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Application-Driven IoT-Based Home-Gardening System

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The 'internet of things' is a computer-science branch that offers concepts as well as methods for connecting a broad variety of digital gadgets in order to speed up mechanical operations. People living in cities, who struggle to maintain their own gardens, find expert gardeners. This study presents a NodeMCU or Arduino-based microcontroller-based Internet of Things (IoT) method for monitoring smart gardens, enabling users to check critical temperature, moisture, and humidity characteristics of their indoor plants and gardens. A prototype is developed to show how the recommended technique may be used in practise. An Android smartphone application is made to display the real-time profiles of environmental factors such as temperature, wetness, and humidity. With the use of this technology, users will be able to better take care of the development and health of their plants in their gardens. This scientific endeavour takes the place of the need for gardeners and the challenges associated with maintaining gardens in major cities. The purpose of this study is to advance IoT innovation for smart cities in our culture.

«Інтернет речей» — це галузь інформатики, яка пропонує концепції, а також методи підключення широкого спектру цифрових ґаджітів для пришвидшення механічних операцій. Люди, які живуть у містах і яким важко доглядати за власними садами, знаходять досвідчених садівників. У цьому дослідженні представлено метод Інтернету речей (IoT) на базі мікроконтролера NodeMCU або Arduino для моніторинґу розумних садів, що дає змогу користувачам перевіряти критичні характеристики температури, сирости та вологости своїх кімнатних рослин і садів. Було розроблено прототип, щоб показати, як рекомендований метод можна використовувати на практиці. Було створено застосунок для смартфонів Android, який відображатиме профілі факторів навколишнього середовища в режимі реального часу, таких як температура, сирість та вологість. Завдяки використанню цієї технології користувачі зможуть ліпше піклуватися про розвиток і здоров'я своїх рослин у садах. Це наукове зусилля замінює потребу у садівниках і проблеми, пов'язані з доглядом за садами у великих містах. Метою цього дослідження є просування інновацій IoT для розумних міст у нашій культурі.

Key words: internet of things (IOT), fertilization, humidity, water level sensor.

Ключові слова: інтернет речей (IoT), удобрювання, вологість, давач рівня води.

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1. INTRODUCTION

Agriculture is considered the primary sector of the Indian economy, and its growth plays a crucial role in achieving sustainable economic development on a global scale. The tropical climate of India provides an excellent environment for cultivating diverse crops that can be used for consumption. However, the availability of freshwater and fertile land is even more critical for the success of agriculture in India. These natural resources are the backbone of the country's agricultural production and must be managed effectively to ensure sustained growth in the sector. As such, it is essential to focus on preserving and efficiently utilizing these resources to maximize the potential of agriculture in India. Water scarcity is a major issue in India, a country that heavily relies on agriculture as a key driver of its economy. Insufficient water supply has a significant impact on crop yields and agricultural output, which in turn affects food production. Farmers face numerous challenges in producing crops due to a lack of water, making it increasingly difficult to meet the growing demand for food in the world. As a result, addressing water scarcity has become a critical concern for policymakers, stakeholders, and communities involved in the agricultural sector in India. It is essential to implement effective measures to manage and conserve water resources to ensure sustainable agricultural practices and food security in the country.

According to the International Water Management Institute (IWMI), around 70% of land-based water consumption is used for domestic, industrial, and environmental purposes, exacerbating the issue of water scarcity. This makes it necessary to explore better ways of managing water resources, especially in agriculture, where water usage can be minimized. Irrigation is a technique used to water food or cash crops, and it has been shown to increase agricultural production. However, traditional irrigation methods can be wasteful, leading to an overuse of water. To address this issue, irrigation management techniques based on the World Bank have been developed to enhance irrigated regions and increase earnings.

The use of water-efficient agricultural systems has been shown to boost economic development. Robotic equipment has largely replaced traditional watering methods, but it may not be suitable for areas with water scarcity. Therefore, before implementing automatic irrigation, factors like soil and plant moisture conditions, water availability, and operational relevance of irrigation systems must be considered. A smart watering system, which can automate the entire watering process, could be a better alternative to traditional irrigation methods.

The proposed project aims to monitor the irrigation network automatically, without requiring human intervention. This is particularly useful for farmers who may have fields located far away from their place of residence, making it difficult for them to visit and inspect their crops regularly. With the implementation of an IoT system, farmers can manage their plants remotely. The system works by using a Node-MCU microcontroller to detect the present temperature, moisture, and dampness parameters of the plants and gardens. The data collected is then displayed in real-time on a mobile application for smartphones, which also provides information on external elements such as temperature, humidity, and wetness. This approach allows farmers to modify the amount of water flowing from the pump and adjust the intervals between watering cycles as needed, providing greater control over the irrigation process. Overall, this IoT-based technique offers a smarter way to monitor gardens and crops, enabling farmers to make informed decisions regarding irrigation management. This research project aims to provide garden owners with the tools to have better manage their gardens in terms of plant growth and health, particularly in urban areas where space is limited. The use of IoT technology can help address the challenges faced by gardeners in urban settings. The primary objective of this research is to implement and develop IoT systems for smart cities, focusing on the specific application of smart gardening. By utilizing IoT sensors and devices, gardeners can monitor key parameters such as temperature, humidity, and moisture levels, and adjust irrigation and other gardening practices accordingly. This approach can lead to more efficient use of resources, reduced wastage, and improved overall garden health. Ultimately, this research aims to promote the use of IoT technology in urban gardening to create sustainable and thriving green spaces in smart cities.

2. LITERATURE SURVEY

The research conducted by Jinling *et al.* proposed a remote-control system for greenhouses, which is based on the Global System for

Mobile GSM-SMS. This system is capable of sending temperature, ambient temperature, and humidity status *via* SMS, as well as controlling watering equipment through remote machines. Additionally, factories utilize sensors and automation devices to improve their operations and efficiency [1]. Gautam and Reddy suggested a novel on-board irrigation system that can be controlled remotely using GSM and Bluetooth technology [2].

Suresh and colleagues presented a framework based on the functionalities of present and future microcontrollers, as well as their usage demands [3]. Kansara *et al.* introduced an IoT-based smart irrigation system that reduces the need for human intervention. This system uses sensors to detect changes in temperature and humidity in the bypass region, and then sends a signal to the microcontroller to enable or disable the irrigation setting. The microcontroller in this system is designed to minimize power usage and extend the system's lifespan by reducing power consumption [4].

Archana and Priya have proposed a system based on a microcontroller that monitors the water level and irrigated area. This system includes sensors that detect the presence of water in the fields. Anitha proposed an IoT-based waste monitoring system that employs sensors on the lid of the waste container to detect the level of waste based on the height of the container. This system provides real-time information on the waste level, allowing for efficient and timely waste management. Uddin *et al.* proposed an automatic microcontroller-based variable irrigation system model that solely uses solar energy as a power source to control the entire system [7].

Sensors are installed in rice fields to constantly detect water levels and transmit the information to farmers to keep them informed about the water level. Farmers can remotely monitor and control various environmental factors using transparent wireless sensor networks (WSN) developed by Chavan and Karande. These networks are designed to monitor soil moisture, temperature, humidity, and other factors in agricultural environments, which can be crucial for efficient crop management. Anitha proposed an IoT-based home security system that includes motion sensors and a camera to detect any suspicious activities in the home. The system also includes an alarm that is triggered, when a potential threat is detected, and notifications are sent to the homeowner's mobile phone. The system can be remotely controlled through a mobile application, allowing the homeowner to monitor their home from anywhere. Additionally, the system includes a smoke sensor to detect any fire hazards and alert the homeowner [9]. Parameswaran *et al.* proposed an irrigation system that utilizes soil moisture sensors and solenoid valves to regulate water flow in crops [10].

The system takes into account not only the climatic conditions but also the pH levels of water and soil, as they are important factors in crop production. Monitors are used to display information on pH, moisture content, and temperature, thus improving the agricultural system and increasing productivity. The system can also provide remote monitoring and control, allowing farmers to adjust irrigation levels and pH values from a distance. This technology can be very useful in areas where water resources are scarce or in instances where manual monitoring and adjustment of irrigation systems are not feasible.

3. MATERIALS AND METHODOLOGY

The research paper lists the necessary components for the system, which includes Arduino Uno, fertilizer sensor, moisture sensor, relay, pump. The software requirements are Arduino IDE, MIT App Inventor.

3.1. Arduino Uno

Arduino Uno is a type of open-source computer hardware that is designed to simplify the creation of microcontroller-based projects by providing a user-friendly programming environment and a community of users who can share resources and knowledge. A microcontroller board can be used to sense and control various inputs and outputs. The Arduino Uno is a popular board in the Arduino family due to its affordability, ease of use, and compatibility with a wide range of operating systems. It can be programmed using various programming languages, including C++ and JAVA. A visual representation of an Arduino Uno is displayed in Fig. 1.

3.2. Fertilizer Sensor

The sensor used for fertiliser monitoring is illustrated in Fig. 2. Its

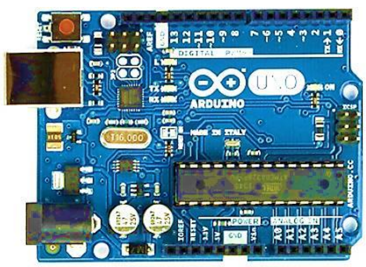

Fig. 1. Arduino Uno board.

Fig. 2. Fertilizer sensor.

function is to measure the concentration of ammonium in the soil, which is utilized by soil bacteria to produce nitrites and nitrates. In conjunction with meteorological data, pH readings, and soil conductivity measurements, the sensor employs machine learning to calculate the optimal timing for fertilisation. Based on this information, it predicts the total nitrogen present in the soil currently and in the next 12 days.

4. MOISTURE SENSOR

Soil moisture sensors (Fig. 3) are widely used for measuring the water content in soil. Traditional methods for measuring soil moisture require drying and weighing samples, which can be time-consuming and labour-intensive. However, modern soil moisture sensors utilize various indirect methods such as dielectric constant, electrical resistance, or neutron interaction to estimate soil moisture. These factors can be affected by factors like temperature, soil type, and electrical conductivity, which, in turn, influence the accuracy of the measurement.

The dielectric constant of soil is related to its water content, and soil moisture sensors utilize capacitance to measure the dielectric permittivity of the soil and determine its water content. These sensors are inserted into the soil and provide the water content status as a percentage. The data collected from these sensors can be used for a variety of applications in hydrology, agriculture, soil science, and environmental science. These sensors are also helpful in teaching concepts related to horticulture, biology, and agriculture.

5. WATER PUMP

Figure 4 illustrates a water pump, which is a mechanical device that increases water pressure for conveying it from one place to another. These pumps are utilized worldwide to provide water for domestic, agricultural, industrial, and municipal purposes. By guaranteeing that the correct amount of water is supplied to every section of a field, water pumps enhance irrigation efficiency and speed up crop growth. These pumps are easier to maintain due to their less complicated design and fewer moving components, which results in less maintenance work.

6. RELAY

A relay is a switch that operates using electricity. It consists of a set of input terminals for one or more control signals and a set of

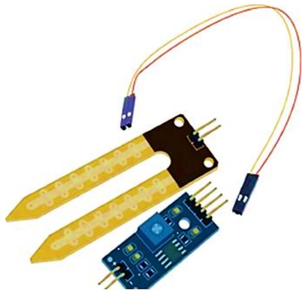

Fig. 3. Soil moisture sensor.

Fig. 4. Water pump.

Fig. 5. Relay.

functional contact terminals. Relays use electromagnetism to convert weak electrical inputs into stronger currents, where the electromagnets break or create circuits in response to these inputs. The device is designed for simple updates to contacts and isolates the activation component of the actuating part. It can operate at high temperatures and requires little current to function, yet it can power large machinery. Figure 5 shows a general image of a 5-V relay.

7. PROPOSED METHODOLOGY

The purpose of this study is to develop a system that can remotely monitor soil moisture levels in agricultural fields to maintain optimal moisture levels for crop growth. This IoT-based system is designed to accomplish this task. The prototype developed in this study allows for monitoring and maintenance of soil moisture levels in any agricultural field. This framework is expected to operate and generate reports in real-time. Although adjustments in sensing components, technologies, and source code may be necessary for actual implementation, the proposed approach and control remain consistent. The proposed system was demonstrated using ThingSpeak cloud, an IoT analytics platform that allows for real-time data stream aggregation, visualization, and analysis. ThingSpeak also allows for the execution of MATLAB code and can be used for prototyping and proof of concept IoT systems that require analytics. This system has the potential to promote sustainable agriculture practices in any country.

7.1. PROPOSED SYSTEM

According to the presented methodology, data is gathered from various sensors including soil moisture level, temperature of the area, air moisture, and water level. These sensors are connected to a breadboard, which is further connected to an Arduino board. The collected data is then transferred to the Arduino IDE for processing. The programming language utilized in the system runs instructions to extract and display the data. If the data is found to be invalid, the process is terminated, as illustrated in Figs. 6 and 7.

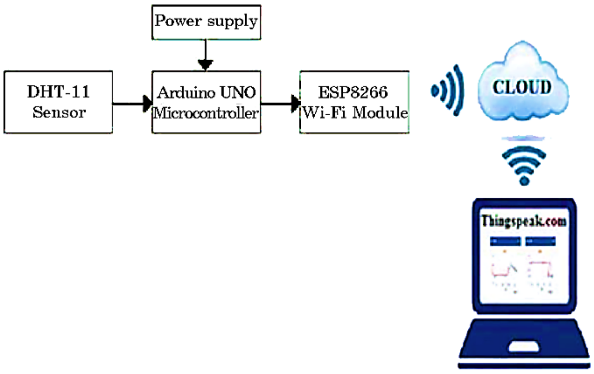

Fig. 6. Proposed system.

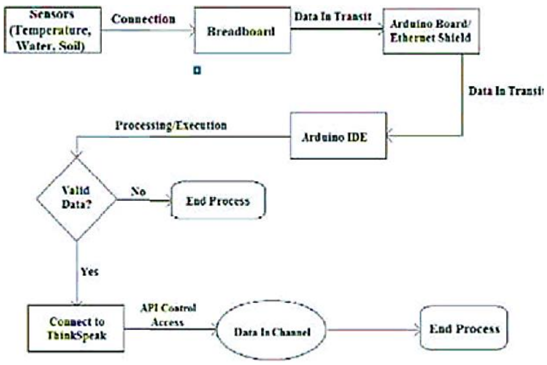

Fig. 7. Data flow diagram of the proposed system.

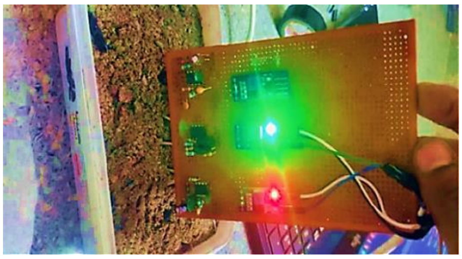

Fig. 8. Working model of the proposed system.

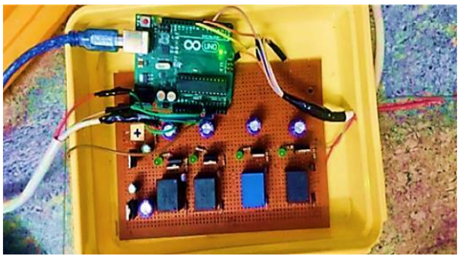

Fig. 9. Complete connection of the system.

8. IMPLEMENTATION OF THE PROPOSED SYSTEM

The proposed system aims to automate and regulate the irrigation process by monitoring the moisture level of the field. This smart irrigation device is designed to be a useful tool for farmers and gardeners who have limited time to water their plants. Moisture sensors and temperature sensors are used to measure the water content and temperature of the plants. If the moisture level is found to be below the desired level, the moisture sensor sends a signal to the Arduino board, which activates the Water Pump to supply water to the specific plant. The system can also be extended for outdoor use. The operational model of the proposed system is illustrated in Figs. 8 and 9.

9. EXPERIMENTAL ANALYSIS

The DHT11 sensor was chosen due to its high sensitivity and accuracy in measuring temperature and humidity. A digital sensor communicates with the ESP8266 NodeMCU *via* a single-wire serial interface. The NodeMCU's analogue pin A0 was utilised to read the analogue output from the moisture sensor, which is a variable resistor that changes its resistance based on the moisture content in the soil. The analogue value read by the NodeMCU is then converted to a digital value using the built-in ADC (analogue-to-digital converter). To control the water pump, a relay module was used to switch the higher voltage required by the motor pump. The NodeMCU's GPIO pins can only supply up to 3.3 V, which is not sufficient to operate the motor pump. The relay module acts as a switch that can handle higher voltage and current, allowing the NodeMCU to control the pump. An external 5-V power supply was also used to power the DHT11 and moisture sensors, as they require more power than what the NodeMCU can provide. Overall, the selection of these components and their integration into the system design is crucial in ensuring the accuracy, reliability, and efficiency of the automated irrigation system.

The table below lists the information gathered from various sensors.

TABLE. Sample dataset.

Created at Date	Created Time	Entry Id	A1	A2	A3	A4
09 March 2019	07:22:24	113	35	51	49	1076
23 March 2019	07:28:31	191	40	72	48	547
17 March 2019	06:18:24	138	37	71	44	589
22 March 2019	07:19:52	118	29	68	40	1324
13 March 2019	07:27:16	132	32	51	49	562
23 March 2019	08:05:10	174	37	61	33	1129
09 March 2019	07:21:28	165	36	61	45	703
19 March 2019	06:01:54	172	33	77	45	674
21 March 2019	08:36:26	180	38	53	34	1379
20 March 2019	07:37:26	180	26	78	32	1230
08 March 2019	08:49:11	176	28	50	28	1385
14 March 2019	07:48:11	113	36	70	25	421
20 March 2019	08:08:36	105	38	57	35	1401
10 March 2019	06:59:37	108	29	71	46	1369
11 March 2019	06:30:22	159	40	78	27	304
14 March 2019	07:46:55	105	32	71	37	1242
23 March 2019	07:03:52	130	36	61	33	948
16 March 2019	07:50:15	148	39	79	39	356

Continuation **TABLE.**

Created at	Created	Entry	A1	A2	A3	A4
Date	Time	Id				
08 March 2019	06:10:09	128	30	80	31	625
05 March 2019	06:09:10	107	26	67	35	729
20 March 2019	08:58:26	175	36	71	31	659
23 March 2019	06:33:05	159	38	64	43	986
26 March 2019	07:02:14	108	34	55	25	368
19 March 2019	06:21:19	146	34	57	43	1388
28 March 2019	08:11:07	161	25	65	41	589
19 March 2019	08:14:18	146	34	66	39	804
29 March 2019	07:02:34	186	33	56	34	827
11 March 2019	08:40:52	158	28	65	50	545
07 March 2019	07:10:18	163	32	72	34	785
04 March 2019	07:26:47	129	33	58	33	1262
19 March 2019	08:12:42	136	32	67	27	680
27 March 2019	06:31:06	103	37	69	45	1111
16 March 2019	07:25:23	199	31	73	47	1469
08 March 2019	06:42:43	190	37	76	29	428
10 March 2019	06:49:04	189	40	65	30	916

The data from the sensors for temperature, humidity, soil moisture, and water level are shown in Table under the characteristics A1, A2, A3, and A4, correspondingly.

The temperature measured by the DTH11sensor at various times and dates at various locations in Vellore is depicted in Fig. 10 below.

Similar to that, Fig. 11 of the graph below shows the humidity measured by the DHT11 Sensor at various locations.

The soil moisture level recorded by the soil moister sensors is depicted graphically in Fig. 12.

The water level sensor is used to track the water level in different fields throughout the Vellore districts. The following Fig. 13 makes this very evident.

The ThingSpeak cloud receives this data for visualisation, and a connection between temperature and humidity is computed. When watering plants, the relationship between temperature and humidity is crucial. Therefore, we can turn on or off the irrigation system depending on the correlation. The association is displayed in the following Fig. 14 using ThingSpeak to visualise data from the Matlab.

The working space of Arduino was depicted in Fig. 15.

The proposed work is new since, up until now, the majority of

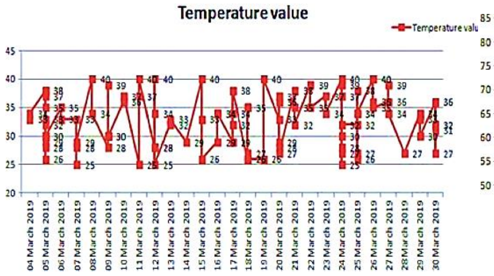

Fig. 10. Temperature recorded by DTH-11 sensor.

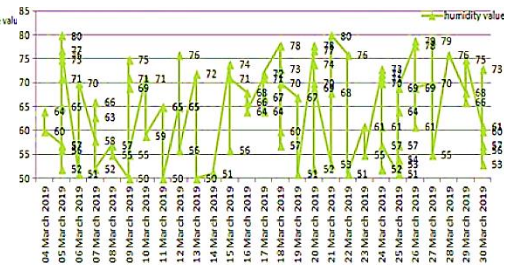

Fig. 11. Humidity recorded by DTH-11 sensor.

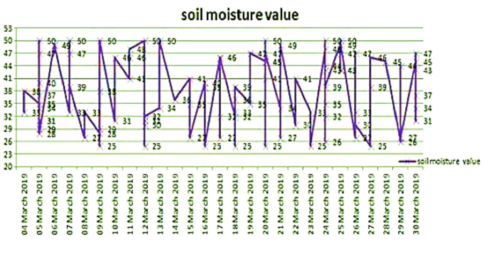

Fig. 12. Soil moisture recorded by soil moisture sensor.

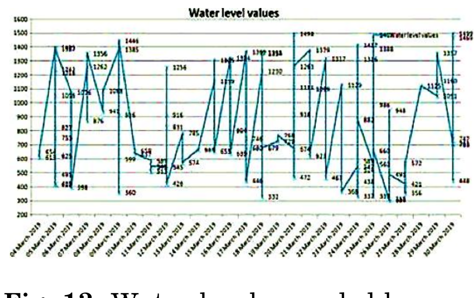

Fig. 13. Water level recorded by water level sensor.

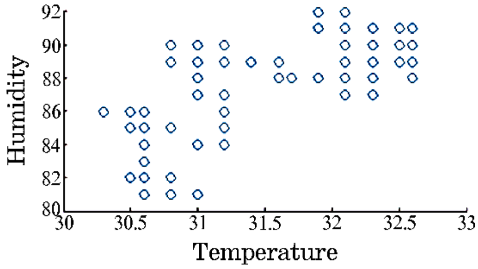

Fig. 14. Correlation map between temperature and humidity.

Fig. 15. Arduino workspace.

research on irrigation systems has typically recorded data and sent SMSs or alarms to the owners to let them know when to water or turn off the water supply. However, the suggested approach uses data gathered from numerous sensors to turn autonomously on and off. Additionally, the captured data is kept in the cloud for later use.

10. CONCLUSION AND FUTURE WORK

In addition to automating the data collection process for soil and plant nutrition requirements, future advancements in intelligent irrigation systems may also involve the use of advanced algorithms to predict soil moisture levels based on collected data. This could result in even greater efficiency and cost-effectiveness in the long run.

Furthermore, the use of sensors to monitor and regulate other important factors such as water level and sand content in soil can also be incorporated into the intelligent irrigation system. By incorporating additional variables, the system can become more precise and effective in delivering the correct amount of water to the plants.

The system described in this study is just the beginning of what is possible with smart agriculture. As more data is collected and analysed, the system can be further tailored for specific applications and scenarios. Ultimately, the objective is to not only save water but also reduce system costs, making it a more sustainable and profitable solution for farmers and agriculturalists.

REFERENCES

1. G. S. Jin, S. Jingling, H. Qiuyan, W. Shengde, and Y. Yan, *2007 8th International Conference on Electronic Measurement and Instruments IEEE*

(16–18 August, 2007, Xian, China), p. 2–82.
2. Indu Gautam and S. R. N. Reddy, *International Journal of Computer Applications*, **47**, No. 13: 1 (2012); https://doi.org/10.5120/7245-0043
3. R. Suresh, S. Gopinath, K. Govindaraju, T. Devika, and N. S. Vanitha, *International Journal of Advanced Research in Computer and Communication Engineering*, **3**: 5654 (2014); https://www.researchgate.net/publication/381583052_Smart_Irrigation_system_using_Internet_of_Things
4. K. Kansara, V. Zaveri, S. Shah, S. Delwadkar, and K. Jani, *International Journal of Computer Science and Information Technologies*, **6**: 5331 (2015).
5. P. Archana and R. Priya, *International Journal of Advanced Engineering and Global Technology*, **4**: 1567 (2016).
6. A. Anitha, 'Garbage Monitoring System Using IoT'. *IOP Conference Series. Materials Science and Engineering* (2017), p. 420–427.
7. M. Uddin, *Measurements of Evaporation During Sprinkler Irrigation* [Doctoral dissertation] (University of Southern Queensland: 2012).
8. C. H. Chavan and P. V. Karande, *Int. J. Eng. Trends Technol. (IJETT)*, **11**, No. 10: 493 (2014); doi:10.14445/22315381/IJETT-V11P296
9. A. Anitha, *Materials Science and Engineering Conference Series*, **263**, Iss. 4: 042027 (2017); doi:10.1088/1757-899X/263/4/042027
10. G. Parameswaran and K. Sivaprasath, *Int. J. Eng. Sci.*, **6**, Iss. 5: 5518: (2016).
11. L. Savadamuthu, S. Muthu, and P. Vivekanandan, *European Journal of Scientific Research*, **69**, No. 1: 64 (2012).
12. L. Savadamuthu, S. Muthu, and P. Vivekanandan, *International Journal of Soft Computing and Engineering*, **1**, No. 4: 2231 (2011).
13. P. Vivekanandan and V. P. Arunachalam, *International Review of Mechanical Engineering (IREME)*, **8**, No. 1: 75 (2014).
14. T. Prakash, Arun G, Arun Kumar B, Deepan. S, and Kalyana Venkata Ramanan, *International Research Journal on Advanced Science Hub (IRJASH)*, **02**, Iss. 04: 7 (2020); https://doi.org/10.47392/irjash.2020.20