwater collection is a good solution and a backup in long dry season or when water level fall and wells are dry, excluding in the most arid or semi-arid regions. Water from the mains supply can be supplemented by RWH networks. Rainfall water from impermeable surfaces (primarily roofs) is captured and deposited in tanks for later potable and non-potable use. Harvested rainwater will partially replace mains service water, minimizing the impact on centralization water supply and delivery networks [25].

Collection and preservation of rainwater for future use is techniques of rainwater harvest. Rainwater harvest is extremely critical for improving domestic water quality, the irrigation food production, and ensuring water safety [26]. Rainwater harvesting is able to address many requirements for domestic interior and exterior water demand, but due to heavy financial resources, it also had extremely long payback periods [27].

Various researches around the world recommend that rainwater harvesting is an alternate source for manage the challenges related to water shortage for human use and support the environment. These researches have been carried out in China. Evaluation of the capacity and economic feasibility of the rainwater harvest mechanism for four various climate regions of China. The results indicated that reliability of rainwater availability ranges dramatically across four cities 3.85%20.55% [28].

Rainwater collection from surfaces of various types of water storage cisterns is practiced since old days in the Middle East and Asia. The Yerebatan Saray is the greatest cistern in the area of the Mediterranean, possibly in Istanbul, Turkey, able to store around 80,000m3 of water [29]. To resolve water shortages and promote water management, rainwater harvesting has been fully implemented in some Indian cities for all new houses [30].

A number of policies to improve access to potable water supplies in developed countries have been implemented, including extension of water supplies in urban areas and borehole development. The use of new water supplies in addition to dominating or current sources is another technique [31].

Water poverty is defined as inadequate available water resources for domestic purposes and food production to stabilize domestic and production requirement. It occurs when water demand is greater than available water supply in specific area Water poverty is characterized as insufficient water supplies accessible for residential use and for agricultural production in order to stabilize domestic requirements and production requirements. It happens when the need for water exceeds the availability of water in some areas [32].

Water poverty is the condition where country cannot afford the cost of water with good quality for all population at any time. Water poverty can be attributed to water scarcity. Water scarcity described by continues water supply-demand gap [33].

The collection systems of rainwater are generally thought to provide clean drinking water without treatment because collection surfaces (toeing) are separated from many of the normal pollution sources (Moseley, 2005). However, 56 households without RWH facilities (22.5 per cent) said the condition of rainwater in the dry season, owing to litter, bacteria and bird drops and the danger of egg pollution in ribs and storage facilities was not suitable for drinking. Of the 108 RWH infrastructure households, 101 (93.5 percent) reported that rain water was clean, and many cooked, albeit rarely. Rainwater assessments are not quantitative research but based on assumptions. The consistency of rainwater has typically been found to be high in Ghana, but pollution is often normally impacted by plants used to gather and maintain them [34].

The rainfall in many regions is high, and for the rest it is low or insignificant; thus, rainwater and rainwater harvesting and storming would help to reduce dry season shortfall. In many countries, rainwater harvesting in the last two decades has undergone a major renaissance. At the heart of this revival was Africa and South Asia, which built tens of millions of roof catchments. Kenya and Thailand were focal points of technological development and were followed by other countries [35].

"Reliability and economic analysis: the potential of extracting rainwater in various commercial buildings of Dhaka". The results have shown that rainwater harvesting during the usual year and rainy years will increase the yearly climate conditions by approximately 11 to 19 percent and by 16 to 26.80 percent on a per capita water demand of 30 liters per day (lpcd), respectively, [36].

Rainwater harvesting has many benefits,: water free of charge; the direct harvesting and storing of the water near its use, removes the need for a delivery system and its repair costs; high quality for many applications; leads to the elimination of street-surrounding runoffs; decreases the need for fresh drinking water for purposes other than drinking. There are six key components of the rainwater collection system, including the catchment area, rainwater spout gutter, filtration structure, storage system, treatment and distribution system [37].

RRWH in Addis Abeba, Ethiopia. Big public entities. In this analysis the RRWH amount was estimated using the rooftop areas of major public establishments and average monthly rainfall. Based on its findings, RRWH could provide 2,3% of Addis Abeba's potable water from major educational entities [38].

Belgium has national law supporting RWH, which requires a rainwater recycling scheme on all new housing developments that will be used to wash the toilet and outdoor water. In Flanders 10of household water intake today is expected to come from RWH and could rise to 25% by 2025. It is estimated that 72% of the overall rainwater usage in Flanders is in households [39].In Portugal, the ERSAR guidelines promote the use of RWH exclusively as an irrigation plant for non-potable purposes. ANQIP published a scientific paper detailing the method of implementing water storage systems in Portuguese buildings, a non-profit organization for buildings supporting Water Sustainability in Portuguese in 2012 (National Association for Quality of Building Installations) [40].

An evaluation of alternate water supply technologies should be part of every emerging national water strategy instead of the usual major central technical solutions. The formal (i.e., permanent collection/ storage systems) and formal (e.g. pots under the roof edges) of domestic rainwater harvesting are carried out in different parts of the world. Due to improved safety, accessibility, reliability, use of locally available resources, potential savings and reduced prices than some centralized treatment methods, this technology has become increasingly common in developed countries. It is also consistent with the conditions in the urban poor [41].

2.3 Rainwater Harvesting at Different Universities

Tan et al [42] "Development of green campus in China" From the studies, they find that the large scale expansion of energy resource effective growth of campus in China, mainly targeting the energy conservation application and campus energy management, has been actively supported by the National Government through policy support and financing. A big push is being made to transform the electricity and capital intensive campus from green campus to sustainable education and low-carbon projects on campus.

Indonesia University (IU) has researched environmental and services as a healthy campus. Spectacular greenery, around 70% of the area was recognized by IU, covering about 320 ha. The project has been planned for healthy communities, such as the lawn area (park), bay field, bus stop, free and closed channels, irrigation canals and ornamental plants throughout the project. Throughout the energy management program substitute existing lighting with LED lamps. The energy use will decrease to almost 50% [43].

Determining the "Management of Sustainable Campus in Malaysia" Sustainable development as a technology that improves human life quality while supporting social, ecological, and economic balance goals and benefits through living within environmental capability. Sustainability will be accomplished if the present demand is fulfilled without threatening future generations' ability to fulfil their own needs [2].

"Campus sustainability (A Case Study in University Malaysia Sabah)". They demonstrate that the key issue of the sustainable campus of Malay is the lack of knowledge about the idea of sustainability within the campus population. They often describe the UMS group with a high degree of experience and awareness regarding sustainable campuses, while the under known sustainability activities tend to impact its sustainability practices [44].

"The green campus project and its effect on the quality of life of students in green and non-green campus universities". They observed that students of studied Green Universities were more reserved than students from non-green campus universities surveyed, and had a somewhat better quality of life experience [45].

"The estimation and design of rainwater harvesting structure to Siddharth group of institution, Puttar." They found that $23.627219 \times 10^3 m^3/year$ was recharge through rainwater harvesting. Total estimation of rainwater harvesting system from rooftops was 2.51 lakh [46].

The collection system for rainwater may allow for the capturing of rainwater. In general the rainwater harvest scheme consists of direct rain water collection from roofs and other catchments installed for usage of residential, industrial, agricultural, environmental use, as well as the collection of sheet drainage from land or natural surface catchments and rock waters. The structures can be classified as massive, medium and small [47].

There are apparent significant sustainable advantages, rather than trying to handle and veined the water out, due to the harvesting of rainwater from building assets. It is also obvious that experimental work on the success of alternative water management systems in line with sustainable goals must be carried out urgently [48].

Rainwater harvesting is useful when used in urban areas; but because different rural areas are available in the world with little or restricted access to drinking water, the use of rainwater harvesting systems is equally important for people's potential livelihood in these areas [49].

Toilet water flushing generally constitutes a large fraction of all residential water use and a possible easy approach for a sustainable development is to substitute a mobile water with an alternative water supply. In Hong Kong, water wash was used and contributed about 22 per cent of the overall water source covering about 80 per cent of the city [50].

In different regions of the world, drainage of the rainwater for domestic use is very common. Because climate change, along with rapid urban indifference and population development, have an effect on water sources in many areas, the importance of collecting rainwater for domestic water demand is now commonly acknowledged. Drinking water is a desirable and efficient way to minimize usage of domestic drinking water supply, rather than in the dry and semi-arid regions, in the application of rainwater storage schemes (RWH) [51].

Studies on the effect of RWH on buildings of Coventry University found that RWH would meet around 25% of the demand for water at the university. They explored how RWH in cities improves building and urban landscapes and the underlying communities both biodiversity and resilience [52].

Rainwater harvest (RWH) is an alternative used in many parts of the world, where con vetiver water supply schemes have not fulfilled people's needs. When applied in combination with water demand control, and interventions to enforce water recharge are said to be effective for collection and use. The methods of rain water harvest, the nature of the collected water, the cost-effectiveness by using local materials and know-how, and socio-cultural and economic factors were to be examined. Demonstration programme to increase civic acceptance and to further remove structural hurdles should be pursued [53].

The inadequate city drainage infrastructure found it impossible for people to dispose easily of rainwater as a nuisance. As a resource, Rainwater was overlooked. But in a year of around 73 million cubic meters in the city the piped water was overwhelmed by 306 million cubic meters of rain. It can harness and use this rain. It is important to reclaim the city's rainwater as a resource and the value of water securing by a shift from "offsite" to "onsite" sources [54].

A survey of 277 societies in sub-Saharan Africa by [55]. Showed that around 86% were mainly dependent on agriculture, 6% on livestock and husbandry and farming were codominant for a further 3%. Other sources include 2% mostly fisheries; 1% fishing and livestock equally; and some hunting and collecting minorities. The way of life in this area is, therefore, dependent on the status of natural environments for small-scale rural agriculture, with low production rates, and simple tools. Rainy season governs most people's lives because it decides how they operate to make a living dependent on the use of land resources. The runoffs are primarily obtained from land catchments as well as from ephemeral streams (water collection) and irrigation of roads/paths. Stored in various installations, primarily auxiliary irrigation systems or the ground profiles (tanks, reservoirs, dams, water cabins etc. (for in situ and flood irrigation). RWH may be regarded as an irrigation method [56].

The distinction with RWH is that the farmer doesn't have time leverage, since runoff can only be harvested by rain. For example, a 50% decrease in seasonal precipitation may lead to a complete food shortages in areas where livestock are fully rain forced [57].

There must be a series of reforms aimed at reversing the unsustainability of the soil and groundwater extractions to satisfy water requirements. Rainwater harvest (RWH) is regarded as an alternative to sustainable urban water cycle management. It provides many benefits, i.e. it will reduce urban outdoor water demands and reduce water constraints by the promotion of significant water savings, the reduction of polluting loads from non-point sources, the reduction of urban rush, flood control and a reduction in world climate change [58].

The advantages that rainwater harvesting provides to 23 metropolitan areas in seven different parts of the United States of America by implementing rainwater harvest systems. The findings suggest that the harvesting of rainwater is 1 to 17 percent less drained [59].

The main determining factors for the sustainable harvesting of rainwater are little understood. Water source reliability and potential depend on the variability, form and location of the RWH system in the rainfall. Efficiency improves with accurate use of water, which in turn depends on local expertise and capacity for investment. In relation to the hydrological sensitivity of the area, impacts vary with water use intensity and form and locations of the RWH system [60]. In Australia, the government has promoted storm water harvesting through media campaigns and provided resources and grants to encourage ideas and creativity in water saving. For e.g., Victoria provides discounts of up to $500 for people installing new rain water tanks. Increased uses of rain water collecting and other basic advanced technology may mitigate environmental impacts from .water stocks and water recycling systems that lead to climate change. This transition also has a minor advantage as a major element of urban water supply [61].

By evaluating a water equilibrium, the water regime of a given region can be well understood. The balance of water inbound from precipitation and water outbound by evapotranspiration, groundwater recharging and stream flux measured for a whole water bodies is the equilibriums. Simply put, a water balance is a budgetary exercise to measure the rainfall proportion to stream flow (or flush), evapotranspiration and drainage (or groundwater recharge). The roof has been preserved in urban areas and used for freshwater reloading. This top-of-the-roof rainwater solution connects the outlet pipe from the rooftop to either natural wells/tube wells and wells or specially constructed wells. Rooftops for rainwater collection in India have been built in various urban housing complexes, or institutions used to collect the roof for water charging [62].

Rainwater collection consists of a wide variety of methods to capture and store water on the ground and ex situ. In situ, soil maintenance techniques are soil irrigation, which improves moisture infiltration and reduces rinses on surfaces such as terracing, pitting or recycling methods. In the field in which the plant grows the rainwater collection region is the soil acts simultaneously as the means of storage and sharing. Development throughout the world in several countries Ex situ solutions provide collection areas outside to storage, which are a natural surface soil with a small infiltration potential or a minimal or no penetration potential synthetic layer. The roofs, sidewalks, floors and hills are depicted as widely used impervious areas. Stocking structures also consist of reservoirs, lakes, ponds or cisterns. Due to growing water shortages internationally, rainwater production in many countries has expanded rapidly over the last decade [63].

An assessment of the potential of RWH by [64] concluded that in the four main cities in the United States (New York, Philadelphia, Chicago and Seattle) RWH could minimize potable water requirements by more than 65 percent and roof runoff by 75 percent with $100m^2$ and $5m^3$of water tanks in the catchment area.

2.4 Rainwater Harvesting and Potable Water Saving

Water is a valuable gift of nature and life exist where water is available. It has many usages in human life. With the increase in population, the demand of this natural resource is increasing day by day. Now a days water scarcity is a big challenge in many developing countries like Pakistan for the use of future generation [65],[66]. Fresh water resources are limited and because of increased demand in comparison to an increasingly growing world population, industrialization, urbanization, global climate change and water is becoming a scarce resource. Water conservation is essential, rainwater harvesting technique is an effective way for conservation [67].

"Rainwater harvesting in Jordan: potential water saving, optimal tank sizing and economic analysis." He observed that Jordan could save 30.5 m^3 per year on possible rainwater, with an average saving of 8 percent on total domestic demand [46].

"Investigation on rainwater harvesting in residential areas of arid and semi-arid regions case study: Turbot-e- Jam, Iran." They found that the total harvested amount of rainwater was 5,606 m^3 considering the total surface of the roofs and the annual rainfall in the study area. The areas of Turbot-e Jam, the harvested rainwater was estimated as 772,806 m^3. There result shows that 15.5% water was saved [68].

"Rainwater utilization in Germany: efficiency, dimensioning, hydraulic and environmental aspects." They prove that the method of rainwater harvesting in Germany has saved water from 30% to 60% depending on the roof area [69].

"Potential for potable water savings by using rainwater and greywater in a multistory residential building in southern Brazil" there result show that across the three blocks, the average possible savings in potable water ranges from 39.2 to 42.7 per cent, provided that toilet washing, clothing washing and cleaning water need not be drank. The savings in drinking water will range from 14.7% to 17.7% when using rain waters. The saved potable water is higher, for greywater alone, from 28.7% to 34.8%. The saving of drinking water for combined rain and greywater ranges from 36.7 to 42.0% [70].

Determined "Potential for potable water savings by using rainwater: An analysis over 62 cities in southern Brazil." They find that the ability to save water by using rain water ranges between 34 and 92 percent, based on the regulated drinking water needs of 62 cities, with an average water saving potential of 63 percent [71].

Rain water harvesting (RWH) has been found in a current Sudan case study to have an alternative drinking water source due to urban population growth in a changing physical environment [72]. Our most valuable natural resource is water, which most of us take for granted. We are constantly conscious of the importance of water to our life, as well as its scarcity. Humans use water for a variety of reasons. Water covers the majority of the earth's atmosphere 71%. Just 1% of the actual amount of water present on the earth's surface is pure and potable water, with 97 percent being saline water, 2% being ice and glaciers, 1% being fresh and potable water [73].

The rainwater harvesting opportunity in an urban population living in Bangladesh's poor South Agar of Chittagong. A multi-criteria decision analysis analytical hierarchy process (AHP) reveals that the rainwater collection system could be used to augment up to 20 liters of rainwater per person per day over the year, while at the same time rainwater collection from surfaces on the roof could reduce the issue of water squeak age by around 26% [74].

The capital costs for massive rainwater tanks attached to trade roofs in Melbourne can be recovered at potential rate water price increases within 1521 years. Several findings with respect to the device scale have been discovered on various levels of RWH systems viability. In fact, there was probably substantial spatial variation in a region, even in a large city [75].

The most viable option for the urban water supply scheme may be Rainwater Harvesting (RWH). This will reduce water crisis, reduce the pressure on existing water supplies, reduce non-point source pollution, handle water logging issues, avoid floods, assist with climate change effects and contribute to control of storm water, etc [76].

Australian people largely collect rainwater in underground tanks because of water shortages rural areas. Rainwater harvesting can provide for up to 50% of water necessary for toilet flushing, laundry, hot water and outdoor irrigation in residential multi-unit buildings [77].

In Brazil, potential for drinking water savings by rainwater is already reported to vary greatly in terms of geographical area, i.e. from 48 percent in the South-Eastern region to 100 percent in the North [78].

Rainwater is a renewable plant water supply (free from salt). This will mitigate salt deposition by collecting rainwater and lead to root growth in the healthy soil climate. When rainwater percolates are deposited deeply into the earth and diluted usable salt are collected in the root area of plants. This would lead to further root growth and water absorption, thus increasing the plant drought resistance. There are few restrictions to the harvest of rainwater and successful nature effectively complies with them [79].

As indicated by GEF [80]. Domestic and industrial water demand will rise as the world's population grows and as planned industrial expansion occurs, especially in Africa. People in cities with insufficient water supplies rely on tanker systems, whose quality is unknown. Water contamination has exacerbated the problem in many countries, making rainwater harvesting an important choice for ensuring water protection.
Jackson [81] listed a variety of explanations for the increased popularity of rainwater harvesting to meet rising water demands, including climate change. These reasons are:

- About half of the world's available freshwater drainage has now been allocated for human consumption.

- More than 1 billion people do not have access to safe drinking water, and almost 3 billion do not have access to basic sanitation facilities.
- The population is increasing higher than available freshwater rises (per capita availability of freshwater will decrease in the coming century).
- The climate change would lead the Earth's hydrological cycle to intensify over the next 100 years, usually with increased precipitation, evapotranspiration, intensity of storms and huge changes in biogeochemical processes affecting the quality of the water.

Set several actions on the campus to ensure sustainability. In various subjects, including energy effectiveness, food and accommodation, waste minimization and water management, the university also explored its sustainable nature. Sustainable water activity has been developed such as reducing domestic water use by 25% and restricting irrigation to two days a week by using drinking water. The waste created on sites has also been reduced, further reused, recycled and composted. Sustainable campuses provide a vital role to address the needs of the current and future in the models from around the world [82].

In Lipari, an island in southern Italy, researchers investigated the large-scale installation of rainwater harvesting systems. They looked at multi-family residential buildings and the possibility of using rainwater to meet non-potable water demands. Rainwater harvesting systems could minimize water usage by 30 to 50 percent in 94 percent of these buildings in Lipari, according to the authors [83].

RWH is a feasible, but disputed approach to tackle multiple water issues concurrently. A RWH is a multifunctional, integrated facility to increase water supplies, replace high-quality non-drinking drinking water, as well as mitigate storm water runoff and water waste, one of the main sources for flood and municipal water pollution. Unlike the current centrally located and single source urban water systems [84].

Rainwater harvested is a sustainable source of hot, household and country water. Water collection technologies deliver modular technologies that address the needs of current and modern and vast sites efficiently. The lower cost relative to other water supply schemes that are readily available and easily managed in the home is the main appeal of the rainwater harvesting [85].

Stresses current water supplies in urban growth and the demand. Caution is now on renewable supplies of precipitation, such as rainwater services, as additional multi-purpose water resources. The increasing demand on the resources that are available is the dilemma of scientists, engineers and decision makers as the entire growth of the country in various areas depends on this critical resource being available [86].

Water and food conservation are the main threats of climate change, since they are also particularly vulnerable to evolving climate trends [87]. Food preservation is a complicated sustainability agenda for the procurement of safe and nutritious foods by people to sustain balanced and active living. In this sense, the amount and quality of water available is closely linked to food safety, since all food supplies are water demanding directly or indirectly [88].

The appropriate size is dependent on a variety of variables, sizing a rainwater tank using computer based modelling can be very difficult. The best tank size is determined by the collection system, the region of the roof where water will be stored, the amount of water that the tank will be needed to provide, whether demand will be constant or intermittent, the required efficiency of the tank's water supply, the depth of precipitation that can be predicted, and the rainfall pattern of the area where the tank will be installed [89].

A systematic water for life analysis recently conducted strongly advocates the need to follow a limited catchment strategic plan for improving irrigation cultivation [90].

Substantial field trials and lending facilities were identified to smallholder farmers of the Potsheni drainage basin in South Africa to fund these institutions. Such collection organizations could play a significant role in the response to natural changes such as rainfall fluctuations, floods and droughts for citizens and eventually ecosystem processes. One additional parameter, essential in the sustainable development of rainwater production by harvesting, may be the capacity of such an entity to include upward, midstream, and downward water users in changing processes [91]. Water is diminishing and unpredictable in Africa. During 19701994 the population increased by 180 percent, while the availability of water for basic need in Africa decreased by 16 percent in Europe [92].

Rainwater harvesting is an increasing technique to improve water efficiency dramatically, thus alleviating the lack of farm water and enabling rises in crop production levels. In some sections of the SSA, several traditional and newly evolved rainwater collection methods are used. Any traditional strategies in the drylands of Western Asia have been adopted and universally spread [93].

Three-quarters of the incremental food needed by the world's population over the next few years can be met by up to 80% of the level of production generated by world-class low-yield farmers on comparative soil. The biggest possible yield growth is in rainforest areas where many of the rural poor people in the world live and where water conservation is the key to such growth [94].

The most effective irrigation is rain water, since it is fresh in nature and can be easily treated and used for non-potable purposes. But many still refuse to follow the Australian rainwater management scheme (RWHS). Statistics from the Australian Bureau of Statistics (ABS) show that approximately 47 percent say 'higher prices' are the primary explanation why the rain tank is not built [95]. Collection of rainwater in South Korea will be possible for 6 months of the year only. They also discovered that a profit-cost ratio of 20% could not be achieved because water costs in South Korea are too low. It proposed that water costs in South Korea need to be raised by approximately five to make the RWHS financially viable [96].

2.5 Rooftop Rainwater Harvesting

Rooftops may be built to rainwater collecting to minimize storage costs and maintenance to resolve difficult problems. When the system is integrated into the building design and development process, the costs of the system will be very small [97].

The sustainability techniques of a sustainable campus should extend across education, research and campus acts (i.e., waste, energy and water) [98].

They rooftop rainwater harvesting structure design at the University campus in India. During the non-monsoon season, rainwater harvesting can resolve water shortage issues by storing a massive amount of water 6109.42 m^3 each year on the university campus. This system will improve the water availability for development projects, planting and also encourage with the artificial recharge of the ground water table [99].

Rainwater collection in Jordan has been used to supply water for a wide variety of domestic and agricultural products. Despite the provision of water delivery facilities, Jordanians need to catch rainwater because of the water crisis. A series of characteristic previous events, including successful water harvesting methods are located in Jordan, in areas with a yearly rainfall ranging from 100 to 1000 mm [100]. A roof drainage system consist usually of a catchment area (usually the roof), filter, warehouse, a supply chain, pipes and an overflow system The main operating criteria affecting operating quality are therefore rainfall, water volume, tank volume, and reliability of the collection and the filter, in terms of economic viability [101].

Roof-top harvesting is popular in areas where the roofing materials are fine. When compared to a field or rock catchment, this form of water collection is less prone to pollution. Impermeable surfaces and impermeable soils are examples of ground catchments. These techniques are often used in areas with low annual rainfall or a lack of sufficient roof-top space. Natural depressions are sealed off and storage tanks are created by erecting walls. While these catchments are less expensive to construct, they do necessitate appropriate locations [102]. The rooftop rainwater harvesting (RRWH) rooftops in Syria. Complete roof areas were used for each county and average rainfall in urban areas to measure the RRWH volume. The RRWH is nearly 35 from urban areas in Syria [103].

The efficiency of the rainwater harvesting system for a large building. The study showed that for an office-based rainwater harvesting system, about 87% water saving capacity could be obtained over an eight-month span [104].

The city of Dhaka's rainwater harvesting sustainability, quantity of water and quality is investigated. A RWH system is reliable and cost efficient for a residential building with a capacity area of $170m^2$ and a normal water requirement of 135 liter/capita/day, in addition to many water quality requirements for controls. Rainwater harvesting is a sustainable solution that has been more common in both rural and urban areas in the developing world because of its diversity and quality [105].

In the rainwater harvesting process, the impact of roof surface area on rainwater runoff quality and quantity. They conclude that roof catchment has a significant impact on rainwater collection quantity, quality and can be used as a protected water supply by a simple water treatment facility [106]. Multi-criteria analysis of device configurations for the harvest of rainwater in UK Buildings. Result show that rainwater is best way for reduction of capital costs, maximum efficiency in water saving, minimization of operational water energy consumption, minimization of peak storm water releases and annual storm water releases [107]. Rainwater harvesting-an alternative water supply in the future for Pakistan. The results showed that 45% of potable water was saved by using rainwater harvesting [108].

In cities the big, impermeable spaces (roofs, garages, parks, flanks and so on) are an alternative source of water and sustainable urban growth. Rainwater harvesting opportunities. However, it is important to consider public opinion about them and the reasons of their discord for the effective introduction and introduction of alternative and emerging technologies. Since there are significant differences in public opinion at various geographical places, the easiest way to support publics with government's decision would be to achieve the suitable solution. Perception experiments, amongst the most effective tools for eliciting public sentiment in the hopes of gaining insight into the problem, are one of the most powerful tools for eliciting public sentiment [109]. Domestic rain water harvesting (DRWH) describes the concentration, collecting, storing and use in small sizes of rainwater from rooftops, corridors and other imperious domestic surfaces. USEPA is widely recognized for the replacement of drinking water from the water supply for certain water uses that are less taxing in houses such as toilets flushing, terrace washing or private watering in the backyard. In addition, amid research on the prevalence of toxins at rooftop rainwater from various parts of the world [110].

RWH is actually used by a substantial share of households in Malta. 35.4 percent collect it in underground tanks and the figure in plastic containers is lower, at 1.8 percent. In a new construction plan that covers the creation of water collecting surfaces on the roof, tank sizes and capacity, etc. the RWH has been used by the MEPA (Malta Environment and Planning Authority) since 2004 [111]. Annual precipitation and cumulative rooftop volumes to measure the future RRWH volume in Lebanon. The theoretical RRWH amount on rooftops in Lebanon is about 23 MCM, based on their findings [112].

Almost 22 per cent of domestic demands for water could be fulfilled with RHS in Islamabad. Reported there was, however, no thorough study of RHS effectivity assessment in Pakistan to encourage the development of RHS by engineers and residents through methods for modelling and approaches to water stress alleviation. In addition, there is a research void to track environmental and financial benefits of RHS throughout Pakistan under various climatic conditions [113].

With a population of approximately 22% of the world's population, China has only 7% of the global resources for fresh water. This very low supply is spatially and temporarily unfavorably distributed across the country. With a total agricultural land of about one-third and 700 million people, the southern part of China has almost 81 per cent of the country's water resources. In comparison, only 19 percent of the country's usable water is available in northern regions with 40% of the population and two thirds of the land. There were water scarcity and water quality concerns over 430 towns in 668 cities investigated in China in 2000 [114].

Estimation of rooftop rainwater harvesting potential using application of google earth pro and GIS. He found that the volume of water harvested from various types of rooftops were 11,65,3,860 liters to the annual water demand 3,06,60,000 liters [115]. Rainwater harvesting potential by using ArcGIS in Almasguda region India. They obtained 436708288.17 liters of water from both runoff and rooftops rainwater harvesting. The obtained water is more than adequate for at least 46398800 liters of domestic demand and sufficient. They conclude that rainwater harvesting is a convincing method [116].

Rainwater collection consists of a technique which allows rainwater to easily be collected from rooftops, land surfaces or rocks. Rainwater collection in its elementary form uses clear storage reservoirs and tanks to store the runoff from infrastructure for potential use in this or in near proximity facilities. More complex methods, like underwater check dams, are similarly used to obtain comparable results [117].

A domestic RWH report on Chephalonia has reported in Greece that the chemical content of rainwater collected is appropriate and it is carried out in compliance with the guidelines for chemical parameters laid down in Directive 98/93/EU. They concluded that RWH is a viable solution to the availability of freshwater, in particular to unpolluted regions, as water shortages and demand grow. In a study on water management policies in the city of Phoenix, USA [118].

RWH has the advantages of minimizing the treatment cost, cost of pumping, service and raise rates, decreased peak flood runoffs and a reduction in storm water collection costs as part of a regional reticulated delivery scheme. Moreover, RWH decreases the production of greenhouse gas by reducing pumping dependency and future rises on sources such as desalination. RWH will make local water reserves with risks (surface and contaminated water). Despite climate changes projections, the financial advantage being that rain is renewable at sufficient amounts. In general, RWH systems are low in running cost since they supply water at the consumption stage [119].

The main installation of rainwater storage systems on residential structures raises questions about drinking water and protection from existing facilities. While some care should be taken, Rainwater can be obtained from almost any roofing surface. Roofs can be stopped for any plumbing or plumbing flash. Anything unique should not be called arsenic roofs with separate fibers for rainwater collecting due to asbestos protection problems [120]. Despite its advantages, a green roof garden needs extra irrigation water, which has hardly been debated in the literature. It is promising that rainwater collection can effectively be applied to the toilet flushing without any significant improvements to the current scheme. Using rainwater collection as an efficient urban water supply scheme offers optimum sustainable city development for various water sources [121].

RWH's efficacy in reducing climate change's possible impacts on combined wastewater overflows in Toldeo City, Ohio. In contrast, RWH's $0.76m^3$ systems with storage capacity in one half of the town's buildings can reduce potential impacts on the urban drainage network and toilet flushing water supply requirements, which are the largest percentage of indoor water use [122].

Water scarcity is a situation in which the world is unable to afford high quality water costs to all the people at any time. Poverty of water may be due to shortages of water. Scarcity of water characterized as a continuing gap in water demand [123].

Ghana is one of the nations that in recent years have stressed the use of rainwater by government authorities and development partners. This is because the country's water quality condition has long been inadequate [124].

Main source of water supply in the research area is only groundwater. The water demand is growing exponentially in the campus mostly for drinking, lab works, washrooms, kitchens, canteens, floors cleaning, and irrigation etc. Rainwater harvesting is the most widespread alternate source for the current water requirement and to meet the future water demands in research area [125].

The rainwater harvesting scheme in India, they discovered that rainwater harvesting is useful for multiple purposes such as washing the clothes, washing the vehicle, planting and one of the key benefits is to cut the water bill by 50 percent to 60 percent. They also note that surplus rain water can also be used through artificial recharging methods to restore underground aquifers [126].

2.6 Potable Water Saving Through Rainwater Harvesting

Although water becomes scarcer, a water resources management solution is required, covering all water users, forms of uses and water supplies. However, water conservation should never be an objective, it forms an important part of agricultural and land farming and must therefore be aimed at protecting and improving the condition of land users. High-input methods for smallholders, though, may be too costly or impractical for local biophysical and social environments. Many land owners will benefit from higher approaches that are more suitable for their characteristics and circumstances and therefore improve the quality and safety of water usage. Land users are encouraged to implement several cost-effective water conservation technologies. While several of these developments are still not known, many are still available to land users. Consequently, water shortage can be questioned according to Lisa [127].

Especially in comparison galvanized metal rooves with the roofs of asphalt and found metal rooftops to be both an enhanced source of Zinc and Cadmium pollution [128].

The amounts of lead, zinc or copper were not substantial in ruins on asphalt roofs and metal roofs suggesting large variations in findings between related roof-based studies [129].

The decision on the installing of a RWH scheme, [130]. Indicated, was based on budgetary expenditures and advantages, while staying in the context on publicly acceptable problems and the condition of water. Therefore, the economic viability of RWH schemes is especially important to assess. Prior to its administration, conventional facilities such as wastewater and concentration camps, concentrate rain water from the catchment. Source control SC, on the other hand, attempts to contain and/or penetrate tiny amounts of rainwater as near as possible to its point of fall. These devices are often referred to as best management practices (BMP) [131].

Urban communities are among the most vulnerable because they are subject to high environmental pressure, combined with huge biological footprints, and mostly rely on water from remote rivers, which is delivered by large infrastructure. About 50% of the world's population lives in those regions and over 70% in North America, Europe and Oceania [132].

Frequently scarcity and population expansion in urban areas help to raise the need for water in order to satisfy predominantly household needs. Power shortages and the depletion of traditional supplies encourage greater reliance on imported water for these needs [133].

Includes waterproof catchments for the rainwater system, for instance, for collecting rainwater, for distribution of rainwater to storage reservoirs, and ultimately for storage tanks. In order to maintain high reliability, it is advised to use plastic or metal equipment in systems [134].

Water shortages can exist almost everywhere because of the demands of water that go beyond available water supplies. Shortages is generally linked to arid conditions and poor water supply regions. However, it may also occur attributable or improper suburban irrigated agriculture use in areas with heavy plaster rainfall. This then emphasizes the need for continuous access to water supplies [135].

Assessment of the RWH framework sustainability index in six metropolitan cities in the United States using indices of stability, durability, and vulnerability. They demonstrated that the sustainability index of the city improves by rising the storage space of RWH systems [136].

A main feature of the environmental pillar which is the principal pillar on urban sustainability has been found to include relevant water quality metrics in an article on the designation of European urban areas [137]. The challenge of a lack of water can be widespread and its consequences can be devastating, but human populations can embrace many sustainable opportunities and approaches through behavioral change [138]. Despite the difficulties of expanding the usage of rainwater in the region, RWH's interest in the sustainable alternative water collecting and storage technique is rising worldwide, to ease the increasing water shortages and shortages problem caused by periodic droughts, rising population, the water contamination and depleting aquifers [139].

The RWH method can also be used for small farming needs in both cities and towns as a supply of water. In several rural zones and on islands, RWH is a main source of [140].
RWH will offer a more resilient and cost-effective way of improving water quality in areas where there is growing water shortage than the complicated municipal water grid [141].

A variety of questions such as saving water quantity, water price, interest rates, environmental advantages as well as efficient use and fetching saved time (which can be used for other productive purposes, alternative water sources costs and maintenance of the system) are to be examined in the economic study of RWH [142].

In remote areas, RWH contributes to achieve one of sustainability's goals. The machine rainwater (RWH) is mostly used as an alternative supply of water for non-potable applications in urban environments (e.g. washrooms, toilets, water irrigation and automotive washing), as well as storm waters [143].

A time-series model approach was employed to calculate a flood reduction in RWH tanks in three locations for a wide range of conditions. With an annual average supply below the annual domestic requirements, this study has shown that increasing the size of the RWH tank leads to more accumulation of the flood and a reduction in flood volume and peak [144].

The impacts of RWH in a condominium of houses in Curitiba have been tested, in various situations and reduced peak flow even though certain considerations relating to construction, tank capability, rainfall characteristics and land usage influence the effect of the RWH system on drainage [145].

Studied a construction of RWH tanks in a suburban urban block in Genoa to assess the efficiency of RWH systems in storm water flood control (Northern Italy). The authors find that peak flow decreases by 33 percent average and the amount of rain absorbed by 26 percent [146].

The scheme for RWH offers the opportunity to integrate certain facets of the flow of soil and water. Beginning with rainfall, part of the water is either directed into the soil or the process of rinsing begins. Surface ruin may be caught in ponds and poured into the farming field or released to the lower one. This integration contributes to additional factors that affect the rush generation process in the watershed. In order to schedule and control rain water harvesting, the implementation of the sub water runoff study through the fall also becomes necessary [147].

The rinse generation operation, the size of a catchment and form of storage can be categorized as the rainwater harvesting systems. Runoff cycles generate rivers, reservoirs and precipitation. The storage type could be a storage within the ground, tank or reservoir and whether it is a micro or macro device is determined by the size or scale of the system [148].

The World Health Organization (WHO) is committed to ensuring that every person, irrespective of the extent of their growth and of social and economic circumstances, has the right to access sufficient safe drinking water. The WHO estimates (1997) that a minimum of 100 liters per day is household and urban water required. Rainwater (RWH) practice spreads exponentially around the globe in urban areas [149].

It is in the growth of all continents. The lack of water has contributed to the use of rainwater in Australia for many years, and today 3.2 million Australians have only used RWH for drinking water [150].

In a significant range of examples, a time series modelling methodology was used for measures of flood reductions in relation to RWH tanks in three locations. When the average annual supply is smaller than the annual domestic demand, this study has shown that an increase in the size of the RWH tank leads to more water preservation and a reduction in flood volume and peak [151].

The daily demand for toilet flushing was required in order to mimic the water balance of the RWH tanks. The analysis used in this study to assess the pattern of toilet splash demand was based on water utilization data obtained during a seven houses surveillance programme in Palermo during the 2002-2004 period. The toilet flush tank was 9-10 liters in each of the camp homes. (10 liters is found for all houses in water balance simulations). These details are analyzed by Liuzzo [152].

One of the driest provinces in China is Gansu. In order to support local farmers, a rainwater field, two tanks and a field for farming were provided by the Provincial Government of Gansu. The scheme provided 1.3 million people with drinking water in 1995/6 and 1.97 million people in 2004 [153].

Water is also not easily accessible to the poor of the planet, being one of the most basic human needs. A number of water supply and delivery technologies in developed countries have been successfully applied to provide safe and secure water near to their end-users. To meet this need. One such alternative available in all countries or in all socio-economic backgrounds for rainwater harvesting. It is able to provide drinking, heating, bathing, and cleaning water for various household purposes. Rainwater irrigation is one of the most fundamental forms of the collection of water and has been used worldwide for centuries as a tool to gather and store water for potential use. The harvest of rainwater does not only consist of rooftops, it can also cover catching water that has fallen to the ground by the accumulation of runoff. Impervious material should be mounted on the floors, or exposed floor caps can be used to corral water in the storage tanks. The former will include building a concrete floor, whereas the other may use a big hill [154].

The scale of the collecting surface is the annual rainfall for a region. There can be no more water accumulated than the surface drop. A personal water storage tank would also be far lower than one rain collected in a municipal house. It is really interesting to remember other ways in which people get clean water while building a tank. If the main supply of domestic water for the storage of rain water is to be the tank wide enough to ensure while there is water at the end of summer [155].

Studies were carried out on the cost efficiency in the entire lives of domestic rain-water systems in Great Britain, and the rainwater harvesting was found to be considerably cheaper than using mains water alone. The domestic RWH structures in their analysis typically led to financial losses almost equivalent to their cost of capital. Therefore it is doubtful that the domestic RWH is cost-effective for all predictable situations without substantial financial assistance [156]. The shifting environment and freshwater resources use poses an issue of safe water provision for many rural Indians, as well as the seasonal fluctuations and gradual decreases in groundwater table. Rajasthan, one of the driest countries in India, depends on soil water for 90% of its portability and 60% of its irrigated agriculture [157].

Vibrational surface water supply leads to this strong reliance on freshwater. With over 10% of India's geographical area as well as 5% of India's population, Rajasthan is Indian's biggest country, and it only holds 1% of its overall water supply [158]. RRWH from the village of Pirwadi Kolhapur, Maharashtra (India). The possible amount of RRWH that can be harvested from the findings of this analysis is 11457 m^3 [159].

In Pakistan, drinking water availability is becoming a big problem. The present 141 million in Pakistan population is projected to cross approximately 221 million by 2025. This development would directly affect the water demand in order to serve various purposes. The supply per capita of water has declined from 5,000 m^3 in 1951 to 1100 m^3 which is only above the globally recognized point of scarcity. By 2025, the supply of water was estimated to be less than 700 cubic meters per capita. The aim of this study to suggest effectiveness of rainwater harvesting in institutes where vast area and population more than 4000 no. exist in Pakistan. This will help in reduction of ground water pump age and also helps in recharging the ground water [160].

2.7 Measuring Tools

Three different tools (Google earth pro, ArcGIS and SamSam Water rainwater harvesting) are used in this study. Google earth pro is used to calcite the different area such as impervious area (parking space and sidewalks), pervious areas such as (playground and green lawns) and building covered areas. ArcGIS is used to convert the google earth pro file which saved in KMZ (Keyhole Markup language Zipped) into shapefile. SamSam water rainwater harvesting tool is used to calculate the storage tank size for the catchments.

2.7.1 Google Earth Pro (GEP)

Google Earth Pro is a popular tool that allows for the simulation, evaluation, overlay, and construction of geospatial data, despite not being a true GIS. This user-friendly tool is also a good starting point for people who want to study more about GIS but want to start with the basics. Google Earth Pro could also be used to display its ultra-high-resolution satellite images, upload or import geographic information in its popular fully integrated file format (KML), and locate places.

Google Earth Pro is a software-based product developed by Google to view both a 2D and a 3D image of the earth's surface. In comparison to other Earth Surface views, Google Earth Pro has many benefits. For e.g., from the specific goal users might see the earth's surface. Using the media of Google Earth Pro, the earth's surface shape, land use and pitch can be seen [161].

Instead of doing field surveys, Google Earth Pro will save you 38 hours. Because of many reasons, MA in Magelang Regency has the ability to use Google Earth Pro internet [162].

The use of Google Earth Pro software is consistent with the information flow of the investigation template. The study teaching method has important nutrients features, inviting students to search for truth, then to present issues and to solve them [163]. One opportunity to use immersive learning tools is possible. It is planned that active learning tools will infrastructure so that learning can be more efficient and interesting. It will allow students to readily understand the principles of terrain [164]. It is established long that the "facilities" from which it can be accessed are heavily affected by domestic water use. So households that carry water man-made from a distant spring normally consume less than 10 liters per capita per day (lpcd), while households in the same country consume more than

100 lpcd when they have a stable tap source. This 'ease' is not strongly correlated with cost, so water supply can be argued for a price distortion. Certainly there are economies of scale, which normally cost more supply to remote rural buildings than to concentrates. For these and other reason, municipal water is mostly piped in developed countries and rural water is seldom piped [165].

The advantages of using digital content are to extend, increase and enhance awareness and promote learning to learn creativity and innovation. This network will show a learning opportunity which sounds more alive and clarifies the introduction of express or implied subjects [166].

The need for digital technology will motivate learners' abilities to interpret, critique and form opinions focused on observation and thorough analysis known as logical conceptual understanding [167].

Satellites and spatial data was used to create the photographs in GE (images from airplanes, kites and balloons). Town or state legislatures also have certain videos. This photographs are not actual; elevated images have an average lifespan of 6 months to 5 years. (Google Earth). This is why GE photos need to be reviewed for precise preparation because they do not represent recent landscape changes (new urban development, recent disasters etc.) The majority of the land area is 15 meters per pixel resolution and some inhabited centers throughout North America and Europe have even higher resolutions (few meters per pixel), while oceans have much less than 500 m resolution. The standard of picture information in GE varied greatly in general, but are much less precise in rural areas in developed countries. The illumination of certain areas of concern often affects clouds, shadows and thick vegetation [168].

2.7.2 ArcGIS

ArcGIS is a technology that enables data analysts to generate personalized maps and conduct geospatial analyses in order to make more intelligent decisions. The combination of evidence, technologies, research techniques and skills is continually changing. GIS may be used to explore themes through geographical locations in a variety of ways. Examples on how GIS should be used include forest fire spread simulation, building a new neighborhood health center and get a research site for monitoring of samples. Chances are unlimited and GIS systems are increasingly capable of innovation.

Six crucial considerations, i.e. hydrology, geography, soil, agriculture, topo graphing and socio-economic factors, are used for selecting the rainwater collection site. In addition to making it time consuming particularly where a broad reservoir is concerned, consideration of all these factors can increase the complexity of selecting a location. Location selection process for rainwater collection systems has been simplified by the reduction of the planned site number and by choosing only suitable areas, thanks to GIS technologies [169].

The location selection procedure for rainwater harvesting using GIS technologies is based on help judgement guidelines, depending on the assessment criteria [170].

GIS has a powerful geostatistical feature that can be applied to the development of hydrological models. GIS is commonly used to investigate the connections between urbanization and hydrology. The use of a (GIS) in urban drainage modelling entails encoding, processing, interpreting, and presenting data in a spatial context. In addition to the production of GIS technologies, land-use charts, digital elevation models (DEM), soil imperviousness maps, contour data, digital orthographic aerial images, and pipe-network drainage maps, parameter values for rainfall-runoff models can be produced [171].

GIS are valuable because they offer a mechanism for capturing, organizing, assessing, converting, and viewing geographical and non-spatial data for specific objectives [172].

Probable runoff generation sites, and thus priority areas for rainfall harvesting, were identified using GIS in a research area at CUST Islamabad. To reach the task of representing the spatial distribution of rainfall and prioritizing sites for rainfall harvesting, it was important to define and gain relevant information, create the appropriate databases, and determine how these data are to be used in a GIS working context.

2.7.3 SamSamWater Rainwater Harvesting

The goal of Sam Sam Water Organization is to raise the number of customers who have sustainable and secure access to clean drinking water in developing nations. Sam is 'together' 'Sam Sam.' they work together to achieve our objective: clean and secure water for all! We believe in realistic solutions, implemented with our allies and recipient groups in close cooperation.

2.8 Summary

It is clear from above history that in literature the strategy for sustainable campus development requires for a better balance between economic, social and environmental goals in policy formulation as well as a long-term perspective about the consequences of todays campus activities. It is necessary to understand of the factors involved in the development, construction, maintenance and the overall operations of the sustainable campus. Rainwater harvesting is a sustainable technique of potable water saving for future generation.

Chapter 3

Study Area, Methodology and Data

3.1 Background

With climate change and rising environmental issues, the idea of sustainability is growing.Campus sustainability calls for universities to support green buildings and can reduce energy and water usage.Humanity faces big environmental threats such as climate change, rising energy needs, food availability, water shortages, rising water contamination, and rapid urbanization. All of these require a more sustainable approach collaboration among various knowledge fields is necessary in order to find solutions. Wide cooperation would become increasingly necessary between universities and other social acts.

3.2 Study Area

The selected area for this study is the Capital University of Science & Technology (CUST) Islamabad. CUST is a private university located in Islamabad at coordinates 33'32'54.24N, 73'113.83E, having an elevation about 500 meters (1,600 feet) above mean sea level. Islamabad receives an average annual precipitation of 1250 mm (49 in), including more than 250 mm (10in) per month in July and August. The temperature ranges from 0° C T to 39° C.

(https://www.climatestotravel.com/climate/pakistan)

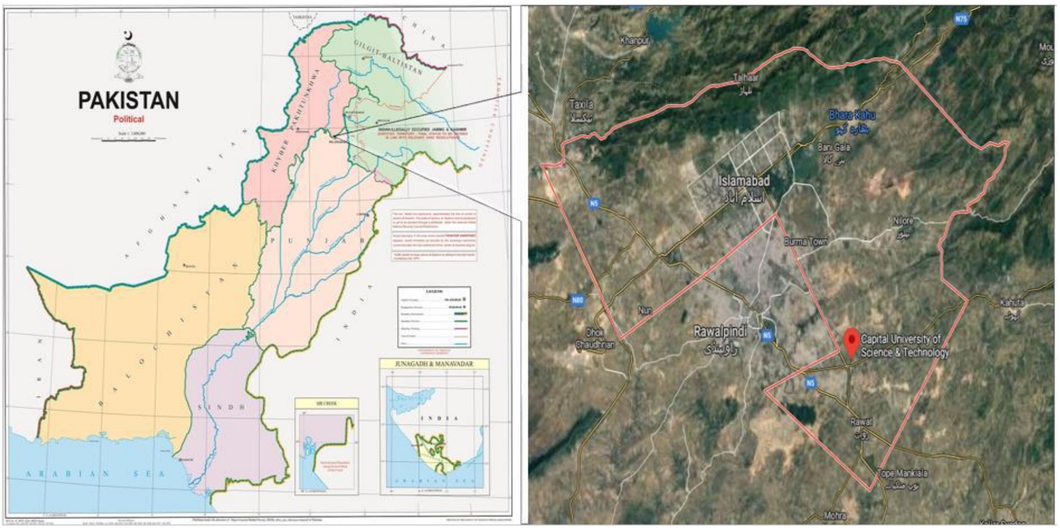

FIGURE 3.1: Study Area Location

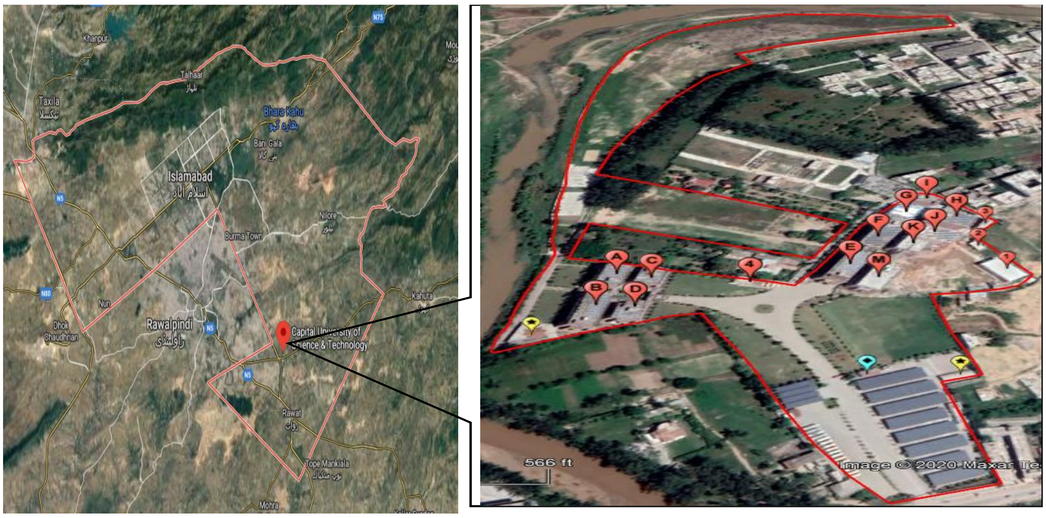

FIGURE 3.2: A clear view of Study area

3.3 Data Collection

The population data of students, faculty and staff were obtained from university administration.Google Earth Pro (GEP) and ArcMap software are used to do research related to geo-space. Both are freely available and user friendly. ArcGISwas used to note the elevation of study area. Area was measured with the help of polygon tool which is available in GEP. Average annual rainfall data has been obtained from metrological department of Pakistan is 1.25m/year.

3.4 Methodology

This research is conducted on selected private sector university near kakpul for analysis of green infrastructure techniques for sustainable campus develop. This study focuses on:

- Review of campus master plan.
- Rainwater harvestingfor potable water saving.
- Rainwater collected from roof tops of different blocks of an institute is an adequate source of sustainable water supply that could be harvested by constructing RWH tanks at appropriate location. Greening in campus is needed to ensure healthy life of a conducive research environment.

3.4.1 Review of Campus Master Plan

It is a basic requirement of now a days to do planning and development of an institute to replace it to green infrastructure. The basic conditions for such development include:

(a) To have more pervious area that allow gardening and quick infiltration of rainwater.

(b) To device and have mechanism for storage and reuse of rainwater that occurred on the campus.

3.4.1.1 Determination of Impervious and Building Covered Areas

Google Earth Pro has been used to determine the total area, impermeable area and building covered area of the campus.It is extremely time-saving technique in comparison with field measures to calculate the linear distance and closed boundary area. It is used to locate the observed coordinates on specified ground and measure the area of chosen ground. Impervious surfaces are predominantly built surfaces protected with impenetrable materials such as asphalt, concrete, and stone-sidewalks, roads, and parking lots.Figure 3.3 shows that 12 main blocks, canteens, parking space, green lawn and playgrounds. The campus isconsists of alluvial soil, which is fairly level.

FIGURE 3.3: Area Identification using GEP

3.4.2 Rainwater Harvesting

In the study area, groundwater is the main source of water. In campus, there is a high demand for water mostly for drinking, in laboratories, washrooms, kitchens, for use in building floor washing as well as classes, for use in gardening etc. Therefore, uncontrollable groundwater extraction will disturb the hydrological balance; hence ecological and sustainable water retention methods are necessary.One of the capable alternatives to the current water requirement and to meet the campus future water needs is rainwater harvesting.

The methodology includes the following steps to achieve the objectives of the study:

Step 1	• Segregation of Different land usage.
Step 2	• Measurement of different areas
Step 3	• Calculation of potential for rainwater harvesting by using Gould and Nissen formula.
Step 4	• Calculation of elevations and slope
Step 5	• Estimation of water demand
Step 6	• Identifying and recommending suitable sites for rainwater harvesting.
Step 7	• Calculation of storage tank capacity on basis of daily discharge

3.4.2.1 Segregation of Different land Use

Area was divided into impervious and previous areas. Impervious area consists of parking space, side walks building covered area. Previous area consist of play-grounds and green lawns.

3.4.2.2 Measurement of Different Areas

Polygon method in Google Earth Prowas used to measure the impervious areas (sidewalk and parking) and different rooftops.

3.4.2.3 Calculation of Potential for Rainwater Harvesting by Using Gould and Nissen Formula

The Gould and Nissenis one of the most popular runoff estimation method used for estimating peak discharges for small drainage areas by using equation 3.1. It estimates only the volume using average rainfall per annual, area, and a land use factor.The Gould and Nissen, and estimation of its parameters to calculate S, plays a key role in hydraulic design ofstorm sewers.The average rainfall per annum

(R) is the mean precipitation rate in m/annum.Gould and Nissen formula is given below.

$$S = R \times A \times Cr \tag{3.1}$$

Where:

S = Potential of rainwater harvesting (m^3).

Cr = Co-efficient of runoff.

R = Average annual rainfall (m).

A = Area in (m^2).

The runoff coefficient is the fraction of rainfall striking the drainage area that becomes runoff from that drainage area. It is an empirically determined constant, depend on the nature of the drainage area surface [173]. An impervious surface like a concrete parking lot have different runoff coefficient.Table 3.1 is shows runoff coefficient values.

Table 3.1: Runoff coefficient "C" values.

Type of drainage area	**Runoff coefficient**
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.30-0.70
Residential:	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.35-0.40
Industrial:	
Light areas	0.30-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.30-0.40

Type of drainage area	**Runoff coefficient**
Unimproved areas:	
Sand or sandy loam soil, 0-3%	0.15-0.20
Sand or sandy loam soil, 3-5%	0.20-0.25
Lawns:	
Sandy soil, at 2%	0.05-0.10
Sandy soil, average 2-7%	0.10-0.15
Sandy soil, steep 7%	0.15-0.20
Streets:	
Concrete	0.90-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.95
Roofs	0.75-0.95
Tuff tiles	0.70-0.85
Iron sheet	1

3.4.2.4 Calculation of Elevations

Elevations of the study area were developed by using ArcGIS. A google earth pro file was export in to ArcGIS for developing elevations of the study area.

3.4.2.5 Estimation of Water Demand

Estimation of water demand is calculated against the number of students, worker and number of faculty and staff. These numbers were given from university which were 5335 and liter per capita per demand is taken from building code of Pakistan which was 23 lcpd.

3.4.2.6 Suitable Site for Rainwater Harvesting

Identification and recommendation of suitable site for water storage tank is based on the slope, elevations of area and exiting drainage direction.

3.5 Portable Water Saving

The supply of water is the most important thing in everyday activities, particularly for washing, cleaning, lab use, ablution and bathing. We waste large amount of water during each washing process. The loss of water starts as the tap is turned on and off. Unfortunately, people often forget to turn off the water tap, which makes water wasteful as shown in figure 3.4. As a result, a lot of fresh water flows unnecessarily into the sewer. Currently, supply of water at study area by pumping the groundwater to fill a water tank.Water pumps are manually turned on and off to operate.The manually water pump is not reliable, because the water pump cannot automatically turn on and off. When someone forgot to turn off a pump, the situation allows the water to overflow.

FIGURE 3.4: Wastage of water by manually water tap

The best way of saving water seems to be using the automatic or sensor water tap.The sensor detects the presence of human and works only when necessary.The user also does not have to touch the valve to start a flow of water.This automated control device can minimize excess water consumption when doing laboratory work, washing hands, ablution and other activities.

3.6 Summary

The CUST campus is selected for the study purposes. Google Earth pro software is used for determine impervious/pervious area and building covered area. Polygon method was used for measuring area of academics block of campus. Master plan review for measuring sustainable techniques in terms of review of campus master plan, pervious/impervious area, waste water recycling, renewable energy and Rainwater harvesting.

Chapter 4

Results and Discussions

4.1 Background

The selected study area is discussed in previous chapter. Where different methods for measurement of impervious/pervious area, rainwater harvesting and storm water have also been discussed. Google Earth pro software has been selected due to free and open source software it offers premium high-resolution photos. Polygon method has been for measuring area of academic blocksand impervious area of campus. This chapter discuss the results obtained by using methodology described in chapter 3.

4.2 Review of Master Plan of Campus

Capital University of Science and Technology (CUST) is located in the attractive surrounding of Sihala on the bank of river soan, just a one kilometer from main Islamabad expressway. Its span over 177 kanals (23.13 acre or 93603.789 m^2) of land and provides educational facilities to thousands of students. The university campus is a state of art facility in private sector and development process is continuously going on. The campus built up area is only 7.28 acre (29461.11 m^2) at the present. The gross construction area of the existing buildings is 1.76 acres

(7103.02 m^2). Four blocks (A, B, C and D), one main canteen are located in SW (South-West), eight blocks (E, F, G, H, I, J, K and M), three other buildings such as shed, animal house, UTM lab are located WN (west-north), one canteen, admin office and transformer room are located NS (North-South). A large parking area adjacent to main entrance gate in which left side for campus transport and right side for faculty and students. Area of campus was consist of alluvial soil, fairly leveled. Soanriver originates from the foot hills near Murree. CUST campus constructed on the bank of Soanriver, this thing adds beautiful site view and aesthetic sense to campus site. Islamabad Highway cross this river near Sihala where the famous KakPulbridge is constructed over it. The Ling stream joins the Soan River just before the Kak Pul and nearest to the CUST as shown in fig 4.1. Retaining wall is constructed south to west side of the campus back side of A and B academic blocks for protection of Soan river flood during raining season. Waste water of university and nearby housing societies is drain into Soan River. Playgrounds are located at the back side of campus. All these details are shown in fig 4.1. Further master plan of CUST is review in three ways such as:

- Building cover area.
- Impervious area.
- Pervious area.

Figure 4.1: Arial view of CUST show Soan River

4.2.1 Determination of Building Covered Area

Different academic rooftops of the study area are digitized by using the polygon tool available in Google Earth Pro software. The process includes digitized buildings of 18 concrete roofs with solar panel on 9 roofs and 1 shed (Iron sheet) rooftop of the study area that have been saved as KM (Keyhole Markup) and represent in figure 4.2. Table 4.1 showed the measured area of each block of campus. Covered area percentage of building was calculated using formula showed in equation 4.1.

$$\%Building\ Covered\ Area = \frac{Total\ Building\ Covered\ Area}{Total\ Area} \times 100 \qquad (4.1)$$

TABLE 4.1: Building Roof Area of CUST Campus

Sr.No	**Blocks**	**Type of roof material**	**Roof Area** (m^2)
1	Block A	Roof Concrete	377.11
2	Block B	Roof Concrete	621.62
3	Block C	Roof Concrete	372.6
4	Block D	Roof Concrete	359.13
5	Block E	Roof Concrete	726
6	Block F	Roof Concrete	790.65
7	Block G	Roof Concrete	349.32
8	Block H	Roof Concrete	543.43
9	Block I	Roof Concrete	167.74
10	Block J	Roof Concrete	563.43
11	Block K	Roof Concrete	298.44
12	Block M	Roof Concrete	598.91
13	Adman office	Roof Concrete	55.87
14	Shed	Iron Sheet	464.15
15	Transformer room	Roof Concrete	134.02
16	Canteen 1	Roof Concrete	127.3

Sr.No	Blocks	Type of roof material	Roof Area (m^2)
17	Canteen 2	Roof Concrete	390.02
18	Generator room	Roof Concrete	93.28
19	Animal house	Roof Concrete	70
	Total		7103.02

FIGURE 4.2: Academic Roofs Area by Polygon

$$\%Building\ Covered\ Area = \frac{7103.02}{93603.789} \times 100 = 7.588\%$$

4.2.2 Determination of Impervious Area

Polygon method is also use to calculate the impervious area of the campus.Impervious surfaces are also includes constructed surfaces covered by impenetrable materials such as concrete and stone pavements, sidewalks and parking lots. Total impervious area of campus is 5.52 acre (22326.33m^2). Further details of impermeable area are shown in table 4.2 and in figure 4.3.

TABLE 4.2: Impervious area of CUST Campus

Sr.No	**Types of Impervious Area**	**Area** (m^2)
Area 1	Pavers tiles	13340
Area 2	Pavers tiles	4069.75
Area 3	Pavers tiles	1002.64
Area 4	Pavers tiles	432.02
Area 5	Pavers tiles	1134.56
Area 6	Pavers tiles	238.42
Area 7	Pavers tiles	233.95
Area 8	Pavers tiles	100.59
Area 9	Pavers tiles	162.72
Area 10	Pavers tiles	250.25
Area 11	Pavers tiles	268.3
Area 12	Pavers tiles	583.33
	Total	22326.33

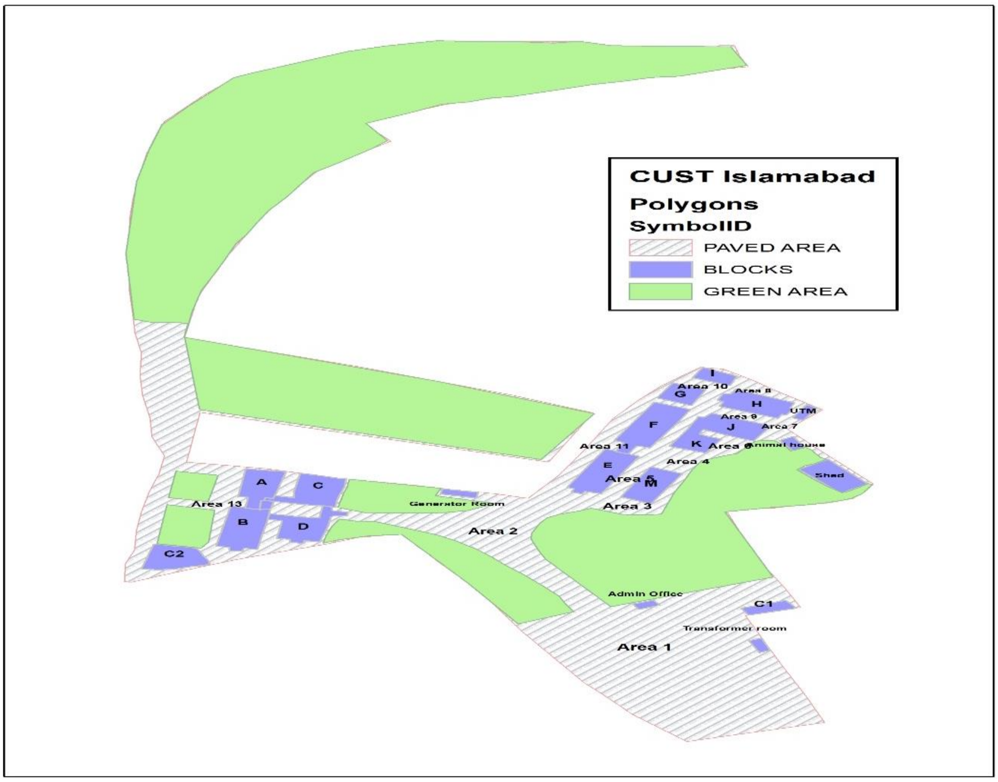

FIGURE 4.3: Layout of impervious area

$$\%Building\ Covered\ Area = \frac{Total\ Impervious\ Surface\ Areas}{Total\ Area\ of\ CUST} \times 100 \qquad (4.2)$$

$$\%Building\ Covered\ Area = \frac{22326.33}{93603.789} \times 100 = 23.851\%$$

4.2.3 Determination of Pervious Area

A permeable surface is a surface that allows the percolation of water into the underlying soil.Pervious area was calculated by subtracting impervious area and building covered area out of total area of campus. Building and impervious areas are measured with the help of polygon method of Google Earth Pro software. In pervious areas planted areas, playground, lawns and green beltsare include.Pervious areas of campusare shown by green color in Fig 4.4 andpercentage of campus areas impervious, building covered areas and pervious areas Fig 4.5.

A_p = 93603.789 - 22326.33 - 7103.02 = 64174.439 m^2

$$\%Pervious\ Surface\ Area = \frac{Total\ Pervious\ Surface\ Areas}{Total\ Area\ of\ CUST} \times 100 \qquad (4.3)$$

$$\%Pervious\ Surface\ Area = \frac{64174.439}{93603.789} \times 100 = 68.559\%$$

FIGURE 4.4: Pervious Areas of Campus

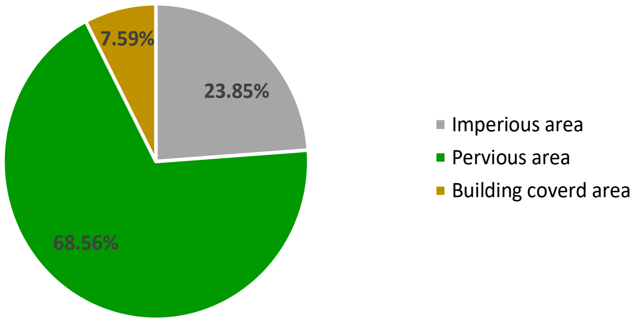

Figure 4.5: Percentage of Impervious/Pervious and Building Covered Area

4.2.4 Contour Plan of Study Area

Contour plan of all area is measured by using ArcMap software. Grading point data showing levels of each point is also shown in figure 4.6 below. The elevation points of the site ranging from minimum of 446.4467m and maximum elevation of 452.1796m, which shows that the natural slope of the area is flat. Detail of grading points along with their level is mentioned in figure. Blue color show minimum valve and red color show maximum. The maximum elevation is on the H block side and minimum elevation is on the A and B blocks side which are located on river bank. Elevations are shown in table 4.3.

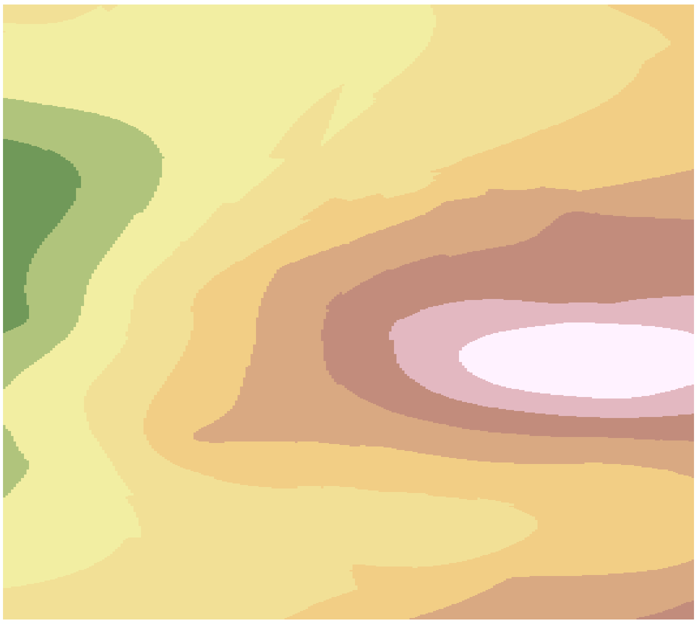

Figure 4.6: Contour Lines of Study Area

TABLE 4.3: Elevations of study area by ArcMap

Points No.	Elevation(m)	Northing	Easting
1	450.195	33° 32' 41.5536"	73° 11' 50.658"
2	450.289	33° 32' 42.1764"	73° 11' 7.7982"
3	449.762	33° 32' 43.1376"	73° 11' 7.454"
4	449.671	33° 32' 43.0008"	73° 11' 4.8112"
5	449.271	33° 32' 44.106"	73° 11' 6.972"
6	448.506	33° 32' 46.2264"	73° 11' 3.7968"
7	449.203	33° 32' 46.2372"	73° 11' 4.0416"
8	449.904	33° 32' 44.2682"	73° 11' 5.2623"
9	449.688	33° 32' 47.3748"	73° 11' 5.5932"
10	449.168	33° 32' 48.9841"	73° 10'59.0772"
11	450.585	33° 32' 49.3836"	73° 11' 3.6312"
12	451.218	33° 32' 49.3836"	73° 11' 5.5428"
13	451.993	33° 32' 50.0352"	73° 11' 6.2052"
14	452.144	33° 32' 51.2592"	73° 11' 7.6344"
15	451.206	33° 32' 52.3464"	73° 11' 7.9764"
16	450.927	33° 32' 51.5472"	73° 11' 2.6952"
17	450.758	33° 32' 53.2572"	73° 11' 6.9576"
18	451.22	33° 32' 50.2863"	73° 11' 3.5268"
19	451.628	33° 32' 51.3744"	73° 11' 4.0956"
20	452.183	33° 32' 50.5752"	73° 11' 5.7048"
21	451.666	33° 32' 52.0442"	73° 11' 7.7568"
22	450.526	33° 32' 49.3836"	73° 11' 3.6312"
23	449.823	33° 32' 48.6456"	73° 11' 0.4884"
24	449.704	33° 32' 47.6556"	73° 11' 6.7848"
25	447.867	33° 32' 50.8212"	73° 10'56.6472"
26	447.805	33° 32' 51.3168"	73° 10'57.0828"
27	448.047	33° 32' 47.3568"	73° 10'57.7704"
28	446.901	33° 32' 56.1848"	73° 10'57.2916"
29	449.302	33° 32' 49.9884"	73° 10'59.9412"

Points No.	Elevation(m)	Northing	Easting
30	450.708	33° 32’ 52.7352”	73° 11’ 2.6952”
31	448.705	33° 32’ 50.2262”	73° 10’59.0268”
32	446.444	33° 32’ 47.4828”	73° 10’56.046”
33	448.271	33° 32’ 50.5032”	73° 10’57.6228”
34	447.961	33° 33’ 38.1325”	73° 11’ 2.9868”
35	449.014	33° 32’ 54.1428”	73° 10’59.2716”

4.3 Determination of Rainwater Harvesting Potential

In this research, a case study of CUST Islamabad has taken to estimate the rainwater harvesting potential. Google Earth Pro is used for digitization of various types of rooftops. Campus have 23.851% impervious area which includes sidewalks and parking lot. ArcMap is used to determine the elevations of campus for the identification of location of water storage tank.

4.3.1 Segregation of Different Land Usage

Area is divided into impervious (parking and sidewalks) and different size rooftops in the GEP and pervious area. Then file is saved as KMZ (Keyhole Markup language Zipped). This file was imported in to ArcMap and converted into the shapefile as shown in figure 4.7.

4.3.2 Measurement of Different Areas

Polygon method was used to measure the impervious areas (sidewalk and parking) and different rooftops. Table 4.4 shows the measured impervious area and rooftops area.

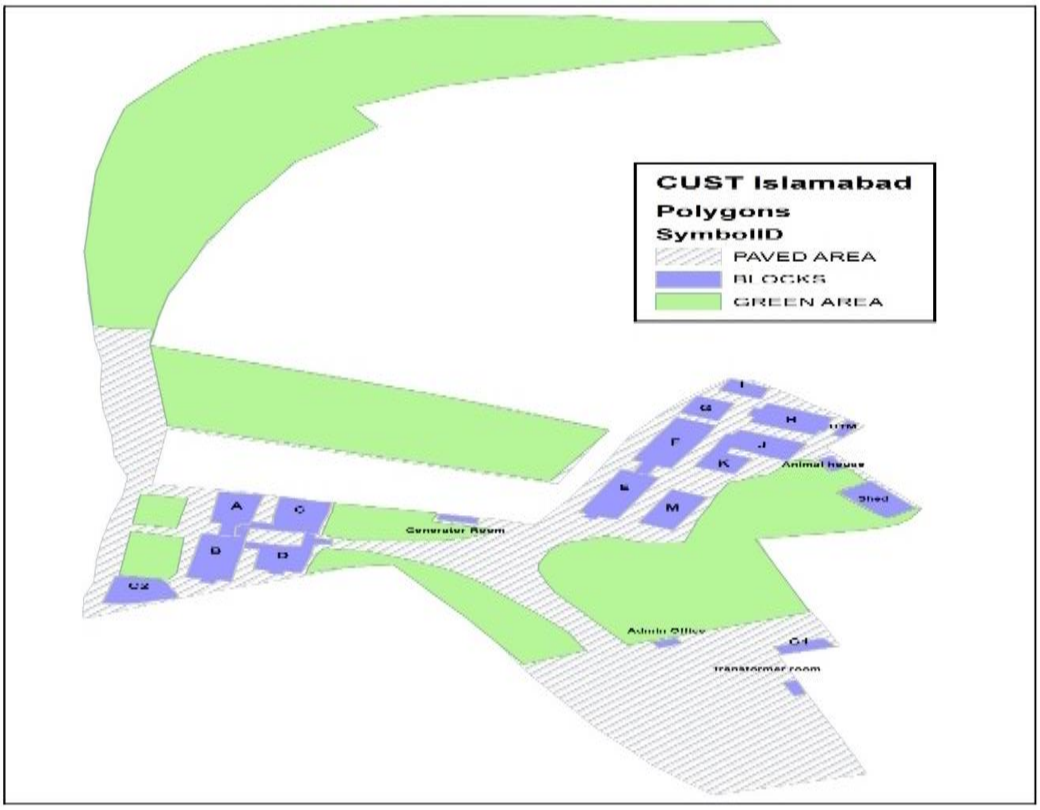

FIGURE 4.7: Shapefile by using ArcMap

TABLE 4.4: Elevations of study area by ArcMap

Sr. No	**Name of Area**	**Types of Material**	**Total Area** (m^2)
1	Paved area	Pavers Tiles	22,326.33
2	Academic Blocks	Concrete	6,638.87
3	Shed	Iron Sheet	464.15
	Total		**29,429.35**

4.3.3 Calculation of Potential for Rainwater Harvesting

Gould and Nissenis used to calculate runoff from a catchment;the equation of which is provided below as equation 3.1. Co-efficient of runoff for rainwater harvesting have different values for different types of material which are given in table 3.1. Volume calculations from impervious and academic blocks are shown in table 4.5 and 4.6 respectively.

Table 4.5: Discharge Calculation of Impervious Area

Sr. No	**Blocks**	**Average Rainfall (R)**	**Area** (m^2)	**Runoff Coefficient "Cr"**	**S=R*A*Cr*** (m^3)**/year**
1	Area 1	1.25	13340	0.85	14173.75
2	Area 2	1.25	4069.75	0.85	4324.109
3	Area 3	1.25	1002.64	0.85	1065.305
4	Area 4	1.25	432.02	0.85	459.021
5	Area 5	1.25	1134.56	0.85	1205.47
6	Area 6	1.25	238.42	0.85	253.321
7	Area 7	1.25	233.95	0.85	248.572
8	Area 8	1.25	100.59	0.85	106.877
9	Area 9	1.25	162.72	0.85	172.89
10	Area 10	1.25	250.25	0.85	265.891
11	Area 11	1.25	268.3	0.85	285.069
12	Area 12	1.25	583.33	0.85	619.788
	Total		**22326.33**		**23180.063**

Table 4.6: Discharge Calculation of all Blocks.

Sr. No	**Blocks**	**Average Rainfall (R)**	**Area** (m^2)	**Runoff Coefficient "Cr"**	**S=R*A*Cr*** (m^3)**/year**
1	Block A	1.25	377.11	0.95	447.818
2	Block B	1.25	621.62	0.95	738.174
3	Block C	1.25	372.6	0.95	442.463
4	Block D	1.25	359.13	0.95	426.467
5	Block E	1.25	726	0.95	862.125
6	Block F	1.25	790.65	0.95	938.897

Sr. No	Blocks	Average Rainfall (R)	Area (m^2)	Runoff Coefficient "Cr"	S=R*A*Cr* (m^3)/year
7	Block G	1.25	349.32	0.95	414.818
8	Block H	1.25	543.43	0.95	645.323
9	Block I	1.25	167.74	0.95	199.191
10	Block J	1.25	563.43	0.95	669.073
11	Block K	1.25	298.44	0.95	354.398
12	Block M	1.25	598.91	0.95	711.206
13	Adman office	1.25	55.87	0.95	66.346
14	Shed (Iron sheet)	1.25	464.15	1	580.188
15	Transformer room	1.25	134.02	0.95	159.149
	Total		**7103.02**		**8434.836**

Table 4.7: Discharge Calculation of Rooftops and Impervious Area

Sr. No	Name of Area	Types of Material	Avg. Rain fall (R)	Area (m^2)	Value of "Cr"	S=R*A*Cr* (m^3)/year
1	Surface area	Paver Tiles	1.25	0.85	22326.33	23,721.73
2	Rooftops	Concrete	1.25	0.95	6638.87	7,883.66
3	Shed	Iron Sheet	1.25	1	464.15	580.19
			Total			**32,185.58**

Table 4.7 gives Discharge calculation of rooftops and impervious area. A value of 1.25m/year has been used as depth of rainwater taken from MET data as shown

in Annexure A.

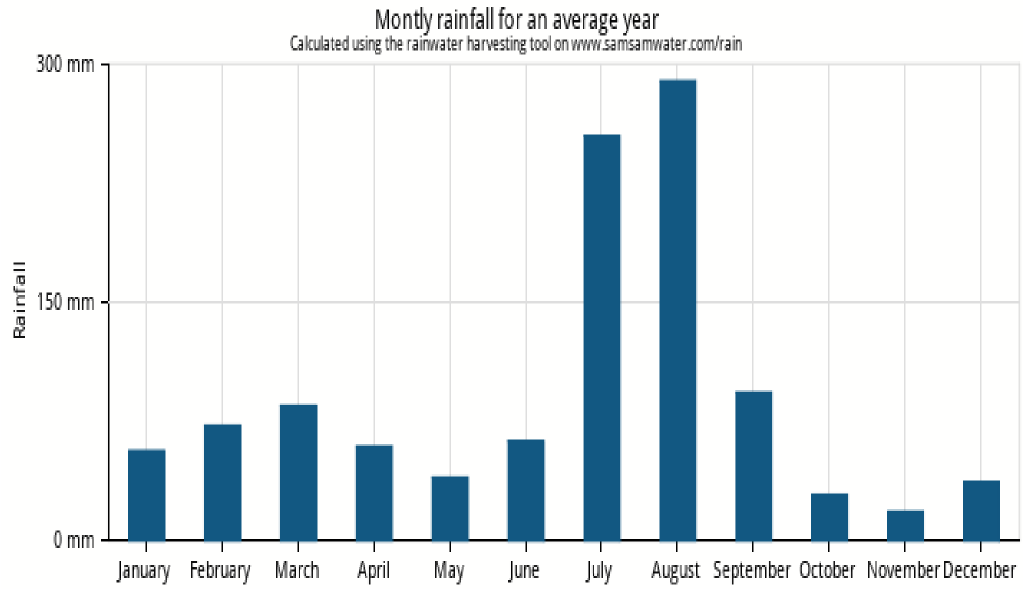

FIGURE 4.8: Monthly rainfall for average year

Fig 4.8 gives the comparison b/w water demand and water supply of the study area.

4.3.4 Calculation of Elevations and Slope

Contour plan of study area is developed by ArcGIS. The elevation points of the area ranging from minimum 446.45m to maximum elevation of 452.18m which shows that natural terrain of study area is flat. Based on the slope, drainage path and elevations overall rainwater harvesting capacity, the study area is divided into three catchments as shown in figure 4.9. Capacity of rainwater harvesting for each catchment is estimated and show in table 4.8.

TABLE 4.8: Capacity of Catchments

Sr. No	**Catchment**	**Blocks and Areas**	**Capacity (m^3)**
1	Catchment 1	E, F, G, H, I, J, K, M, UTM, Shed, Animal house, Area 3 to Area 12.	10,526.14

Sr. No	Catchment	Blocks and Areas	Capacity (m^3)
2	Catchment 2	Area 1, Area 2, Canteen 1, Admin office and Transformer room	18,874.53
3	Catchment 3	A, B, C, D Area 13 and Canteen 2.	2,792.91

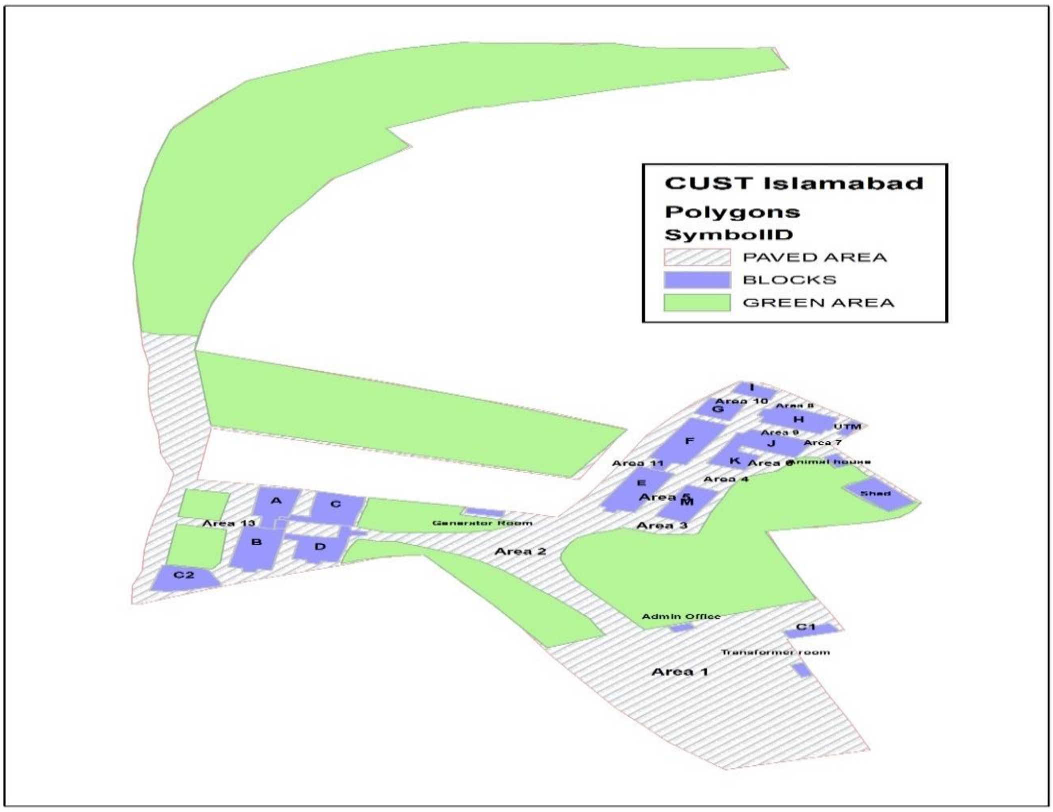

FIGURE 4.9: Impervious Areas Catchment Wise

4.3.5 Estimation of Water Demand

As per data gained from university, the estimated population of students in the campus is 5000, numbers of faculty and staff is 300 and workers are 35 which take residence in the campus.The students and faculty / staff attend the institute for 261 days except the residents which remain available for 365 days. According to the standards, water requirement for universities is 23 lpcd are sufficient.The calculated water requirement of the campus is shown in table 4.9.

TABLE 4.9: Discharge Calculation of Rooftops and Impervious Area

Sr. No	**Population**		**No. of days**	**Per Capita Demand.**	**Total Water Requirement Per Annual**	
				Liters	**Liters**	m^3
1	Students	5000	261	23	30,015,000	30015
2	Faculty and staff	300	261	23	1800900	1800.9
3	Workers	35	365	23	2,93,825	293.825
	Total				**3,21,09725**	**32109.73**

Above calculationsshows that rainwater harvesting potential is 32,185.58 m3 against the water demand of 32109.73m3. This shows that 100% demand of water will be fulfilled through this harvesting technique.

Water available one person = 32185580/5335 = 6032.9 liters/year.

Water available for one student or faculty member = 6032.9/261 = 23.11 liters/day.

From above calculation it is clear that rainwater that could be harvested is that makes 100% of water demand (23lpcd).

4.3.6 Identifying and Recommending Suitable Sites for Rainwater Harvesting

According to the measured the elevations, direction of drainage, slope and from observed runoff of each catchment, rainwater harvesting storage tank sites are identified, recommended and shown as ST1, ST2 and ST3 in figure 4.10.

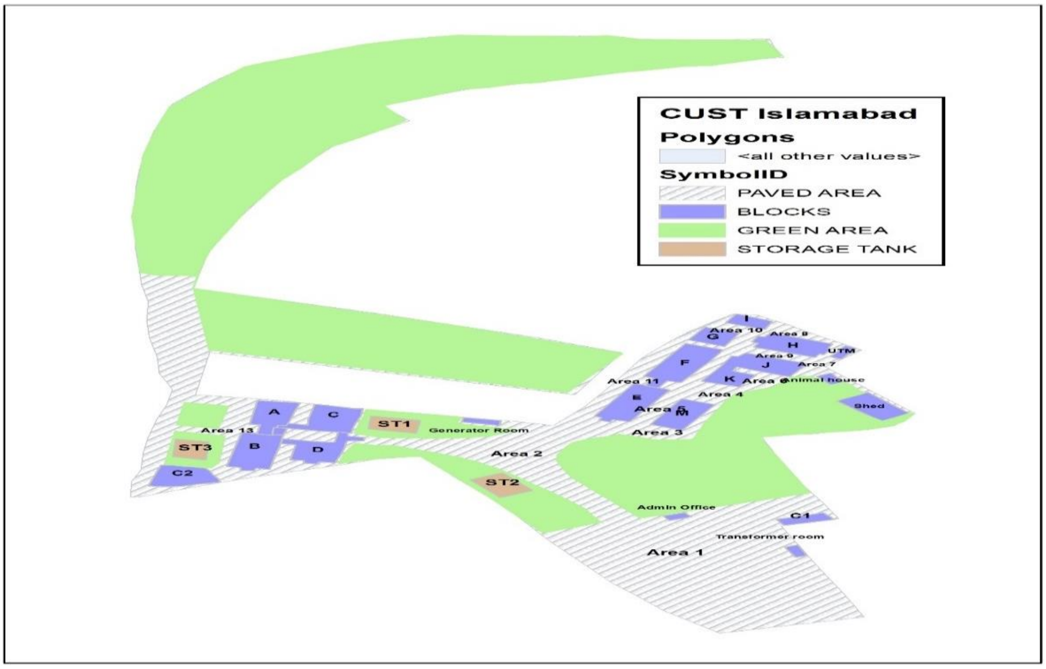

FIGURE 4.10: Location of Storage Tank

4.3.7 Calculation of Storage Tank Capacity Using SamSam Water Rainwater Harvesting Tool

SamSam tool is used to calculate the storage tank size for the catchment. SamSam works out user precipitation data and a weighted C value of 0.70 for user defined area. The capacities of RWH tanks are given in table 4.10.

TABLE 4.10: Storage Tank Size and Capacity

No. of Catchment	**Length (m)**	**Width (m)**	**Depth (m)**	**Total (m^3)**
Catchment 1	44	22	2.7	2614
Catchment 2	58	29	2.7	4541
Catchment 3	24	12	2.7	778

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

Rainwater collection systems, which absorb and use rainfall runoff, are a popular way to combat water shortages by conserving available water supplies and the energy used to transport water to the water supply system. Rainwater collection will also help to mitigate the effects of climate change on water supplies. Rainwater irrigation is becoming an increasingly important aspect of global water supply. Since semi-arid climates have low precipitation and high temperatures, rainwater collection systems would be extremely useful in these regions, at least for non-potable applications such as irrigation and household use.The ability of rainwater harvesting in CUST was studied in this report. The rainwater potential was calculated using the SamSam model. The monthly and hourly rainfall is calculated using daily rainfall data from previous years. Furthermore, a rainwater collection scheme was suggested to show its ability. The reservoir positions were selected based on their relative areas, and reservoir volumes were determined after determining the campus's intake. The study's aim was not to optimize the system; instead, it was to see if there was any room for rainwater harvesting on campus.Since this is a preliminary analysis to determine the feasibility of building a rainwater collection scheme, there is also more work to be done to analyze various facets of the project. This project would entail a cost-benefit review before it can be implemented.This research analyzes the ability to cope with the general demands for water in the campus through rainwater harvesting. In order to accomplish the research goals, Google Earth Pro was used to compute current impervious area (sidewalks and parking) green area and different size rooftops in the campus. ArcMap was employed to measure the elevation and slope of the study area. Potential for rainwater harvesting at campus has estimated by using rational method. Results presented that the rainwater harvesting potential of the CUST campus are 32,185580 liters against the total annual water requirement 3,21,09725 liters. Therefore, it fulfil 100% of the total requirement. Major consumer were students followed by faculty, staff and worker respectively. The above study thus concludes that the rainwater harvesting is a best a technique for water saving in the campus rainwater harvesting play important to resolve the many water issues such as water shortage, flooding and pressure on underground water etc. We should to promote and adapt the rainwater harvesting for the sake of our country because our country facing a big challenges of water shortage.

5.2 Recommendations

In the view of above study some specific recommendations for further research such as:

- Effects of the existing solar panels at the roofs and parking areas on the quality and quantity of rainwater harvesting.

Bibliography

[1] I. Chilvers, *The Oxford dictionary of art and artists.* Oxford University Press, 2009.

[2] S. Mat, K. Sopian, M. Mokhtar, B. Ali, H. S. Hashim, A. K. A. Rashid, M. F. M. Zain, and N. G. Abdullah, "Managing sustainable campus in malaysia-organisational approach and measures," *European Journal of Social Sciences*, vol. 8, no. 2, pp. 201–214, 2009.

[3] R. Razman, A. H. Abdullah, and A. Z. Abdul Wahid, "Sustainable development in higher education institutions (heis): Towards sustainable campus operations (sco)," 2014.

[4] N. Saygin and P. Ulusoy, "Stormwater management and green infrastructure techniques for sustainable campus design," *Politeknik Dergisi*, vol. 14, no. 3, 2011.

[5] M. Bakhshi, M. Mohtashami, and M. H. B. Wahab, "Sustainable drainage system from urban designer perception in university technology malaysia kuala lumpur campus."

[6] M. Abd-Razak, N. Utaberta, and A. N. Handryant, "A study of students perception on sustainability of campus design: A case study of four research universities campus in malaysia," *Research Journal of Environmental and Earth Sciences*, vol. 4, no. 6, pp. 646–657, 2012.

[7] J. D. Allan, "Landscapes and riverscapes: the influence of land use on stream ecosystems," *Annu. Rev. Ecol. Evol. Syst.*, vol. 35, pp. 257–284, 2004.

[8] B. Mark and E. McMahon, "Green infrastructure: Linking landscape and communities," 2006.

[9] J. M. C. da Silva and E. Wheeler, "Ecosystems as infrastructure," *Perspectives in ecology and conservation*, vol. 15, no. 1, pp. 32–35, 2017.

[10] Y. Lim, "The university in a garden: development proposal," *Universiti Sains Malaysia, Pulau Pinang*, p. 19, 2006.

[11] J. Foster, A. Lowe, S. Winkelman *et al.*, "The value of green infrastructure for urban climate adaptation," *Center for Clean Air Policy*, vol. 750, no. 1, pp. 1–52, 2011.

[12] W. Bank, *Water resources management: A World Bank policy paper.* The World Bank, 1993.

[13] R. Lozano, K. Ceulemans, M. Alonso-Almeida, D. Huisingh, F. J. Lozano, T. Waas, W. Lambrechts, R. Lukman, and J. Hugé, "A review of commitment and implementation of sustainable development in higher education: results from a worldwide survey," *Journal of cleaner production*, vol. 108, pp. 1–18, 2015.

[14] R. Roy, S. Potter, and K. Yarrow, "Designing low carbon higher education systems," *International journal of sustainability in higher education*, 2008.

[15] R. Lukman, A. Tiwary, and A. Azapagic, "Towards greening a university campus: The case of the university of maribor, slovenia," *Resources, Conservation and Recycling*, vol. 53, no. 11, pp. 639–644, 2009.

[16] M. Z. Abd Razak, N. A. G. Abdullah, M. F. I. M. Nor, I. M. Usman, and A. I. Che-Ani, "Toward a sustainable campus: comparison of the physical development planning of research university campuses in malaysia," *Journal of Sustainable Development*, vol. 4, no. 4, p. 210, 2011.

[17] M. Martín-Gamboa, D. Iribarren, D. García-Gusano, and J. Dufour, "A review of life-cycle approaches coupled with data envelopment analysis within multi-criteria decision analysis for sustainability assessment of energy systems," *Journal of Cleaner Production*, vol. 150, pp. 164–174, 2017.

[18] R. K. Norton, A. Brix, T. Brydon, E. Davidian, K. Dinse, and S. Vidyarthi, "Transforming the university campus into a sustainable community," *Planning for Higher Education*, vol. 35, no. 4, pp. 22–39, 2007.

[19] F. Nifa, M. Nawi, S. Musa, W. Osman, and M. Rajemi, "Integrated project delivery framework for sustainability in design for campus development: a study on jpp uum," in *joint international conference on nanoscience, Engineering and Management, Penang Malaysia*, 2013, pp. 19–22.

[20] S. S. Y. Lau, Z. Gou, and Y. Liu, "Healthy campus by open space design: Approaches and guidelines," *Frontiers of Architectural Research*, vol. 3, no. 4, pp. 452–467, 2014.

[21] E. Amrina and F. Imansuri, "Key performance indicators for sustainable campus assessment: A case of andalas university," in *Industrial Engineering, Management Science and Applications 2015.* Springer, 2015, pp. 11–18.

[22] S. Payne, "Open space: People space," 2009.

[23] H. M. Alshuwaikhat and I. Abubakar, "An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices," *Journal of cleaner production*, vol. 16, no. 16, pp. 1777–1785, 2008.

[24] G. W. Frasier, "Harvesting water for agricultural, wildlife, and domestic uses," *J. Soil Water Conserv*, vol. 35, no. 3, pp. 125–128, 1980.

[25] A. Oloruntade and P. Oguntunde, "Effective water resources management as a panacea for climate change problems in nigeria," *Journal of Engineering and Earth Sciences*, vol. 3, no. 2, pp. 18–25, 2009.

[26] F. R. Spellman, *Handbook of water and wastewater treatment plant operations.* CRC press, 2013.

[27] L. Domènech and D. Saurí, "A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the metropolitan area of barcelona (spain): social experience, drinking water savings and economic costs," *Journal of Cleaner production*, vol. 19, no. 6-7, pp. 598–608, 2011.

[28] C. Shiguang and Z. Yu, "Water saving potential and economic viability assessment of rainwater harvesting system for four different climatic regions in china," *Water Supply*, vol. 21, no. 1, pp. 386–400, 2021.

[29] P. Syed Azizul Haq, *Harvesting rainwater from Buildings*. Springer, 2016.

[30] A. Emmanuel and M. J. Napoleon, "Rainwater harvesting-a potential safety net for water security in ghana," *Asian Journal of Environment & Ecology*, pp. 1–10, 2019.

[31] S. Opare, "Rainwater harvesting: an option for sustainable rural water supply in ghana," *GeoJournal*, vol. 77, pp. 695–705, 2012.

[32] E. Salameh, "Redefining the water poverty index," *Water International*, vol. 25, no. 3, pp. 469–473, 2000.

[33] F. Molle and P. Mollinga, "Water poverty indicators: conceptual problems and policy issues," *Water policy*, vol. 5, no. 5-6, pp. 529–544, 2003.

[34] D. A. Barnes, "Assessment of rainwater harvesting in northern ghana," Ph.D. dissertation, Massachusetts Institute of Technology, 2009.

[35] V. Kisakye, M. Akurut, and B. Van der Bruggen, "Effect of climate change on reliability of rainwater harvesting systems for kabarole district, uganda," *Water*, vol. 10, no. 1, p. 71, 2018.

[36] M. Karim, B. Sakib, S. Sakib, M. A. Imteaz *et al.*, "Rainwater harvesting potentials in commercial buildings in dhaka: Reliability and economic analysis," *Hydrology*, vol. 8, no. 1, p. 9, 2021.

[37] A. Che-Ani, N. Shaari, A. Sairi, M. Zain, and M. Tahir, "Rainwater harvesting as an alternative water supply in the future," *European Journal of Scientific Research*, vol. 34, no. 1, pp. 132–140, 2009.

[38] D. Adugna, M. B. Jensen, B. Lemma, and G. S. Gebrie, "Assessing the potential for rooftop rainwater harvesting from large public institutions," *International journal of environmental research and public health*, vol. 15, no. 2, p. 336, 2018.

[39] P. Campling, L. De Nocker, W. Schiettecatte, A. Iacovides, T. Dworak, M. Arenas, C. Pozo, O. Le Mat, V. Mattheiß, and F. Kervarec, "Assessment of the risks and impacts of four alternative water supply options," *European CommissionDG Environment: Brussels, Belgium*, 2008.

[40] C. M. Silva, V. Sousa, and N. V. Carvalho, "Evaluation of rainwater harvesting in portugal: Application to single-family residences," *Resources, Conservation and Recycling*, vol. 94, pp. 21–34, 2015.

[41] J. R. Mihelcic, J. B. Zimmerman, and A. Ramaswami, "Integrating developed and developing world knowledge into global discussions and strategies for sustainability. 1. science and technology," 2007.

[42] H. Tan, S. Chen, Q. Shi, and L. Wang, "Development of green campus in china," *Journal of Cleaner Production*, vol. 64, pp. 646–653, 2014.

[43] M. Anis, A. Z. Afiff, G. Kiswanto, N. Suwartha, and R. F. Sari, "Managing university landscape and infrastructure towards green and sustainable campus," in *E3S Web of Conferences*, vol. 48. EDP Sciences, 2018, p. 02001.

[44] N. F. M. NAWI and E. CHOY, "Campus sustainability: A case study in universiti malaysia sabah (ums)," *Journal of Sustainability Science and Management*, vol. 15, no. 1, pp. 113–124, 2020.

[45] R. Tiyarattanachai and N. M. Hollmann, "Green campus initiative and its impacts on quality of life of stakeholders in green and non-green campus universities," *SpringerPlus*, vol. 5, no. 1, pp. 1–17, 2016.

[46] S. Sailaja, C. N. Raju, C. A. Reddy, B. D. P. Raju, Y.-D. Jho, and B. S. Reddy, "Optical properties of sm3+-doped cadmium bismuth borate glasses," *Journal of Molecular Structure*, vol. 1038, pp. 29–34, 2013.

[47] J. Gould, "Contributions relating to rainwater harvesting," *Thematic Review IV*, vol. 3, p. 386, 1999.

[48] M. H. R. Mehrabadi, B. Saghafian, and F. H. Fashi, "Assessment of residential rainwater harvesting efficiency for meeting non-potable water demands

in three climate conditions," *Resources, Conservation and Recycling*, vol. 73, pp. 86–93, 2013.

[49] A. S. Vieira, M. Weeber, and E. Ghisi, "Self-cleaning filtration: A novel concept for rainwater harvesting systems," *Resources, Conservation and Recycling*, vol. 78, pp. 67–73, 2013.

[50] M. Yalçıntaş, M. Bulu, M. Küçükvar, and H. Samadi, "A framework for sustainable urban water management through demand and supply forecasting: The case of istanbul," *Sustainability*, vol. 7, no. 8, pp. 11 050–11 067, 2015.

[51] A. Ammar, M. Riksen, M. Ouessar, and C. Ritsema, "Identification of suitable sites for rainwater harvesting structures in arid and semi-arid regions: A review," *International Soil and Water Conservation Research*, vol. 4, no. 2, pp. 108–120, 2016.

[52] W. Ahmed, C. Staley, K. Hamilton, D. Beale, M. Sadowsky, S. Toze, and C. Haas, "Amplicon-based taxonomic characterization of bacteria in urban and peri-urban roof-harvested rainwater stored in tanks," *Science of the Total Environment*, vol. 576, pp. 326–334, 2017.

[53] D. Maktav, F. Erbek, and C. Jürgens, "Remote sensing of urban areas," *International Journal of Remote Sensing*, vol. 26, no. 4, pp. 655–659, 2005.

[54] M. Murase, "Creating a rainwater utilisation based society for sustainable development," in *Proceedings of the international symposium on efficient water use in urban areas*, 1999, pp. 107–120.

[55] J. Heyer, "Agricultural development policy in kenya from the colonial period to 1975," in *Rural development in tropical Africa.* Springer, 1981, pp. 90–120.

[56] H. Asegedech, "Determinants of child malnutrition: A case study in central zone of tigray, northern ethiopia," Ph.D. dissertation, Mekelle University, 2014.

[57] W. Critchley, K. Siegert, C. Chapman, and M. Finkel, "Water harvesting," *FAO, Rome*, 1991.

[58] R. Farreny, T. Morales-Pinzón, A. Guisasola, C. Tayà, J. Rieradevall, and X. Gabarrell, "Roof selection for rainwater harvesting: quantity and quality assessments in spain," *Water research*, vol. 45, no. 10, pp. 3245–3254, 2011.

[59] C. Reij, P. Mulder, and L. Begemann, "Water harvesting for plant production," 1988.

[60] S. N. Ngigi, H. H. Savenije, and F. N. Gichuki, "Hydrological impacts of flood storage and management on irrigation water abstraction in upper ewaso ngiro river basin, kenya," *Water resources management*, vol. 22, no. 12, pp. 1859–1879, 2008.

[61] D. J. Flower, V. G. Mitchell, G. P. Codner *et al.*, "Urban water systems: drivers of climate change?" *Rainwater and Urban Design 2007*, p. 274, 2007.

[62] S. Sharma, S. K. Sharma, M. Mehta, and S. Marwaha, "Guide on artificial recharge to ground water," *Central Ground Water Board, Ministry of Water Resources, Government of India, New Delhi*, 2000.

[63] J. Barron, *Rainwater harvesting: a lifeline for human well-being.* UNEP/Earthprint, 2009.

[64] N. Rostad, R. Foti, and F. A. Montalto, "Harvesting rooftop runoff to flush toilets: Drawing conclusions from four major us cities," *Resources, Conservation and Recycling*, vol. 108, pp. 97–106, 2016.

[65] D. Prinz, "Global and european water challenges in the 21st century. keynote speech," in *Proceedings, 3rd Inter-Regional Conference on Environment-Water Water Resources Management in the 21st Century*, 2000, pp. 1–3.

[66] S. R. Ali and R. Jain, "Rain water harvesting system for college of engineering, teerthanker mahaveer university, moradabad," *Int J Innov Res Sci Eng Technol*, vol. 3, no. 8, pp. 15 649–15 657, 2014.

[67] H. Bruins, M. Evenari, and U. Nessler, "Rainwater-harvesting agriculture for food production in arid zones: the challenge of the african famine," *Applied Geography*, vol. 6, no. 1, pp. 13–32, 1986.

[68] S. Hoseini and V. Attarzadeh Hosseini, "Rainwater harvesting in residential areas of arid and semi-arid regions (case study: Torbat-e jam, iran)," *Desert*, vol. 25, no. 2, pp. 130–138, 2020.

[69] T. Herrmann and U. Schmida, "Rainwater utilisation in germany: efficiency, dimensioning, hydraulic and environmental aspects," *Urban water*, vol. 1, no. 4, pp. 307–316, 2000.

[70] E. Ghisi, A. Montibeller, and R. W. Schmidt, "Potential for potable water savings by using rainwater: An analysis over 62 cities in southern brazil," *Building and Environment*, vol. 41, no. 2, pp. 204–210, 2006.

[71] E. Ghisi, J. A. Tinker, and S. H. Ibrahim, "Área de janela e dimensões de ambientes para iluminação natural e eficiência energética: literatura versus simulação computacional," *Ambiente Construído*, vol. 5, no. 4, pp. 81–93, 2005.

[72] M. B. Ibrahim, "Rainwater harvesting for urban areas: a success story from gadarif city in central sudan," *Water resources management*, vol. 23, no. 13, pp. 2727–2736, 2009.

[73] W. Janette and H. Tim, "Rainwater harvesting for domestic use," *Digigrafi, Wageningen, The Netherlands*, 2006.

[74] A. Akter and S. Ahmed, "Potentiality of rainwater harvesting for an urban community in bangladesh," *Journal of Hydrology*, vol. 528, pp. 84–93, 2015.

[75] M. A. Imteaz, A. Ahsan, J. Naser, and A. Rahman, "Reliability analysis of rainwater tanks in melbourne using daily water balance model," *Resources, Conservation and Recycling*, vol. 56, no. 1, pp. 80–86, 2011.

[76] M. A. Imteaz, A. Ahsan, and A. Shanableh, "Reliability analysis of rainwater tanks using daily water balance model: Variations within a large city," *Resources, conservation and Recycling*, vol. 77, pp. 37–43, 2013.

[77] J. Mun and M. Han, "Design and operational parameters of a rooftop rainwater harvesting system: definition, sensitivity and verification," *Journal of Environmental Management*, vol. 93, no. 1, pp. 147–153, 2012.

[78] A. Belmeziti, O. Coutard, and B. De Gouvello, "A new methodology for evaluating potential for potable water savings (ppws) by using rainwater harvesting at the urban level: The case of the municipality of colombes (paris region)," *Water*, vol. 5, no. 1, pp. 312–326, 2013.

[79] T. A. Mohammed, M. Noor, and A. H. Ghazali, "Study on potential uses of rainwater harvesting in urban areas," in *Proceedings of the colloquium on rainwater utilisation, Putrajaya, Malaysia, 19&20 April*, 2007.

[80] S. Heileman, S. R. King *et al.*, "Terminal evaluation of the unep/gef project addressing transboundary concerns in the volta river basin and its downstream coastal area," 2016.

[81] S. Plan, "Annual report for the ithaca campus (2013),," *Sustainability: Today and Tomorrow, Cornell University*.

[82] S. Durdyev, S. Ismail, A. Ihtiyar, N. F. S. A. Bakar, and A. Darko, "A partial least squares structural equation modeling (pls-sem) of barriers to sustainable construction in malaysia," *Journal of cleaner production*, vol. 204, pp. 564–572, 2018.

[83] C. Silva and C. Oliveira, "Runoff measurement and prediction for a watershed under natural vegetation in central brazil," 1999.

[84] A. Campisano, D. Butler, S. Ward, M. J. Burns, E. Friedler, K. DeBusk, L. N. Fisher-Jeffes, E. Ghisi, A. Rahman, H. Furumai *et al.*, "Urban rainwater harvesting systems: Research, implementation and future perspectives," *Water research*, vol. 115, pp. 195–209, 2017.

[85] S. M. Dos Santos and M. M. M. de Farias, "Potential for rainwater harvesting in a dry climate: Assessments in a semiarid region in northeast brazil," *Journal of Cleaner Production*, vol. 164, pp. 1007–1015, 2017.

[86] F. A. Abdulla and A. W. Al-Shareef, "Roof rainwater harvesting systems for household water supply in jordan," *Desalination*, vol. 243, no. 1-3, pp. 195–207, 2009.

[87] A. K. Misra, "Climate change and challenges of water and food security," *International Journal of Sustainable Built Environment*, vol. 3, no. 1, pp. 153–165, 2014.

[88] V. R. Barros, C. B. Field *et al.*, "Climate change 2014: impacts, adaptation, and vulnerability. part b: regional aspects," 2014.

[89] N. Mizyed, "Impacts of climate change on water resources availability and agricultural water demand in the west bank," *Water Resources Management*, vol. 23, no. 10, pp. 2015–2029, 2009.

[90] D. Molden, *Water for food water for life: A comprehensive assessment of water management in agriculture.* Routledge, 2013.

[91] C. Chikozho, "Policy and institutional dimensions of small-holder farmer innovations in the thukela river basin of south africa and the pangani river basin of tanzania: A comparative perspective," *Physics and Chemistry of the Earth, Parts A/B/C*, vol. 30, no. 11-16, pp. 913–924, 2005.

[92] I. A. Shiklomanov, "Appraisal and assessment of world water resources," *Water international*, vol. 25, no. 1, pp. 11–32, 2000.

[93] T. Oweis, A. Hachum, A. Bruggeman *et al.*, "Indigenous water-harvesting systems in west asia and north africa." *Indigenous water-harvesting systems in West Asia and North Africa.*, 2004.

[94] F. Molle, "water for food, water for life: A comprehensive assessment of water management in agriculture david molden (ed.)," *Natures Sciences Sociétés*, vol. 16, no. 3, pp. 274–275, 2008.

[95] K. C. Wong, G. M. Luscombe, and C. Hawke, "Influenza infections in australia 2009–2015: is there a combined effect of age and sex on susceptibility to virus subtypes?" *BMC infectious diseases*, vol. 19, no. 1, pp. 1–10, 2019.

[96] K. Kim and C. Yoo, "Hydrological modeling and evaluation of rainwater harvesting facilities: case study on several rainwater harvesting facilities in korea," *Journal of Hydrologic Engineering*, vol. 14, no. 6, pp. 545–561, 2009.

[97] T. Thomas, "Domestic water supply using rainwater harvesting," *Building Research & Information*, vol. 26, no. 2, pp. 94–101, 1998.

[98] L. Too and B. Bajracharya, "Sustainable campus: engaging the community in sustainability," *International Journal of Sustainability in Higher Education*, 2015.

[99] U. R. Patel, V. A. Patel, M. I. Balya, and H. M. Rajgor, "Rooftop rainwater harvesting (rrwh) at spsv campus, visnagar, gujarat–a case study," *Int. J. Res. Eng. Technol*, vol. 3, no. 04, pp. 821–825, 2014.

[100] R. AbdelKhaleq and I. Alhaj Ahmed, "Rainwater harvesting in ancient civilizations in jordan," *Water Science and Technology: Water Supply*, vol. 7, no. 1, pp. 85–93, 2007.

[101] E. Agency, "Harvesting rainwater for domestic uses: An information guide," 2003.

[102] D. Wisdom, "Rise, fall and potential of indias traditional water harvesting systems," *New Delhi: Centre for Science and Environment*, 1997.

[103] K. A. Mourad and R. Berndtsson, "Potential water saving from rainwater harvesting in syria," *Vatten: tidskrift för vattenvård/Journal of Water Management and research*, vol. 67, no. 2, pp. 113–117, 2011.

[104] S. Ward, F. Memon, and D. Butler, "Performance of a large building rainwater harvesting system," *Water research*, vol. 46, no. 16, pp. 5127–5134, 2012.

[105] N. L. Cain, "A different path: The global water crisis and rainwater harvesting," *Consilience*, no. 12, pp. 147–157, 2014.

[106] K. Faza and N. Suwartha, "The effect of roof surface area on the quality and quantity of rainwater runoff in the rainwater harvesting system," in *IOP Conference Series: Earth and Environmental Science*, vol. 623, no. 1. IOP Publishing, 2021, p. 012010.

[107] P. Melville-Shreeve, S. Ward, and D. Butler, “Rainwater harvesting typologies for uk houses: a multi criteria analysis of system configurations,” *Water*, vol. 8, no. 4, p. 129, 2016.

[108] I. Hassan, “Rainwater harvesting-an alternative water supply in the future for pakistan,” *Journal of Biodiversity and Environmental Sciences*, vol. 8, no. 6, pp. 213–222, 2016.

[109] D. Omole and O. Okunowo, “People perception of domestic water supply situation in ogun state, nigeria,” *Research Journal of Applied Sciences, Engineering and Technology*, vol. 12, no. 1, pp. 94–99, 2016.

[110] K. Li, M. Coe, N. Ramankutty, and R. De Jong, “Modeling the hydrological impact of land-use change in west africa,” *Journal of hydrology*, vol. 337, no. 3-4, pp. 258–268, 2007.

[111] R. Reitano, “Water harvesting and water collection systems in mediterranean area. the case of malta,” *Procedia Engineering*, vol. 21, pp. 81–88, 2011.

[112] H. Traboulsi and M. Traboulsi, “Rooftop level rainwater harvesting system,” *Applied Water Science*, vol. 7, no. 2, pp. 769–775, 2017.

[113] O. Rashid, F. Awan, Z. Ullah, and I. Hassan, “Rainwater harvesting, a measure to meet domestic water requirement; a case study islamabad, pakistan.” in *IOP Conference Series: Materials Science and Engineering*, vol. 414, no. 1. IOP Publishing, 2018, p. 012018.

[114] P. Li and H. Qian, “Water resources research to support a sustainable china,” 2018.

[115] D. Hari, “Estimation of rooftop rainwater harvesting potential using applications of google earth pro and gis,” *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 9, pp. 2278–3075, 2019.

[116] D. Hari, K. R. Reddy, K. Vikas, N. Srinivas, and G. Vikas, "Assessment of rainwater harvesting potential using gis," in *IOP Conference Series: Materials Science and Engineering*, vol. 330, no. 1. IOP Publishing, 2018, p. 012119.

[117] C. Mansfield, M. Alloy, J. Hamilton, G. Verbeck, K. Newton, S. Klaine, and A. Roberts, "Photo-induced toxicity of titanium dioxide nanoparticles to daphnia magna under natural sunlight," *Chemosphere*, vol. 120, pp. 206–210, 2015.

[118] E. Sazakli, A. Alexopoulos, and M. Leotsinidis, "Rainwater harvesting, quality assessment and utilization in kefalonia island, greece," *Water research*, vol. 41, no. 9, pp. 2039–2047, 2007.

[119] E. De Pauw, F. Nachtergaele, J. Antoine, G. Fisher, and H. Velthuizen, "A provisional world climatic resource inventory based on the length-of-growing-period concept," *National soil reference collections and databases (NASREC)*, pp. 30–43, 1996.

[120] P. Martin, D. McKenzie, R. Netterfield, P. Swift, S. Filipczuk, K. Müller, C. Pacey, and B. James, "Characteristics of titanium arc evaporation processes," *Thin Solid Films*, vol. 153, no. 1-3, pp. 91–102, 1987.

[121] L. Willuweit and J. J. O'Sullivan, "A decision support tool for sustainable planning of urban water systems: Presenting the dynamic urban water simulation model," *Water research*, vol. 47, no. 20, pp. 7206–7220, 2013.

[122] H. Tavakol-Davani, E. Goharian, C. H. Hansen, H. Tavakol-Davani, D. Apul, and S. J. Burian, "How does climate change affect combined sewer overflow in a system benefiting from rainwater harvesting systems?" *Sustainable cities and society*, vol. 27, pp. 430–438, 2016.

[123] F. Molle, P. P. Mollinga, and P. Wester, "Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power," *Water alternatives*, vol. 2, no. 3, pp. 328–349, 2009.

[124] B. A. Gyampoh, M. Idinoba, and S. Amisah, "Water scarcity under a changing climate in ghana: options for livelihoods adaptation," *Development*, vol. 51, no. 3, pp. 415–417, 2008.

[125] W. W. A. P. U. Nations), *Water: A shared responsibility.* Berghahn Books, 2006, vol. 2.

[126] A. Morey, B. Dhurve, V. Haste, and B. Wasnik, "Rainwater harvesting system," *International Research Journal of Engineering and Technology*, vol. 3, no. 4, pp. 2158–2162, 2016.

[127] D. N. Chakkaravarthy and T. Balakrishnan, "Water scarcity-challenging the future," *International Journal of Agriculture, Environment and Biotechnology*, vol. 12, no. 3, pp. 187–193, 2019.

[128] P. C. Van Metre and B. J. Mahler, "The contribution of particles washed from rooftops to contaminant loading to urban streams," *Chemosphere*, vol. 52, no. 10, pp. 1727–1741, 2003.

[129] C. Hart and D. White, "Water quality and construction materials in rainwater catchments across alaska," *Journal of Environmental Engineering and Science*, vol. 5, no. S1, pp. S19–S25, 2006.

[130] V. W. Tam, L. Tam, and S. Zeng, "Cost effectiveness and tradeoff on the use of rainwater tank: An empirical study in australian residential decision-making," *Resources, conservation and recycling*, vol. 54, no. 3, pp. 178–186, 2010.

[131] B. Chocat, "Techniques alternatives," *Encyclopédie de lhydrologie urbaine et de lassainissement, Eurydice*, vol. 92, 1997.

[132] T. Buettner, "Urban estimates and projections at the united nations: The strengths, weaknesses, and underpinnings of the world urbanization prospects," *Spatial Demography*, vol. 3, no. 2, pp. 91–108, 2015.

[133] M. C. Fragkou, T. Vicent, and X. Gabarrell, "Artificial water flow accounting in a mediterranean coastal region," *Environmental Growth: A Global Perspective*, p. 81, 2009.

[134] S. Ward, S. Barr, F. Memon, and D. Butler, "Rainwater harvesting in the uk: exploring water-user perceptions," *Urban Water Journal*, vol. 10, no. 2, pp. 112–126, 2013.

[135] L. Partzsch, "Smart regulation for water innovation–the case of decentralized rainwater technology," *Journal of Cleaner Production*, vol. 17, no. 11, pp. 985–991, 2009.

[136] D. Park and M.-J. Um, "Sustainability index evaluation of the rainwater harvesting system in six us urban cities," *Sustainability*, vol. 10, no. 1, p. 280, 2018.

[137] E. Feleki, C. Vlachokostas, and N. Moussiopoulos, "Characterisation of sustainability in urban areas: An analysis of assessment tools with emphasis on european cities," *Sustainable cities and society*, vol. 43, pp. 563–577, 2018.

[138] T. Hill and G. Symmonds, "Sustained water conservation by combining incentives, data and rates to effect consumer behavioural change," *WIT Transactions on Ecology and the Environment*, vol. 153, pp. 409–420, 2011.

[139] S. K. Gupta, *Modern hydrology and sustainable water development.* John Wiley & Sons, 2011.

[140] L. Hanson and R. Vogel, "Generalized storage–reliability–yield relationships for rainwater harvesting systems," *Environmental Research Letters*, vol. 9, no. 7, p. 075007, 2014.

[141] C. Batchelor, C. Fonseca, and S. Smits, "Life-cycle costs of rainwater harvesting systems," *The Hague, NL: IRC International Water and Sanitation Centre*, 2011.

[142] J. A. Bouma, S. S. Hegde, and R. Lasage, "Assessing the returns to water harvesting: A meta-analysis," *Agricultural water management*, vol. 163, pp. 100–109, 2016.

[143] M. Van der Sterren, A. Rahman, and G. R. Dennis, "Implications to stormwater management as a result of lot scale rainwater tank systems:

a case study in western sydney, australia," *Water Science and Technology*, vol. 65, no. 8, pp. 1475–1482, 2012.

[144] A. Gerolin, R. Kellagher, and M. Faram, "Rainwater harvesting systems for stormwater management: Feasibility and sizing considerations for the uk, proceedings of novatech 2010," *Lyon, France*.

[145] A. Teston, C. A. Teixeira, E. Ghisi, and E. B. Cardoso, "Impact of rainwater harvesting on the drainage system: Case study of a condominium of houses in curitiba, southern brazil," *Water*, vol. 10, no. 8, p. 1100, 2018.

[146] A. Palla, I. Gnecco, and P. La Barbera, "The impact of domestic rainwater harvesting systems in storm water runoff mitigation at the urban block scale," *Journal of environmental management*, vol. 191, pp. 297–305, 2017.

[147] R. N. Concepcion, S. M. Contreras, W. B. Sanidad, A. B. Gesite, G. P. Nilo, K. A. Salandanan, K. M. Manalang, and S. V. de Vera, "Enhancing multifunctionality of agriculture through rainwater harvesting system," *Paddy and Water Environment*, vol. 4, no. 4, pp. 235–243, 2006.

[148] I. A. Ibrahim, "Investigation of rainwater harvesting techniques in yatta district, kenya," Ph.D. dissertation, Master thesis, Nairobi: Jomo Kenyatta University of Agriculture And Technology, 2012.

[149] S. Water, W. H. Organization *et al.*, "Guidelines for drinking-water quality. vol. 1, recommendations," 2004.

[150] P. Coombes, "Integrated water cycle management in australia," in *Proceedings of the Rainwater Harvesting Workshop*, 2005.

[151] A. Gerolin, "Darwins pious idea. why the ultra-darwinists and creationists both get it wrong," 2011.

[152] L. Liuzzo, V. Notaro, and G. Freni, "A reliability analysis of a rainfall harvesting system in southern italy," *Water*, vol. 8, no. 1, p. 18, 2016.

[153] M. Han, "Rainwater harvesting: A new paradigm to meet mdg and sustainability," in *Proceedings of the 1st International Rainwater Harvesting Workshop*, 2004, pp. 1–8.

[154] R. Van Veenhuizen *et al.*, "Cities farming for the future," *Cities farming for future, Urban Agriculture for green and productive cities,(p 2-17). RUAF Foundation, IDRC and IIRP, ETC-Urban agriculture, Leusden, The Netherlands*, 2006.

[155] G. Schulze, "Cistern based water supply in rural areas in low developed countries," *Low Cost Technology–Specialized Con ference of International Water Supply Association. Berlin, West Germany*, 1981.

[156] R. Roebuck, C. Oltean-Dumbrava, and S. Tait, "Whole life cost performance of domestic rainwater harvesting systems in the united kingdom," *Water and Environment Journal*, vol. 25, no. 3, pp. 355–365, 2011.

[157] N. Board, *Cultivation of fruits, vegetables and floriculture.* NIIR PROJECT CONSULTANCY SERVICES, 2005.

[158] M. Rathore, "Groundwater exploration and augmentation efforts in rajasthan–a review," *Institute of Development Studies, Jaipur, India*, 2005.

[159] V. Pawar-Patil and S. P. Mali, "Potential roof rain water harvesting in pirwadi village of kolhapur district, maharashtra (india)-a geospatial approach," *Journal of Research in Humanities and Social Sciences*, vol. 1, no. 4, pp. 19–24, 2013.

[160] W. Bank, "Pakistan strategic country environmental assessment," 2006.

[161] M. Arza-García, M. Gil-Docampo, J. Ortiz-Sanz, and S. Martínez-Rodríguez, "Virtual globes for uav-based data integration: Sputnik gis and google earth applications," *International Journal of Digital Earth*, vol. 12, no. 5, pp. 583–593, 2019.

[162] B. T. Taylor, P. Fernando, A. E. Bauman, A. Williamson, J. C. Craig, and S. Redman, "Measuring the quality of public open space using google earth," *American journal of preventive medicine*, vol. 40, no. 2, pp. 105–112, 2011.

[163] S. D. Setiasih, "Penggunaan model inkuiri untuk meningkatkan hasil belajar siswa pada materi sifat-sifat magnet di kelas v sdn sukajaya kecamatan jatinunggal kabupaten sumedang," Ph.D. dissertation, UNIVERSITAS PENDIDIKAN INDONESIA, 2016.

[164] A. Arda, S. Saehana, D. Darsikin *et al.*, "Pengembangan media pembelajaran interaktif berbasis komputer untuk siswa smp kelas viii," *Mitra Sains*, vol. 3, no. 1, pp. 69–77, 2015.

[165] G. F. White, D. J. Bradley, and A. U. White, "Drawers of water: domestic water use in east africa," *Bulletin of the World Health Organization*, vol. 80, pp. 63–73, 2002.

[166] R. M. Putri, E. Risdianto, and N. Rohadi, "Pengembangan media pembelajaran interaktif dengan menggunakan adobe captivate pada materi gerak harmonik sederhana," *Jurnal Kumparan Fisika*, vol. 2, no. 2, pp. 113–120, 2019.

[167] Z. Zulhelmi, A. Adlim, and M. Mahidin, "Pengaruh media pembelajaran interaktif terhadap peningkatkan keterampilan berpikir kritis siswa," *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, vol. 5, no. 1, pp. 72–80, 2017.

[168] S. Even, "Moving in (to) imaginary worlds: Drama pedagogy for foreign language teaching and learning," *Die Unterrichtspraxis/Teaching German*, vol. 41, no. 2, pp. 161–170, 2008.

[169] M. Giordano, "Global groundwater? issues and solutions," *Annual review of Environment and Resources*, vol. 34, pp. 153–178, 2009.

[170] J. Malczewski, "Gis-based land-use suitability analysis: a critical overview," *Progress in planning*, vol. 62, no. 1, pp. 3–65, 2004.

[171] I. Seth, P. Soonthornnonda, and E. R. Christensen, "Use of gis in urban storm-water modeling," 2006.

[172] A. Padmavathy, K. G. Raj, N. Yogarajan, P. Thangavel, and M. Chandrasekhar, "Checkdam site selection using gis approach," *Advances in Space Research*, vol. 13, no. 11, pp. 123–127, 1993.

[173] H. Tay and N. R. Afshar, "Evaluation of runoff coefficient (samarahan basin)," in *International engineering conference, energy and environment (ENCON 2014) Copyright© 2014 Editor (s), ENCON 2014*, 2014.

Appendix A

MET Data of Islamabad

Islamabad													
Year	Jan	Feb	Mar	Apr.	May	Jun	July	Aug.	Sep	Oct	Nov	Dec	mean
1971	21.6	56.6	11.2	79.0	26.9	239.0	169.9	389.6	75.7	1.3	12.2	8.1	1091.1
1972	72.6	48.3	108.2	67.8	19.0	51.8	40.6	81.5	113.8	74.2	18.8	73.4	770.0
1973	62.7	80.3	75.7	24.6	52.1	111.3	370.1	403.4	93.5	14.2	3.6	19.3	1310.8
1974	32.8	53.8	35.8	15.9	27.0	99.8	477.9	210.1	56.8	0.0	0.0	32.7	1042.6
1975	39.2	59.0	63.6	42.7	33.1	18.0	235.7	391.3	153.6	0.0	0.0	5.8	1042.0
1976	115.9	208.4	117.3	65.0	3.0	33.3	366.9	442.5	202.5	40.1	0.0	1.0	1595.9
1977	72.2	15.2	12.9	54.6	61.0	142.9	618.1	254.4	38.3	19.3	23.3	20.7	1332.9
1978	50.4	32.0	100.1	23.3	14.3	139.8	258.9	496.9	171.7	69.0	70.2	4.1	1430.7
1979	78.2	102.3	171.5	14.1	40.7	28.8	118.5	231.0	97.6	17.3	36.0	22.6	958.6
1980	92.8	93.4	125.8	15.6	23.6	80.0	309.8	189.7	86.2	36.6	14.6	16.0	1084.1
1981	159.8	73.4	224.0	84.1	109.6	19.4	580.2	338.3	131.3	10.0	5.0	0.0	1735.1
1982	74.4	87.3	186.4	191.0	101.7	18.9	159.1	641.4	41.7	25.7	83.0	24.3	1634.9
1983	131.3	51.5	80.7	264.9	26.2	49.4	258.3	582.2	193.0	74.0	2.5	0.0	1714.0
1984	0.0	112.4	75.3	39.6	10.0	202.2	306.2	245.2	131.5	0.0	3.6	16.4	1142.4
1985	54.0	4.5	47.0	47.4	30.4	8.1	456.6	220.4	63.3	37.7	10.7	143.8	1123.9
1986	12.2	149.1	112.6	66.3	29.9	91.8	85.5	172.9	73.0	57.6	40.3	46.2	937.4
1987	0.5	133.8	72.7	51.9	99.0	27.1	63.4	264.5	1.3	74.4	0.0	7.0	795.6
1988	17.1	23.2	153.3	6.9	8.6	97.7	450.4	282.1	126.1	31.2	0.0	72.4	1269.0
1989	67.6	10.7	71.5	12.7	5.3	57.0	365.2	369.5	28.4	3.8	2.0	50.5	1044.2
1990	41.1	105.1	160.2	55.3	TRACE	29.4	327.4	436.0	168.3	21.1	7.9	177.9	1529.7
1991	9.2	106.8	103.9	116.6	16.8	88.6	251.8	264.2	211.5	3.3	3.8	17.1	1193.6
1992	99.2	91.3	119.1	30.5	36.8	14.5	256.7	305.0	257.9	9.0	34.0	7.9	1261.9
1993	36.4	30.0	140.6	22.0	44.7	77.8	152.7	211.2	93.5	6.0	15.4	TRACE	830.3
1994	36.1	51.4	36.0	69.3	36.0	54.8	596.7	637.7	56.2	29.8	1.0	93.2	1698.2
1995	31.5	99.8	104.3	107.4	17.2	20.5	743.3	331.8	39.8	64.6	20.0	35.0	1615.2
1996	80.5	135.9	143.0	36.3	43.4	138.3	199.9	411.7	118.3	57.8	3.4	7.6	1376.1
1997	39.0	20.3	84.3	172.2	46.1	64.7	194.8	496.4	158.0	95.8	22.4	19.8	1413.8
1998	36.7	248.8	75.8	110.0	29.6	27.3	306.0	428.4	138.0	11.0	0.0	TRACE	1411.6
1999	83.1	35.5	80.8	2.0	22.1	33.0	232.3	334.0	145.0	9.5	35.0	0.0	1012.3
2000	129.0	70.6	18.0	2.5	11.0	37.0	207.0	381.0	129.0	0.0	TRACE	14.0	999.1
	1777.1	2390.7	2911.6	1891.5	1025.1	2102.2	9159.9	10444.3	3394.8	894.3	468.7	936.8	37397.0
	59.2	79.7	97.1	63.1	34.2	70.1	305.3	348.1	113.2	29.8	15.6	31.2	1246.6
1246.6 mm/year=1.25 m/year													