MONITORING ENVIRONMENTAL CONDITIONS FOR URBAN TREES PLANTATION AND GROWTH USING INTERNET OF THINGS (IOT): THE CASE OF GREEN LEGACY PROGRAM

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By

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ACCEPTANCE

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DECLARATION

I, the undersigned, declare that this thesis work is my original work, has not been presented for a degree in this or any other universities, and all sources of materials used for the thesis work have been duly acknowledged.

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ABBREVIATIONS

3GPP ------------------------Third Generation Partnership Project
DS ------------------------Design Science
ETSI ------------------------European Telecommunication Standards
GIS ------------------------Geographic Information System
GSM ------------------------Global Subscribe Module
GPS ------------------------Global Positioning System
GPRS ------------------------General Packet Radio Service
IERC ------------------------The IoT European Research Cluster
ICT ------------------------Information Communication Technology
IDE ------------------------Integrated Development Environment
IoT ------------------------Internet of Things
IPv6 ------------------------Internet Protocol Version 6
ITU ------------------------International Telecommunication Union
M2M ------------------------Machine to Machine Communication
MQTT ------------------------Message Queuing Telemetry Transport
NIST ------------------------National Institute of Standard Technology
NFC ------------------------Near Field Communication
RFID ------------------------Radio Frequency Identification
TIA ------------------------Telecommunications Industry Association
UC ------------------------Ubiquitous Computing
WSN ------------------------Wireless Sensor Networks

ABSTRACT

The Ethiopian Government planned to plant 5 billion seedlings this year. Over four billion were reportedly planted in the First Green Legacy Campaign organized in 2019 during the Ethiopian rainy season, which runs from the beginning of June to end of August. However, planting trees across Ethiopia is that it might have the opposite of a beneficial effect, and could even threaten some of the country's ecosystems. Information about stewardship activities such as, watering, treating like air pollution removal, and plantation site improvements are also seldom track consistently after trees are planted despite research demonstrating that such activities may directly affect the health and growth of the trees. Thus, there was a need to design a solution for monitoring environmental condition using the state-of-the-art technologies. In this research a Design science research methodology was used to design and developed an IoT based prototype for monitoring environmental conditions, in order to manage and control urban trees plantation and growth. In the study different devices and technologies were interconnected to creating an embedded system and collect real time data in the field. The systems inter-connected were GSM/GPRS module, Grove Sensors, DHT11 sensor, Arduino microcontroller and ThingSpeak platform. The results of the study show that the automation process using IoT in environmental condition monitoring for urban trees plantation and growth reduced human interaction and improve the efficiency. Testing and evaluation results also confirm that, study was more relevant in their sector, and they envisioned to use the prototype in different ways. With the use such tools greater improvement can be realized in capturing field data. In addition, the thesis provides contributions to knowledge base by identifying the challenge faced in planting trees across Ethiopia, and design and developed an artifact, this could serve as a template for the implementation of such artifact elsewhere.

CHAPTER ONE

INTRODUCTION

1.1 Background

Today, the Internet has become ubiquitous, has touched almost every corner of the globe, and is affecting human life in unimaginable ways. However, the journey is far from over, and we are entering an era of the Internet of Things (IoT)[1]. IoT is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals. In this context, the research and development challenges to create a smart world are enormous[2].

According to International Telecommunication Union (ITU)[2], the definition IoT formulated by ITU has "Internet of things (IoT) is a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies".

According to Agrawal[3], IoT refers to creating a network of objects that communicates with each other, via the Internet, integrating embedded sensors, actuators, computers, Radio frequency identification (RFID), mobile phones and etc. These objects have unique addresses to verify their identities and to be able to exchange and process information according to defined tasks and send reports to end users. Therefore, IoT is a network of Internet enabled objects that interacts with the web services.

The major objectives of IoT is the creation of smart environment and spaces for things to act self-responsively .Among these environment, smart transports, products, cities, buildings, rural areas energy, health, climate, food, energy, mobility, digital society and health applications and in many other areas makes more intelligent using sensor technologies which includes RFID, and Wireless Sensor Network (WSN). Radio frequency identification (RFID) is a simple and cost effective system that allows devices such as sensors and smart phones interconnect with large databases and the Internet to collect and further process that data collected [4]. The sensing technologies will facilitate data collection, which will happen in real time to detect any changes in the environment. And also, integration of RFID and WSN are both important technologies in the IoT domain. RFID can only be uses for object identification, but WSNs serve a far greater purpose and merging them have many advantages.

To collect and communicate between Internet-connected devices such as sensors, actuators, embedded micro-controllers, or smart appliances needs a channel, in this research Arduino mega micro controller board and ThingSpeak platform are used to design and develop the prototype.

ThingSpeak is an open source platform that provides various services exclusively targeted for development of IoT applications [5]. It enables various services like real time data collection, analysis and visualization of collected data via charts. It enables the creation of various plugins, apps collaborating with various web services, social networking and other APIs. Thing speak communicate with the help of Internet connection which acts as a 'data packet 'carrier between the connected 'things' and the ThingSpeak cloud retrieve, save/store, analyze, observe and work on the sensed data from the connected sensor to the host microcontroller such as 'Arduino, TI CC3200 module, Raspberry-pi.

The Arduino is an excellent choice for any IoT application design and, one can carve programs according to the needs and able to form interfaced type circuits to interpret switches and added sensors, Arduino based microcontrollers tender's flexibility and prevails 'one board computer' that endow with an effective way for coding and circuit interface [6]. In this research it was planned to monitor environmental conditions for urban trees plantation and growth using IoT.

Trees in urban settings play a vital role in our communities, weather newly planted or decades old urban trees provides crucial environmental, economic, aesthetical and committal benefits. A healthy urban forest can assist with storm water mitigation efforts, shade buildings to save energy, beautify neighborhoods, increase property values, positively impact human health and encourage community members to spend time outdoors [6]. The government of Ethiopia planned to plant 5 billion seedlings this year and reportedly succeeded it as part of its "Green Legacy" campaign organized in 2019 [7].

Growing a vibrant urban forest requires maintenance, stewardship and consistent plantation of new trees. Plantation campaigns by governmental, non-profit organizations and community groups have resulted in millions of young trees added to cities throughout Ethiopia. While many of these new trees are catalogs and counted as part of the plantation initiative, less data is available about urban trees as they grow and eventually die [8]. Information about stewardship activities such as growth , watering, treating like air pollution removal, and plantation site improvements are also seldom track consistently after trees are planted despite research demonstrating that such activities may directly affect the health and growth of the trees [6].

A recent study shows that temperature and humidity sensors are being used for measurements and are connected with the IoT network, in concluding that by using IoT, the whole process is automated and data are collected using sensors. Thus, there was a need to design a system for monitoring environmental condition prototype using the state-of-the-art technology in order to manage and control urban trees plantation and growth.

1.2 Statement of the Problem

Urban tree plantation and growth monitoring in Ethiopia has so far received limited attention [9]. A recent study conducted shows that, urban forests in different part of the countries are affected by various problems [10]. And also, the current system relies the plant growth and health assessments are still evaluated using a traditional approach and manually by human observations, which are time consuming and destructive [8]. Beside this challenge, the existing small open spaces on the road side way makes it difficult to manage using traditional approach. As a result, urban trees are not given the needed attention in terms of automated monitoring of environmental conditions such us, temperature, humidity and air pollution and water level.

The call to plant more trees is part of Ethiopia's national "Green Legacy" initiative, which according to the prime minister's office, aims to tackle deforestation and the effects of climate change by educating Ethiopians on the environment, and plantation different "eco-friendly seedlings". Perhaps more than other countries, severe droughts, food shortages, and flash floods responsible for mass displacements of people has made the effects of climate change especially felt in the East African country[12]. But one challenge of planting trees across Ethiopia is that it might have the opposite of a beneficial effect, and could even threaten some of the country's ecosystems. Scientists have worried that for the initiative to work, trees planted in the country's different ecological environments need to be tailor-made for their location. If the right trees are not planted in the environments for which they are at, the "Green Legacy" might be doing more harm than good. To solve such a problem, it's scientifically the proven need to employ an automated way of having surveillance on freshly-planted trees and its immediate environmental conditions. In order to manage and control urban trees plantation and growth there was a need to design a system for monitoring environmental condition using the state-of-the-art technology. An automated system for monitoring environmental conditions done with appropriate taxonomies. Recently, IoT would be a great breakthrough in modern agriculture and forest fields; kinds of sensors have been producing for sensing environmental conditions and agricultural objects, such as crops and animals at the same time [11].

Smart technologies are already being applied in environmental and resource management, made all the more accessible with increasing technological capabilities, and with recent calls to action for technology investments in the environment. WSN have been deployed in greenhouse settings to measure and regulate environmental parameters [28]. A ZigBee based energy efficient environmental monitoring alerting and controlling system was proposed [16]. They focused ZigBee based energy efficient environmental monitoring, alerting and controlling system for agriculture is designed and implemented. RFID microchips have been proposed as a means to collect and store information about plant pathology, and to share information via web-based platforms. Similar chips could be used to tag trees for identification and bio monitoring purposes, as well as for "virtualizing green areas". In Europe, most of the funding from the EU and associated partners for smart-city projects has been limited to energy, transit and mobility, and ICTs. India's "Smart City Mission" aims to build 100 smart cities through "smart solutions", which fall within the realms of e-governance, management of waste, water and energy, and urban mobility [28].

However, these solutions fail to mention urban green space and forest management. A report detailing opportunities for smart cities in Southeast Asia highlight smart applications for social infrastructure, utilities, mobility, security, local economy and community, and the built environment but with no reference to green infrastructure. In the scholarly literature [28], recent and comprehensive reviews on smart cities, smart sustainable cities, and smart governance in environmental management fail to elaborate on intersections between smart city trends, technologies, and urban green space management.

According to the survey conducted by A. A. Raneesha [16], in their review focused IoT in agriculture and farming on automating all the aspects of farming and agricultural methods to make the process more efficient and effective. They conclude that the agricultural sector is researched considerably more than compared to the forest sector. This shows that there is a gap in the forest sector. In this research tried to fill the gap in monitoring environmental conditions for urban trees plantation and growth. It focuses collecting information from the field. Environmental factors like temperature, humidity and soil moisture level plays a major role for the growth of planted trees. In this study environmental conditions of planted trees are collected by using different sensor and the sensed data transmitted to the Internet by the wireless sensor network. In addition, a gateway unit handles the sensor information, and transmits data to web applications.

The main aim of this research was to design and develop a prototype that fill the gap in monitoring environmental conditions for urban trees plantation and growth by making long term and real time monitoring using IoT. Through this integration, the environmental conditions can be monitor continuously even in real-time and data can be accumulating in the web application so that it can be better managed and utilized. Thus, there was a need to design a system for monitoring environmental condition using the state-of-the-art technology in order to manage and control urban trees plantation and growth.

In the attempt to solve the above problem, the following research question have been formulated:

- What are the challenges faced in in monitoring urban trees plantation and growth?

- How IoT based environmental conditions monitoring can address the existing problem?
- How feasible and scalable was this technology in solving the challenge faced in urban trees plantation and growth?

1.3 Objectives

1.3.1 General Objective

The general objective was to design and develop IoT based environmental condition monitoring by using IoT, by taking the case of green legacy program in Addis Ababa, Ethiopia.

1.3.2 Specific Objective

The specific objectives are list as follows:

- To review related literature to understand the state-of-the-art IoT technology in monitoring environmental conditions
- To understand the challenges facing in monitoring environmental conditions for urban trees plantation and growth
- To identify the optimum environmental conditions required for urban trees
- To collect and preprocess required data using IoT for urban trees plantation and growth
- To design the proposed architecture for monitoring environmental condition
- To demonstrate the proposed architecture via prototype
- To test the IoT prototype.

1.4 Methodology

The Design science research approach was used and for the data collection, both primary and secondary data sources were used from various sources. In the data collection different tools and techniques are used, and also hardware and software material are used to design and develop the proposed artifact. To analyze gathered data thematic coding and thematic analysis was used. And also, applied Structured Systems Analysis and Design Method (SSADM) for a rigorous system analysis, design and development.

1.5 Scope and Limitation

This research focused on urban trees plantation and growth in the case of green legacy program in Addis Ababa, Ethiopia and the study includes design architecture of environmental condition monitoring for urban trees by using IoT in order to manage the urban trees plantation and growth. The model developed had been tested and evaluated with domain expert in the area.

The research focused in monitoring environmental conditions such as, soil moisture, level, humidity and temperature to fully implement we need more sensing technologies. The study requires hardware equipment to integrate IoT technologies which are costly and need a lot of time to full implementation and further more analysis. The equipment's were microcontroller, Lora WAN sensors and actuators. In addition, the research requires good understanding of sensors, IoT and ThingSpeak technologies to ensure a successful implementation and also there were lack of literature in the environmental conditions monitoring for urban trees using IoT and lack of recent study in the area of urban trees plantation and growth in A.A. Ethiopia.

1.6 Significance of the Study

Monitoring environmental conditions for urban trees plantation and growth could help improve the microclimate and air quality and can be used to combat regional as well as global warming. Long-term monitoring data related to urban trees health, growth and mortality rates and longevity is useful to urban trees professionals, scientists, and local community. In this section discussed the contribution of the study in forest area. IoT based environmental conditions monitoring for urban trees plantation and growth could meet the need of many programs by allowing for the assessment of condition, composition, and extent of the urban trees resource to aid in management and planning. This can be uses in changes and threats to the sustainability of urban trees such as, species and cover changes, invasive species, pest outbreaks; ecosystem services and values like, air pollution removal, carbon storage and sequestration, building energy conservation; basic data for species composition, leaf area, leaf biomass, leaf area index trees biomass and needed for incorporation of urban vegetation with in environmental regulations.

Long-term monitoring of urban trees useful in order to understand and manage factors that alter urban trees to help sustain long-term forest health; to monitor and evaluate the effectiveness of federal and state urban trees program accomplishments; and also, to identify critical resource needs and help direct national and state program funding.

The study could be a synergy for protection and actions to be done in urban trees environmental conditions monitoring in the cities and to select the right plant in the right place. It provides use full information for plantation site selection and it can draw what kind of treatments and protection is needed such as, air pollution removal, watering, protection of human intrusion, carbon dioxide emission. Moreover, the study addresses and creates an awareness about IoT importance's in monitoring environmental conditions for urban trees to the community and it can implicate an effective monitoring solution by using IoT technologies and the concept will encourage other researchers in the country to contribute in these under taking area and it can serve as a base line document for the stake holders and also use full in making of the strategies policies in using this technology by filling the gap.

1.7 **Organization of the Thesis**

This research paper had been organized in to six different but interrelated chapters. The first chapter starts by discussing the background of the research work followed by statement of the problems, objective of the study including general and specific, scope and limitation of the study, methodology followed and significance of the study are discussed in details. Consequently, chapter two starts by overviewing the chapter followed by introducing the concepts of IoT, domain application areas, architectures and also, discuss an overview of urban forest and agriculture, environmental conditions monitoring in Addis Ababa, and finally discuss related work and summarize. In the third chapter discussed the research design and methodologies used in the paper which include overview of the chapter, population, sampling, data collection and analysis, system development methodology and ethical considerations were discussed in detail. The fourth chapter discussed the requirement analysis and design were discussed. The fifth chapter discussed in detail the implementation and design were discussed in detail. The final chapter six discussed conclusion and recommendation are discussed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

In this chapter various materials that had been reviewed to understand the state-of-the-art for monitoring environmental conditions, IoT and smart environment. The review includes; research articles, journal, thesis, and conference papers, manuals that are related to the research topic have been examined. Besides, we had reviewed related works to identify the research gap and formulate the problem statement and research questions of the study. In the following section discussed the concept of IoT with different layered architectures and domain application areas, overview of urban forest and agriculture, environmental conditions monitoring in Addis Ababa, and finally discussed related work done in this area and summarize with observed challenges and gap identified the in the review.

2.2 Internet of Things

According to Kanake, J. M. [4] , the application of Information and Communications Technology (ICT) in agriculture and forest is increasingly becoming more important. Today, it is ensuring productivity by deploying wireless and cloud-connected systems that aid in maximizing yields, automating day-to-day agriculture and forest operations and providing real time monitoring information that enables smart decision making.

According to IERC, the rapid convergence of ICT is taking place at three layers of technology innovation: the cloud, data and communication pipes/networks and device[2]. The Internet of Things provides solutions based on the integration of information technology, which refers to hardware and software used to store, retrieve, and process data and communications technology which includes electronic systems used for communication between individuals or groups.

The IoT is not a single technology, it’s a concept in which most new things are connected and enabled such as street lights being networked and things like embedded sensors, image recognition functionality, augmented reality, near field communication are integrated into situational decision support, asset management and new services. These bring many business opportunities and add to the complexity of IT [1].

The IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment and the confluence of efficient wireless protocols, improved sensors, cheaper processors, and a bevy of start-ups and established companies developing the necessary management and application software has finally made the concept of the Internet of Things mainstream. The number of Internet-connected devices surpassed the number of human beings on the planet in 2011, and by 2020, Internet-connected devices are expected to number between 26 billion and 50 billion. For every Internet connected personal computer or handset there will be 5–10 other types of devices sold with native Internet connectivity[2].

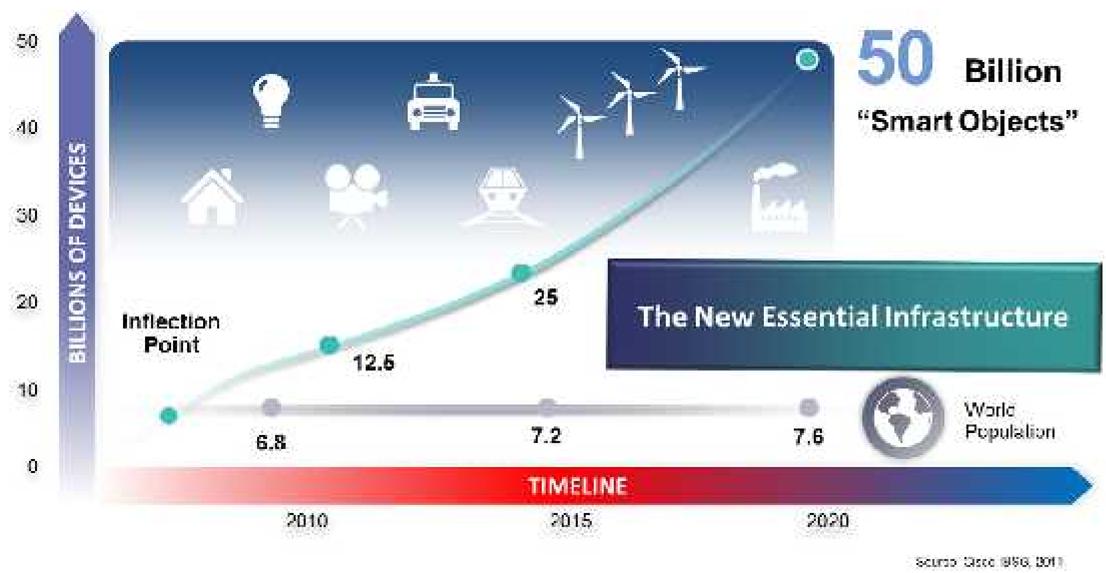

Figure 2.2-1 Internet-connected devices and the future evolution (Source: Cisco, 2011)

IoT is providing access to information, media and services, through wired and wireless broadband connections. The IoT makes use of synergies that are generated by the convergence of Consumer, Business and Industrial Internet Consumer, Business and Industrial Internet[2]. The convergence creates the open, global network connecting people, data, and things. This convergence leverages the cloud to connect intelligent things that sense and transmit a broad array of data, helping creating services that would not be obvious without this level of connectivity and analytical intelligence. The use of platforms is being driven by transformative technologies such as cloud, things, and mobile. IoT has become a common news item and marketing trend.

To accommodate the diversity of the IoT, there is a heterogeneous mix of communication technologies, which need to be adapted in order to address the needs of IoT applications such as energy efficiency, security, and reliability. In this context, it is possible that the level of diversity will be scaled to a number a manageable connectivity technology that address the needs of the IoT applications, are adopted by the market, they have already proved to be serviceable, supported by a strong technology alliance[2]. Examples of standards in these categories include wired and wireless technologies like Ethernet, Wi-Fi, Bluetooth, ZigBee, and Z-Wave.

Most IoT devices are connected together to form purpose-specific systems; they are less frequently used as general-access devices on a worldwide network [13]. Sensor network research spanned a range of configurations. Many of these were designed for data collection at very low data rates. The collected data would then be sent to servers for processing. Traditional sensor network research did not emphasize in-network processing.

Now a day's, IoT has emerged as an important technology with applications in many fields and makes it possible to create networks incorporating the entire manufacturing process that convert factories into a smart environment. The synergy of the access and potential data exchange opens huge new possibilities for IoT applications. Already over 50% of Internet connections are between or with things[2].

According to IERC[2], in 2011 there were over 15 billion things on the Web, with 50 billion+ intermittent connections. By 2020, over 30 billion connected things, with over 200 billion with intermittent connections are forecast. Key technologies here include from sensing device, communication subsystem, data aggregation and preprocessing to the object instantiation and finally service provision, generating an unambiguous definition of the "Internet of Things" is non-trivial.

According to Pallavi Sethi and Smruti R.[1], there is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers. Figure 3 shows detailed IoT layered architecture which include the perception, transport, processing, and application, monitoring, preprocessing, security, storage and business layers. The perception layer is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment.

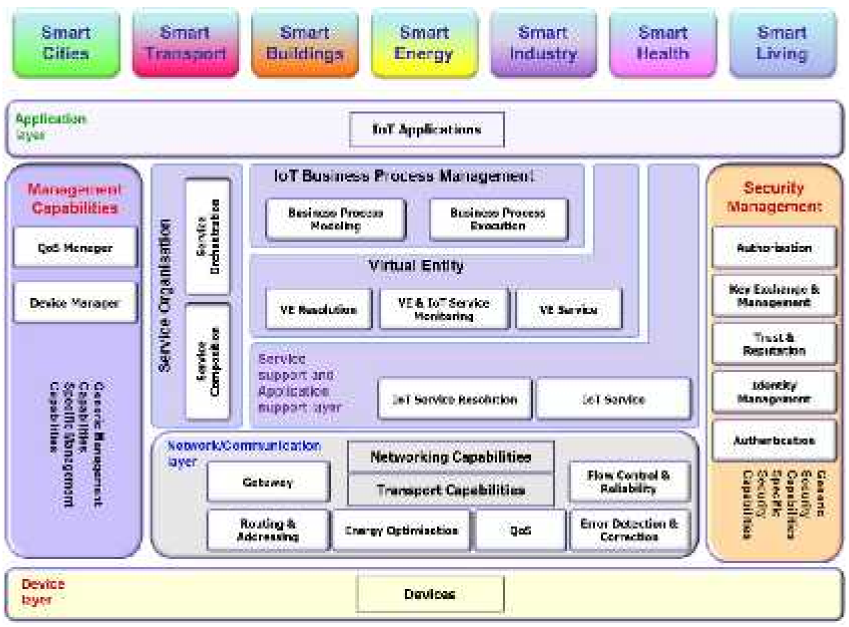

Figure 2.2-2 Detailed IoT Layered Architecture (Source: IERC)

The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data. The application layer is responsible for delivering application specific services to the user. It defines various applications in which the IoT can be deployed, for example, smart homes, smart cities, and smart health which are showed in the above figure. The transport layer transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC. The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules. The business layer manages the whole IoT system, including applications, business and profit models, and users′ privacy. The monitoring layer monitors power, resources, responses, and services. The preprocessing layer performs filtering, processing, and analytics of sensor data. The temporary storage layer provides storage functionalities such as data replication, distribution, and storage. Finally, the security layer performs encryption/decryption and ensures data integrity and privacy. Monitoring and preprocessing are done on the edge of the network before sending data to the cloud. In some system architectures the data processing is done in a large centralized fashion by cloud computers. Such a cloud centric architecture keeps the cloud at the center, applications above it, and the network of smart things below it[1]. Cloud computing is given primacy because it provides great flexibility and scalability. It offers services such as the core infrastructure, platform, software, and storage. Developers can provide their storage tools, software tools, data mining, and machine learning tools, and visualization tools through the cloud.

The IERC is actively involved in ITU-T Study Group 13, which leads the work of the International Telecommunications Union (ITU) on standards for next generation networks (NGN) and future networks and has been part of the team which has formulated the following definition[2]: "*Internet of things (IoT): A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies*". The IERC definition states that IoT is *"A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."*

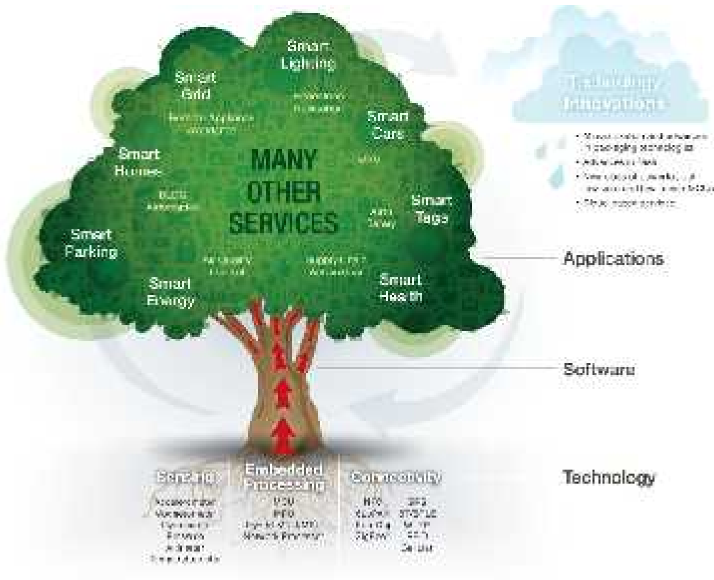

Figure 2.2-3 Different Services, Technologies, and Meanings for Everyone (Source: IERC)

2.2.1 IoT Application

Over the last few years, the evolution of markets and applications, in their economic potential and their impact in addressing societal trends and challenges for the next decades has changed dramatically [1]. There are a diverse set of areas in which intelligent applications have been developed. All of these applications are not yet readily available; however, preliminary research indicates the potential of IoT in improving the quality of life in our society. Some uses of IoT applications are in home automation, fitness tracking, health monitoring, environment protection, smart cities, and industrial settings [3]. Potential applications of the IoT are numerous and diverse, permeating into practically all areas of every-day life of individuals, enterprises, and society as a whole. The IERC[2] has identified and described the main IoT applications, which span numerous applications domains: smart energy, smart health, smart buildings, smart transport, smart industry, and smart city.

According to IERC the IoT application domains identified are based on inputs from experts, surveys and reports. The IoT application covers “smart” environments/spaces in domains such as: Transportation, Building, City, Lifestyle, Retail, Agriculture, Factory, Supply chain, Emergency, Health care, User interaction, Culture and tourism, Environment and Energy. The applications areas include as well the domain of Industrial Internet where intelligent devices, intelligent systems, and intelligent decision-making represent the primary ways in which the physical world of machines, facilities, fleets and networks can more deeply merge with the connectivity, big data and analytics of the digital world. Manufacturing and industrial automation are under pressure from shortened product life-cycles and the demand for a shorter time to market in many areas. The next generation of manufacturing systems will therefore be built with flexibility and reconfiguration as a fundamental objective.

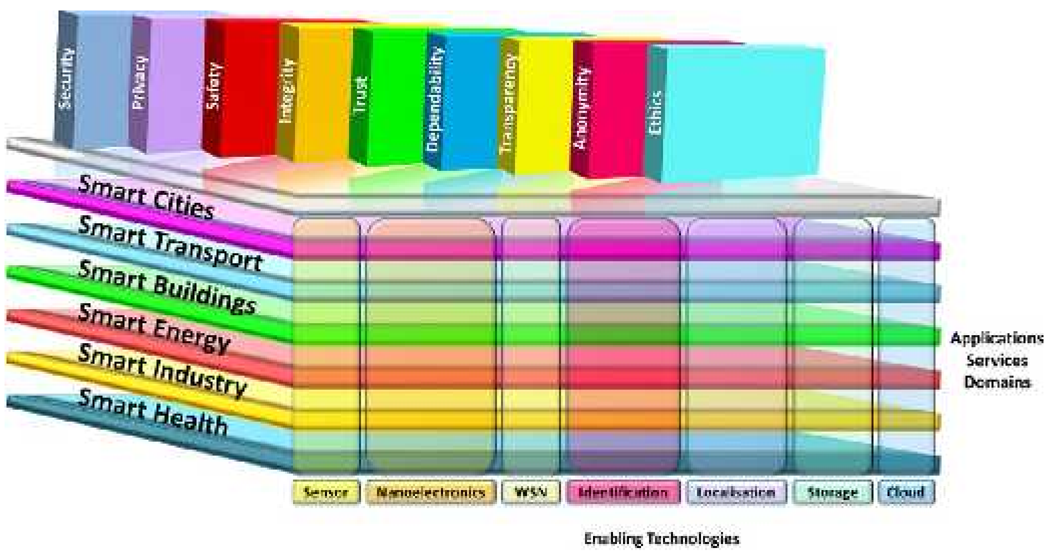

Figure 2.2-4 IoT 3D Matrix (Source: IERC)

Some updated list of IoT applications presented below, includes examples of IoT applications in different domains, which is showing why the IoT is one of the strategic technology trends for the next 5 years [1].

Smart Environment and Agriculture: Environmental parameters such as temperature and humidity are important for agricultural production. Sensors are used by farmers in the field to measure such parameters and this data can be used for efficient production. Production using greenhouses[1] is one of the main applications of IoT in agriculture. Environmental parameters measured in terms of temperature, soil information, and humidity are measured in real time and sent to a server for analysis. The results are then used to improve crop quality and yield.

The applications of IoT in environmental monitoring are broad [2]: environmental protection, extreme weather monitoring, water safety, endangered species protection, commercial farming, and more. In these applications, sensors detect and measure every type of environmental change. In this paper some major application of IoT, in Smart Environment and Agriculture are discussed below:

Smart Food/Water Monitoring (Water Management): Real-time information about water usage and the status of waterlines could be collected by connecting residential water meters to an Internet protocol (IP) network. As a consequence, could be reductions in Labor and maintenance costs, improved accuracy and lower costs in meter readings, and possibly water consumption reductions.

Smart Living (Gas Monitoring): Real-information about gas usage and the status of gas lines could be provided by connecting residential gas meters to an Internet protocol (IP) network. As for the water monitoring, the possible outcome could be reductions in labor and maintenance costs, improved accuracy and lower costs in meter readings, and possibly gas consumption reductions [2].

Air and Water Pollution: Current monitoring technology for air and water safety primarily uses manual labor along with advanced instruments, and lab processing. IoT improves on this technology by reducing the need for human labor, allowing frequent sampling, increasing the range of sampling and monitoring, allowing sophisticated testing on-site, and binding response efforts to detection systems. This allows us to prevent substantial contamination and related disasters [2].

Commercial Farming: Today's sophisticated commercial farms have exploited advanced technology and biotechnology for quite some time, however, IoT introduces more access to deeper automation and analysis. Much of commercial farming, like weather monitoring, suffers from a lack of precision and requires human labor in the area of monitoring. Its automation also remains limited [2]. IoT allows operations to remove much of the human intervention in system function, farming analysis, and monitoring. Systems detect changes to crops, soil, environment, and more. They optimize standard processes through analysis of large, rich data collections. They also prevent health hazards (e.g., E. coli) from happening and allow better control [1].

2.2.1.1 Application of IoT in environmental condition monitoring

These application of IoT can be categorized into five broad categories [29]. These are environmental quality and protection, natural resource management, oceans and coastal management, climate change adaptation and mitigation, and biodiversity conservation and environmental awareness.

I. Environmental quality and protection

Environmental quality and protection cover issues of pollution, [28] hazardous waste management, hazardous chemical management, waste disposal management and waste policy and information management. Toxic waste is a type of waste that can be hazardous to humans, other living creatures and plants. The various types of waste material that fall under this heading can pollute the environment and threaten life in a number of ways. They can be found not only on land but also in the air and water. Radioactive waste is one type of toxic waste. It is produced as a product of other processes, including, but not limited to those that involve the generation of power. Medical waste is another type of hazardous waste. This includes substances that cannot be disposed out with regular trash, such as blood, body tissues, medical instruments and medical chemicals. The agricultural industry can also be a source of toxic waste, such as when chemical fertilizers and pesticides contaminate not only the soil but groundwater [29]. In the next paragraphs discussed how IoT is being applied in different studies for monitoring environmental quality and protection.

For monitor air quality and urban traffic, lessons can be drawn from the European Union (EU) project RESCATAME [29]. Pervasive air-quality sensors network for an environmentally friendly urban traffic management (RESCATAME) is an EU-funded project to monitor air quality and urban traffic through a Waspmote sensor board. With data collected from sensors across the city, providing full-time geographic coverage at low-cost, municipalities can efficiently achieve a way of better managing urban traffic in major European cities. The Waspmotes measure parameters such as temperature, relative humidity, carbon monoxide, nitrogen dioxide, noise and particles. If any of the 7 parameters goes above the threshold, the system analyses the information and reacts by sending an alarm to a central node. In order to know where the sensor is located each Waspmote integrates a GPS, which delivers accurate information. It is also possible to transmit data via GPRS, as a secondary radio module for better availability and redundancy in situations when it is critical to ensure the reception of the message, like possible fire alarms. The GPRS module is quad-band (it can operate in 4 different bands, meaning it supports any cellular provider), making it able to work all over the world [29]. Pigeonblog provides an alternative way to participate in environmental air pollution data gathering. The project equips urban homing pigeons with GPS-enabled electronic pollution sensing devices capable of sending real-time location-based air pollution and image data to an online mapping/blogging environment [29].

The wearable Radio Frequency Identifier (RFID) sensor project by the National Institute of Environmental Health Sciences developed sensors that combine RFID tracking with an acute gas-sensing capability, which can detect the presence of potentially harmful chemical agents in the air. Detecting chemical agents in this way could provide more information about the relationship between a person's health and the environment in which a person lives [29]. An RFID-enabled garbage collection services can offer an easy and automatic means for weighing on- site storage bins during the curbside collection service. Waste collection trucks are fitted with a scale to weigh the waste bin and the household is identified through an RFID tag on the waste bin. An RFID antennae and reader on the refuse truck reads the tag on the waste container when it is placed on the truck's scale. A weight-based pay-as-you-throw system for household waste collection has caused significant increase in household recycling rates in Germany. The RFID-enabled waste-weighing system provides the ability to measure the mass of the waste constituents and identify each waste component with RFID tags on it. RFID tags on each waste component are read simultaneously with the tag on the bin by a collection truck. Usage of this system makes possible the rebates for recycling products. As soon as a recyclable material is put on the bin it can be identified and data relayed through a central system to scrap dealers and other related parties such as internet-based sales services [29].

SeWatch, a waste water and sewerage wireless monitoring system provides a system-wide reporting solution for combined sewer overflow and sanitary sewer overflow discharge or overflow. Water level sensors for sewer system manholes relay information to an application running on a PC or server which alerts on computer screen or via SMS about manhole overflow and spill-overs [29].

Satellite light radiation can detect the level of pollution of water. It uses the wavelength of pollutants to identify the class of pollutant. An example would be a river source that is contaminated with e-coli bacteria. By sensing the speed of water, IoT models can predict when the polluted water will get to the supply dam. That means measures can then be taken to alert the homes in the vicinity of the supply dam on when they can expect an outbreak of e-coli and take preventive measures.

II. Natural resources management

Natural resources are materials and components that are found within the environment. This includes biotic resources, abiotic resources, and renewable resources. Biotic resources as obtained from the biosphere include forest, animals, birds and fish and fossil fuels such as coal and petroleum. Abiotic resources are land, freshwater, air and heavy metals including gold, copper and iron. Renewable resources include sunlight, air, and wind. A recent study address that IoT allows real time detection of animals, for example, during outbreaks of contagious disease, for control, survey and prevention. Livestock would be fitted with RFID chips and RFID readers would be placed at various monitoring spots. It is common for the buffalo which carries foot and mouth disease to venture into the farming areas from the game reserves. It is also common for communally grazed or other animals to venture into game reserves. It may also be required to track animals to avoid such contacts which result in passing on diseases.

In China, a special syringe is used to inject a microchip into a fish's body, storing information about the chip that is species, spawning place, weight, features and breeding record. The chip is wirelessly connected to an information system to enable real-time monitoring. The Electronic Design Group at the University of Zaragoza in Spain is developing a wireless sensor system for early forest fire detection [29].

In tropical forests across South America, Africa and East Asia, over a million-hardwood tress have had plastic barcodes hammered into them, to help sustainable forestry practices and exportation to other countries, as well as preventing illegal logging of the coveted hardwoods. The local forest managers use hand-held computer devices to scan the tag as soon as the tree is cut, uploading the information via satellite, Wi-Fi or any other internet connection to a secure database. The database tracks tree inventory, and provides reports. Trees can be tracked from the forest all the way through its supply chain to the consumer. A sensor network to monitor redwood trees was developed by Tolle [29]. Installing nodes through the height of a 70-meter tree, the system measures temperature, relative humidity and solar radiation. The system logs data every 5 minutes and transmits it via GPRS modem to an external computer for processing.

Botanicals is a plant monitoring system. It has sensor probes, and is placed deep in the soil to measure the amount of moisture present. Readings are sent to a microcontroller built into the unit that translates the data into information that can be sent over the internet through an embedded Ethernet connection. The information is sent to a Twitter account. Twitter sends the plant's information via a message to the user's cell phone [29]. In Israel, drip irrigation, is the crop watering technique that waters only the soil closest to a plant's roots. Linking data on temperature, radiation, humidity and soil water content collected by varied sensors, controls not only where water is released but how much is needed to meet a plant's need for transpiration. Farmers "frigate" their crops or mix nutrients into the drip irrigation system to get fertilizer where it is most needed [29].

Real-time and continuous monitoring and remote monitoring of water quality is a necessity for environmental protection and the health of the citizens. The quality of the water body in key sections of the main basin is monitored through remote wireless monitoring of the point source and early warnings given and a forecast for major pollution incidents given. Using telemetry and remote control of water plant equipment effectively improves water use efficiency, reduces ecological and health risks caused by deterioration of water quality and leapfrogs development of water plant control technology. Environmental protection departments are better placed in understanding the changes in the water quality of the basement and water treatment process of water plants in a timely manner.

Water management can be about having firsthand information on the water situation for quick decision making. An example would be the “virtual” river basin. The ‘virtual” river basin is a web site with real-time presentations of river basins. These river basin web sites, coupled with low-cost automatic control on all major structures, allows for nearly instantaneous decision-making. The ability to see what is happening throughout a river basin and react promptly to changing hydrologic and weather conditions improves the Way Rivers are operated. Sensors monitor the environment in the river basin and wirelessly feed the information into the website. Mathematical models make calculations of the resultant conditions and the results are visualized on the website. The components of the IoT system are: 1) a comprehensive real-time environmental monitoring system, 2) web displays that provide accurate real-time visualizations of conditions, 3) databases and 4) decision support systems [29].

III. Climate change adaptation and mitigation

Severe geophysical or climatic events including earthquakes, volcanic eruptions, landslides, droughts, floods, cyclones and fires that threaten people or property are termed natural hazards. Remote sensing the art of acquiring information about the earth using remote instruments such as satellites is inherently useful for disaster management. Satellites offer accurate, frequent and instantaneous data over large areas anywhere in the world. When a disaster strikes, remote sensing is often the only way to view what is happening on the ground. An early warning system consists of an awareness subsystem, forecasting subsystem, warning subsystem and an action subsystem. Awareness is on monitoring the climate conditions. Forecasting is the prediction of what will happen. The warning subsystem provides communication and the action subsystem is on the evacuation. An early warning system is an orderly structure of either a technical or a biological network of mechanisms that can sense an incoming danger with a purpose of enabling the user to be warned and thereby act according to control or avoid it. A technical warning system refers to man-made sensing devices such as satellites, radar warning, earthquake warning, fire alarm systems and many other tools. Disaster management is a set of activities to reduce risk by reduction of vulnerability of elements at risk, ensuring adequate measures are implemented before disaster strikes and responding efficiently and effectively as possible to disasters when they occur. Vulnerabilities to disaster can be in the form of floods, fires, earthquakes, outbreak of disease, hunger, etc. The following section is an example of applications that can be adopted for disaster management.

Italy's Piedmont Region Hydro meteorological alert and real-time flood forecasting system produces a daily report of observed and expected meteorological situations, paying attention to precipitation forecast. It issues warnings for flood risk due to prolonged heavy rainfall on floodplains endangering towns and infrastructure in the valleys and lowlands, and local hydrogeological flood risk due to short intense storms on small areas. Data is monitored in real time. Numerical modelling is adopted in forecasting floods.

In the Honduras Flood Alert System, with a sensor network events over large geographic regions of approximately 10,000 km2 are monitored. A sensor network for flood prediction that withstands river flooding and severe storms causing floods, monitors and communicates over a 10,000 square kilometer basin, predicts floods autonomously and limits costs allowing feasible implementation of the system in a developing country. To predict flooding, a model that requires knowing how much rainfall falls and what the soil's time dependent response to the rainfall is required. A variety of variables contributing to the occurrence of the event are measured. Detection and prediction of river flooding occurs. To cover long range communication links of 25 km the system uses radios of 144MHz. For short range communications links with an 8km range, the system operates within the 900MHz band. The system consists of 4 different regimes of operation: sensing, computation, government and office interface and community interface. The state of the river, soil conditions and meteorological conditions are measured at nodes powered by solar panels. Due to the inability to populate entire areas with sensors and cost limitations, a network consists of nodes to communicate over long distances in the order of 25km [29].

In flash flood early warning systems, environmental data including rainfall and stream flow information is required. The rainfall information comes from in-situ precipitation gauges, radar measurements and satellite estimates. The Central America Flash Flood Guidance System covers 7 countries. Flash flood guidance, which is rainfall required to produce flash flooding is calculated every 6 hours for stream basins from 100km2 to 300km2. A physically-based hydrologic model is run every 6 hours to simulate soil moisture for the region and determine flash flood guidance. Graphical and text rainfall, soil moisture, flash flood guidance and flash flood threat products are created and posted to the internet for access, analysis and dissemination to disaster preparedness agencies. Digital spatial databases, real-time remotely sensed on-site precipitation and temperature databases are utilized [29].

IoT can also predict where a flood can occur. Geographic Information Systems (GIS) is used to analyses the topography of a catchment area and run models to compare the peak discharge against the minimum peak discharge. A difference between the two will spell flooding down river Scientists from the Urban and Civil Engineering Department at Ibaraki University and the Fukuyama Consultants in Japan are working on wireless sensor integrated circuit (IC) tag to collect and visualize ground environmental information through microscopic vibration and tilt change of ground. This information will be helpful for prevention of disasters in earthquake-prone zones [29].

IV. Biodiversity and conservation and environmental awareness

Biodiversity is the variety of life: the different plants, animals and micro-organisms. It is the degree of variation of life forms within a given ecosystem, biome or entire planet. Biodiversity supports ecosystem services including air quality, climate, water purification, pollination and erosion. Crop diversity aids recovery when the dominant cultivar is attacked by disease or predator. Health risks associated with changes in biodiversity e.g. scarcity of fresh water, distribution of disease vectors as a result of climate change, and availability of food resources. Industries derive raw material from biological materials such as materials, fibers, dyes, rubber, etc. There is an unavailability of tools that foster community participation in conservation and get them interested.

The project Brahma in India is a robust knowledge base for all kinds of information about diversity. The database pulls in various pieces of information such as binomial classification, habitat, geographical distribution, genomic data, and folk medicinal and mythic folklore for every species. The database runs on two entities species pages and query pages. Through technologies such as Twitter, Facebook, YouTube, etc., awareness is spread about the biodiversity.

The birding and internet site provides extensive information on bird species, photographs, range maps, articles on attracting and feeding birds, home study courses in bird biology and participation in international bird studies. It is a leap beyond the paper-based book for the following reasons:

- You are using a computer with sound capability by offering bird calls you can listen to
- Few sites provide video galleries where you can view birds in motion
- The site offers forums to share experience with other birders and even has experts

There is also cellular and Wi-Fi connection o your PC and any other device. Biodiversity data surveying works by enabling human support by mobile devices to become one of the contributors for biodiversity occurrence data. Virtual reality-based applications come in two forms. Virtual- reality based applications allow users to navigate into a virtual world without performing any physical motion. Some applications allow users to explore computer generated spaces and interact with other users and things within these spaces without physical motions. Augmented reality applications superimpose the additional information onto the real world (for example seen through cell phone camera or through augmented reality glasses) [29].

2.2.2 IoT Architecture

IoT needs an open architecture to maximize interoperability among distributed and heterogeneous systems. Architecture standards should consist of well-defined interfaces and protocols, abstract data models and neutral technologies, such as Extensive Markup Language (XML), to support a variety of programming languages and operating systems [4]. The IoT architecture should be designed to be resilient to disruption of the physical network and ensure the nodes use various communication protocols to connect to the IoT since they may have intermittent connectivity. IoT nodes should form peer networks with other nodes through a decentralized approach to the architecture with support for discovery and peer networking. IoT requires prototyping of embedded devices such as the Arduino Chip, which combine the RAM, processor, networking and storage capabilities onto a single chip which makes them more specialized. The chip also runs on low power and is programmable to tailor it to developer specifications[3]. Due to the large volumes of data that will be generated, there is need for routing, processing and storage of the information remotely in the cloud. This will enable effective caching, synchronization, updates and data flows in the architecture.

According to Vermesan and Friess[3], IoT has the following key initiatives and drivers (refer to Table 2.2-1) that has enabled it grow from research and innovation to market deployment.

Table 2.2-1 Key Drivers and Initiatives for IoT (Vermesan & Friess)

IoT Initiatives	**Description**	**Objective**
GRIFS	Global RFID Forum	To maximize global interoperability and collaboration of RFID
CASAGRAS	Coordination and Support Action for Global RFID related activities and Standardization-Embracing a fully inclusive range of EDGE technologies	To develop a framework for international development and issues concerning RFID and IoT in regards to standards and regulation
W3C	World Wide Web	Ensure a semantic web that will allow you to find share and analyze information more easily.
ROLL	Routing Protocols for heterogeneous low power and loss networks	Improvement in the Quality of Service for heterogeneous networks
RACE	Raising Awareness and Competitiveness in Europe for Networked RFID	Dedicated to creating international cooperation about RFID

M2M	Cost effective solutions for M2M communication	M2M communications is a key driver for IoT applications with better Quality of Service (QoS)

According to IERC[2], the rise of cloud computing requires new network strategies for ﬁfth evolution of mobile the 5G, which represents clearly a convergence of network access technologies. The architecture of such network has to integrate the needs for IoT applications and to offer seamless integration. To make the IoT and M2M communication possible there is a need for fast, high-capacity networks. Specialized network protocols enable efficient communication[1] in this environment, including appropriate M2M communication and RFID models. These technologies are emerging with constraints and restrictions for the IoT environment that are different from the typical IT environment, because of the requirements for safety, real-time responses, low power operation, etc.

2.3 Overview of urban forest and agriculture in Addis Ababa

2.3.1 What is Urban forest?

Urban forest is defined here as the planned, integrated and systematic approach to managing urban and per-urban forests for their contribution to the economic, environmental, sociological and psychological well-being of urban society. In simpler terms, urban forest is the management of urban vegetation to meet local needs [9]. Both definitions are people-centered and acknowledge that urban forest should be managed for the benefit of the urban population. The latter definition puts more emphasis on immediate needs and is thus more relevant for the context of a developing country such as Ethiopia.

Urban forest is sometimes used synonymously with urban greening. In this view, urban greening is seen as the integrated, city-wide approach to the planting, care and management of all vegetation in a city to secure multiple environmental, economic and social benefits for urban dwellers. While urban greening may be the ultimate way ahead for making Addis Ababa more livable, provided institutional hurdles can be solved, urban forest will have to become an integral and important part of urban greening activities [9].

2.3.2 Urban Forest in Addis Ababa

According to FAO [14] forest is defined as land spinning 0.5ha with trees higher than 5 meter and a canopy cover more than 10% or trees able to reach thresh holds in situ with the exception of agricultural and urban land uses. Based on this definition most of the forest patches existing in Addis Ababa cannot be considered as a forest because the existing eucalyptus forest of Addis Ababa is either ex situ origin or it is in urban land use. However, arbitrarily the urban forest in Addis Ababa can be classified in to per urban forest and the plantation in recreation parks, road side, riverine vegetation and plantations in private and institutional gardens. It is quite clear that urban forest varies from natural forest in many ways. It is an urban green referring to a re-vegetation by planted trees, shrub or herbs with intended design to improve environmental quality, economic opportunity and aesthetic value.

Large amount of forest is found in six sub cities of the city. Both per urban forests and down town forests supply fresh air to the city and they are considered as the breathing organ of the city. It also protects the city from hazards such as flood coming from the surrounding mountains. In general forest for the city is a base for economic welfare, water supply, improved air quality, stabilized soil, reduced sound pollution, home for wild life, serving as a carbon sink. The urban forest in Addis Ababa like any other cities is making life more comfortable to the residents [14].

Urban agriculture has been perceived and defined from different dimensions by different authors. According to Richter, Renevan and Mougeot [14] it is not the location of urban agriculture which distinguishes it from rural agriculture but the fact that it is embedded in and interacting with urban ecosystem. The general definition of urban agriculture is the growing of plants and the raising of animals for food and other uses with in cities and per urban areas. It also includes the production and delivery of inputs, and the processing and marketing of products. Defines urban agriculture is an industry located within or on the fringe of a town, which grows or raises, processes and distributes a diversity of food and non-food products, using largely human and material resources, products and services found in and around the urban area.

About half of the world population lives in urban areas [14]. It is estimated that by 2020, the developing countries will account for about 75%of all urban dwellers, while urbanization brings a number of socio-economic benefits, the rapid increase in urban population ushers in a number of challenges. The continued expansion of urban areas in to the immediate hinterlands often leads to the conservation of potential agricultural lands in to non-agricultural land uses. Some cities have adopted urban agriculture as a strategy to address the increasing urban unemployment supports food security, and nutrition generates income for the urban poor in general and the disadvantaged groups such as women, the disabled.

In Addis Ababa, urban agriculture is one component of these green frames covering an area of 7,309ha of land. It has a significant role in the city's daily economic activity. To ensure productivities in urban forest and agriculture deploying automated technologies are increasing and becoming more important and IoT has emerged as an important technology with applications in many fields and makes it possible to create networks incorporating the entire environmental, agricultural, forest and farming process that convert into a smart and effective. In the next section discussed an overview of monitor urban trees environmental conditions, and recent study done in the area of agriculture, farming and forest using IoT technology and also related works.

2.4 Environmental Conditions Monitoring for Urban Trees

Urban trees provide a multitude benefits to society such as clean air, water, recreational opportunities, aesthetics, and energy savings [15]. Urban forest merits more attention in Ethiopia, as well as in other developing countries. The rehabilitation of forests in an urban setting is particular challenging due to population pressure, rural-urban migration, urban poverty, landlessness, commercialization of economy, competing land uses and high demand for construction material and cheap fuels. It is suggested that an isolated, traditional government-dominated approach to forest conservation and rehabilitation is doomed to fail [9].

Air and water pollution, inadequate waste management and reduction of green areas are frequently the major environmental problems. Conversion of open, green spaces to urban development reduces water permeable areas, upsets natural drainage patterns and causes serious flooding with subsequent damage to dwellings and infrastructure and sometimes involving even in human casualties. Urban forests improve the quality of urban life in various ways, providing tangible (food, energy, timber, fodder) and social benefits (health, employment) to meet local needs as well as important environmental services. Urban trees are particularly important for the urban poor as they generally bear the greatest burden of urban environmental risks [9].

2.5 Adaption of IoT in agriculture and smart farming toward urban greening

The automated process of forest, agricultural and farming reduces human interaction and improve the efficiency. The reason for that is every country's population depends on agriculture, thus consumers of these resources should use water and land resources optimally [16]. Moreover, it is imperative to have good quality production and crop management in order to maximize profitability. Hence, IoT base agricultural management systems are integral for an agriculturally based country such as Ethiopia. The new systems developed using IoT technologies have reduced the drawbacks associated with traditional approaches and provided many advantages to farmers and government. For example, IoT-based water management systems collect environmental attributes such as temperature, water level and humidity through the sensors and provide accurate irrigation timing [16]. In addition, crop management systems developed using IoT monitor the temperature, humidity and soil through sensors thus providing adequate information so that farmers can manage the crops appropriately.

Overall, these IoT-based systems help to reduce human interaction, power utilization and reduce cost in the field of agriculture and forest [15]. Moreover, IoT-based agricultural related applications have been used in the area of pest control, weather monitoring, nutrient management and greenhouse management.

IoT for agriculture and forest uses sensors to collect big data on the agricultural and forest environment conditions. It discovers, analyses and deals with models built upon big data to make the development of agriculture and forest more sustainable [16]. IoT can provide efficient and low-cost solutions to the collection of data. Weather, Water Scarcity, Soil fertility, humidity, temperature and Pesticides are the significant players in it. IoT will make agriculture and forest beneficiary. Agriculture and farming depend on water. Farmers depend on rainfall for all their agricultural needs. Fertilizer also plays a very significant role in the field of agriculture by helping to increase the productivity of plants.

By using IoT, farmers can manage soil condition more effectively and at less expense by monitoring them from any location [16]. A recent study conducted in this area show that how IoT and technologies are used in conserving water, fertilizer and energy in the agricultural industry by combining new technologies. This has benefits for the development of the economy of countries as well as the wealth of the people. With the combination of both advanced technologies in hardware and software, IoT can track and count all relevant aspects of production which can reduce the waste, loss and cost. The information needed to make smart decisions can be obtained merely by using electronic devices. IoT transforms the agricultural industry and enables farmers to overcome different challenges. Innovative applications can address these issues and therefore increase the quality, quantity, sustainability and cost-effectiveness of crop production [15]. IoT provides more benefits to the farming industry by improving the health of animals through better food and environment, addressing the labor shortage issue as well cost savings through automation, increase in milk production, and increase in some animals during the breeding period through detection of estrus cycle and additional revenue streams from waste.

A survey conducted [16] had analyzed recently developed IoT applications in the fields of agriculture and farming to address current issues such as unnecessary human interaction leading to higher labor cost, unnecessary water consumption and water-saving measures for the future, higher energy consumption, energy-saving measures for the future and crop monitoring difficulties. According to their analysis, they can identify a focus on water and crop management as sub-verticals in the agriculture and farming sectors. Their survey also focusses on other agriculture and farming sub-verticals to identify the gap between IoT application developments in the least researched areas. The IoT generates enormous data, so- called big data (high volume, at a different speed and different varieties of data) in varying data quality.

Analyzing the IoT system and its key attributes are the key to advancing smart IoT utilization. In their study they try to explore recently created IoT applications in the forest, agriculture and farming industry to give the more profound understanding about sensor data collection, used technologies, and sub- verticals, for example, water and crop management.

Moreover, they analyze the current issues such as higher human interaction, high labor cost, and higher water consumption and save water for future, higher energy consumption and save energy/electricity for future, crop monitoring difficulties in IoT for agriculture and farming. The result of their analysis incorporation of IoT for the development of applications in the agriculture and farming sectors. Their study focuses on sub-verticals and collecting data for measurements and technologies in the field of forest, agriculture and farming to increase productivity and efficiency with the help of IoT.

2.6 Related Work

Use of technology in the field of forest and agriculture plays important role in increasing the production as well as in reducing the man power efforts. Research for improving agricultural production by utilizing different controllers like PIC microcontroller, 8051 controller, Arduino, ARM 7 etc. and also monitoring done by different communication technology like ZigBee, Wireless sensor network (WSN), even using GSM.

Greenhouse monitoring and control system based on wireless Sensor Network by Marwa Mekki et al.[3] In this paper a WSN was implemented by deployed wireless sensor nodes in a greenhouse with temperature, humidity, moisture light, and CO_2 sensors. To control the environmental factors, the used microcontroller programmed to control the parameters according to preset values, or manually through a user interface panel.

A ZigBee based energy efficient environmental monitoring alerting and controlling system by K. Lokesh Krishna et al. They focused ZigBee based energy efficient environmental monitoring, alerting and controlling system for agriculture is designed and implemented. This system utilizes an ARM7 processor, various sensors and ZigBee communication module. Sensors gather various physical data from the field in real time and transmit it to the processor and to the end user via ZigBee communication. Then necessary actions are initiated to perform action on behalf of people to reduce or eliminate the need of human labor [16].

Embedded based Green House Monitoring system using PIC microcontroller by S. Arul Jai Singh at al. [15], the paper deals with a simple, easy to install, microcontroller-based circuit to monitor and record the value of temperature, humidity, soil moisture and sunlight of the natural environment that are continuously modified and controlled in order optimize them to achieve maximum plant growth and yield. The controller communicates with the various sensor modules in real-time in order to control the light, aeration and drainage process efficiently inside a greenhouse by actuating a cooler, fogger, dripper and lights respectively according to the necessary condition of the crops.

N.K.Choudhari and Mayuri Harde [15] proposed an cost effective automated irrigation system which can effectively monitor and send the details regarding all the factors that affect the growth of the plant.

S. Ponni, and Mr. P. Vijayakumar-Sr Grade [11] focused creates an awareness about the automation in agricultural field here where in manual intervention can be reduced by irrigating plants automatically and the whole information about the agricultural field can be viewed in android applications. IOT and cloud computing collectively makes a system that controls the environmental conditions effectively. Their project applied to achieve great results with most types of crops. The measured value of the soil moisture and the humidity present in the atmosphere are shown graph.

Mustafa Akkasa and Radosveta Sokullub [17] proposed a system based on IOT for measuring the humidity level in Real time and the measured information will be sent through the communication module, so that improvement can be achieved in the next set of farming process.

K. Lakshmi and S. Gayathri [12] by receiving the images of plant processing is performed and the result is used to identify the current growth of the plant and whether it is affected by any pesticides or by any other external problems, they have achieved a better result in terms of identifying the condition of the plant.

Srinidhi Siddagangaiah [17] By sensing all the factors related to the growth the information will be send to the cloud platform using the corresponding module and depends up on the outcome of the process the alert message will be passed to the particular authority, so the farmers can get the data related to the factors that are affecting the growth immediately.

K. Lakshmi and S. Gayathri [12] focused on, the growth of banana trees and paddy are taken for analysis. Environmental factors like temperature and humidity plays a major role for the growth of a plant. Temperature and humidity sensors are used for the measurement and are connected with the IoT network. The optimal temperature range for banana trees is about 25°C to 30°Cand Paddy is 20°C to 27°C. The data's collected from Temperature and Humidity sensors are given to Arduino UNO kit from which the information is communicated to the farmers.

Richa Phalke et al. [17] analyzed the use of IoT in the field of agriculture and they also described bout ho it is going to benefit us and detail about the IoT components.

Hemant Kuruva and Balumuri Sravani [15] used Raspberrypi and other sensors for monitoring the temperature and the humidity and through the corresponding module the information can be passed to the person immediately, they have done experiments on the home garden.

L.Rama Devi et al. [17] Proposed a method for identifying the water level in the soil by using a sensing unit and the information gathered from the sensing unit is processed by a control unit and that will be send to a GSM module to display the status of the soil condition.

Shweta B. Saraf and Dhanashri H. Gawali [11] uses a cloud based module for monitoring ,they have collected the data and the information is passed though the ZigBee to the ground station and the further processing is performed to find out the status.

Priyadharsnee.K and Dr.S.Rathi [12] have considered both soil and the pesticide detection , both the conditions are gathered by using the appropriate sensor and accurate information is processed to take appropriate action.

D. Ramya et al. [17] In order to make the nursery more profitable they proposed an approach by which soil moisture and the temperature level will be identified and according to that proper action can be taken.

According to the survey conducted by A. A. Raneesha Madushanki1 et al.[16], in their review focused IoT in agriculture and farming on automating all the aspects of farming and agricultural methods to make the process more efficient and effective. Traditional approaches in livestock management (such as cattle detection) are not fully automated and have many inefficiencies such as higher human interaction, labor cost, power consumption, and water consumption. Their results from the reported studies show water management is the highest sub vertical (28.08%) followed by crop management (14.60%) then smart farming (10.11%). From the data collection, livestock management and irrigation management resulted in the same percentage (5.61%). In regard to sensor data collection, the highest result was for the measurement of environmental temperature (24.87%) and environmental humidity (19.79%). Their study indicates that many researchers have focused on environmental temperature (24.87%), humidity (19.79%) and soil moisture (15.73%) as environmental measurements. In their review types of data were collected for measurements with environmental temperature and humidity being considered the most critical parameters for agriculture, farming and forest. There are also some other sensor data regarding soil moisture (15.73%) and soil pH (7.61%). They conclude that the agricultural sector is researched considerably more than compared to the forest sector. This shows that there is a gap in the forest sector. Their study referenced for members of the agricultural and related industry to improve and develop the use of IoT to enhance forest and agricultural production efficiencies. The study also provides recommendations for future research to include IoT systems' scalability, heterogeneity aspects, IoT system architecture, data analysis methods, size or scale of the forest and agricultural domain, IoT security and threat solutions/protocols, operational technology, data storage, cloud platform, and power supplies.

2.6.1 Smart cities, urban green spaces, and urban forest

A review conducted [28] by Sophie A. addresses that smart technologies are already being applied in environmental and resource management, made all the more accessible with increasing technological capabilities, and with recent calls to action for technology investments in the environment.

Palomino focused on artificial intelligence, the simulation of human intelligence processes (such as learning and reasoning) by computer systems, has been employed to predict and model forest fires. Google Earth Engine, a cloud-based geospatial processing platform, has been used to monitor, map, and analyze international forest change [28].

Elliott, focused on unmanned aerial vehicles (UAVs), or drones, assist in forest regeneration through surveying, fertilizer spraying, and precision aerial seeding [28].

Luvisi and Lorenzini, have been proposed [17] radio-frequency identification (RFID) microchips as a means to collect and store information about plant pathology, and to share information via web-based platforms. Similar chips could be used to tag trees for identification and bio monitoring purposes, as well as for "virtualizing green areas"[16].

Alonzo et al., focused on remote sensing technology (e.g., LiDAR, hyperspectral imagery), aided by machine learning, has mapped and assessed the species and structure of individual trees [17].

Mesas-Carrascosa et al, [17] have been deployed wireless sensor networks in greenhouse settings to measure and regulate environmental parameters.

Despite the fact that smart city planning is currently one of the fastest growing discourses in urban sustainability, it is unclear whether urban green space and forest management are gaining significant traction in smart city planning. Indeed, there is little mention of green infrastructure and natural asset management in funding mechanisms and policy initiatives for smart cities [28].

According to Climate and Energy Fund in Europe, most of the funding from the EU and associated partners for smart-city projects has been limited to energy, transit and mobility, and ICTs [16].

According to Government of India's, "Smart City Mission" aims to build 100 smart cities through "smart solutions", which fall within the realms of e-governance, management of waste, water and energy, and urban mobility. However, these solutions fail to mention urban green space and forest management [28].

A report by McKinsey & Company detailing opportunities for smart cities in Southeast Asia highlight smart applications for social infrastructure, utilities, mobility, security, local economy and community, and the built environment but with no reference to green infrastructure [28].

In Canada, the Smart Cities Challenge was launched in 2017 to encourage municipalities to address local issues and improve the lives of their residents through the "use of data and connected technology". The Smart Cities Challenge received 130 [28] applications from across the country, and the finalists' visions and challenge statements focus on energy systems, transportation, and health.

In the scholarly literature, [28] recent and comprehensive reviews on smart cities, smart sustainable cities, and smart governance in environmental management fail to elaborate on intersections between smart city trends, technologies, and urban green space management. In this review, they address this gap by exploring current and emerging smart city trends and technologies, and highlight practical applications for urban forest and green space management.

SUMMARY

In this document analysis, we addressed a major gap in the current literature and the review started by exploring the concept of IoT with its application and architecture and also discussed about urban agriculture and forest, finally discussed related works done in this area and in the finding the agricultural sector is researched considerably more than compared to the forest sector. This shows that there is a gap in the forest sector. In the review one of the challenges identified in the forest sector in the country is lack of automated technologies and adoption of recent technologies in this sector. Beside this challenge, the existing small open spaces on the road side way makes it difficult to manage using traditional approach. Moreover, the review address that environmental factors like temperature, humidity and soil moisture level plays a major role for the growth of planted trees. If the right trees are not planted in the environments for which they are at, the “Green Legacy” might be doing more harm than good. Current “smart urban forest” projects reveal a focus on novel monitoring techniques using sensors and Internet of Things (IoT) technologies. Thus, there was a need to design an IoT based environmental condition monitoring artifact using the state-of-the-art technology in order to manage and control urban trees plantation and growth. In the next chapter discussed the methodology used in this research to fill the gap identified in the study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter contains the approaches that were used to carry out the research. This includes the research design used, research methodology, type of data collected and source of data, study population and sampling, data collection and analysis method, system development methodology and environment, data presentation, and ethical consecrations.

3.2 Research Design

Design Science Research (DSR) approach was used in this study. The DSR has included identifying the problem, design and develop an artifact to solve the problem (s), demonstrate and evaluate the artifact using a prototype whether the artifact meets desired functions with respect, cost, environmental consequences and utility [18].

3.3 Research Methodology

3.3.1 Target Population

The research population dealt with urban trees and the target population was employees of Addis Ababa city Government Environmental Protection and Green Development Commission. In environmental protection and green development commission department thirty-six (36) employees who are distributed as shown in table 3-1.

Table 3-1 Employees at environmental protection and green development commission department.

Role of Employee	Number
Managers	2
Employees	28
Total	36

3.3.2 Sampling Design

The sample that was used in this research was thirty-six (36). According to Tremblay et al. [30], for small populations (with fewer than 100 people or other units), there is little point in sampling survey the entire population. This constituted the entire population who work in Addis Ababa city Government Environmental Protection and Green Development Commission. The ideal number of population (participants) depends on the objective of the study: smaller groups require each participant to be more active while larger groups may lead to social loafing (Morgan) [30]. Participants were informed about the project previously to interview conduction. Participation was on a voluntary and not on a reward basis.

3.3.3 Data Collection Methods and Tools

The research made use of both primary and secondary data. Primary data was useful in getting first-hand and new information from the various stakeholders. This data was collected by observation and face-to-face interviews to researcher, experts and mangers of the environmental and forest research institute and city government environmental protection and green development commission. The main strength of interview was that a large number of questions was asked about a given topic and gave flexibility to the analysis. Secondary data was used to understand the state-of-the-art in environmental condition monitoring for urban trees and selecting one that was appropriate to design an IoT system that would enable recording of environmental conditions, analyze them and display them to various end-users.

This data was collected by reviewing various literature. In addition, the secondary data was used to identify ways of developing future works such automating processes in the urban trees such as automatic watering and plantation site prediction.

3.3.4 Data Analysis

Thematic coding and thematic analysis were used to analyze the gathered data. Thematic analysis is an established method of organizing qualitative data and has good potential in capturing knowledge and experienced of workers and experts. Boyatzis[32] described thematic analysis is a method to identify, analyze and report patterns (themes) within the data. By gathering data using different instruments, (e.g. observation, questionnaires with interviews on one study) with participants in different environments, Thematic Analysis will produce and present the data more effectively and reflect the reality of the data collection[32].

The interview data were analyzed using thematic analysis to identify the optimum environmental conditions required in an urban trees and challenges faced in urban trees plantation and growth. The method of thematic analysis is commonly used in qualitative research to capture the complexities of meaning within a textual data set [32].

3.3.5 System Development Methodology and Development Environment

The researcher used Structured Systems Analysis and Design Method (SSADM) for a rigorous system analysis, design and development. It involved logical data, data flow and entity event modelling [3]. SSADM is a set of standards for systems analysis and application design. It uses a formal methodical approach to the analysis and design of information systems. SSADM is a waterfall method by which an IS design can be arrived at; SSADM can be thought to represent a pinnacle of the rigorous document led approach to system design, and contrasts with more contemporary Rapid Application Development methods[33]. One of the main features of SSADM is the intensive user involvement in the requirements analysis stage. The users are made to sign off each stage as they are completed assuring that requirements are met. The users are provided with clear, easily understandable documentation consisting of various diagrammatic representations of the system. SSADM breaks up a development project into stages, modules, steps and tasks. The first and foremost model developed in SSADM is the data model. It is a part of requirements gathering and consists of well-defined stages, steps and products. The techniques used in SSADM are logical data modeling, data flow modeling and entity behavior modeling[33].

SSADM is a waterfall view approach whereby there are sequences of events that run-in series and each step leads on from the last. There are five steps in total, and each step can be broken down further[33]. The step involved are feasibility study, requirements analysis, requirements specification, logical system specification, physical design. The step involved in this research were requirements analysis, requirements specification, and system design.

3.3.6 Ethical Considerations

This study required the participation of human respondents therefore certain ethical issues were considered and addressed. The consideration of these ethical issues was important for the purpose of ensuring privacy of the participants. The ethical issues that were considered include consent and confidentiality. In order to secure the consent of the selected participants, the researcher relayed all important details of the study. The confidentiality of the participants was ensured by not disclosing their names or personal information in the research. Only relevant details that helped in answering the research questions were captured and recorded.

CHAPTER FOUR

REQUIREMENT ANALYSIS AND DESIGN

4.1 Overview

This chapter discussed the requirement analysis and design to design and develop the proposed system, which includes requirement analysis, in this section discussed the optimum environmental conditions for urban trees and the challenge faced with the proposed system overview. In requirement specification discussed hardware, software and platform used in the study. Finally discussed system design with the proposed system architecture and sub-system decomposition.

4.2 Requirement Analysis

For requirement analysis, secondary data sources were collected from various sources documents and literature. Secondary data were obtained from existing framework, research articles, journal, thesis, and conference papers, manuals and reports in order to get data on measurements and, used technologies, challenges in current approach, and also to get data on their level of awareness and challenges faced in urban trees.

4.2.1 Optimum environmental conditions for urban trees

In this research its first objective was to find out the optimum environmental conditions for urban trees. Secondary data used to provide an insight into this by document analysis and literature review. The most important environmental conditions that need to be controlled for optimal urban trees climate are temperature, humidity, water and carbon dioxide emission. Temperature, Humidity and Soil moisture level are the most important condition in urban trees operations which plays a significant role in plant trees growth and development. When the humidity and temperatures are too low plant trees growth is limited whereas too high result to wilting and death of the plants.

The CO_2 concentration in urban forest greatly influences the planted trees growth rate through the photosynthesis process where plants combine it with water to produce oxygen and sugars. The optimum CO_2 concentration is about 1000 ppm (parts per million) for most plants but due to photosynthesis can bring it down to 200ppm which is low enough to impact the growth of plants negatively. Water is also a key requirement for planted trees in urban area mainly for watering which enables transpiration and photosynthesis to take place. Transpiration is the loss of water from plants in form of vapor. This process is important for plants to ensure they do not wilt on hot and sunny weather. Photosynthesis is the process where the plants make food. Water is important in this process because it goes through the plant's stem and further moves to the leaves where photosynthesis takes place.

Spatial scales of cooling: According to the study conducted by Kieron Doick and Tony Hutchings the surface temperature within a green space may be 15–20 °C lower than that of the surrounding urban area, giving rise to 2–8 °C cooler air temperatures and a cooling effect that extends out in to the surrounding area [20].

4.2.2 Specious Selection for urban trees

According to the study by Aramde and Hailu the vicinity of Addis Ababa was once covered with mixed indigenous forest consisting of trees species such as; Juniperus procera (Tid), Podocarpus falcatus (Zigba), Oela Africana (Weira), Hagenia Abyssinica (Kosso), Acacia Abyssinica (Bazra girar) [21]. And also, the study conducted by Alexander Horst, indigenous trees need to be promoted in Addis Ababa as a valuable natural heritage [9]. They remain nowadays only in small pockets and are endangered. Besides, they are site-adapted and, by and large, better suited for watershed protection and erosion control. A far more contentious issue is to what extent Eucalyptus and other exotic trees can be tolerated. Many local people favor Eucalyptus for its economic Benefit and experts argue that Eucalyptus is naturalized in Ethiopia. As a matter of fact, natural regeneration of indigenous trees, particularly Juniperus procera, can be frequently found in Eucalyptus plantations. Especially on degraded and denuded sites, fast growing exotics (e.g. Acacia saligna, Acacia decurrens, Eucalyptus globules) have the ability to withstand harsh environmental conditions and rapidly attain canopy closure [9]. Therefore, the extent to which vegetation cools the urban climate depends on species selection and strategic placement.

4.2.3 Challenges faced in urban trees

The second objective was to identify the challenges faced in urban trees in Addis Ababa. The document analysis includes previous study done in the urban foresters that are found in Addis Ababa. In the following section discussed the challenge faced in Addis Ababa:

4.2.3.1 Lack of proper and long-term plans for sustainable management of the urban trees

Urban trees in Addis Ababa are affecting by various problems such as encroachment, illegal cuttings, low legal enforcement and improper trees selection. At present, the forests of Addis Ababa are almost transforming to urban habitats accommodating an excessive population due to a high rate of rural–urban migration. In addition, industrialization within the urban areas and conversion of different land use within the city and the surrounding urban areas has caused the rapid depletion of existing trees cover during the past 100 years. This depletion of green resources has indicated that succeeding city governments had no proper long-term plans to keep the city green with the exception of intervening in some areas such as the establishment of a few parks and roadside plantations under a city beautification programmer.

With the rapid expansion of the city, wide roads replaced narrow and unpaved roads, leaving a host of disturbed areas. However, there are no plans to plant new trees along these roads and fill the space created by different development activities. No serious effort has been made to reclaim land in a well-planned manner to allow the city to have adequate space along with its growth. These interventions also have diverse problems for sustainable management of the urban trees.

4.2.3.2 Problems with selection of appropriate urban trees species

From the assessment made by Addis Ababa Environmental Protection Authority, they observed that most of the trees planted in Addis Ababa do not fulfil any specific selection criteria [10]. For example, no evidence exists to show consideration for factors such as the purpose of the trees (shade, fruit, seasonal color, windbreak), location of the plantation site (overhead and/or below-ground wires, existing utilities), size of trees (i.e. space to accommodate large, medium or small size trees), and existing soil conditions (depth, fertility and structure). Due to the lack of these factors, most of the trees planted within the city are facing several problems detrimental to their survival. Therefore, it is critical to note that maximum benefits are gain from planting the right trees in the right place. Many conflicts can be reduced or avoided by proper and longtime planning and by matching trees characteristics to site conditions.

4.2.3.3 Absences of automated technologies and legal framework

A study done in urban forest show that, the main challenges of urban forest in A.A. is hampered by weak policy and legal framework , lack of monitoring and controlling environmental conditions, lack of quality water sources, poor watering, plantation site and species selection, pests and diseases and also lack of training on appropriate technological advancements in forest sector.

4.3 Proposed System

In this research, tried to address one of the challenges faced in urban trees plantation and growth monitoring. Urban trees in Ethiopia are not given the needed attention in terms of monitoring environmental conditions such us, temperature, humidity and soil moisture level. As a result, the existing small open spaces on the road side way makes it difficult to manage and monitor using traditional approach. Thus, there was a need to design a system for monitoring environmental condition using the state-of-the-art technology. An automated system for monitoring environmental conditions done with appropriate taxonomies. In this research proposed IoT based environmental condition monitoring prototype in order to manage and control urban trees plantation and growth. It focusses on collecting information from the field. Environmental factors like temperature, humidity and soil moisture level plays a major role for the growth of planted trees. In this proposed prototype environmental conditions of planted trees are collected by using different sensor and real-time data transmitted to the Internet by the wireless sensor network. In addition, a gateway unit handles the sensor information, and transmits the data to web applications for further more visualization.

The automation process using IoT in environmental condition monitoring reduced human interaction and improve the efficiency. In a broader context, the artifact could serve as a template for the implementation of such artifact elsewhere. Moreover, the system could serve as a model for the development of similar artifact, such as one that was developed for automatic predicting plantation site and watering, to serve other public or business needs. Furthermore, the proposed solution can be a synergy for re greening Ethiopia and to enhance the “green legacy” that initiated by the government of Ethiopian.

4.4 Requirement Specification

In this section different hardware, software and platform required for deploying the proposed system were discussed.

4.4.1 Software Requirement

4.4.1.1 Arduino IDE Software

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and is derived from the IDE for the Processing Programming Language and the wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a "sketch" [24].

4.4.2 Hardware Requirement

4.4.2.1 The Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (Datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started [24].

4.4.2.2 Grove Soil Moisture Sensor

This sensor measures the volumetric content of water inside the soil and gives us the moisture level as output. The sensor is equipped with both analog and digital output, so it can be used in both analog and digital mode [25]. The soil moisture sensor consists of two probes which are used to measure the volumetric content of water. The two probes allow the current to pass through the soil and then it gets the resistance value to measure the moisture value. When there is more water, the soil will conduct more electricity which means that there will be less resistance. Therefore, the moisture level will be higher. Dry soil conducts electricity poorly, so when there will be less water, then the soil will conduct less electricity which means that there will be more resistance. Therefore, the moisture level will be lower.

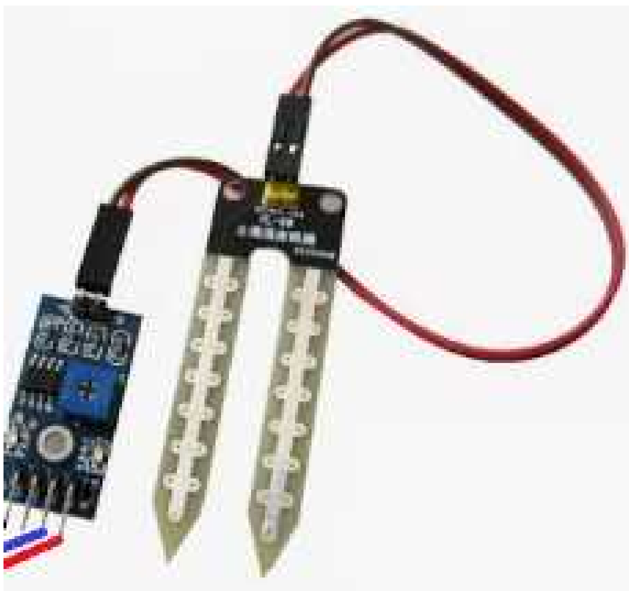

Figure 4.4-1 Soil moisture sensor

4.4.2.3 DHT11 - Humidity and Temperature Sensor

The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds [26].

This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programmers in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20-meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package and in following figure 18, shows interfacing DHT11 with Arduino.

DHT11 pin out:

- The first pin of the DHT11 is VCC pin.
- The second pin of the DHT is Data pin.
- The third pin is not used.
- The fourth pin of the DHT sensor is ground.

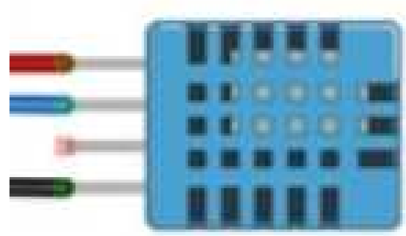

Figure 4.4-2 DHT11 Sensor

4.4.2.4 A6 GSM/GPRS module

At the heart of the module is A6 GSM cellular chip from Ai-Thinker (Manufacturer of ESP8266 Wi-Fi modules). It communicates with a microcontroller over UART and supports baud rate from 1200bps to 115200bps with Auto-Baud detection. All the necessary data pins of A6 GSM chip are broken out to 0.1″ pitch headers [26]. Working frequency is quad-band network, 850/900/ 1800/1900MHz- working voltage: 4.8-9VDC(On-board voltage regulator circuit supply power for A6 module)- working Current: maximum of 2A- Sleep Current: 5mA- Onboard Micro SIM card holder, you can install

Micro SIM card Onboard Micro USB interface for external power supply- Communication Interface: TTL serial port / RS232 serial port- Baud rate: 115200bps and it can also be set by AT command.

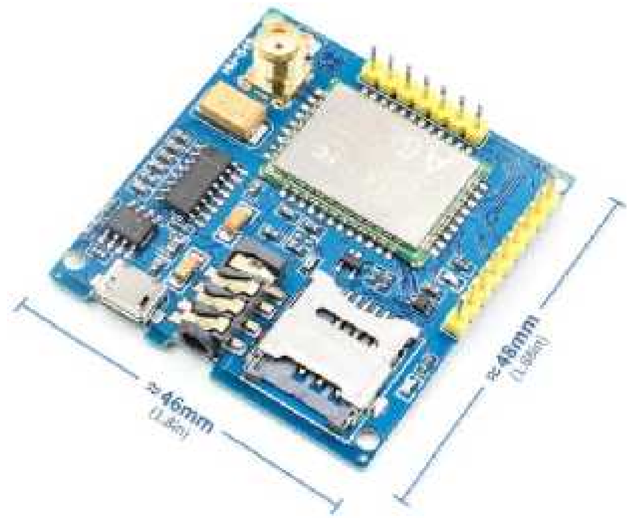

Figure 4.4-3 A6 GSM/GPRS Module

Interface logic voltage: 3.3V- Make and answer phone calls using a headset and electret microphone. - Send and receive SMS messages. - Send and receive GPRS data (TCP/IP, HTTP, etc.).- Be used to test the Ai-Thinker GPRS A6 module- Pin pitch: 2.54mm-Onboard antenna interface: SMA and IPX If you connect this with Arduino for AT commands, you need only 4 wires. To start with, connect U_TxD and U_RxD pin on module to digital pin#3 and #2 on Arduino as we'll be using software serial to talk to the module. Connect VCC pin on module to external power supply rated 5V 2A. Do not be tempted to connect this pin to 5V supply on Arduino, as the module will not work due to the lack of supply current and connect all the ground in the circuit [25].

4.4.3 Platform Requirement

4.4.3.1 ThingSpeak Platform

The ThingSpeak API is an open source platform which listens to incoming data, timestamps it, and outputs it for both human users (through visual graphs) and machines (through easily parse-able code). ThingSpeak is a Web Service (REST API) that lets you collect and store sensor data in the cloud and develop IoT applications and it works with Arduino, Raspberry Pi and MATLAB (premade libraries and APIs exists) [4].

For the purpose of connecting an object to the IoT, we focus on the ThingSpeak API. The interface provides simple communication capabilities to objects within the IoT environment, as well as interesting additional applications (such as ThingTweet, which will be further discussed in a later section). Moreover, ThingSpeak allows you to build applications around data collected by sensors. It offers near real-time data collection, data processing, and also simple visualizations for its users. Data is stored in so-called channels, which provides the user with a list of features [27]. Each channel allows you to store up to 8 fields of data, using up to 255 alphanumeric characters each. There are also 4 dedicated fields for positional data, consisting of: Description, Latitude, Longitude, and Elevation. All incoming data is time and date stamped and receives a sequential ID. Once a channel has been created, data can be published by accessing the ThingSpeak API with a 'write key', a randomly created unique alphanumeric string used for authentication. Consequently, a 'read key' is used to access channel data in case it is set to keep its data private (the default setting). Channels can also be made public in which case no read key is required.

4.5 System Design

4.5.1 Design Goal

The proposed system was expected to solve the problems of the existing environmental condition monitoring, the case of green legacy program and help the stakeholders in order to manage urban trees plantation and growth.

4.5.1.1 Interface

The interface of the system should be user friendly, that is, it should be understandable, usable and corrective.

4.5.1.2 Security Issue

Login and access to the system should be secured. Only authenticated and authorized users should log and use the secured system functionalities

4.5.1.3 Performance

The performance of the system should be reliable and the response time of the system should be short. In this research used two different sensor DHT11 and Grove sensor for monitoring soil moisture level, humidity and temperature. The sensors are very popular for electronics hobbyists because there are very cheap but still providing great performance. And also, DH11 sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, o ering excellent quality, fast response, anti-interference ability and cost-e ectiveness.

4.5.1.4 Reliability

The proposed system will minimize crash during its runtime, since more than one user could use the ThingSpeak API simultaneously. DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability.

4.5.1.5 Maintainability

The proposed system should be developed for easy future maintenance and enhancement if there are additional sensor and actuators requirements, system failure, new technological shift, etc. IoT platforms provide security features, scalability, and capacity for pulling in, storing, and analyzing data. It may connect machines, people, applications, or all three. Like any intelligent network, it provides innate predictive qualities that use data for the purposes of maintenance and troubleshooting. The user interfaces are intuitive and extensible, allowing for the future development of application extensions and the necessary scalability to track an increasing number of connected devices, people, and data sources.

4.5.2 System Architecture

The proposed architecture was monitoring environmental condition for urban trees plantation and growth with the process flow are showing in the following figure 4.5-1 and discussed below.

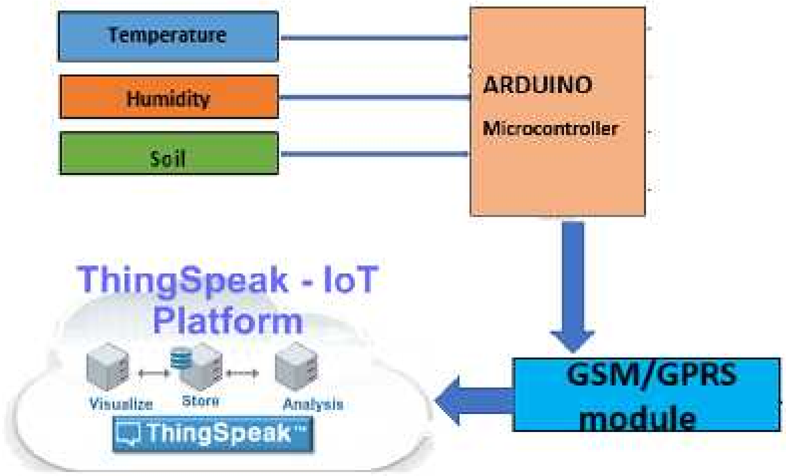

Figure 4.5-1 Proposed Architecture for Monitoring environmental conditions

The proposed system mainly focuses on collecting the information from the field. Environmental factors like temperature, humidity and soil moisture level plays a major role for the growth of a plant trees. The sensors devices used for collecting the information, the type of sensors that used are soil moisture sensor, humidity sensor and temperature sensor.

Figure 4.5-2 Different types of Sensors uses in collecting information

The types of sensors that are shown in the above figure were used in this research; in which the temperature and humidity sensor will give the details of the air content and the soil moisture sensor measures the water content in the soil. Temperature, humidity and soil moisture sensors are uses for the measurement and are connect with the IoT network.

The Arduino microcontroller is the heart of this architecture. It constantly performs the analogue to digital conversion of the various sensors, verifies them and checks if there is need for any corrective action is to be taken at that instant of time. A GSM/GPRS module been incorporated in this architecture to upload the real time data to the Internet. ThingSpeak IoT platform provides very good tool for IoT based projects [4]. By using ThingSpeak IoT platform, we can monitor our data over the Internet from anywhere, and we can also control our system over the Internet, using the channels and webpages provided by ThingSpeak. ThingSpeak 'Collects' the data from the sensors, 'analyze and visualize' the data and 'Acts' by triggering a reaction. The proposed architecture had four sections, firstly soil, humidity and temperature sensor DHT11 senses the humidity and temperature data, and Grove sensor senses soil moisture level. Secondly Arduino extracts the DHT11 and Grove sensor's data as suitable number in percentage and Celsius scale, and sends it to GSM/GPRS module. Thirdly GSM/GPRS module uploads the data to ThingSpeak's Sever. And finally, ThingSpeak analyses the data and shows it in a graph form. In this research we are planned to monitor soil, humidity and temperature over the Internet using ThingSpeak IoT platform for monitoring real time data from anywhere in the world.

4.5.3 Sub-system Decomposition

The system has three main functionalities which are data recording, converting and notifications. Data recording functionality is where the sensors carry out data abstraction in real time. The sensors record temperature, humidity and soil moisture.

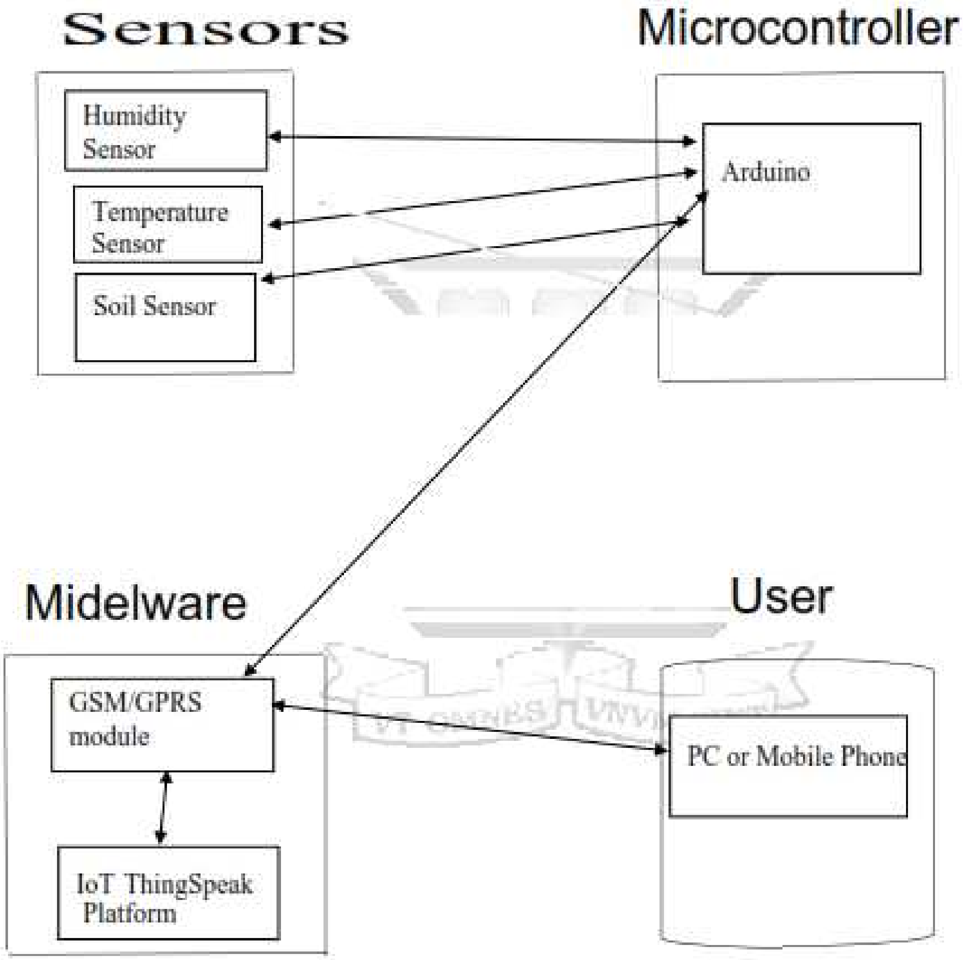

Figure 4.5-3 System Structure of Proposed Architecture

The values are converted from analog to digital values. This functionality is achieved by the Arduino board with the assembled sensors. Event-processing service functionality involves having IoT ThingSpeak platform where the user can view the trends of the environmental condition.

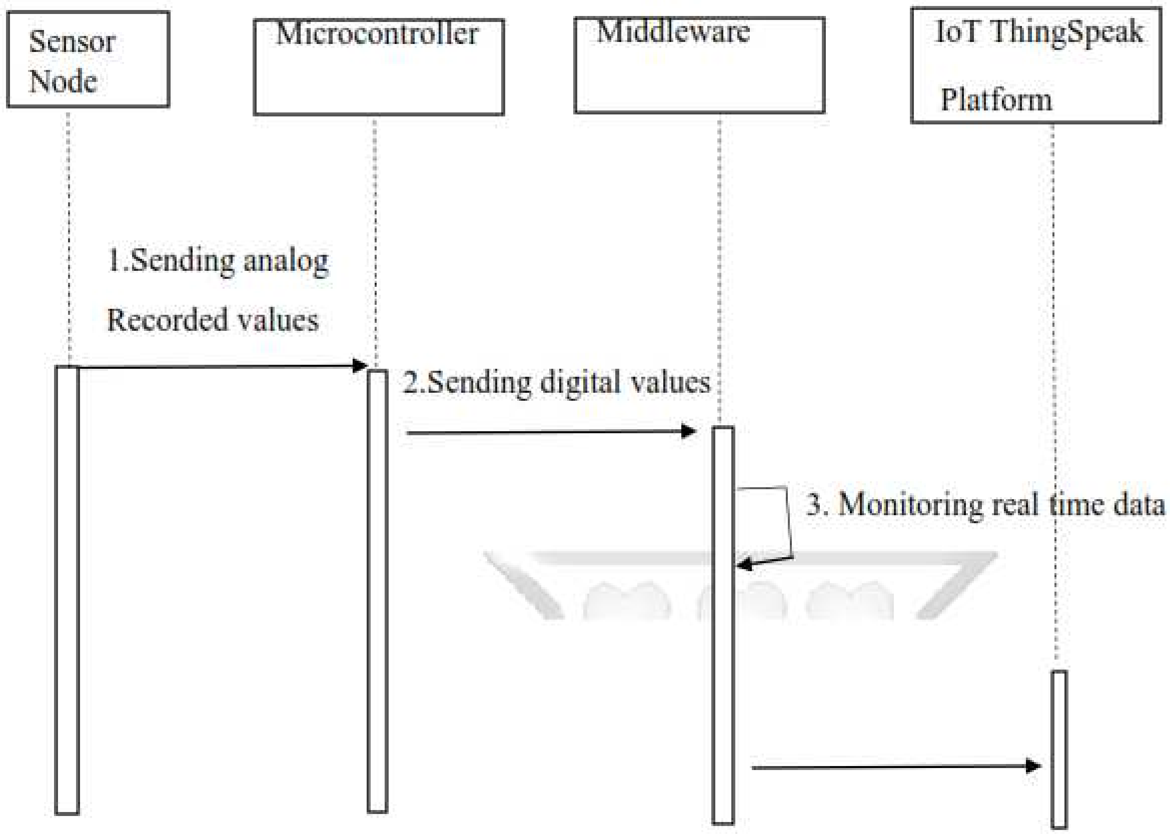

Figure 4.5-4 Sequence Diagram for the proposed system

Figure 4.5-4 depicts the process of data being recorded by the sensors, converted to digital values which are then sent to the middleware for visualize and analysis. According to the need the analyzed information is also stored in the server for historical data analysis and for further visualization in graph. In the following figure discussed the proses flow of the proposed system.

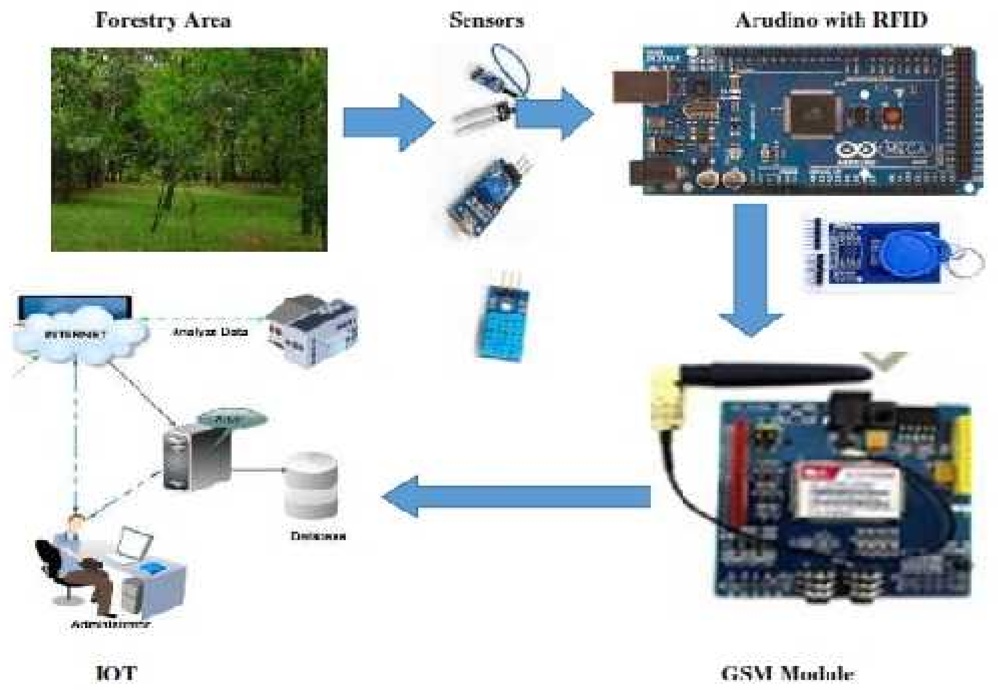

Figure 4.5-5 Process flow

The above figure 4.5-5 process flow of the proposed system. The initial data is collected from the planted trees area by the sensors. Different types of sensors are installed in the area for collecting different set of data. The information that was collected by the sensors will be passed to the Arduino and depends upon the data received the corresponding action will be taken. The other process will be the information is sent to the stakeholders through the GSM/GPRS module. The stakeholders can get the details about the current condition of the planted trees area from any location, such as; Humidity, Temperature, Soil moisture level using Internet. The other mechanism will be depending upon the result of the process what are the actions can be taken. The humidity sensor will send the data related to the water level and the data is processed and depend upon the outcome whether the level is low or high corresponding action will be taken by the stakeholders (administrator). The programming part can be done by using the Arduino IDE, different set of actions are initiated depends upon the functionality that is given in the program.

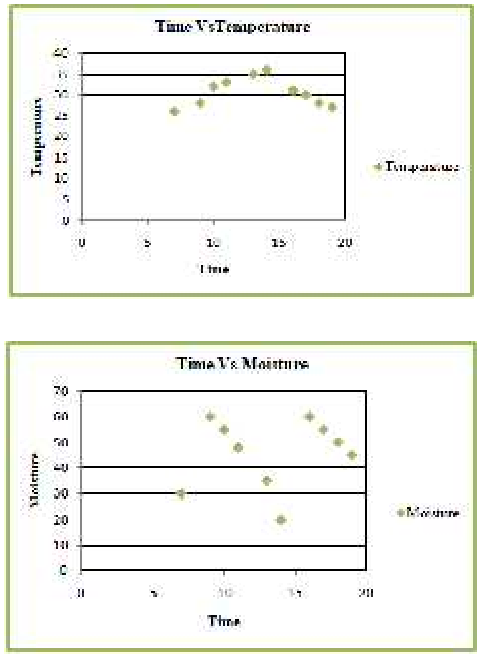

Figure 4.5-6 a) Time (Hrs.) vs. Temperature and Humidity (Celsius) b) Time (Hrs.) vs. Moisture Level

The graph shown in figure 4.5-6 describes both the Time vs. Temperature, Humidity and the Time vs. Moisture level. The temperature will be increasing depend on the time from Morning to evening and then it will start decreasing or may be staying at a constant level. This condition is for normal days and depends upon the season it will differ. The moisture level will be decreased depends upon the time. The moisture level will be monitored and the corresponding action will be taken. This process will maintain the moisture level of the soil and it will in turn make an increase in the growth of the planted trees. By using a web based open API IoT source information platform ThingSpeak that comprehensive in storing the sensor data of varied IoT applications and conspire the sensed data output in graphical form at the web level. ThingSpeak cloud retrieve, save/store, analyze, observe and work on the sensed data from the connected sensor to Arduino. This collected data can be analyzed, store and visualized using graphs and charts to give a better understanding of environmental conditions to the stakeholders.

CHAPTER FIVE

IMPLEMENTATION AND TESTING

5.1 Overview

This section discussed implementation of the proposed prototype and testing of the proposed solution weather it meets the desire function and user needs. And it also discussed how to interface different hardware and software to design and develop the prototype. Finally, the results of test were summarized using table.

5.2 Implementation

In this section, discussed the implementation the prototype using Arduino microcontroller, sensors and GSM/GPRS module to communicate with ThingSpeak platform and the results are displayed in figures. The following figure shows implementation the prototype in planted trees.

5.2.1 Development Tools

In this research different hardware, software and platform are used to design and develop the proposed prototype. In the following section discussed about the development tools and how to interface the prototype.

5.2.1.1 Interfacing Soil Moisture Sensor and Arduino

To connect the sensor in the analog mode, we will need to use the analog output of the sensor. When taking the analog output from the soil moisture sensor FC-28, the sensor gives us the value from 0-1023. The moisture is measured in percentage, so we will map these values from 0 -100 and then we will show these values on the serial monitor. The connections for connecting the soil moisture sensor FC-28 to the Arduino are as follows.

- VCC of FC-28 to 5V of Arduino
- GND of FC-28 to GND of Arduino
- A0 of FC-28 to A0 of Arduino

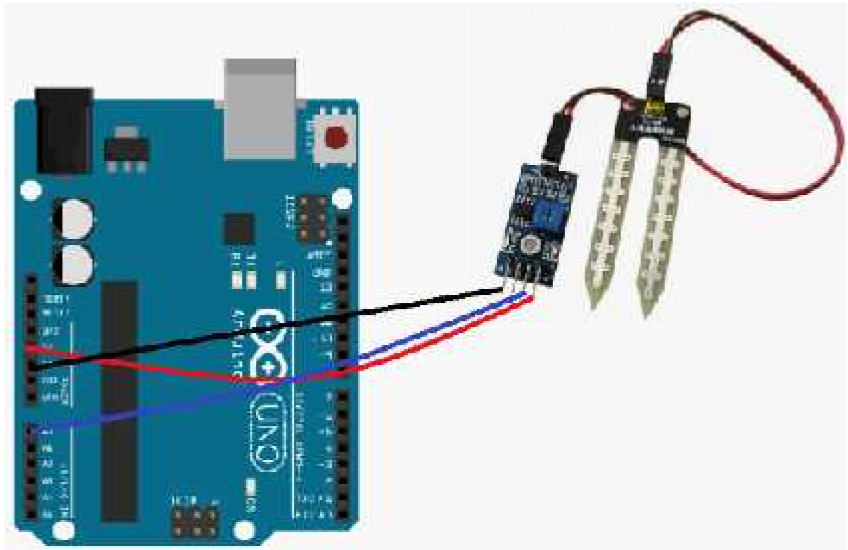

Figure 5.2-1 Wiring soil moisture sensor

Note (Calibration): To get accurate readings out of your soil moisture sensor, it is recommended that you first calibrate it for the particular type of soil that you plan to monitor. Different types of soil can affect the sensor, so your sensor may be more or less sensitive depending on the type of soil you use.

5.2.1.2 Interfacing DHT11 with Arduino

DHT11 sensor is used to measure the temperature and humidity. It has a resistive humidity sensing component and a negative temperature coefficient. An 8-bit micro controller unit (MCU) is also connected in it which is responsible for its fast response. It is very inexpensive but it gives values of both temperature and humidity at a time.

Speciation of DHT11

- It has humidity range from 20 to 90% RH
- It has temperature range from 0 – 50 C
- It has signal transmission range of 20 m
- It is inexpensive
- It has fast response and it is also durable

DHT11 Pin out

- The first pin of the DHT11 is VCC pin.
- The second pin of the DHT is Data pin.
- The third pin is not used.

- The fourth pin of the DHT sensor is ground.

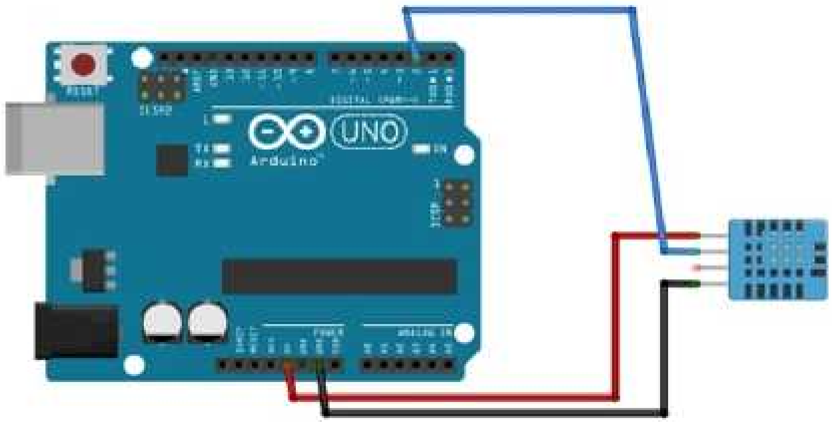

Figure 5.2-2 Wiring DHT11

5.2.1.3 Interfacing A6 GSM module to Arduino

To start with, connect U_TxD and U_RxD pin on module to digital pin#3 and #2 on Arduino as we'll be using software serial to talk to the module. Connect VCC pin on module to external power supply rated 5V 2A. Do not be tempted to connect this pin to 5V supply on Arduino, as the module will not work due to the lack of supply current and connect all the ground in the circuit.

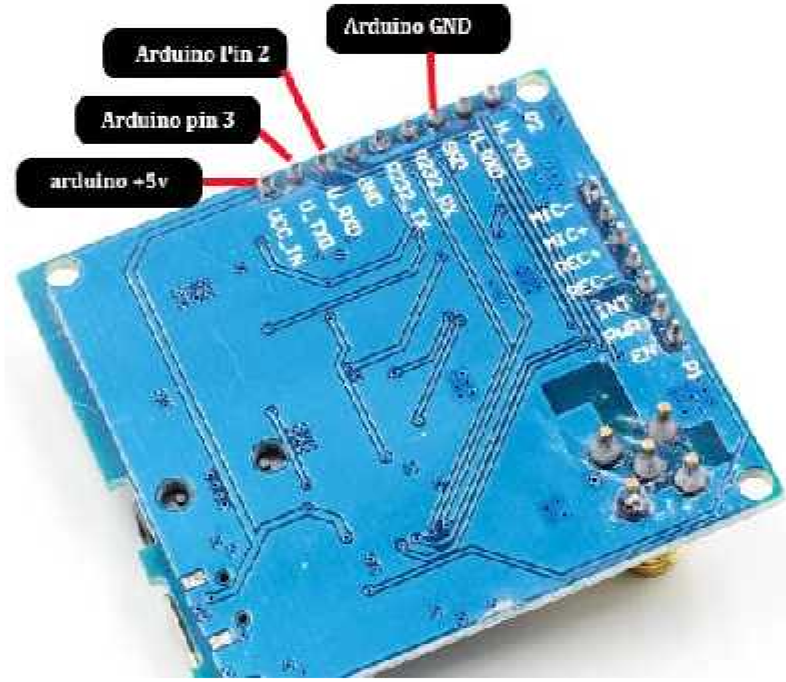

Figure 5.2-3 Wiring A6 with Arduino

A6 GSM/GPRS module is a miniature GSM modem, which can be integrated into a great number of IoT projects. You can use this module to accomplish almost anything a normal cell phone can; SMS text messages, make or receive phone calls, connecting Internet through GPRS, TCP/IP, and more! To top it off, the module supports quad-band GSM/GPRS network, meaning it works pretty much anywhere in the world [23].

5.2.2 Prototype

The prototype runs on Windows operating system, installed on a laptop or desktop machine. The steps below are used to set up the proposed prototype:

Step I: Assembling the sensors and GSM/GPRS module with the Arduino expansion board

Figure 5.2-4 Implementing of the prototype in planted trees

The next step is uploading soil moisture and temperature and humidity sensor data to ThingSpeak channel through Arduino Mega and GSM/GPRS module. Before creating a channel, you need to sign in to things speak. You can easily sign in either using your either ThingSpeak account or Mathswork account, or create a new Mathswork account via following link: https://thingspeak.com/users/sign_up

Step II First of all, user needs to Create an Account on ThingSpeak.com, then Sign In and click on Get Started.

Step III Now go to the 'Channels' menu and click on New Channel option on the same page for further process.

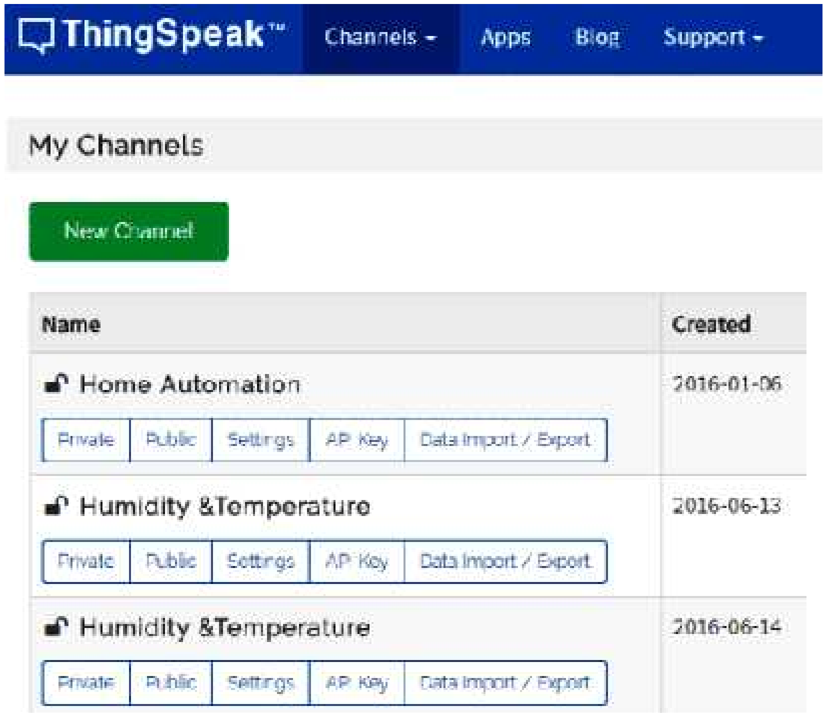

Figure 5.2-5 Create a Channel over ThingSpeak

Step IV. Now you will see a form for creating the channel, fill in the Name and Description as per your choice. Then fill 'Humidity' and 'Temperature' and "Soil moisture" in Field 1 and Field 2 labels, tick the checkboxes for both Fields. Also tick the check box for 'Make Public' option below in the form and finally Save the Channel. Now your new channel has been created.

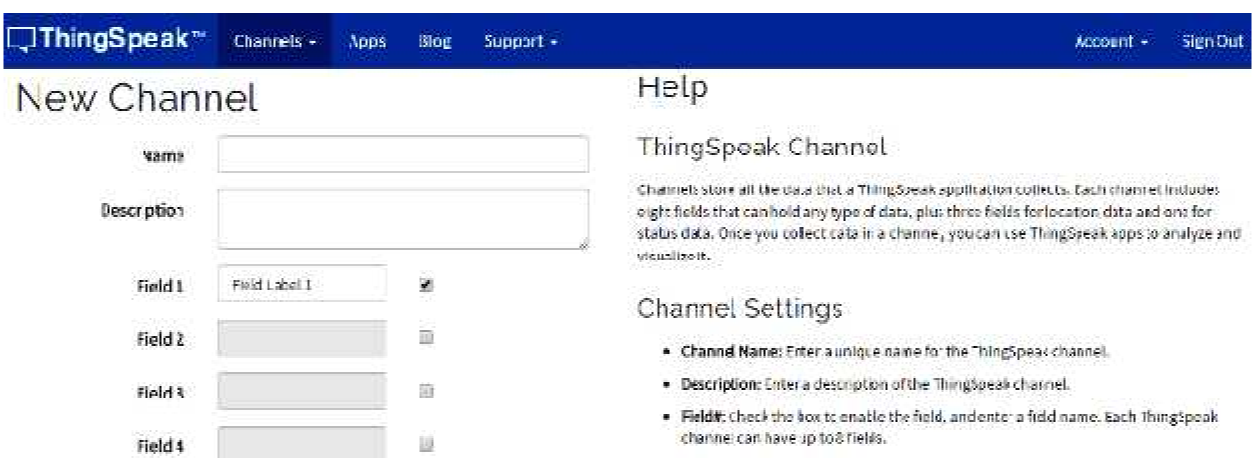

Figure 5.2-6 Create Name and Description in ThingSpeak

Step V. Now click on ‘API keys’ tab and save the Write and Read API keys, here we are only using Write key. You need to Copy this key in char *api_key in the Code.

Figure 5.2-7 Generating API key

Step VI. After it, click on ‘Data Import/Export’ and cop the update channel feed Get request URL, which is:

https://api.thingspeak.com/update?api_key=SIWOYBX26OXQ1WMS&eld1=0

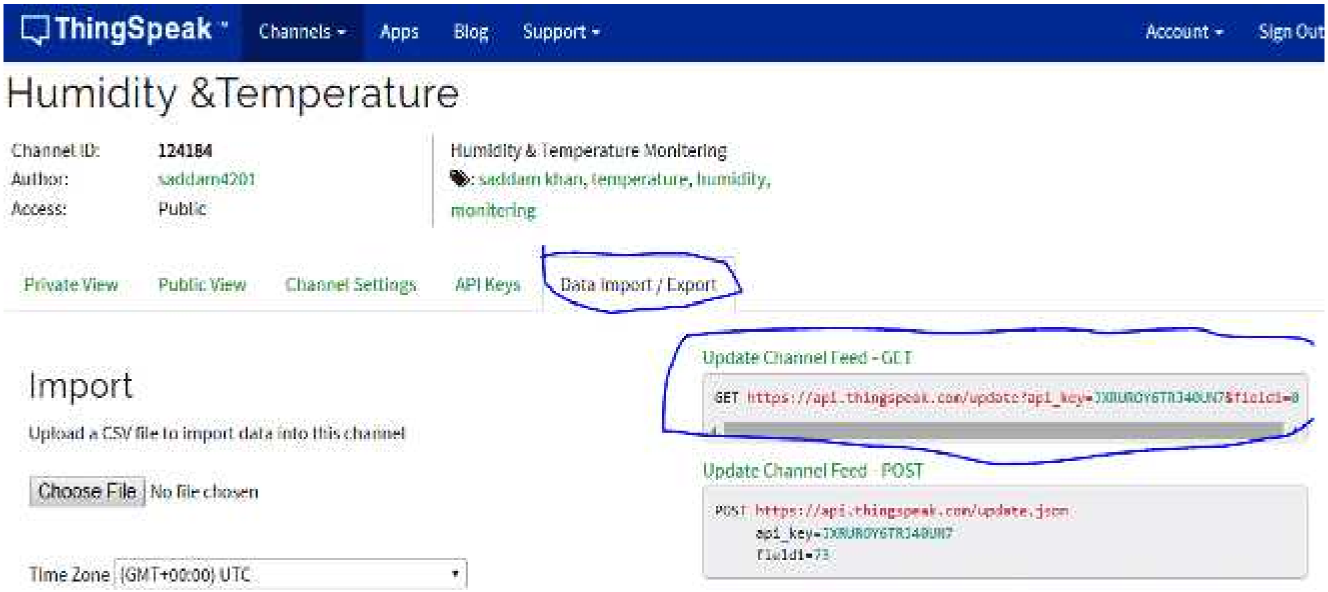

Figure 5.2-8 Data import/export

Step VII. Now user need to open “api.thingspeak.com” using the httpGet function with the postURL as “update? api_key=SIWOYBX26OXQ1WMS&eld1=0” and then send data using data feed or update request address. Finally, the raw data gathered from different sensors are converted using Arduino board and displayed using Arduino software and ThingSpeak platform.

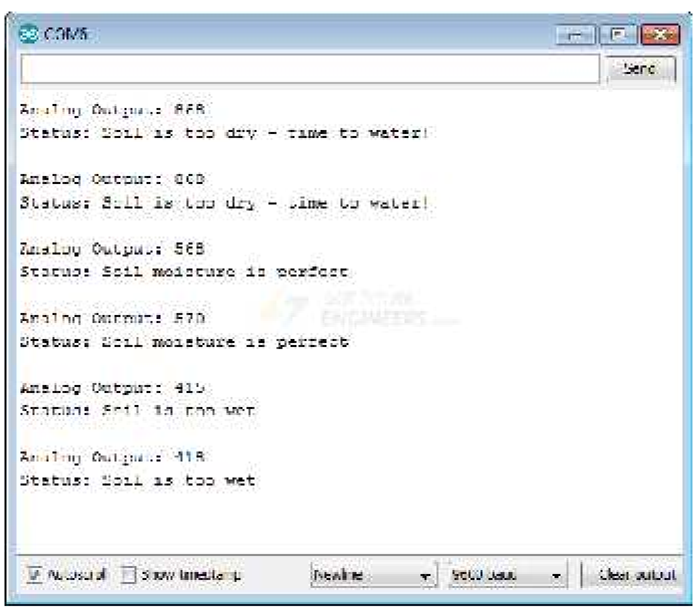

Figure 5.2-9 Output of Soil moisture

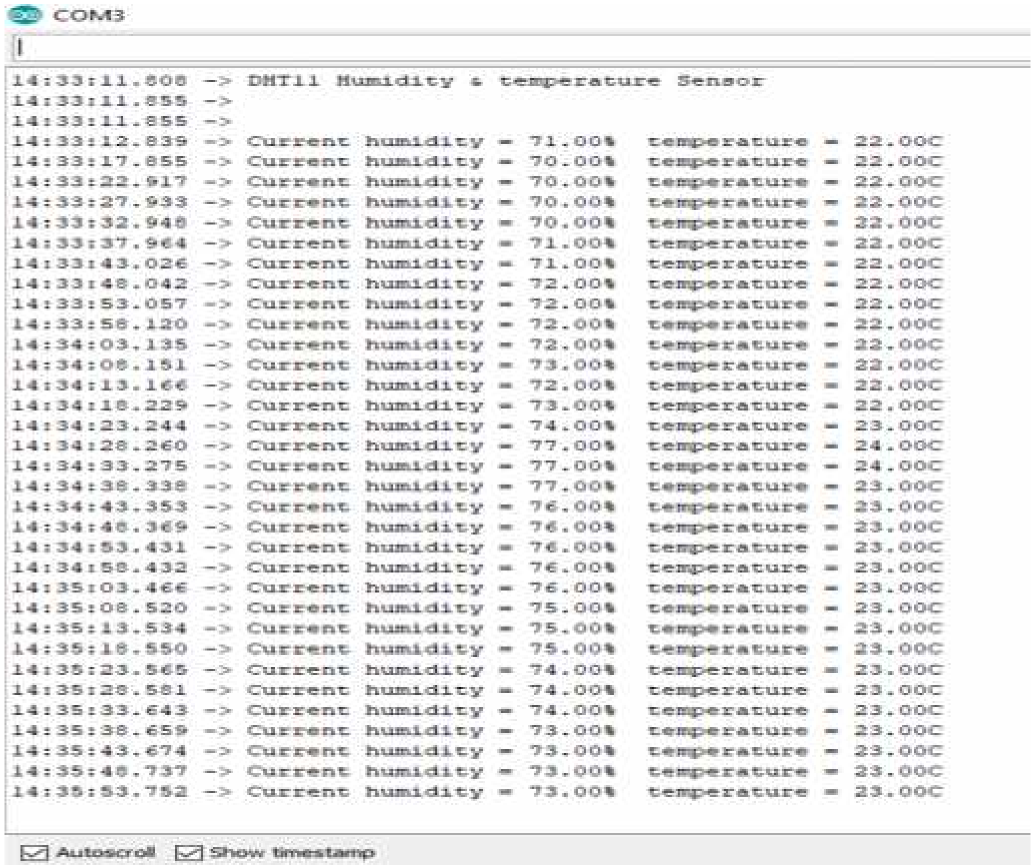

Figure 5.2-10 Output of Humidity and Temperature

In the following figure the ThingSpeak result shown and according to its need we can analyze and visualize in graphical form.

Figure 5.2-11 Output of Humidity and Temperature ThingSpeak Result

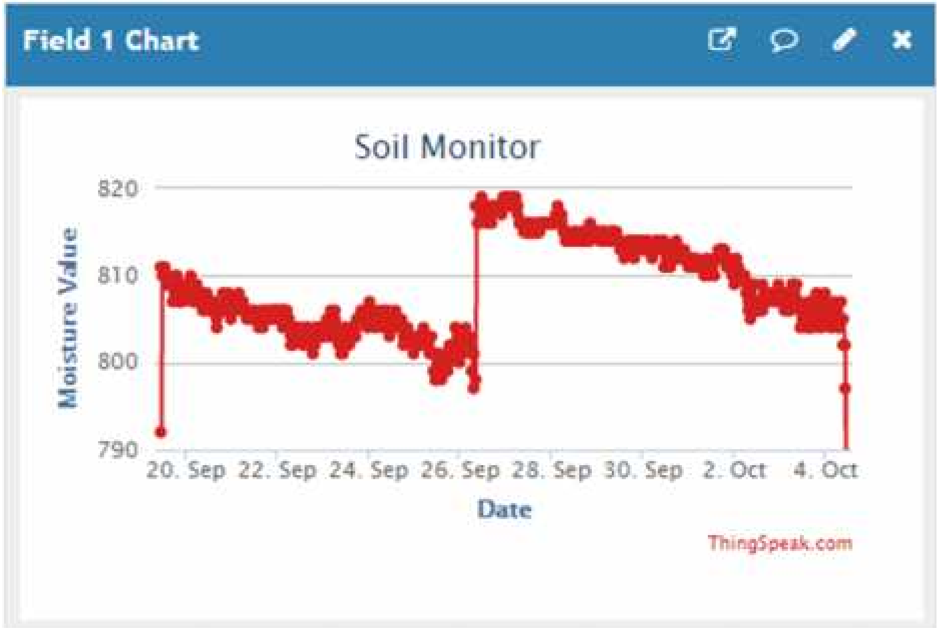

Figure 5.2-12 Output of soil moisture ThingSpeak Result

The sensor data are simultaneously read with data from DHT11 and Grove sensor and soil moisture level, humidity level and temperature levels from planted trees may be measured in real-time.

5.3 Testing

According to Hevner [27], IT artifacts can be tested and evaluated in terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organization, and other relevant quality attributes. In this study construct detailed scenarios around the artifact to demonstrate its utility with the stake holders. The prototype has been discussed and test by user and experts in the area urban forest. Expert sampling was carried out on the basis of theoretical principles of expert evaluation and testing, taking into account that experts should have research and management experience, and knowledge of the environmental protection activities. The study included sixteen experts; it was determined that because of information saturation a bigger number is no longer necessary [31]. The expert has many years of research and management experience and participate in environmental protection, plantation and growth activities.

To test its usability the following table 3 shows what was the user feedback to use the artifact?” where they answer choices range from “Strongly Disagree (metric)” to “Strongly Agree (metric)”. All choices are measured on a 5-point Likert scale, where 1-Strongly disagree, 2-Disagree, 3-Neutral (neither disagree nor agree), 4-Agree, 5-Strongly agree

Table 5.3-1. The proposed artifact usability test scale and result.

Usability Question		**Strongly Disagree/ Agree**				
No.		**1-Strongly Disagree**	**2-Disagree**	**3-Neutral**	**4-Agree**	**5-Strongly Agree**
1.	I think that I would like to use this artifact frequently (36 respondents)	**0(0%)**	**2(5.5%)**	**2(5.5%)**	**21(58.3%)**	**11(30.6%)**
2.	I found the artifact innovative in monitoring environmental condition (16 respondents)	**0(0%)**	**0(0%)**	**3(18.75%)**	**10(62.5%)**	**3(18.75%)**
3.	I thought the artifact was easy to use (16 respondents)	**0(0%)**	**0(0%)**	**2(12.5%)**	**8(50%)**	**6(37.5%)**
4.	I think that I would need the support of a technical person to be able to use	**0(0%)**	**5(13.9%)**	**12(33.3%)**	**15(41.7%)**	**4(11.1%)**

	this artifact (36 respondents)					
5.	I found the various functions in the artifact were well integrated (16 respondents)	**0(0%)**	**0(0%)**	**2(12.5%)**	**8(50%)**	**6(37.5%)**
6.	I thought there was too much consistency in this artifact (36 respondents)	**0(0%)**	**6(16.6%)**	**10(27.8%)**	**10(27.8%)**	**10(27.8%)**
7.	I imagine that most people would learn to use this artifact very quickly (16 respondents)	**0(0%)**	**0(0%)**	**2(12.5%)**	**10(62.5%)**	**4(25%)**
8.	Advantages of having the artifact to address existing issues (16 respondents)	**0(0%)**	**1(6.25%)**	**2(12.5%)**	**13(75%)**	**1(6.25%)**
9.	I felt very confident using the artifact (36 respondents)	**0(0%)**	**2(5.5%)**	**2(5.5%)**	**30(83.3%)**	**2(5.5%)**
10.	I needed to learn a lot of things	**0(0%)**	**0(0%)**	**3(8.3%)**	**28(77.8%)**	**5(13.9%)**

	before I could get going with this artifact (36 respondents)					

The data collection methods and testing questions to be investigated and discussed its usability. In testing and evaluating feedback experts understand how the features of the proposed artifact monitor environmental condition for urban trees plantation and growth. And also, how the proposed artifact addressed the challenges faced in urban trees plantation and growth.

5.3.1 Result and Discussion

In this study the researcher tried to identify challenges encountered in urban trees plantation and growth, and design and developed a solution with the potential to meet the need build a prototype and test whether the prototype meets desired functions with respect, environmental consequences.

Employees were asked several questions regarding to show the level of satisfaction with the artifact usability and better understand the needs of user. Responses were measured on five-point Likert scales. These results demonstrate that most respondents (80.3%) indicated that they felt comfortable and envisioned to use the artifact and that they felt welcome. However, a small majority were neutral (14.9%) and disagreed (4.8) that they would need the support of a technical person to be able to use this artifact.

According to the result a large number of respondents given that the study was more relevant in this sector, and monitoring of the survival and growth of plantation including the factors associated with the observed performance is always a challenging task. With the use such tools greater improvement can be realized in capturing field data. And also, the Directorate suggest that collaboration with the Addis Ababa Environmental Protection Office can facilitate the implementation of study in Addis Ababa.

The proposed prototype was found to be flexible and effective in this field. The prototype had the following strengths which make it a stronger architecture to be deployed.
The prototype allows for inter-operability where different devices and technologies to interconnect creating an embedded system. The systems inter-connected are GSM/GPRS module, Grove Sensors, DHT11 sensor and ThingSpeak platform. This collected data can be analyzed, store and visualized using graphs and charts to give a better understanding of environmental conditions to the stakeholders.

The prototype also achieved scalability through cloud computing where a stakeholder's manager can have distant monitoring of the environmental condition via a web based open API IoT source information platform "ThingSpeak" that comprehensive in storing the sensor data of varied IoT applications and conspire the sensed data output in graphical form at the web level.

Results clearly showed that the automation process using IoT in environmental condition monitoring for urban trees plantation and growth reduced human interaction and improve the efficiency. Moreover, this study identified most considered collected sensor data and technologies for the development of IoT based applications in forest, agriculture and farming sector towards the significant improvement of the business and environment. In a broader context, the artifact could serve as a template for the implementation of such artifact elsewhere. Furthermore, the architecture and prototype could serve as a model for the development of similar artifact, such as one that was developed for automatic predicting plantation site and watering, to serve other public or business needs.

According to a survey conducted by A. A. Raneesha and Malka N Halgamuge, et al. [16], address that, in 2020 IoT objects will be semi-intelligent and an important part of human social life. IoT can further be defined as a fusion of heterogeneous networks including chip technology that scopes gradually more and more, expanding due to the rapid growth of Internet applications such as logistics, agriculture, smart community, intelligent transposition, control and tracking systems. Future research could draw more attention to further automate current processes in agriculture, waste management, smart lightening and forest by reducing existing drawbacks since it has received the least research attention in the considered period.

Furthermore, while IoT has solved many issues related to forest, agriculture and farming there are limitations that we need to consider. Lack of interoperability and compatibility in devices, network flexibility issues when more devices are connecting, and sensor lifetime is some of the limitations to be addressed in future research.

CHAPTER SIX

CONCLUSSION AND RECOMMENDATION

6.1. Conclusion

The main challenges of urban forest in Ethiopia are hampered by lack of monitoring and controlling environmental conditions, poor watering, plantation site and species selection, and also lack of training on appropriate technological advancements in forest sector. The Ethiopian Government planned to plant 5 billion seedlings this year. Over four billion were reportedly planted in the First Green Legacy Campaign organized in 2019 during the Ethiopian rainy season, which runs from the beginning of June to end of August. However, planting trees across Ethiopia is that it might have the opposite of a beneficial effect, and could even threaten some of the country's ecosystems. To solve such a problem, it's scientifically the proven need to employ an automated way of having surveillance on freshly-planted trees and its immediate environmental conditions. In the study different devices and technologies were interconnected to creating an embedded system and collect real time data in the field. The systems inter-connected were GSM/GPRS module, Grove Sensors, DHT11 sensor, Arduino microcontroller and ThingSpeak platform. This collected data were analyzed, store and visualized using graphs and charts to give a better understanding of environmental conditions to the stakeholders.

Results clearly showed that the automation process using IoT in environmental condition monitoring for urban trees plantation and growth reduced human interaction and improve the efficiency.

6.2 Recommendations

Here under some serious pointes the researcher wants to recommend, referring the findings drawn. There should be an immediate need for tree planting to be smartly run, fitted with Internet of Things (IoT). The type of soil we spot for seedlings nursery sites should be scientifically identified and should be planted at the right place suitable to grow. Better to understand the significance of smart farming for the urban greening and climate resilient initiatives to bear fruit. Skilled personnel, needed financial demands and infrastructures should be met before expecting any green legacy to be successful. Plat forms should be organized for stakeholders of tree planting to scientifically and cooperatively act in urban farming and greening. Further researches should be conducted on how to supervise and nurture newly trees. In a broader context, the artifact could serve as a template for the implementation of such artifact elsewhere. Furthermore, the architecture and prototype could serve as a model for the development of similar artifact, such as one that was developed for automatic predicting plantation site and watering, to serve other public or business needs.

APPENDIX

Appendix A- Interview question

Interview guidelines for Gulele botanical garden, Ethiopia Environmental and Forest Research Institute, Addis Ababa city Government Environmental Protection and Green Development Commission administrators, experts and officers.

Dear respondents

I am conducting a study entitled ‘monitoring environmental condition for urban trees plantation and growth using Internet of Things (IoT): the case of green legacy program and your answers for the interview questions are great help. All your responses will be kept confidential. You don’t need to write your name.

Thank you in advance for your co-operation

- How to address the issue of environmental pollution: - particularly factorial and vehicular pollution?

____
____
____

- How to monitor air quality?

____
____
____

- How to monitor water level for urban forest?

____
____
____

- When and in which conditions watering is done?

____
____
____

- How to choose plantation site?

____
____
____

- How to choose trees specious for plantation?

____
____
____

- How to monitor environmental conditions of urban forest?

____
____
____

- What are the challenges faced in growing urban forest?

____
____
____

- Which trees specious are largely planted in Addis Ababa forest?

____
____
____

Appendix B- Request for Evaluation and Testing

Dear respondents I am Gemechis Garuma, a post graduate Computer science student in St. Mary's University, currently working on a research title 'Monitoring environmental condition for urban trees plantation and growth using IoT Internet of Things (IoT): the case of green legacy program' and used for fulfillment of the requirements for the degree of master of Computer Science

The aim of this research was to design and develop a prototype that fill the gap in urban trees plantation and growth by making long term and real time monitoring environmental conditions using IoT. Through this integration, the environmental conditions can be monitor continuously even in real-time and data can be accumulating in the web application.

Here I attached the research evaluation check list and I would like to kindly ask in your esteemed institute to consider my request and test the proposed prototype. Yours testing and evaluation is very important for the success of the study.

I would like to thank you for your co-operation.

Questions

1. To what extent is this artifact likely to be **effective** in achieving monitoring the environmental condition of urban trees using IoT?

2. To what extent is this artifact likely to be **feasible** in environmental and forest field sectors?

3. To what extent is this prototype likely to be **functional** in environmental and forest field sectors?

4. To what extent is this prototype likely to be **viable** in the current plantation campaign and "green legacy"?

5. To what extent is this prototype likely to be **support** and satisfactory in environmental and forest field sectors?

Appendix C-Code for Soil moisture sensor

```
#define soilWet 500  // Define max value we consider soil 'wet'

#define soilDry 750  // Define min value we consider soil 'dry'

// Sensor pins
#define sensorPower 7
#define sensorPin A0
void setup() {
 pinMode(sensorPower, OUTPUT);
  // Initially keep the sensor OFF
 digitalWrite(sensorPower, LOW);
  Serial.begin(9600);
}
void loop() {
 //get the reading from the function below and print it
 int moisture = readSensor();
 Serial.print("Analog Output: ");
 Serial.println(moisture);
 // Determine status of our soil
 if (moisture < soilWet) {
  Serial.println("Status: Soil is too wet");
 } else if (moisture >= soilWet && moisture < soilDry) {
  Serial.println("Status: Soil moisture is perfect");
 } else {
  Serial.println("Status: Soil is too dry - time to water!");
 }
  delay(1000); // Take a reading every second for testing
     // Normally you should take reading perhaps once or twice a day
 Serial.println();
}
// This function returns the analog soil moisture measurement
int readSensor() {
 digitalWrite(sensorPower, HIGH); // Turn the sensor ON
 delay(10); // Allow power to settle
 int val = analogRead(sensorPin); // Read the analog value form sensor
 digitalWrite(sensorPower, LOW);  // Turn the sensor OFF
 return val;// Return analog moisture value
}
```

Annex 4

Code for Humidity and Temperature Sensor

```
#include <dht.h>
#define dht_apin A0 // Analog Pin sensor is connected to
 dht DHT;
 void setup(){
  Serial.begin(9600);
 delay(500);//Delay to let system boot
 Serial.println("DHT11 Humidity & temperature Sensor\n\n");
 delay(1000);//Wait before accessing Sensor
 }//end "setup()"
 void loop(){
 //Start of Program
   DHT.read11(dht_apin);
    Serial.print("Current humidity = ");
  Serial.print(DHT.humidity);
  Serial.print("% ");
  Serial.print("temperature = ");
  Serial.print(DHT.temperature);
  Serial.println("C ");
    delay(5000);//Wait 5 seconds before accessing sensor again.
  //Fastest should be once every two seconds.
 }// end loop()
```

Appendix D-Code for GSM/GPRS get and post

```
#include <SoftwareSerial.h>
SoftwareSerial gprsSerial(2,3);
 #include <String.h>
#include <DHT.h>
 #define DHTPIN A0
DHT dht(DHTPIN, DHT11);
void setup()
{
 gprsSerial.begin(9600);   // the GPRS baud rate
 Serial.begin(9600);  // the GPRS baud rate
 dht.begin();
  delay(1000);
}
void loop()
{
   float h = dht.readHumidity();
   float t = dht.readTemperature();
   delay(100);
    Serial.print("Temperature = ");
   Serial.print(t);
   Serial.println(" °C");
   Serial.print("Humidity = ");
   Serial.print(h);
   Serial.println(" %");
 if (gprsSerial.available())
  Serial.write(gprsSerial.read());
  gprsSerial.println("AT");
 delay(1000);
  gprsSerial.println("AT+CPIN?");
 delay(1000);
  gprsSerial.println("AT+CREG?");
 delay(1000);
  gprsSerial.println("AT+CGATT?");
 delay(1000);
 gprsSerial.println("AT+CIPSHUT");
 delay(1000);
  gprsSerial.println("AT+CIPSTATUS");
 delay(2000);
  gprsSerial.println("AT+CIPMUX=0");
```

```
 delay(2000);
 ShowSerialData();
 gprsSerial.println("AT+CSTT=\"etc.com\"");//start task and setting the APN,
 delay(1000);
 ShowSerialData();
 gprsSerial.println("AT+CIICR");//bring up wireless connection
 delay(3000);
 ShowSerialData();
 gprsSerial.println("AT+CIFSR");//get local IP address
 delay(2000);
 ShowSerialData();
 gprsSerial.println("AT+CIPSPRT=0");
 delay(3000);
 ShowSerialData();
 gprsSerial.println("AT+CIPSTART=\"TCP\",\"api.thingspeak.com\",\"80\""); //start up
the connection
 delay(6000);
 ShowSerialData();
 gprsSerial.println("AT+CIPSEND");//begin send data to remote server
 delay(4000);
 ShowSerialData();
  String str="GET https://api.thingspeak.com/update?api_key= 5Q4KRNN8CSDOP5OK
&field1=" + String(t) +"&field2="+String(h);
 Serial.println(str);
 gprsSerial.println(str);//begin send data to remote server
  delay(4000);
 ShowSerialData();
  gprsSerial.println((char)26);//sending
 delay(5000);//waitting for reply, important! the time is based on the condition of internet
 gprsSerial.println();
 ShowSerialData();
 gprsSerial.println("AT+CIPSHUT");//close the connection
 delay(100);
 ShowSerialData(); }
void ShowSerialData() {
 while(gprsSerial.available()!=0)
 Serial.write(gprsSerial.read());
 delay(5000);  }
```

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