Institute of Research and Publication Indonesia
IJEERE: Indonesian Journal of Electrical Engineering and Renewable Energy
Journal Homepage:https://journal.irpi.or.id/index.php/ijeere
Vol. 3 Iss. 1 June 2023, pp: 36-46
P-ISSN: 2797-1155 E-ISSN: 2797-0898

An Economic and Smart Greenhouse System using Microcontroller for Sustainable Agriculture: A Case Study

Samir Raj Bhandari[1*], Upendra Kumar Khang[2], Aman Kumar Yadav[3], Diwas Pradhan[4], Manjila Shrestha[5], Sweety Adhikari[6]

[1]Lecturer, Department of Electrical and Electronics Engineering, Oxford College of Engineering and Management, Nepal.
[2,3,4,5,6]Student, Department of Electrical and Electronics Engineering, Oxford College of Engineering and Management, Nepal.
Corresponden E-Mail: [1]bhandari.samirraj@gmail.com, [2]k.upendra1231@gmail.com

Makalah: Diterima 29 November 2022; Diperbaiki 22 January 2023; Disetujui 14 February 2023
Corresponding Author: Samir Raj Bhandari (ORCID iD: 0000-0003-2722-8008)

Abstrak

Permintaan makanan terus meningkat dibandingkan dengan produksinya karena urbanisasi yang cepat, pertumbuhan populasi dan perubahan iklim. Dalam skenario ini, rumah kaca merupakan alternatif untuk memaksimalkan produksi pangan tanpa menambah lahan subur. Rumah kaca pintar menggunakan sistem sensor terintegrasi untuk mengontrol dan memantau lingkungan di dalam rumah kaca. Penelitian ini berfokus pada perancangan sistem pemantauan parameter yang hemat biaya dan otomatis untuk rumah kaca yang ada menggunakan mikrokontroler. Penelitian ini dilakukan dalam dua bagian, awalnya umpan balik mengenai rumah kaca saat ini dan ruang lingkup otomatisasi dikumpulkan melalui survei lapangan dengan petani dan kemudian model percobaan dikembangkan sesuai dengan pengumpulan data. Dari analisis data survei lapangan, ditemukan bahwa rumah kaca saat ini memiliki masalah dalam pengendalian suhu dan irigasi yang efektif. Dengan demikian, model yang dirancang melakukan pendinginan dan irigasi otomatis dengan pemantauan yang efektif dari parameter ini dalam tampilan. Selanjutnya, berdasarkan analisis ekonomi, biaya tenaga kerja untuk pemantauan rumah kaca adalah NRs. 1, 66, 860 uper tahun yang akan dikurangi. Sementara itu, analisis periode pengembalian yang didiskon menunjukkan bahwa investasi awal akan pulih setelah 2.34 tahun dengan biaya konversi ke rumah kaca pintar sebesar NRs 552 meter persegi.

Kata kunci: sistem pendingin otomatis, sistem irigasi otomatis, pemrograman, rumah kaca pintar.

Abstract

The demand of food is continuously increasing as compared to its production due to the rapid urbanization, population growth and climate change. In this scenario, greenhouse is an alternative to maximize the food production without increasing fertile land. The smart greenhouse uses integratedsensor system to control and monitor the environment inside the greenhouse. This research focuses on designing cost effective and automatic parameter monitoring system for existing greenhouses using microcontroller. The research was carried out in two parts, initially, feedbacks regarding the current greenhouse and scopes for automation were collected through field survey with the farmers and later, an experimental model was developed in accordance with the data collection. From the data analysis of field survey, it was found that current greenhouses had problems in effective temperature and irrigation control. Thus, the designed model carries out automatic cooling and irrigation with effective monitoring of this parameter in a display. Furthermore, upon economic analysis, labor cost for monitoring of greenhouse wasNRs. 1, 66,860per annum which will be reduced. Meanwhile, discounted payback period analysis showed that initial investment will recover after 2.34 years with the cost for conversion to smart greenhouse atNRs 552 sq. meters.

Keywords: *automatic cooling system, automatic irrigation system, programming, smart greenhouse.*

1. INTRODUCTION

1.1 Background

The radiation from sun propagates through space to the earth in interval of different wavelength with a determined frequency and if frequency is higher lower is the wavelength and vice-versa[1]. Electromagnetic spectrum is the entire distribution of the electromagnetic radiation according to wavelength or frequency although all the electromagnetic waves travel at speed of light in a vacuum[2]. The figure below shows the electromagnetic spectrum:

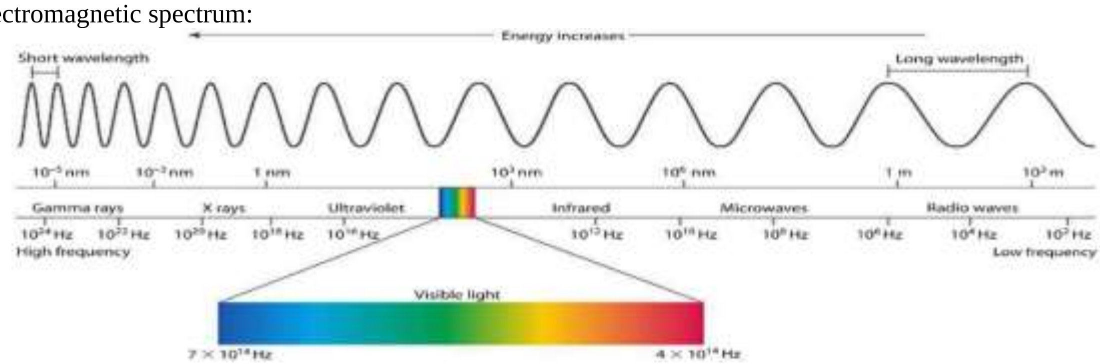

Figure 1: Electromagnetic Spectrum*[2].*

Natural greenhouse effectis the process in which emission of electromagnetic radiation by atmosphere warms the planet's surface.The atmosphere composes of different gases are relatively transparent to incoming visible light from sun. The greenhouses work on the principle of natural greenhouse effect[3]. The figure shows below is working of greenhouse works:

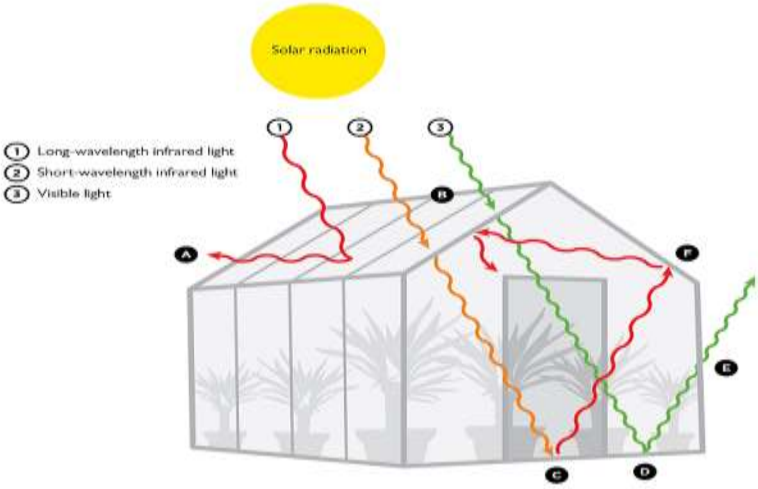

Figure 2: Working of Greenhouse[4]

Solar radiation from the sun strikes on the transparent glass or plastic panel where the long wavelength infrared light is reflected, short wavelength infrared light and visible light are refracted through glass or plastic panel. The visible light escape from green house but the short-wavelength infrared light trapped inside the greenhouse which hit the ground and warms air around it. The warmed air around surfaceheats and rises up the green house. Since greenhouse panel or plastics are good at trapping heat.

Smart greenhouse includes Internet of Things (IoT) based technologies which automatically adjust the climate condition according to a particular set of instructions[5]. With adaptation of smart greenhouse has reduced the human intervention, thus making entire process cost effective and increases accuracy at the same time and by using various sensors like humidity, temperature, moisture sensors builds modern greenhouse in which automatic irrigation and automatic climate control according to the crops can be adjusted[5]. These sensors collect and transmit the real time data which helps in monitoring the monitoring the greenhouse precisely in real time[5].

1.2 Literature Review

1.2.1 Smart Greenhouse in Past

Greenhouse farming technology was first introduced commercially during 19th century in the Netherlands and France[6]. In 2011, IoT based environmental monitoring system for the green house is introduced with integrating wireless network, mobile network and the internet to perform remote monitoring of the plants in real time[7]. In 2014, design a portable measurement system which included sensor to measure air humidity, temperature, and moisture of the soil to control the irrigation system of the vegetables via smart phones and wireless sensor network[8]. In the year 2004, Nepal started a prototype test greenhouse at 3000 meters altitude in Simikot, Humala under Rural Integrated Development Service (RIDS) Nepal[9].
In Indonesia, lower cost, simple design rain shelter were built with plastics, wooden frames or steel frames for growing the crops during the heavy rain to reduce financial burden and on small scale forced air coolers were adopted and later on modern green house and hydroponics technology were used.[10]

1.2.2 Smart greenhouse in present

Plastic low tunnel nursery, local type greenhouse, naturally ventilated greenhouse, shade net houses are major greenhouse technology adopted by farmers in Nepal. Some more fan and pad cooling system and soil-less culture are also at very initial stage of greenhouse technology in Nepal. Due to initial cost of construction, necessary arrangement for cooling, heating option and irrigation system within greenhouse makes the greenhouse product more expensive than normal crops in the open fields. The greenhouse technology is still in its preliminary stage in Nepal. We visited some of greenhouses for data collection and found that most of the farmers are still using conventional greenhouses. Some of the greenhouses were equipped with drip irrigation system, fan for air circulation technology. Various researches have also shown the interest of people toward automatic system [11].
Smart green house is also part of the efforts to encourage agriculture digitalization, with the end goal of improving agriculture production. Itsimplementation in agriculture, optimizes digital technology for agriculturedevelopment. The function of smart greenhouse is more a medium to simulate plants with various engineering in the greenhouse such as regulating temperature, humidity, irrigation and nutrient needed by plants. Indonesian farmers have not fully implement smart greenhouse because there are still some obstacles for farmers to adopt related technology such as IoT[12]

1.2.3 Smart Greenhouse in Future

The demand of the food in future will be very high as compared to the production of the food due to population growth, urbanization of the fertile land, global warming[13]. One way to meet the demand of the future is smart greenhouse where monitoring of plant health, nutrition in the soil for the plants and monitoring of the environment inside the greenhouse is automatic. Smart greenhouse provides controlled environment independent of the outside environment. This will increase the production of the greenhouse without increase in fertile land. Thus, we can say that farming may be shifted to smart greenhouse.
Smart green house will feature smart farming agriculture and farmers no longer need to go to monitor their crops manually.Several sensors are installed within smart green house to monitor temperature, irrigation and light needs. All of them are controlled through a sensor. Smart green house resolves issues in the agriculture sector by presenting modern agriculture with the implementation of technology and innovation adjusted to the condition of productive activities and needs in the agriculture sector.This modern agriculture is realized through forward-looking and anticipative innovation development and creation.Smart green house is also projected to attract millennials or increase their interest in the agriculture sector, specifically in the horticulture field[14]

1.3 Objectives of the study

To design a cost effective and technically smart green house. The proposed model is estimated to reduce the human effort through automation.

2 MATERIALS AND METHOD

2.1 Block Diagram of the Study Design

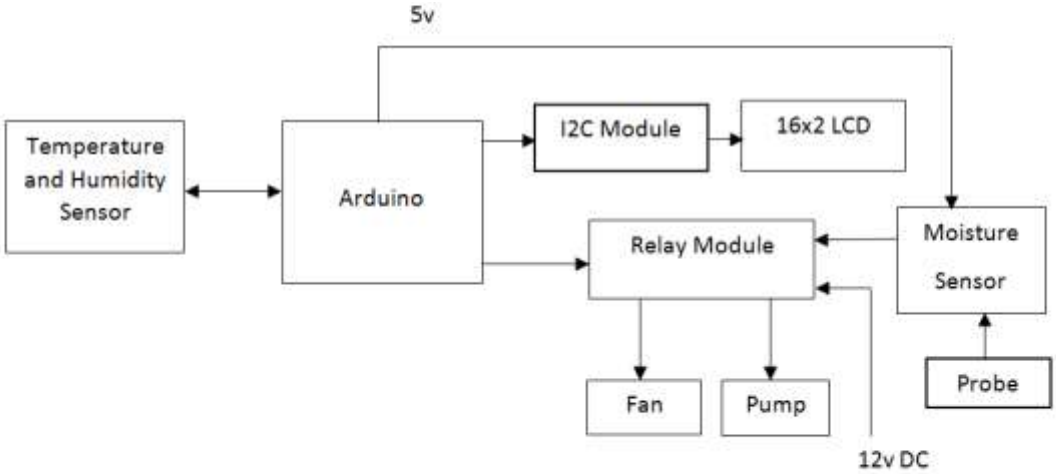

Figure 3: Block diagram of the system

DHT11 sensor is used to detect the humidity and temperature inside the greenhouse. The output ofDHT11 temperature sensor is fed to the pin 7 of Arduino UNO. The Arduino process the data from DTH11 sensor and sends signal to the relay module accordingly with the programing is saved in Arduino. When relay modulereceives signal,the relay is activated and turn on the fan connected to it. Also the temperature and humidity measure by the sensor is displayed in LCD connected to the Arduino. The LCD display is connected through I2C module with Arduino UNO. The moisture sensors which measure the water content in the soil and supplied with 5v from Arduino. The signal from moisture sensor is directly fed to the relay module. Signal from moisture sensor activates the relay which turns on the pump connected to relay module. The 12v adapter is used to supply the fan and motor.If the temperature is below the specified value there is no signal to the relay module. If temperature exceeds specified value the Arduino generate signal to the relay which turn on the fan.

2.2 Research Methods

This research intends to design an economical and intelligent microcontroller-basedgreenhouse monitoring system on the basis of data obtained from field survey. The research flow diagram can be seen in the figure 3. The research starts with the problem identification of current greenhouses. Then, questionnaire were prepared covering all the information required for developing a system model and data from farmers were collectedby interviewing. The data obtained from field survey were analyzed. The outcome of the analysis is that there were manly two problems associated with current greenhouses i.e. irrigation and temperature control.After that, testing of system model wasdesigned and the model were tested and analyzed until it was compatible. If the model were incompatible with the initial requirement then the system design would be repeated. And if the system model is compatible then jumps to next step i.e. making a conclusion, and the research is done.

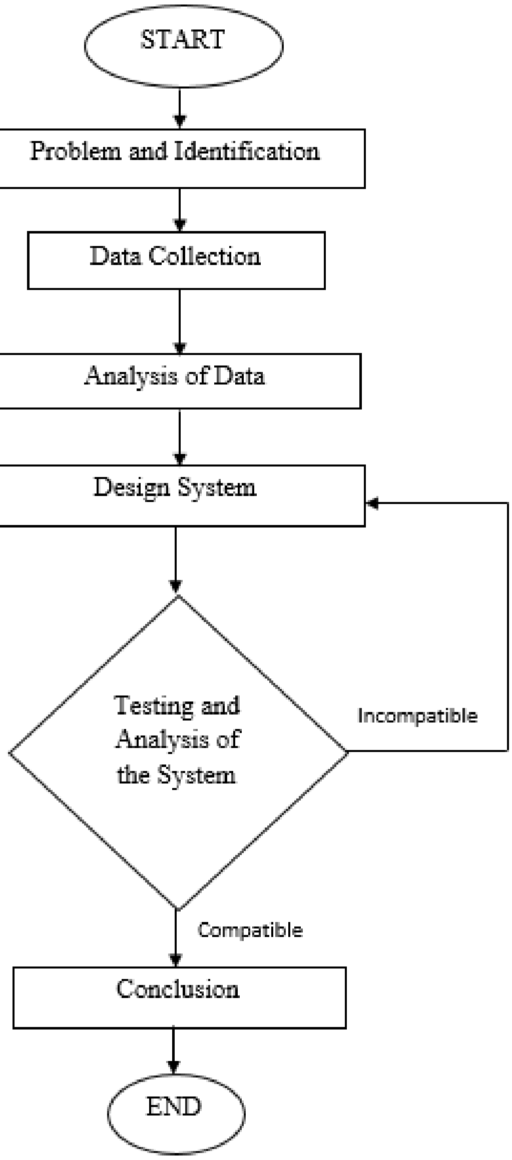

Figure 4: Research flow diagram

2.3 Hardware Requirements

Arduino UNO

The Arduino UNO is an ATmega328P microcontroller based board. It has 14 digital inputs/outputs pins 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, and ICSP header, and a reset button. It can be powered with either 12v power source or simply connect it to a computer with a USB cable.

DHT11 Sensor

TheDHT11 Sensor is a humidity and temperature sensor which generates calibrated digital output. It can be interfaced with microcontroller like Arduino. DHT11 is a part of DHTXX series sensors. It consists of three main components i.e. a resistive type humidity sensor, a negative temperature coefficient thermistor and an 8-bit microcontroller which converts analog signal from sensors and sends out digital signal. It contains three pins. Two pins for power supply and a middle pin for digital output signal.

Relay Module

Relay is an electromechanical switch that uses an electric current to open or close the contacts of a switch. It consists of six pins in general those are Vcc, common pin, ground pin, Normally Open (NO) pin, Normally Close (NC) pin and relay trigger pin.

LCD 16x2

A liquid crystal display (LCD) is a flat panel display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.

Moisture Sensor

Soil moisture sensor has been used for green house to monitor and it is benefit in process of irrigation. The set threshold value of sensing data of moisture soil sensor is conditioned to meet the plants necessary requirements. When soil gets dry it will send signal to start irrigating the soil.

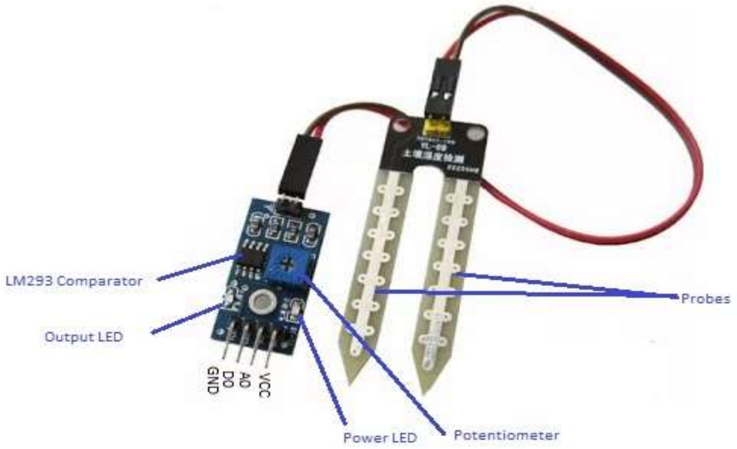

Figure 5: Soil Moisture Sensor[15]

3 RESULTS AND DISCUSSION

3.1 Feasibility study

The various data obtained from the field survey is shown below:

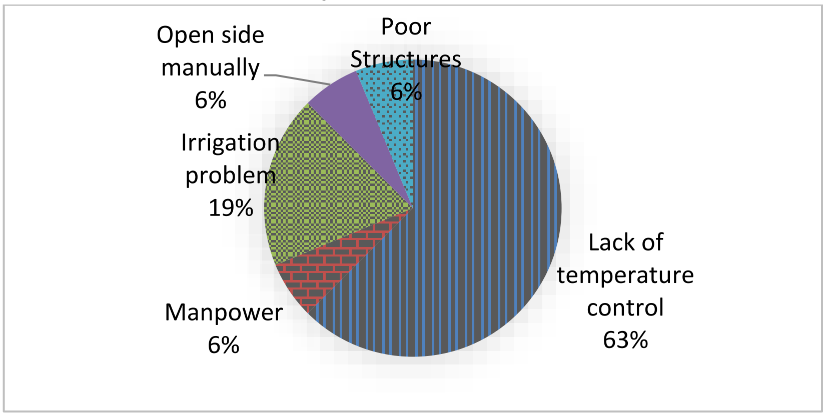

Figure 5: Problems Exists in Current Greenhouse

The pie chart shows above information about problem exists in existing greenhouse. Above pie chart shows that problem associated with most of the current greenhouses are temperature control and irrigation problem. So, the design is concentrated to solve the problems related temperature and irrigation control. Keeping this in view the programming in the microcontroller has been done accordingly.

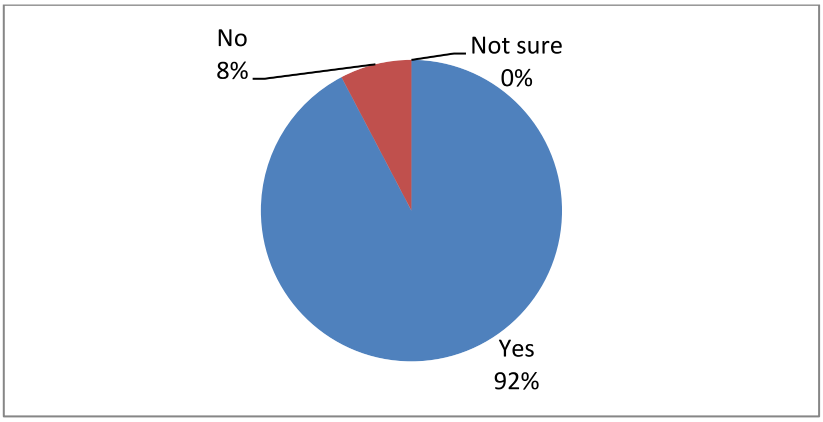

Figure 6: Urged to upgrade smart greenhouse

The pie chart shows above information about respondents felt a need to upgrade to smart greenhouse. The chart above shows that majority of respondents are positive to upgrade an existing greenhouse into intelligent greenhouse. This type of enthusiasm showed by the respondents and farmers led to the development of this prototype and various types of economic as well as feasibility study is carried out which has shown very promising results and is presented in later section of this research.

3.2 Economic Analysis

3.2.1 Budget of Natural Greenhouse

Table 1: Budget of Smart Natural Ventilated Greenhouse

Abstract of Cost

Project: Smart Greenhouse
Job: Summary of Costs

S.N.	Description of Works	No. of Blocks	Total Amount	Remarks
1	Natural ventilated 20mx28m Poly House	1	1,703,852.91	
2	Cost for Electrical System	1	178,532.61	
3	Cost for Automation of Greenhouse	1	130,823.02	
	Total Budgetary Cost Estimate		2,013,208.54	

<u>Amount in Words:-</u> Nepalese Rupees Twenty Lakhs Thirteen Thousand Two Hundred Eight and 54 Paisa

The table 1 shows the cost estimation of a 20m x 28m i.e. 560 sq. meter poly house (a type of green house). The greenhouse is naturally ventilated. The greenhouse is built with 50% stabilized shade net with manually operated mechanism for expanding and retracting and the shade net should be equal to the floor area of green house. The maximum height of the greenhouse from the ground is 6 to 6.5 meter from foundation level. The whole structure is made from galvanized iron. The structure should withstand to minimum wind velocity of 100 km/hr. The house is fully covered with 200 micron plastic that's why it is called poly house.
For the lighting, power socket installation and other electrical facility the estimated cost is Rs. One lakh seventy eight thousand five hundred thirty two and sixty one paisa. There are 12 bulbs included in estimation. The cost of single IP65 bulbs is NRs 5000 according to district rate of Kathmandu.
For installation and fixture of 1 hp water pump, 30 sprinklers, four moisture sensors two power socket and a control circuit to automate the cooling and irrigation of the greenhouse, it is estimated that it costs Rs. One lakh thirty thousand eight hundred twenty three and two paisa.
The total budget of the project including infrastructure, electrical systems and automation system is NRs. Twenty lakhs thirteen thousand two hundred eight and fifty four paisa.

3.2.2 Calculation of payback period

Our project reduces the human effort required for opening the ventilation, monitoring soil moisture and watering whenever required. Thus cost required for the employee is reduced. Let's consider one employee required for the monitoring soil moisture and watering whenever required and opening the ventilations manually charges NRs. 15,000. Therefore, NRs. 180,000 required per annum for employee. Thus, cost for employee saved can be taken as the revenue. Also consider the system consumes 3 KWh per day and cost for 1 KWh is NRs. 12.

Cost for employee per month = NNRs. 15,000
Cost for employee per annum = NRs.180,000
Energy consumption per annum = 1095 KWh
Cost of energy consumption = NRs. 13,140
Net revenue = NRs. (180000-13140) = NRs. 166,860
From the total cost smart greenhouse table,
The initial cost for the project =NRs. (178553+130823) = NRs. 309,355.
Let, MARR =15%
Now, discounted payback period can be calculated as shown in table below:

Table 2: Calculation of discounted payback period

Period (year)	Net Cash flow(NRs)	Discounted cash flow at present @15%	Cumulative Cash Flow(NRs)
0	-309,355	-309,355	-309,355
1	166,860	145,095.65	-164,259.35
2	166,860	126,170.13	-38,089.22
3	166,860	109,713.15	71,623.93

The cumulative cash flow sign changes between period 2 and 3. Thus the payback period lies between 2 and 3.By interpolating, we can calculate the simple payback period is equal to 2.34 years. Thus initial investment of the project recovered after 2.34 years.

3.3 Technical Analysis

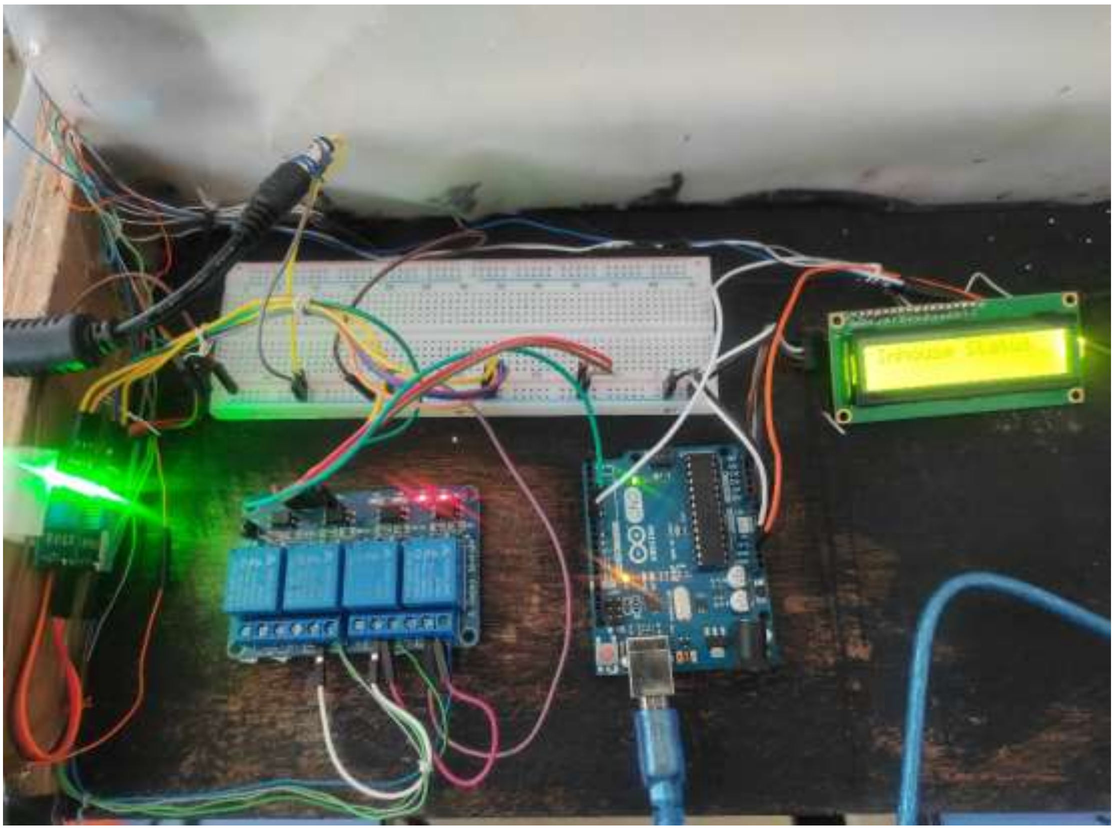

Figure 7: Control circuit of the system

The control circuit of the system is shown in figure above. The relay module, two moisture sensors and LCD are supplied from Arduino with 5v. The fan and pump are supplied with 12v from 12v adapter. But for the mega project pumps and fans might be operated from 230v supply. And the control system works only on five volt in both scenario. The Arduino can be supplied from the 12v dc power for mega project. For mega project four or more than four moisture sensor can be used for 20m x 28m greenhouse. The moisture level can be adjusted through a switch provided with the soil moisture sensor. The moisture level can be adjusted instantly whenever required.A moisture sensor can sense only around 7 cm and the probe must be placed on such areas which can represent whole area to be watering. Thus for mega project we estimated that four moisture sensor can cover 20m x 28m area. The moisture sensor probes are placed in such areas which covers all the area of the greenhouse.

For demonstration prototype model two moisture sensors are used for two motor i.e. one motor for one soil moisture sensor. The fan is turned on whenever the temperature read by the sensor exceeds the predefined level. The LCD screen displays “Smart Greenhouse”, humidity and temperature measured by DHT11 sensor and the status of either fan is on or off. The temperature level above which fan is turned on can be redefined in the programing.

Code in microcontroller for program Initialization

```
#include <DHT.h>
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
#define RELAY_FAN_PIN A3
LiquidCrystal_I2C lcd(0x27,16,2);
#define DHTPIN 7
#define DHTTYPE DHT11
int h;  //Stores humidity value
int t; //Stores temperature value
constint TEMP_THRESHOLD_UPPER = 25; // upper threshold of temperature,
```

```
void setup()
        {
          Serial.begin(9600);
          Serial.println("Temperature and Humidity Sensor Test");
          dht.begin();
          pinMode(RELAY_FAN_PIN, OUTPUT);
          lcd.init(); //initialize the lcd
          lcd.backlight(); //open the backlight
          lcd.setCursor(0,0);
          lcd.print("Smart Greenhouse");
          lcd.setCursor(1,1);
          lcd.print("     OCEM     ");
          delay(3000);
          lcd.clear();
        }
```

4. CONCLUSION

The paper mainly focuses on designing an economical and smart microcontroller based greenhouse monitoring system which can be capable of automating irrigation and cooling of the greenhouse results in reduction of human effort.The cost for upgrading a 20 m x 28 m existing greenhouse is Rs Three Lakh Nine Thousand Three Hundred and Fifty Five.Thus, the cost for convertion into a smart greenhouse is NRs. Five Hundred and Fifty Two per sq. meter.The investment will recover after 2.34 years. The developed model is capable of solving irrigation and cooling problem of an existing greenhouse.Smart greenhouse can reduce labor cost required for monitoring, opening ventilation and irrigation. The precise monitoring system for smart greenhouse can be capable of maintaining ideal microclimate require for particular crops which increases productivity and gives advantages over convention greenhouse.The disadvantages of normal greenhouse is, farmers have to observe greenhouse frequently and makes decision regarding irrigation, fertilization, cooling, etc which may be inefficient. The system would be better if the status of the greenhouse is displayed on the smart mobile phone and based on IoT.

REFERENCES

[1] N. Castilla, dalam *Greenhouse technology and management*, Cabi, 2013.

[2] “Britannica,” Encyclopedia Britannica., 12 August 2022. [Online]. Available: https://www.britannica.com/science/electromagnetic-spectrum. [Diakses 15 09 2022].

[3] J. K. Casper, “Greenhouse effect,” dalam *Greenhouse Gases: Worldwide Impacts*, Infobase Publishing, 2010.

[4] “Comsol,” [Online]. Available: https://www.comsol.com/blogs/the-greenhouse-effect/. [Diakses 22 09 2022].

[5] P. Tomar dan G. Kaur, “Smart Greenhouse,” dalam *Artificial Intelligence and IoT-based Technologies for Sustainable Farming and Smart Agriculture*, IGI Global, 2021.

[6] R. Rayhana, G. Xiao dan Z. Liu, “Internet of things empowered smart greenhouse farming,” *IEEE Journal of Radio Frequency Identification*, vol. 4, no. 3, pp. 195-211, 2020.

[7] S. L. Li, . Y. Han, L. Ge, . M. Zhang, . L. Zhang dan . Q. Ma, “Design and Implementation of Agricultral Greenhouse Environmental Monitoring System Based on Internet of Things,” *In Applied Mechanics and Materials,* Vol. %1 dari %2121-126, pp. 2624-2629, 2011.

[8] N. Kaewmard dan S. Saiyod, “Sensor data collection and irrigation control on vegetable crop using smart phone and wireless sensor networks for smart farm,” *IEEE Conference on Wireless Sensors,* pp. 106-112, 2014.

[9] “ Rural Integrated Development Services - Nepal,” 2013. [Online]. Available: http://www.rids-nepal.org/index.php/Greenhouse.html. [Diakses 19 09 2022].

[10] JI.Jend.Sudirman, “Horticulture Prospects for Selected Greenhouse Production Areas in Indonesia,” AMARTA, Indonesia, May 28, 2007.

[11] S. R. Bhandari, "An Elaborative Study in the Market Potential of Home Automation and Security Products: A case Study of Chitwan District in Urban Nepal.," *OCEM Journal of Management, Technology and Social Sciences,* vol. 1, no. 1, pp. 107-117, 2019.

[12] I. A. S. A. Nurfilihan Bafdal, "Application of internet of things on microclimate Monitoring system in ALG unpad green house based on Raspberry," *Agricultural Engineering,* vol. 11, pp. 518-530, 2022.

[13] T. Searchinger, R. Waite, C. Hanson, J. Ranganathan, P. Dumas, E. Matthews dan C. Carni, "Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. Final report.," Wrld Resources Institute, 2019.

[14] S. Haryati, "Smart green house expected to boost production, draw millennials," *Antara Indonesian News Aency,* 27th December 2022.

[15] "CircuitsToday," 2020. [Online]. Available: https://www.circuitstoday.com/arduino-soil-moisture-sensor. [Diakses 20 09 2022].

[16] P. N. atreya, A. Kafle, B. D. Subedi dan S. B. Shrestha, "Precision and protected horticulture in Nepal," *Nepal Horticulture Society,* vol. 1, 2019.