

Low Cost Smart Ground System for Rainwater Harvesting for Indian Houses Using IoT Technology

Gaurav Verma (✉ gaurav.iitkg@gmail.com)

Jaypee Institute of Information technology <https://orcid.org/0000-0001-7350-0813>

Research Article

Keywords: Rainwater, Arduino Nano, NodeMCU, IoT, Sensors, Cost Analysis

Posted Date: May 27th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-531034/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

LOW COST SMART GROUND SYSTEM FOR RAINWATER HARVESTING FOR INDIAN HOUSES USING IoT TECHNOLOGY

¹Gaurav Verma

¹Department of Electronics & Communication Engineering,
Jaypee Institute of Information Technology, A-10, Sector-62, Noida (U.P.), India.

Abstract— Water conservation is critical because it is one of the most significant factors for all species' survival. According to the Central Ground Water Board's estimates, underground water will be scarce in 15 Indian states by 2025 [1]. However, as per the report from Ministry of Environment and Forest, only 10 to 20% rainwater is harvested. In urban areas, it is seen that nowadays concrete structures are constructed everywhere, so it is not possible to recharge the water table by natural process of raining. All the rainwater which is one of the sources for fresh water goes to drain. This causes the depletion of groundwater level which may be fatal in the future. Therefore, a rainwater harvesting system is required in Indian household to conserve water. On the other hand, the urban cities are having high pollutant levels which in turn affecting the quality of water. The government has defined certain parameters for quality checking of water. With the aid of the suitable sensors and IoT boards, quality checking, monitoring and water segregation can be easily achieved. In this work, an efficient and cost effective technique of rainwater harvesting has been presented. Some real case studies have been done at Indian houses in order to validate the effectiveness of system in terms of its implementation and cost analysis. As a result, the proposed system becomes one of the smart solutions to address the modern problem of rainwater harvesting with water quality management in low cost.

Keywords: Rainwater, Arduino Nano, NodeMCU, IoT, Sensors, Cost Analysis.

Corresponding author:

Gaurav Verma
Department of Electronics and Communication Engineering,
Jaypee Institute of Information Technology, Noida, (U.P.), India.
Email: gaurav.iitkg@gmail.com

1. INTRODUCTION

“*Panch Tatva*” i.e. Ether (*Akash*), Wind (*Vayu*), Fire (*Agni*), Water (*Jal*) and Earth (*Prithvi*) are the basis of the cosmos. Here “*Panch*” stands for five and “*Tatva*” stands for elements. These *Panch Tatva* forms the basis of life. Therefore, maintenance and conservation of such essential components is necessary for their efficient utilization. The growth in population and industries lead to increased utilization of these elements specifically water. However, the fresh water is limited and it is required for various activities like for agriculture, household chores and for drinking. But due to vast globalization, urbanization and modernization, quality of our surrounding is degraded which in turn affects the quality of water. The pollutants exhausted from vehicles and industries lead to the formation of toxic gases [2]. The toxic gases like sulphur dioxide and nitrogen dioxide mixed with water and form sulphuric and nitric acid. This in turn received as precipitation and termed as acid rain. The acid rain water is not suitable for drinking and other day to day activities in houses. So, the conservation of quality water is the need of hour and smart solutions for it are gaining importance too [3]. Advancing technologies can help in coping up with the current problem of water scarcity. As the problem is faced by the people all over the world thus it become extremely important to find out different ways to harvest and store water. One such method to harvest and store it for future usability is smart rainwater harvesting system [4]. Although, rainwater harvesting is among the most ancient methods and widely used. However, with the help of some technological modifications, it can be used more efficiently and can be deployed to solve the real world related issues with water nowadays. The main concern is to establish low cost rainwater harvesting system because the available commercial rainwater harvesting systems are very costly. For its effective usage harvesting systems should be made available for household which are cost efficient.

1.1 NEED OF RAINWATER HARVESTING SYSTEMS IN HOUSEHOLDS

In households a large amount of water is used for carrying out activities like washing clothes, cleaning, gardening, washing car, etc. As a major proportion of household usage of water is for household chores, the rainwater which might not be good for drinking purpose can be used for these day to day activities. Also, in some households the supply of water is still irregular, so the rainwater harvesting system would be boon in these areas. In urban areas, it is seen that nowadays concrete structures are constructed everywhere, so it is not possible to recharge the water table by natural process of raining [4]. All the rainwater which is one of the sources for fresh water goes to drain. This causes the depletion of groundwater level which may be fatal in the future. As in urban areas all people are dependent on groundwater so it becomes mandatory to come up with some solution to stop the flow of natural water to drains and keep a check of groundwater usage of people. As prevention is better than cure, so it is alarming time to test and deploy rainwater harvesting systems everywhere. By implementing rainwater harvesting in households, the water table can be recharged and meet the needs of water for their daily use as well. Many states and municipal corporations after dealing with droughts and depleted level of ground water have made it compulsory for newly constructed buildings to install rainwater harvesting systems. In 2003, the Tamil Nadu government passed an ordinance on rainwater harvesting. The order mandated that all

buildings should install rainwater harvesting systems and store water. Thus, the need of rainwater harvesting systems for residential and office areas is well realised by all.

On the other hand, the quality checking of water is extremely important. Due to excessive abuse of fossil fuels the pollution gets mixed in the atmosphere and in turn received through precipitation. This precipitated water is very harmful and not suitable for usage. So, it is must to check the quality of rainwater before it storage. Various parameters are taken by the government to deal with these issues like colour, turbidity, biological oxygen demand, total hardness (as CaCO₃), PH value, odour, coliform, anionic detergents, pesticides, and dissolve solids [5, 6]. Financially feasible measures should be adopted for home utilization to check the quality of rainwater. The proposed system focussed on two parameters i.e. turbidity and colour from the point of view of usage of water for various purposes in Indian houses. The colour of water is an important parameter [7] as it can be easily recognized through naked eye. The turbidity signifies the haziness of water caused by large number of individual particles. The rest of the parameters can be managed by filtration process through RO system that is generally available in Indian houses. The turbidity and LDR sensor is utilized in the proposed system for the said purpose which makes the system financial feasible.

2. PREVIOUS WORK

International Status of Rainwater Harvesting Systems

The concept of rain water harvesting is very old i.e. the period earlier than 2000BC. The rain water harvesting has been done worldwide. In Asia, it was carried out since 9th century. Constructing dams for the collection of rain water has been in practice in the rural areas of Southeast Asia. The usage of rain water for farming and residential use is a well-known practice and has been adopted by many countries like Israel, India, Srilanka, Malaysia, Thailand, South Africa and countries of Europe and USA. Thailand is popular in applying innovation in rainwater collection since many hundred centuries back. Very few automated and smart solutions are reported at international level. Some of them are listed below and explained here. Ruijie et al. have evaluated the performance of tanks using sensors for overflow condition during storm in heavy rainfall season. This has been important from the point of view of urban flooding [8]. Martin et al. have introduced the concept of smart barrel based on IoT technology. His concept is focused towards the automation of rain water management for irrigation purpose using weather forecasting [9]. Asadi et al. used the concept of remote sensing and GIS to study the topographical area of Bhutan for effective water management [10]. Muhamad Asrah et al. evaluated the quality of water at rooftop by using different types of sensors required for water quality testing. A number of samples of rain water has been collected and then compared with the set parameters defined by WHO [5]. Yazar et al. compile the effective techniques for rain water harvesting in dry areas, where most of the rural community depends upon rain water only [11]. A US patent was taken by John Larrison in 2017 regarding automation of rainwater collection system. He has mainly focussed on automating the process of using the rain water for flush [12]. O'Driscoll Nigel proposed a cost effective solution in his patent for collecting the rainwater in small collectors

at rooftop and stored this water on rooftop tank through a pump. The process has been automated using sensors and checks the level of water in tank to fill it up [13].

Indian Status of Rainwater Harvesting Systems

In India, the rain water harvesting has been done since ancient times. The results of some pioneer works done Indus valley civilization has been found in archaeological findings. Indian people have constructed many more innovative and operative structures in different parts of India. For example: Jhalaras, Talabs, Bawaris, Taanka Ahar pynes, Johads Khadins, Kund and Baoli etc. From baoli, everyone could draw water. Some more such structures are Nadi, Bhandara Phad, Zing, Kuhls, Zabo, Bamboo Drip Irrigation, Jackwells, Ramtek Model, Pat System, Eri, etc. Although these techniques are not very popular today, some of them are still in use. The government are continuously striving to revive the old conventional methods [14, 15]. Very few works has been reported in literature in terms of automation and smart rain water harvesting system. The works has been described as follows: Kalyan et al. have proposed a method for measuring the flow of rain water in real time using the ultrasonic sensor. The estimation has been done based on notch equation and prior calibrated optimized coefficient of discharge (Cd) [16]. Chandrika et al. have proposed a smart approach for the flow measurement of rain water. The system is self-sustainable and works on IoT technology. However, the system is not fully automatic and not talked about the quality of rain water, underflow and overflow of tank. His main focus of the work is to estimate the average rain fall over Andhra Pradesh region in India [17]. Rahu et al. proposed a rain water harvesting system from the point view of smart irrigation. The system used the soil moisture sensor deployed in field to cater the need of water related to specific crop. The system also proposed a convertible roof to safeguard it from hailstorms. The convertible roof can be controlled through a mobile app. The water sensors are deployed to maintain the flow of water from tank to agricultural field [18]. Vardhman et al. proposed a scheme of segregation of water based on pH sensor. The system detects the rainfall through rain water sensor and stores the segregated into two different reservoirs for further use. The system is based on IoT technology and stores the real time pH values on cloud. However, there is no ground system and no methodology has been explained for further use of water. Moreover, the water quality has been tested using pH sensor only [19]. Vinod et al. proposed a very simple method for storing the rain water into the ground pit. The system used a rainfall sensor to detect the rain and open the gate of the pit to store the water. The ultrasonic sensor is used to detect the water level of the pit [4].

3. PROPOSED SYSTEM

Figure 1 shows the proposed layout of the self-sustainable low cost rainwater harvesting system. However, the actual sites may have different layout and can be deal on case to case basis accordingly. Section 4 represents some practical case studies in order to show the economic feasibility and deployment of the system. As shown in figure 1, the roof is the collection point of the rainwater. There are two drainage points at the roof connected with the PVC pipes. The PVC pipes are further connected together using a T-point at its two different ends at the ground side. One of the PVC pipe would be connected at T-point with a little

slope. The third end of the T-point would be connected to the ground system with a U curve. This curve leads settle down dust particles at one end of the U curve before raising the water into the other side. The LDR and turbidity sensors are fixed at the U-point using a suitable mechanical arrangement, so that they are properly exposed to the rainwater. The ground system would be mounted in between the PVC pipe and the ground water tank using a suitable mechanism. The water would be segregated in ground water subsystem. There would be two outlets from ground subsystem. First outlet would be used for dirty water to direct it towards the ground for purpose of gardening. Second outlet would be used to direct the clean water to ground water tank. A water pump would be used to pump the water towards rooftop water tank. The ground system is using the IoT technology for communication and powered using the solar panel to make it self-sustainable.

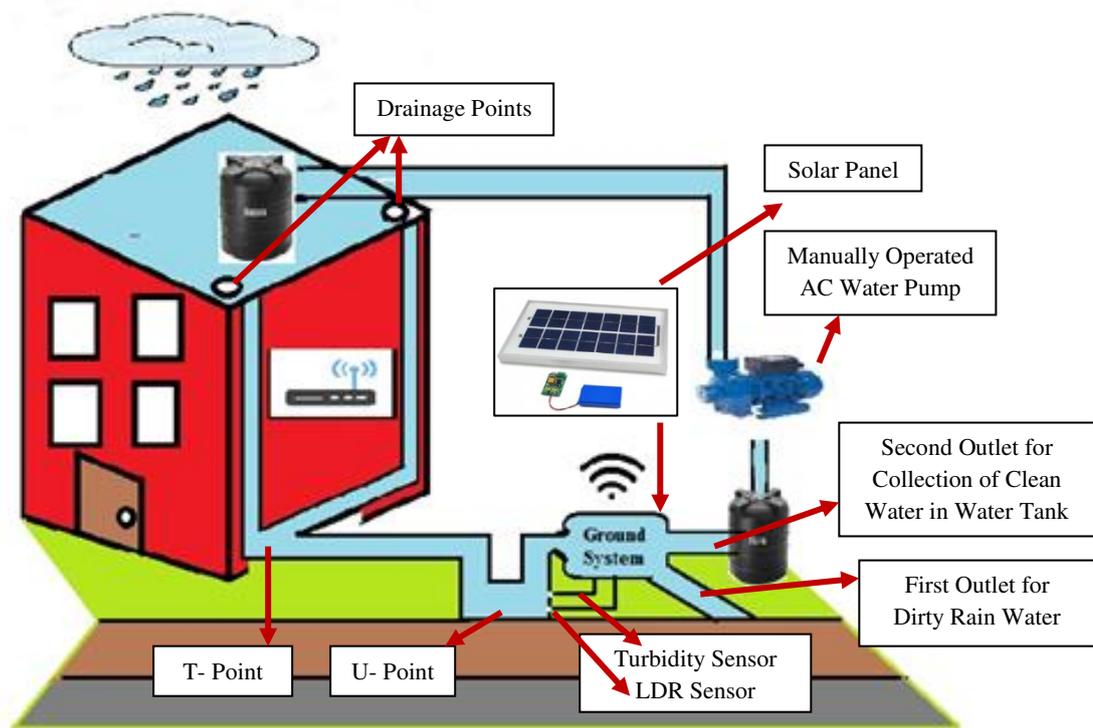


Figure 1: Layout of the self-sustainable low cost rainwater harvesting system

3.1 Description of the Ground System

The ground system is powered up using a solar panel. It consists of an Arduino Nano board connected to relay, turbidity and LDR sensor module. The turbidity sensor module is used to measure the haziness of water and the LDR sensor is used to detect the colour of rain water for acid rains (also considered as dirty water). Both these sensor values are utilized to segregate the rain water as clean and dirty. A threshold (in terms of Nephelometric Turbidity Unit) is set for the Turbidity sensor. Similarly, a colour values is used to identify the colour of rainwater. Both these threshold values are used to trigger the relay and send the dirty water into the ground for gardening purpose. A NodeMCU IoT board is also used to send the sensor values on the ThingSpeak cloud. A cloud interface is used to monitor the status of both the sensors from a remote place. A 4051 multiplexer is used to select one of the sensor values (LDR or Turbidity) and send it to NodeMCU at its A0 (analog pin). NodeMCU sends the

select signal values on the A, B, C pins of the multiplexer IC to select one of channel for acquiring the value of LDR or Turbidity sensor.

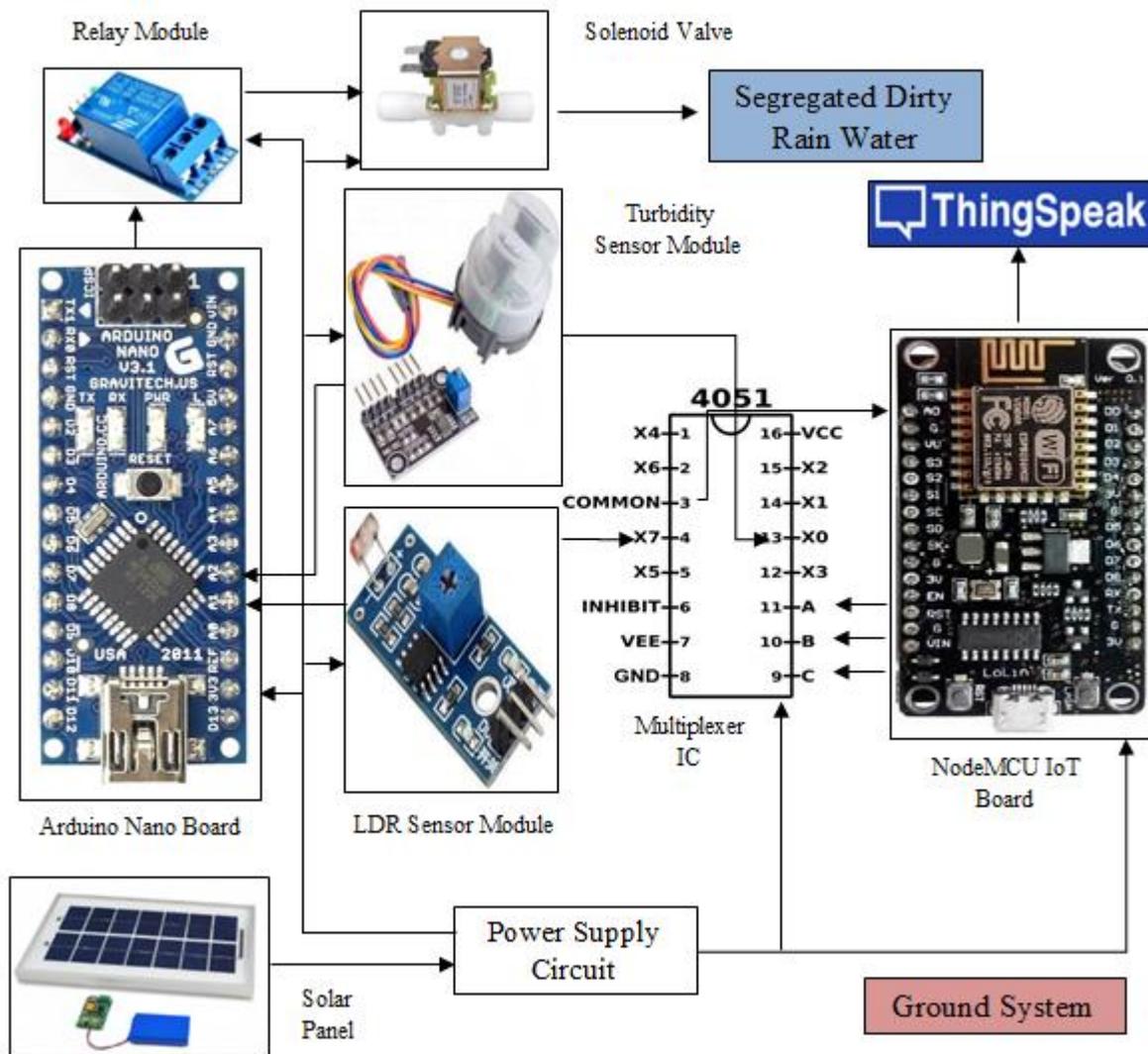


Figure 2: Block diagram of the ground system for rainwater harvesting

3.2 Working Flow of the Ground System

Figure 3 shows the operation of the ground system. The ground system operation is controlled by two boards i.e. Arduino Nano and NodeMCU. The system powers up and default conditions of the actuators are set. In the default condition, the relay is OFF and solenoid valve is OFF. It ensures that the rain water is directed towards the second outlet. Afterwards, the LDR and turbidity sensor gets activated. LDR senses the colour of rainwater and turbidity sensor senses the haziness of rainwater. The sensed values of the sensor are given to Arduino Nano and NodeMCU for performing their respective actions.

Arduino Nano Section: If any colour is detected other than the water colour as per specified conditions [20], the rain water classified as dirty and directed towards first outlet by switching ON the solenoid valve through relay. Further, if rain water is transparent (no colour is detected) then it directed towards turbidity check. If turbidity is greater than 1.8 NTU, the

rain water classified as dirty and directed towards first outlet by switching ON the solenoid valve through relay. Otherwise, the rain water classified as clean and directed towards second outlet. The complete process repeats itself again and again as long as power is ON in the system.

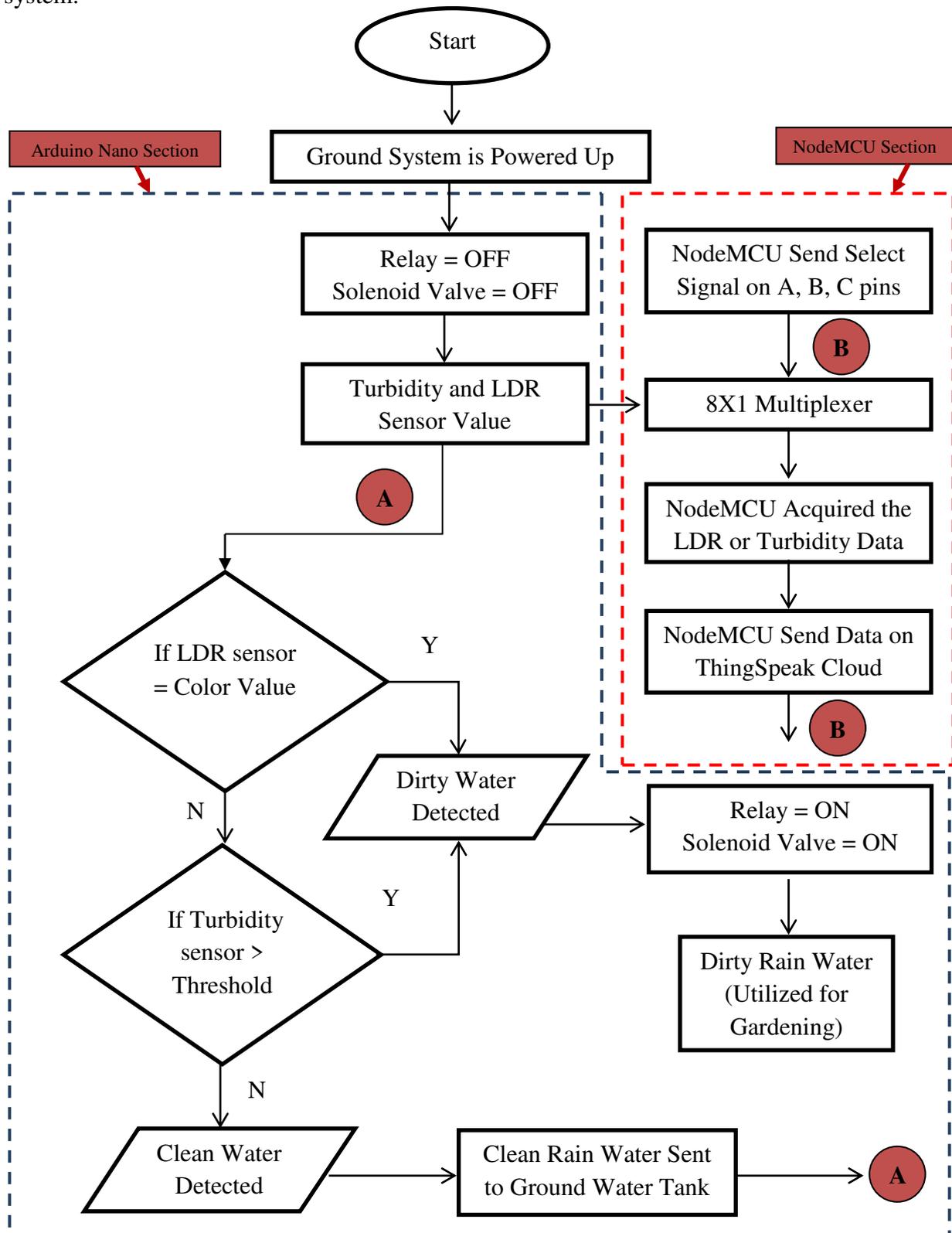


Figure 3: Working flow of the ground system for rainwater harvesting

NodeMCU Section: The turbidity and LDR sensor output is also connected at one of input pin of the 4051 multiplexer IC. The NodeMCU sends the select signal on A, B, C (select pins) pin of 4051 multiplexer IC. The multiplexer IC then output one of the sensor values and NodeMCU receives it at its analog pin. Further, NodeMCU send this signal on to the ThingSpeak cloud for monitoring purpose. The complete process repeats itself again and again as long as power is ON in the system.

3.3 PCB Schematic of the Ground System

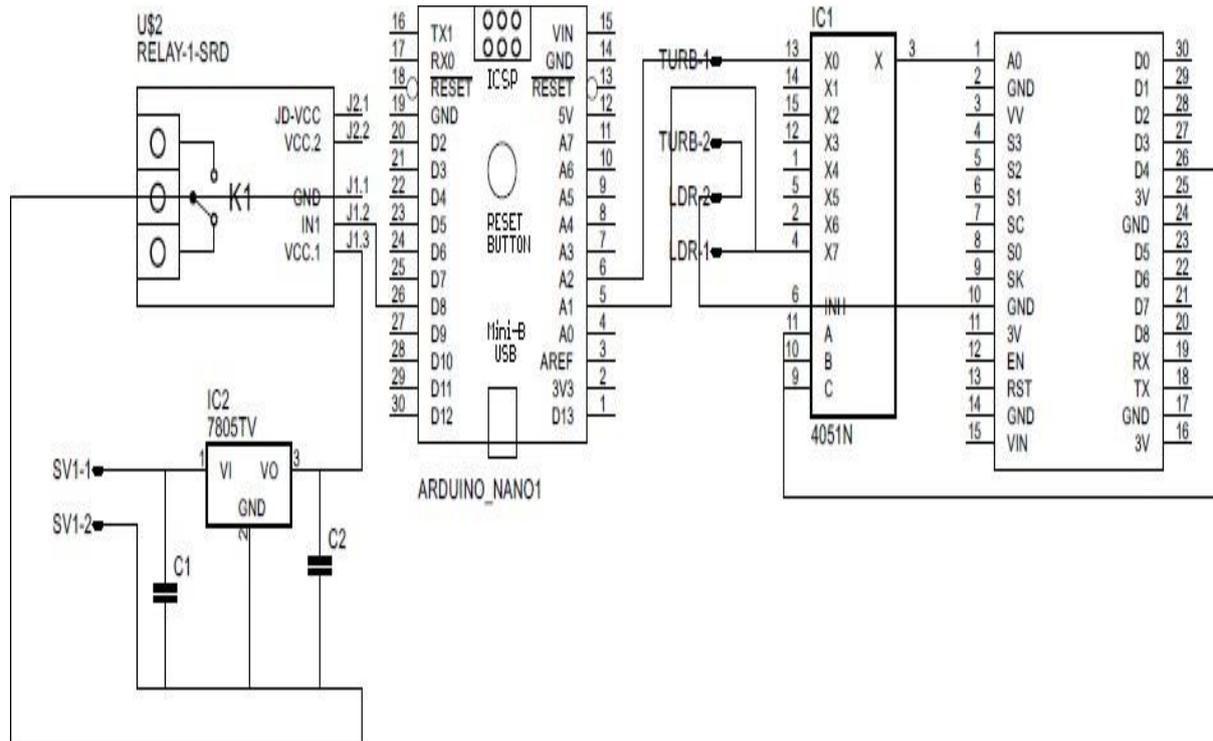


Figure 4: Schematic of the ground system for rainwater harvesting

The schematic of the ground system is shown in figure 4. It utilizes two boards Arduino-Nano and NodeMCU. The analog pins A1 and A2 of the Arduino Nano board are connected to the turbidity and LDR output pin respectively. The output pins of turbidity and LDR are also connected to the X0 and X7 input pin of the 4051 multiplexer IC. The common output pin (X) of multiplexer IC is connected to analog pin A0 of NodeMCU board. The digital pin D4 of NodeMCU board is connected to the three select pins A, B, C of the 4051 multiplexer IC. The digital pin D8 of Arduino Nano board is connected to the relay input. The output of relay is utilized to control the solenoid valve. The complete system is powered using a solar panel whose outputs are connected to SV1-1 and SV1-2 input of power management circuit. This schematic is designed using Eagle software and then converted into PCB layout as shown in figure 5. EAGLE application provides the features of schematic and PCB layout designing along with auto-routing and computer-aided manufacturing (CAM).

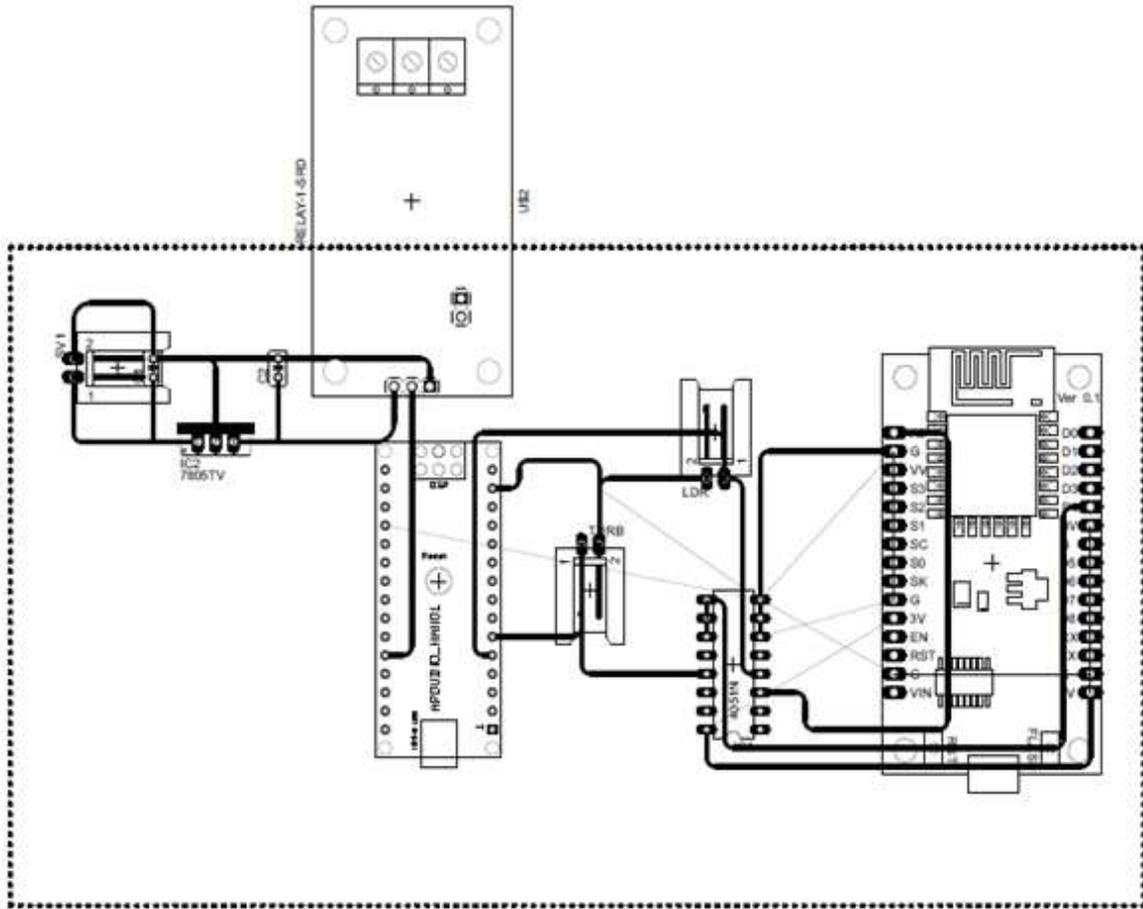


Figure 5: PCB layout of the ground system for rainwater harvesting

4. RESULTS AND ANALYSIS

The results of turbidity and LDR sensor for various types of solutions and colours can be referred from Gaurav et al. previous work [20]. Gaurav et al. also demonstrated the prototype of system and ThingSpeak plot. This paper represents the extended results of their work in terms of implementation efficacy and cost analysis for Indian houses represented in section 4.2.

4.1 COST ANALYSIS

The cost analysis represents the evaluation of ground system cost and the total implementation cost of the system for deployment at a particular house/site. The ground system cost is one of the components of total implementation cost as shown in section 4.1.1 4.1.2 and 4.1.3.

4.1.1 Ground System Cost

This cost includes the cost of the individual components as shown in table 1 and the cost of PCB manufacturing.

$$\text{Ground System Cost} = \text{Cost of Equipments} + \text{Cost of PCB Manufacturing} \quad (1)$$

$$\text{Total Cost of Equipments} = \sum (\text{Unit} \times (\text{Per Unit Cost})) \quad (2)$$

$$\text{Cost of PCB Manufacturing (depends upon size and type)} = \text{Unit} \times (\text{Per Unit Cost}) \quad (3)$$

Using equation 2 and depicted in table 2, the total cost of equipment is **Rs. 2856 (approx)**. Using equation 3, the cost of a single layer PCB is **Rs. 250 (approx)**. The exact cost depends upon the selection of vendor, size, type and number of PCB required. Using equation 1,

$$\boxed{\text{Ground System Cost} = 2856 + 250 = \text{Rs. 3106 (approximately)}}$$

Table 1: Equipment's cost

S.No.	Equipment Name	Unit	Price/Unit	Total Cost
1.	Arduino Nano	1	160	160
2.	NodeMCU	1	329	329
3.	Program cable for Arduino Nano (Small Mini USB –B Type)	1	42	42
4.	Program cable for NodeMCU (Small Mini USB –C Type)	1	100	100
6.	Turbidity Sensor Module	1	1000	1000
7.	LDR Sensor Module	1	55	55
8.	Solenoid Valve	1	450	450
9.	Relay Module	1	100	100
10.	Multiplexer IC (4051)	1	20	20
11.	Solar Panel	1	500	500
12.	Power Circuit	1	100	100

4.1.2 Total Implementation Cost

This cost includes the total cost of deployment of the system at a particular site/house.

$$\text{Total Implementation Cost} = \text{Cost of PVC Pipes (depend upon size in inch)} + \text{Cost of Ground System} + \text{Cost of Ground Water Tank (depends upon capacity in liters)} + \text{Miscellaneous Cost} \quad (4)$$

$$\text{Cost of PVC Pipes} = \text{Length of PVC Pipe from Roof Top to Ground System (in mt)} \times (\text{Per mt Cost}) + \text{Cost of T Point (depend upon size in inch)} + \text{Cost of U Point (depend upon size in inch)} \quad (5)$$

$$\text{Cost of TPoint} = \text{Unit} \times (\text{Per unit cost}) \quad (6)$$

$$\text{Cost of UPoint} = \text{Unit of elbows} \times (\text{Per unit cost}) \quad (7)$$

$$\text{Cost of Ground Water Tank (depends upon capacity in liters)} = \text{capacity in liters} \times (\text{Per liter cost}) \quad (8)$$

$$\text{Miscellaneous Cost} = \text{Labour Cost} + \text{Basic material required during fitting} \quad (9)$$

$$\text{Labour Cost} = (\text{Fiting rate of pipe per mt} \times \text{Total length of PVC pipe including T and U points}) \times (\text{Per Labour})$$

(10)

4.1.3 Implementation Cost Analysis of Different Houses

This section describes the implementation cost analysis for three different houses of Delhi-NCR area. The first house belongs to the Ghaziabad city and rest of the two houses belongs to the Noida city. The analysis has been done on the basis of map information of the houses available with the owner.

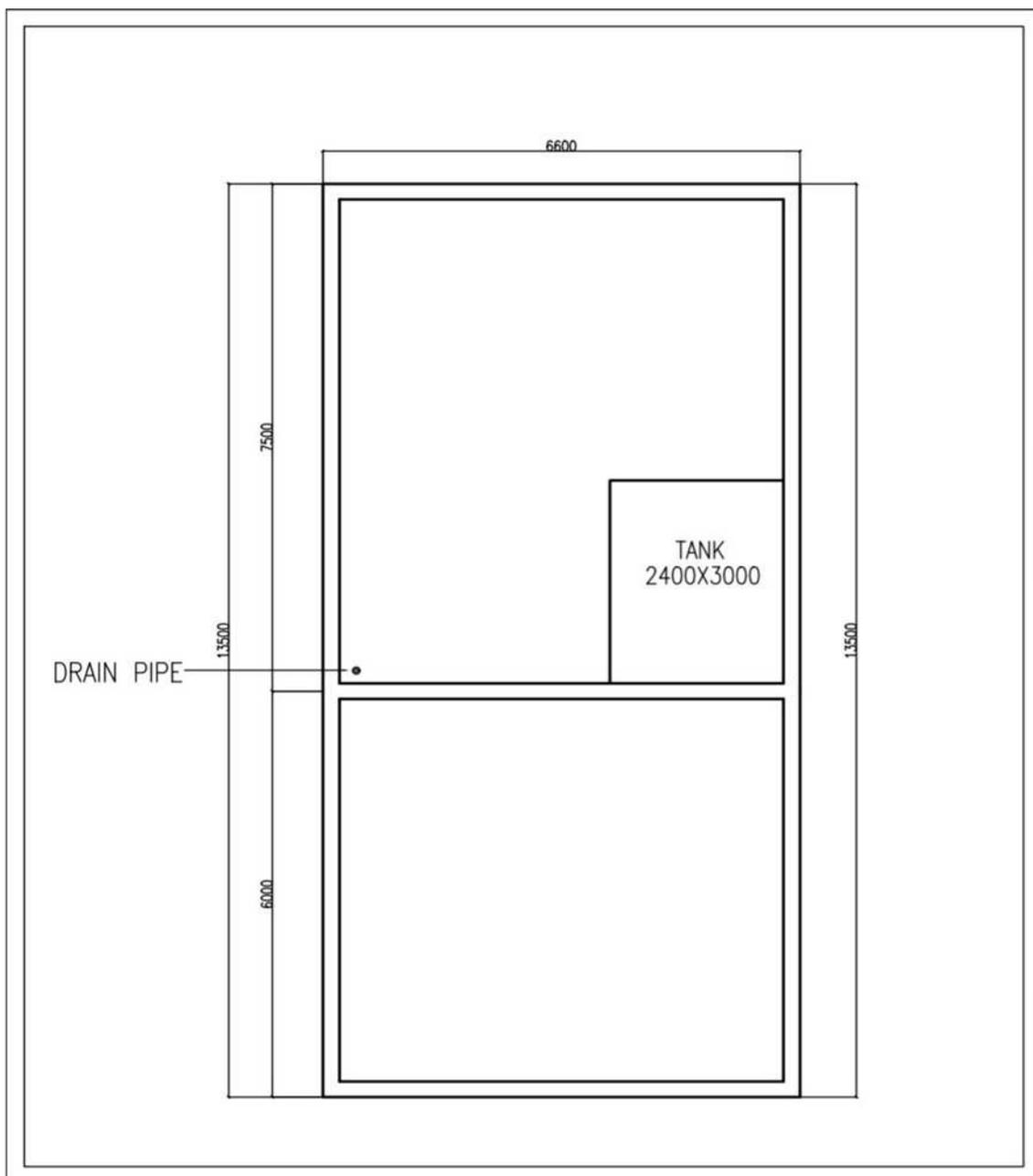


Figure 6: Roof Area of House 1

House 1: Address: 232, Old Panchwati Colony, Nehru Nagar, Ghaziabad, Uttar Pradesh, India.

The total roof area exposed to the rain is the area of roof sections excluding the area of room and toilet section as shown in Figure 7. All the dimensions are given in millimetre.

$$\text{The roof area exposed to the rain} = (6600 \times (7500 + 6000)) - (2400 \times 3000) = 89100000 - 7200000 = 81900000 \text{ mm}^2 = 81900 \text{ mt}^2$$

The drain pipe from the top roof leaves the water on the extended roof of the floor below it i.e. the roof with area $6000 \times 6600 \text{ mm}^2$ as shown in Figure 6. In this case, the PVC pipe is placed at this roof's edge. The length of PVC pipe required from roof edge to ground System is approx. 12 mt. There is no requirement of T-point as there is only one drain pipe. Total 5 elbows are required. The cost of PVC pipe (4 inch) is Rs. 100/mt and cost of one elbow (4 inch) is Rs. 50. The cost of ground water tank liter tank is Rs. 4.1/lit. Only one labour is required having rate of Rs.100/mt for pipe fitting and Rs. 250 for basic material.

$$\text{Using equation 5, 6, and 7, Cost of PVC Pipes} = 12 \times 100 + 0 + 5 \times 50 = \text{Rs. 1450}$$

$$\text{Using equation 8, Cost of Ground Water Tank} = 1000 \times 4.1 = \text{Rs. 4100}$$

$$\text{Using equation 9 and 10, Miscellaneous Cost} = 100 \times 12 + 250 = \text{Rs. 1450}$$

$$\text{Using equation 4, Total Implementation Cost} = 1450 + 3106 + 4100 + 1450 = \text{Rs. 10106}$$

House 2: Address: H-29, Sector-11, NOIDA, Gautam Budh Nagar, Uttar Pradesh, India.

The total roof area exposed to the rain is the area of roof sections excluding the area of tank section as shown in Figure 6. All the dimensions are given in millimetre.

$$\text{The roof area exposed to the rain} = (9000 \times 10500) - (2800 \times 3000) - (2100 \times (1500 + 900)) = 94500000 - 8400000 - 5040000 = 81060000 \text{ mm}^2 = 81060 \text{ mt}^2$$

The drain pipe comes straight down from roof, so there is no need of piping from roof to ground as shown in Figure 7. However, the length of PVC pipe required from pipe end to ground System is approx. 3 mt. There is no requirement of T-point as there is only one drain pipe. Total 5 elbows are required. The cost of PVC pipe (4 inch) is Rs. 100/mt and cost of one elbow (4 inch) is Rs. 50. The cost of ground water tank liter tank is Rs. 4.1/lit. Only one labour is required having rate of Rs.100/mt for pipe fitting and Rs. 250 for basic material.

$$\text{Using equation 5, 6, and 7, Cost of PVC Pipes} = 3 \times 100 + 0 + 5 \times 50 = \text{Rs. 550}$$

$$\text{Using equation 8, Cost of Ground Water Tank} = 1000 \times 4.1 = \text{Rs. 4100}$$

$$\text{Using equation 9 and 10, Miscellaneous Cost} = 100 \times 3 + 250 = \text{Rs. 550}$$

$$\text{Using equation 4, Total Implementation Cost} = 550 + 3106 + 4100 + 550 = \text{Rs. 8306}$$

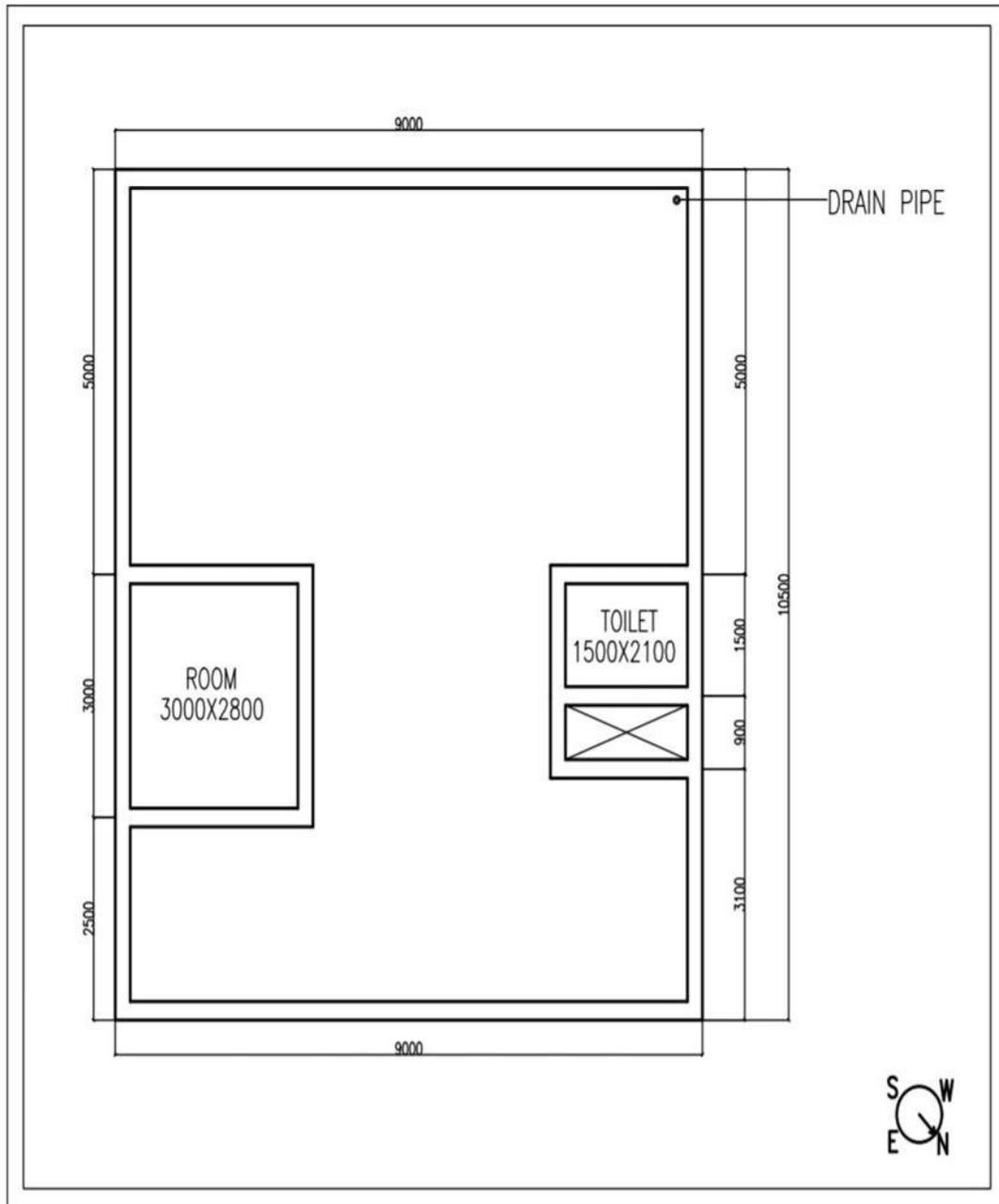


Figure 7: Roof Area of House 2

House 3: Address: T-21, Sector-12, NOIDA, Gautam Budh Nagar, Uttar Pradesh., India.

The total roof area exposed to the rain is the area of roof sections excluding the area of lift section as shown in Figure 8. All the dimensions are given in millimetre.

$$\text{The roof area exposed to the rain} = (12000 \times 22500) - (8000 \times 5000) = 270,000,000 - 40,000,000 = 230,000,000 \text{ mm}^2 = 230000 \text{ mt}^2$$

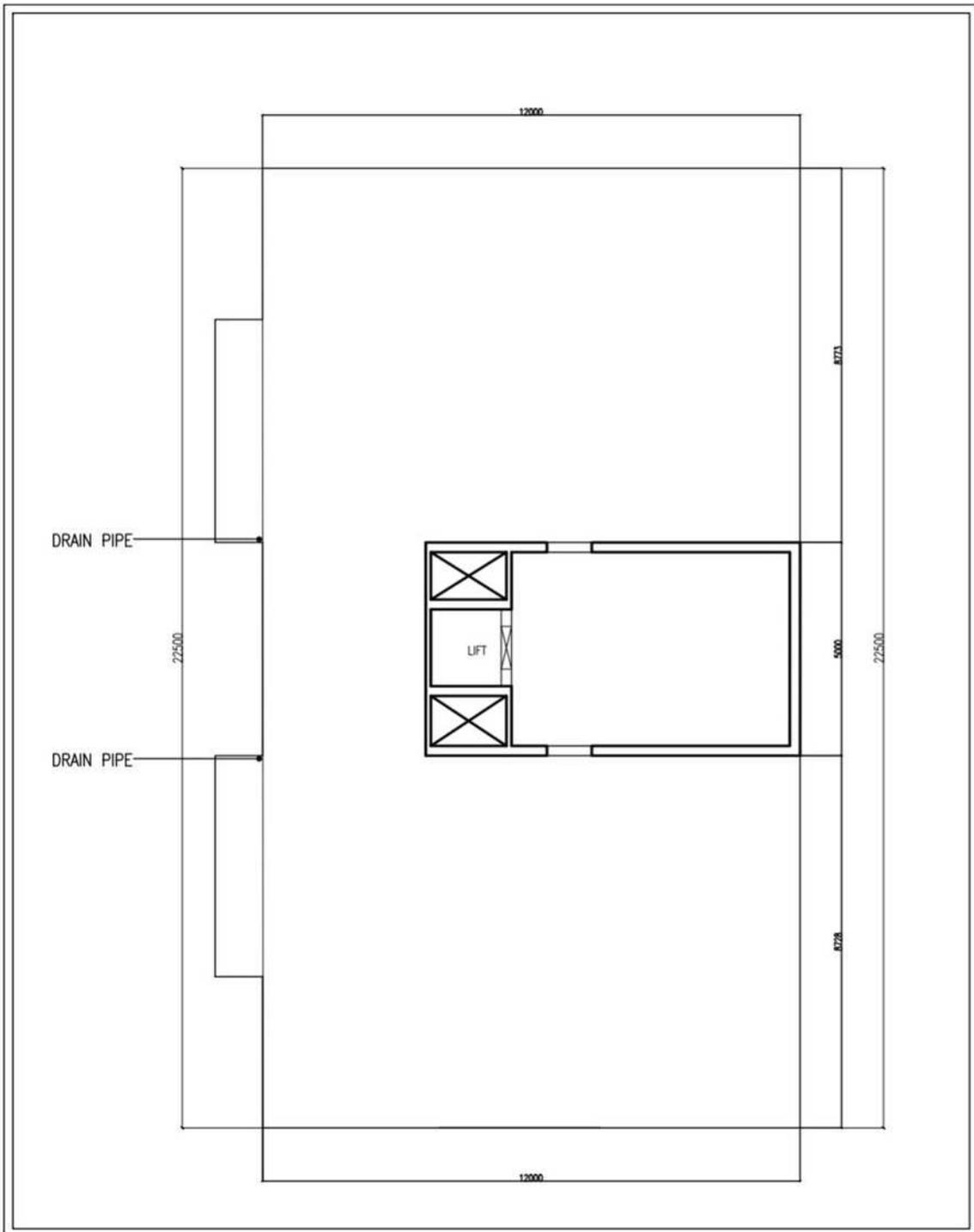


Figure 8: Roof Area of House 3

There are two drain pipes comes straight down from roof, so there is no need of piping from roof to ground as shown in Figure 8. However, there are two options either clogged one of the pipe or join both the pipes at ground side using the T point as shown in figure 1. In case of joining the pipes, the length of PVC pipe required for joining is 5 mt and from pipe end to ground System is approx. 3 mt. There is a requirement of one T-point as the joint of all three pipes. Total 5 elbows are required. The cost of PVC pipe (4 inch) is Rs. 100/mt, cost of one T

pipe (4 inch) is Rs. 200 and cost of one elbow (4 inch) is Rs. 50. The cost of ground water tank liter tank is Rs. 4.1/lit. Only one labour is required having rate of Rs.100/mt for pipe fitting and Rs. 250 for basic material.

Using equation 5, 6, and 7, ***Cost of PVC Pipes*** = $5 \times 100 + 1 \times 200 + 5 \times 50 = \text{Rs. 950}$

Using equation 8, ***Cost of Ground Water Tank*** = $1000 \times 4.1 = \text{Rs. 4100}$

Using equation 9 and 10, ***Miscellaneous Cost*** = $100 \times 5 + 250 = \text{Rs. 750}$

Using equation 4, ***Total Implementation Cost*** = $950 + 3106 + 4100 + 750 = \text{Rs. 8906}$

5. CONCLUSION

The problem of water scarcity is prevailing in different states of India inspite of receiving the highest rainfall every year. The ground water goes down from the threshold level and other water resources become dried. In urban area, mostly population relies on ground water for their survival. Therefore, an effective and smart solution for rainwater harvesting for Indian household usage perspective based on IoT technology has been presented. The proposed does not require any major constructional investment. Rather, the system can be easily implemented in any Indian house with very little modification as depicted by case studies. The total implementation cost of the system is low as shown by the cost analysis. Moreover, the cost of ground system which is the heart of the system is also cost effective as compared to other traditional solutions available in the market. The proposed system powered up using solar panel which makes it self-sustainable. Further, the system can be incorporated with rain sensor for detecting the rainfall. It would be helpful in power management by triggering the system at a particular instance. The level sensors can be deployed at ground water tank for automatic control.

6. DECLARATIONS

Funding: Not Applicable

Conflict of Interest: The author declares no conflict of interest regarding the publication of this research paper.

Availability of data and material: Not Applicable

Code availability: All the experiments have been performed using open source software Arduino Sketch and no code exact code has been copied for research paper.

REFERENCES

1. Firstpost. Two-third of the world, much of India to face water scarcity, stress by 2025: Expert. <https://www.firstpost.com/tech/science/two-third-of-the-world-much-of-india-to-face-water-scarcity-stress-by-2025-expert-5675721.html> Accessed 05 December 2018.

2. Gautam, A., Verma, G., Qamar, S., Sushant, S. Vehicle Pollution Monitoring, Control and Challan System Using MQ2 Sensor Based on Internet of Things. *Wireless Pers Commun* 116, 1071–1085 (2021).
3. Pule, M., Yahya, A., Chuma, J. Wireless Sensor Network: A Survey on Monitoring Water Quality. *J. Applied Research and Technology*, 15(6), pp.562-570, (2017).
4. Vinoj, J., Gavaskar, S. Smart City Rainwater Harvesting Technique. *International Journal of Scientific Development and Research*, 3(8), pp. 1-6, (2018).
5. Bin, M. A., Abidin, M. Z. Water Quality Assessment of Rainwater Collected from Rooftop at UTM. *Proceedings of Faculty of Civil Engineering, University Teknologi Malaysia, Malaysia*, pp. 86 -93, (2016).
6. Dehua, W., Pan, L., Bo, L. U., Zeng, G. Water Quality Automatic Monitoring System Based on GPRS Data Communication. *Proceedings of International Conference on Modern Hydraulic Engineering*, pp. 840 -843, (2012).
7. Louis, G., Kumar, A. S. “The Red Rain Phenomenon of Kerala and its Possible Extra-terrestrial Origin”. *Astrophysics and Space Science*, 302(1), pp. 175-187, (2016).
8. Liang, R., Matteo, M. Di., Maier, H. R., Thyer, M. A. Real-Time Smart Rainwater Storage Systems: Potential Solution to Mitigate Urban Flooding. *Water (MDPI)*, 11(2428), (2019).
9. Oberascher, M., Zischg, J., Kastlunger, U., Schöpf, M., Kinzel, C., Zingerle, C., Rauch, W., Sitzenfrei, R. Advanced Rainwater Harvesting through Smart Rain Barrels. *Proceedings of World Environmental and Water Resources Congress*, pp. 75-82, (2019).
10. Asadi, S. S., Kumar, N.V., Rajyalakshmi, K., Kumar, M. S. “Designing of Water Harvesting Structures for Water Resources Management: A Model Study from Chelila Watershed, Bhutan. *International Journal of Mechanical Engineering and Technology*, 8(10), pp. 666-679, (2017).
11. Yazar, A., Ali, A. Water harvesting in Dry Environments. In: Farooq, M., Siddique, K (ed). *Innovations in Dryland Agriculture*. Cham: Springer, (2016).
12. Larrison J. Automated Rainwater Collection System Controller. US Patent 9,633,532 B1, April 25, (2017).
13. Nigel, O. Rain Water Harvesting System. England Patent WO 2009/133405 A1, November 5, (2009).
14. Borthakur, S. Traditional Rain Water Harvesting Techniques and its Applicability, *Indian Journal of Traditional Knowledge*, 8(4), pp. 525-530, (2009).
15. Bhattacharya, S. Traditional Water Harvesting Structures and Sustainable Water Management in India: A Socio-Hydrological Review. *International Letters of Natural Sciences*, 37, pp. 30-38, (2015).
16. Dusarlapudi, K., Chandrika, V. S. P., Kota, C. R., Annepu, M., Narayana, V. Accuracy Analysis of an Ultrasonic Sensor Over an Open Channel Rectangular Notch for Rainwater Harvesting. *International Journal of Scientific & Technology Research* 9(1), pp. 2813-2816, (2020).
17. Chandrika, V. S. P., Kota, C. R., Annepu, K. D., Sreelatha E., Tiruvuri C. S. Smart Approach of Harvesting Rainwater and Monitoring Using IoT. *Journal of Advanced Research in Dynamical & Control Systems*, 12(2), pp. 91-100, (2020).

18. Rahul, H. K., Rakesh, M., Manjula, R. B., Rakesh, C. G., Rahul, R. Rain Water Harvesting and Smart Farming using IoT. *International Research Journal of Engineering and Technology*, 7(5), pp. 1330-1339, (2020).
19. Ranjan, V., Reddy, M. V., Irshad M., Joshi, N. The Internet of Things (IOT) Based Smart Rain Water Harvesting System. *Proceedings of 2020 6th International Conference on Signal Processing and Communication (ICSC)*, Noida, India, pp. 302-305, (2020).
20. Verma, G., Gupta S., Gupta, R. IoT Based Technique for Household Rainwater Harvesting. *Proceedings of 2020 Global Conference on Wireless and Optical Technologies (GCWOT)*, Malaga, Spain, pp. 1-4, (2020).

Figures

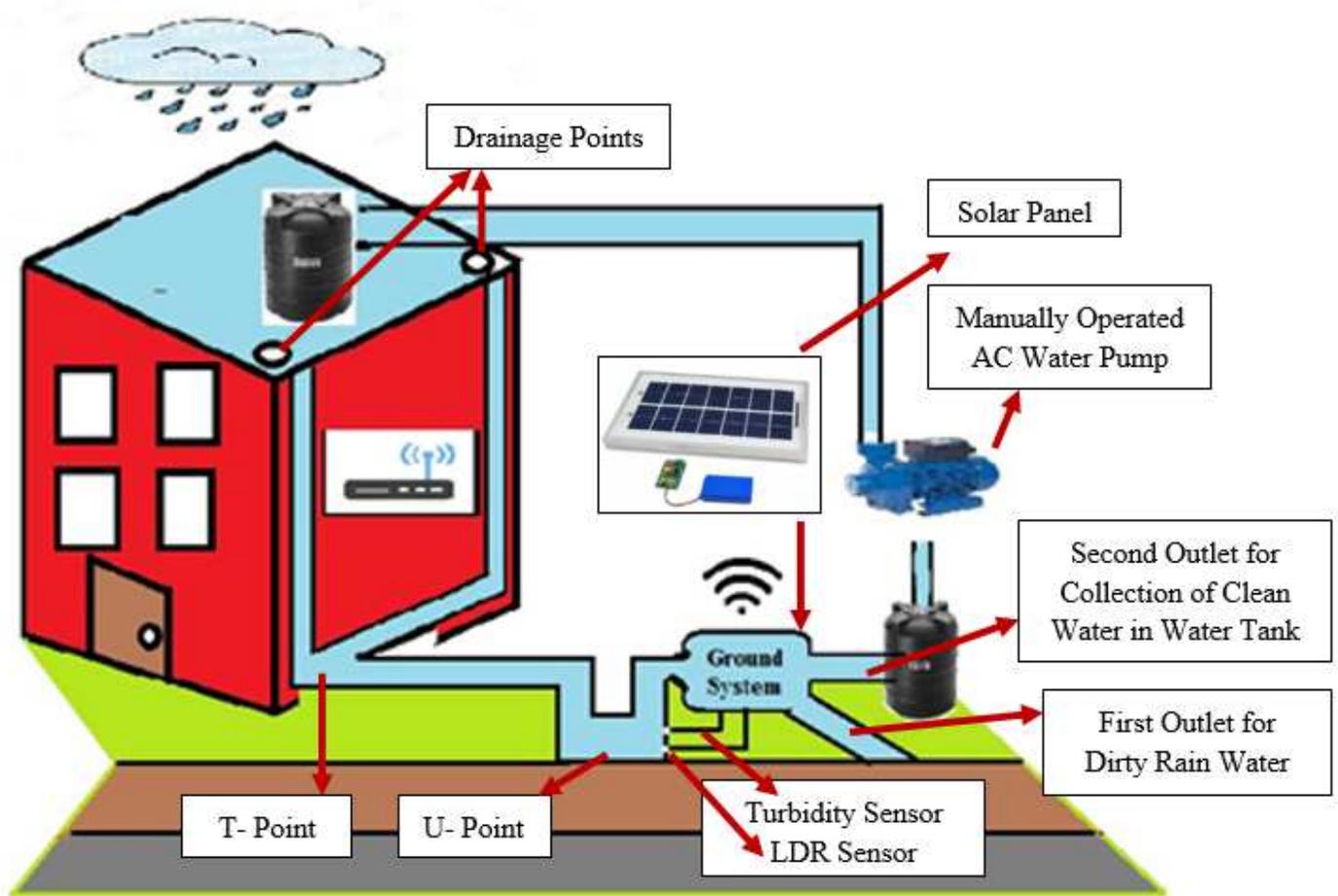


Figure 1

Layout of the self-sustainable low cost rainwater harvesting system

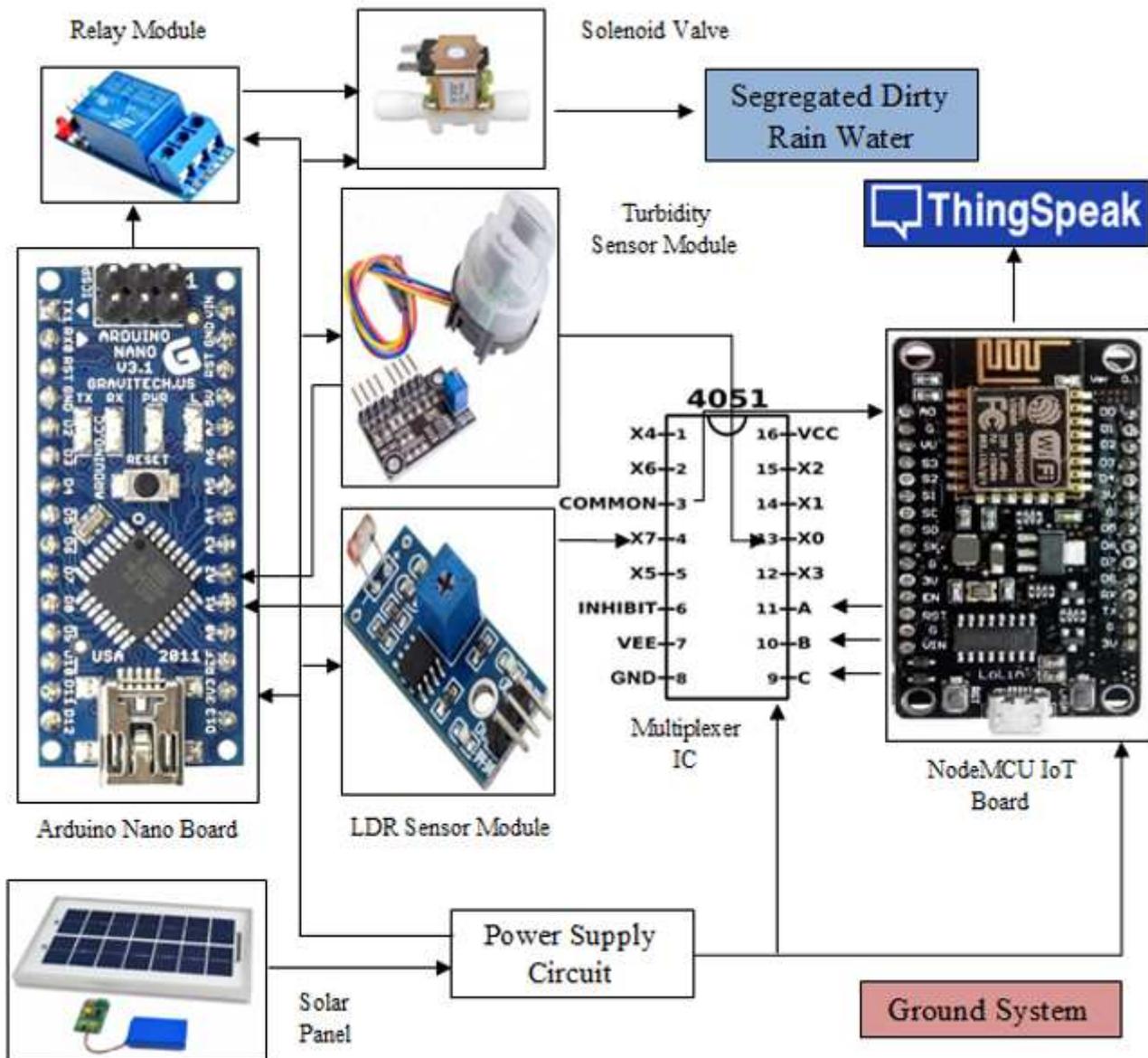


Figure 2

Block diagram of the ground system for rainwater harvesting

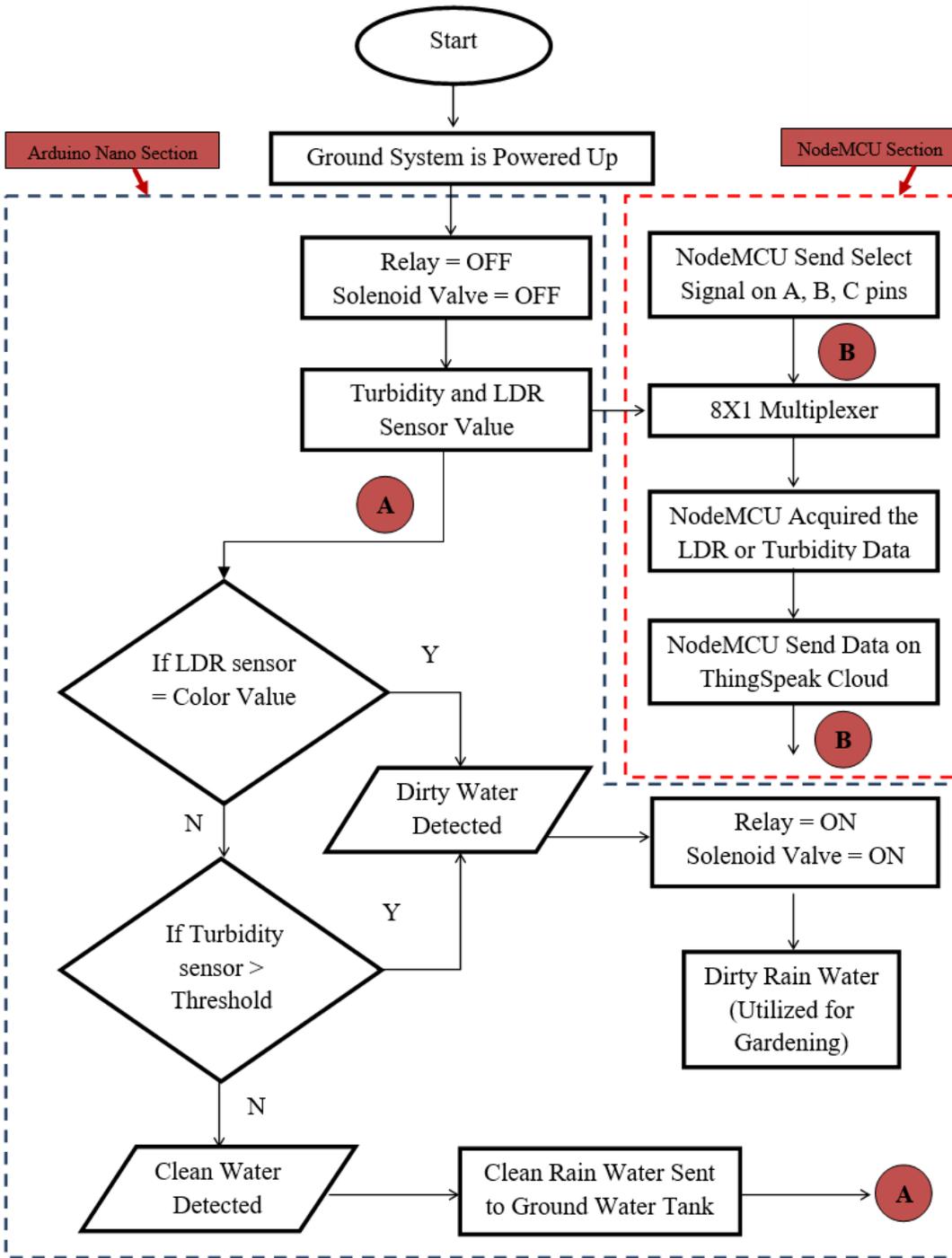


Figure 3

Working flow of the ground system for rainwater harvesting

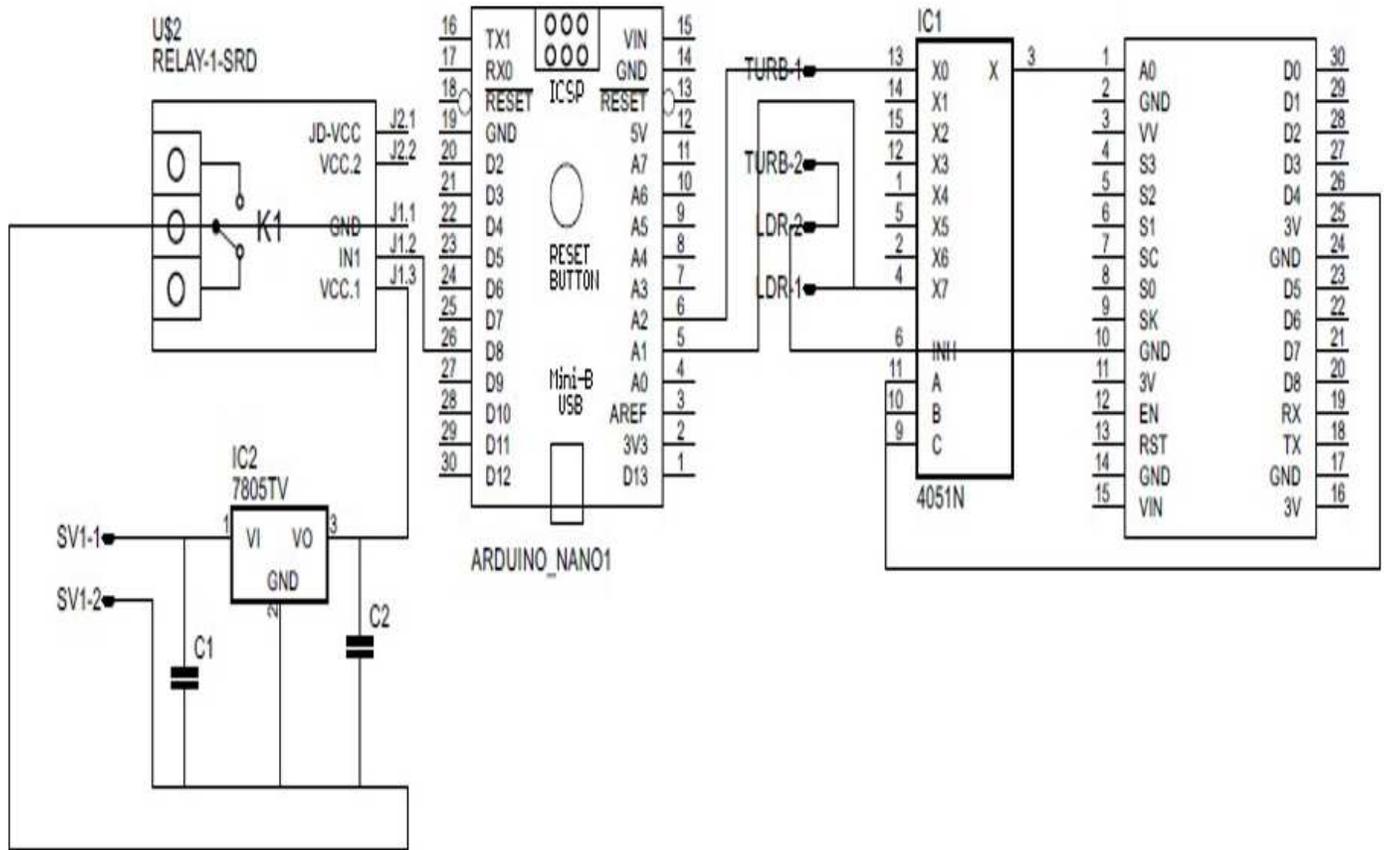


Figure 4

Schematic of the ground system for rainwater harvesting

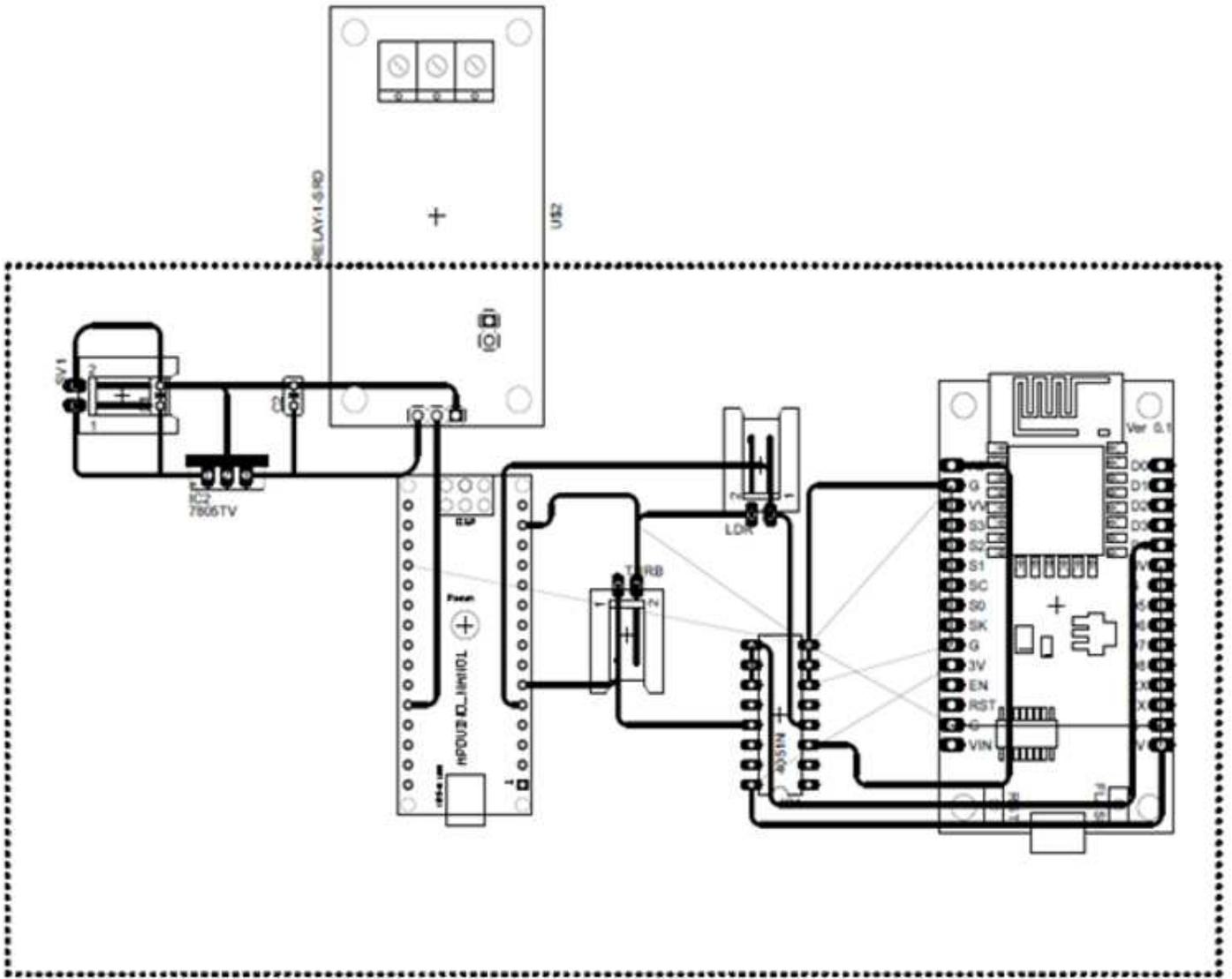


Figure 5

PCB layout of the ground system for rainwater harvesting

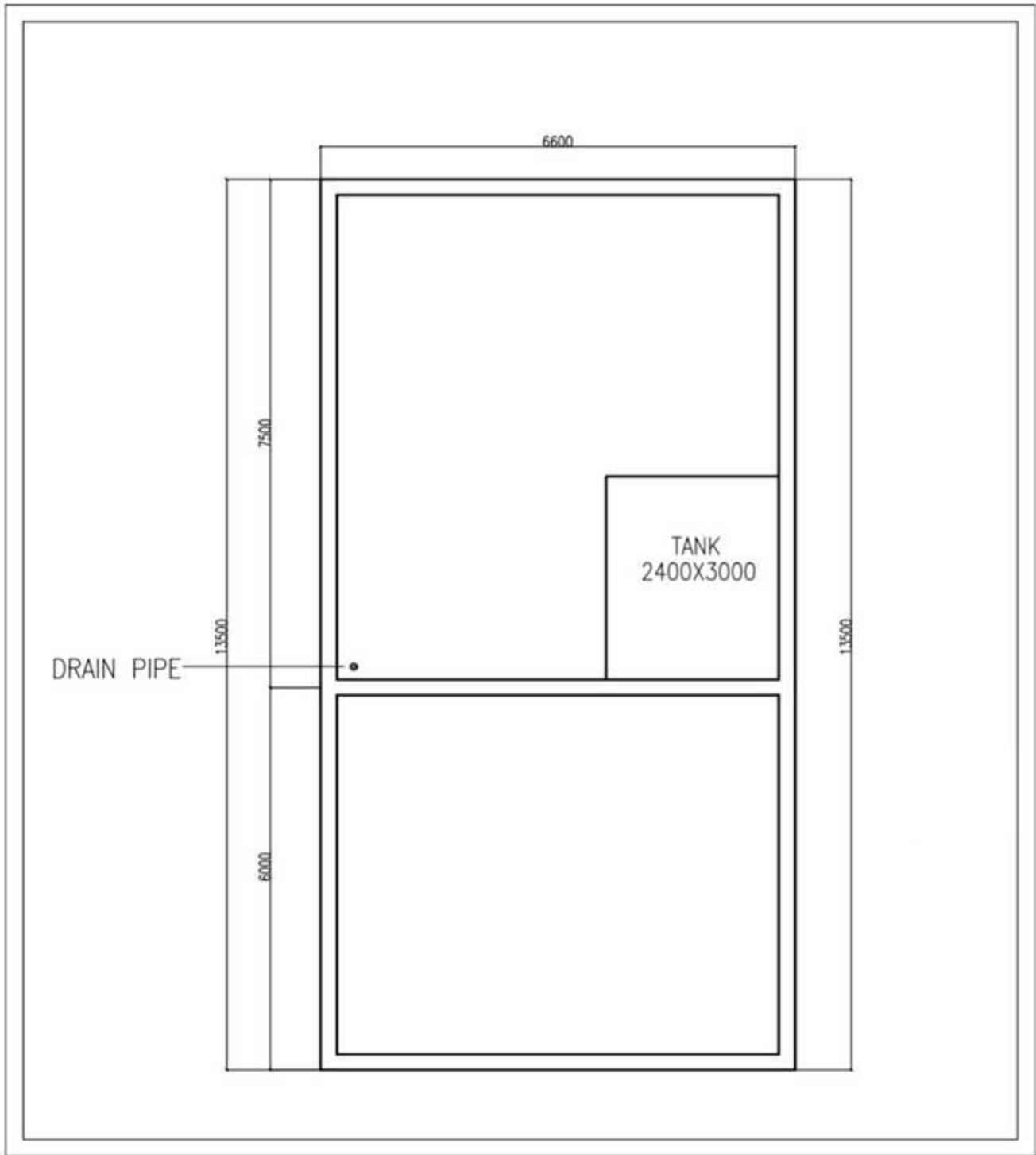


Figure 6

Roof Area of House 1

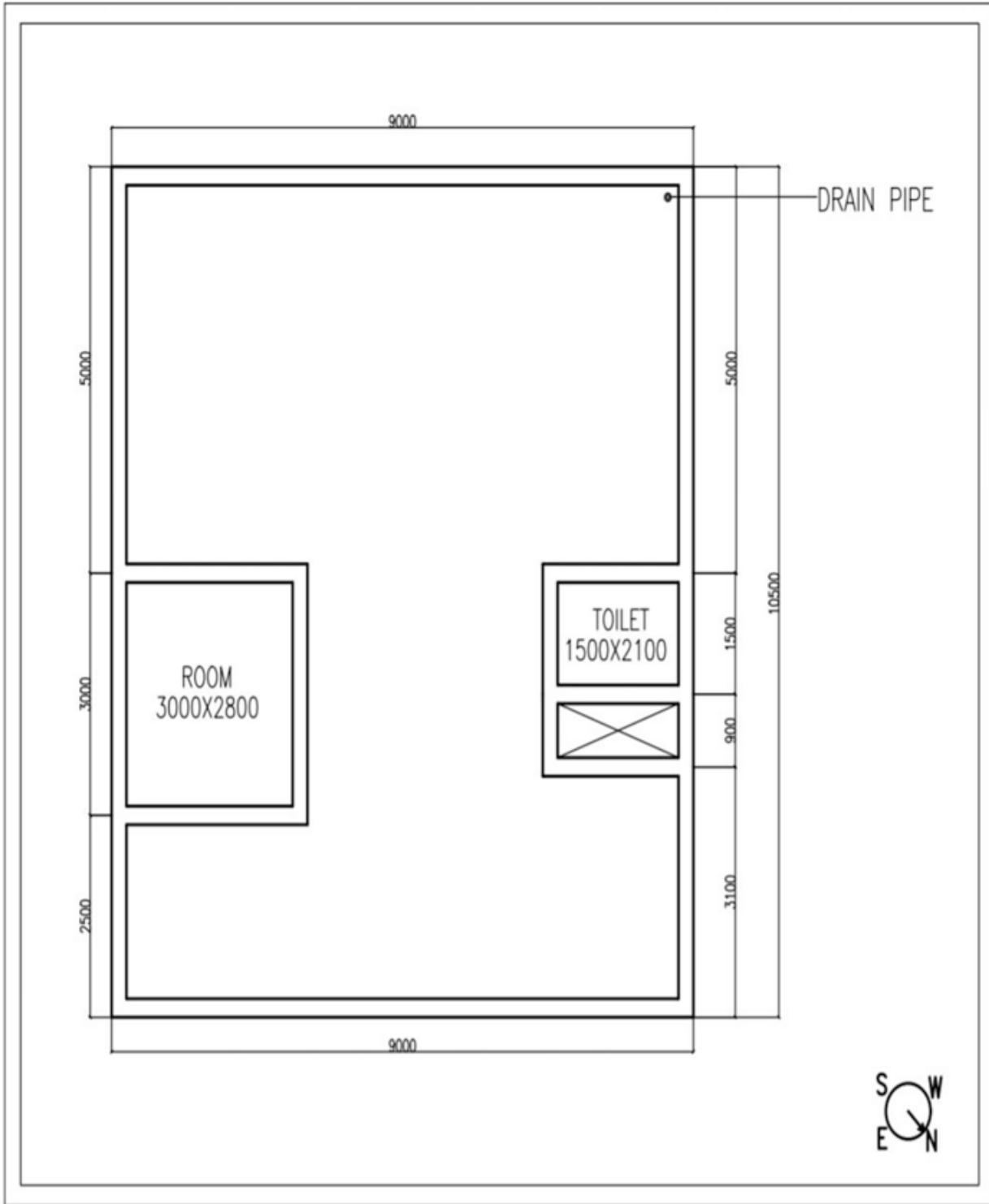


Figure 7

Roof Area of House 2

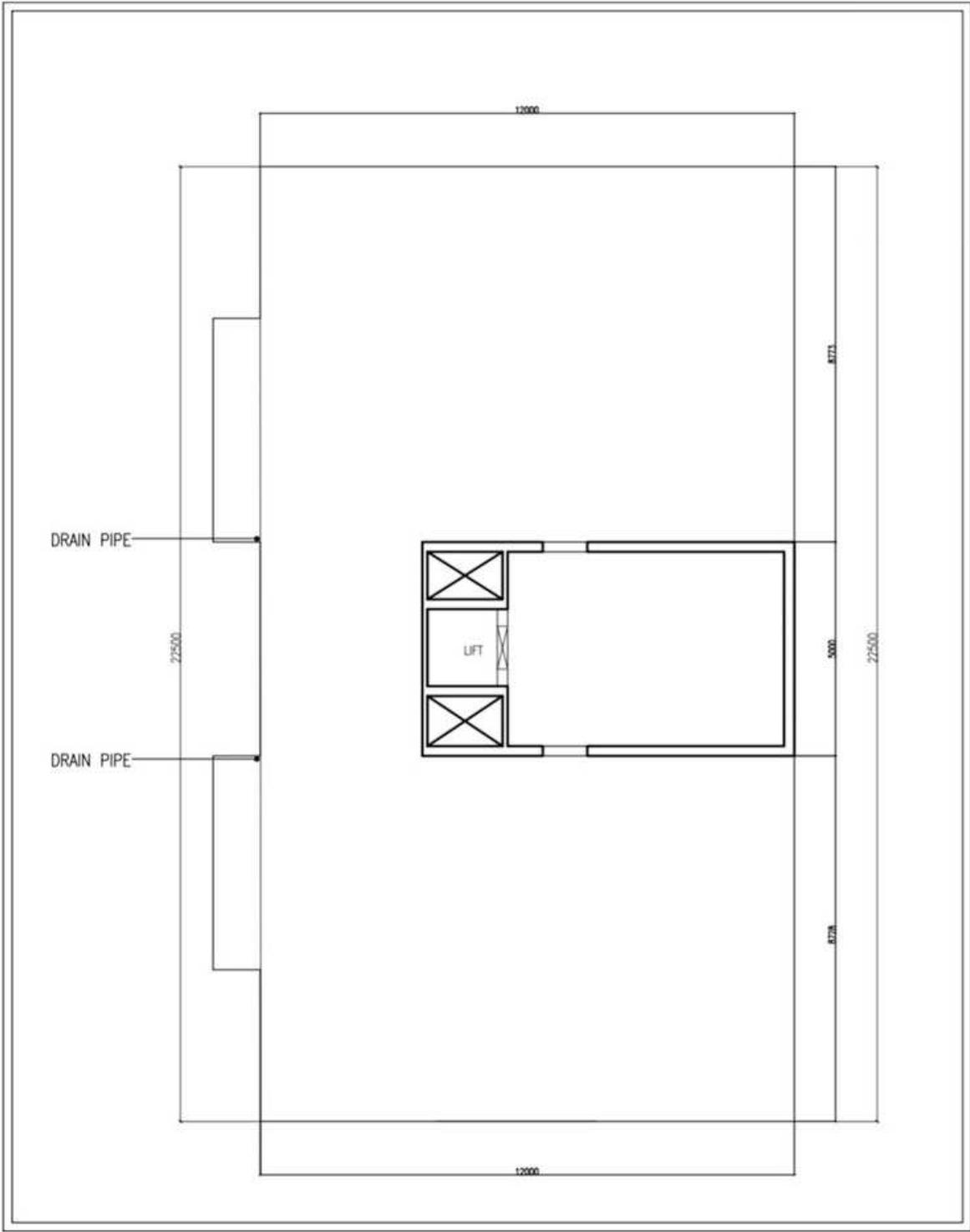


Figure 8

Roof Area of House 3