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A systematic literature review for smart hydroponic system

Haifaa Jassim Muhasin[1], Ali Yahya Gheni[1], Nur Ilyana Ismarau Tajuddin[2], Nor Aziyatul Izni[3], Yusmadi Yah Jusoh[4], Khairi Azhar Aziz[4]
[1]Department of Computer Science, College of Education for Pure Science/Ibn Al-Haitham, University of Baghdad, Baghdad, Iraq
[2]Pusat Tamhidi, Universiti Sains Islam Malaysia, Nilai, Malaysia
[3]Centre of Foundation Studies, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil, Dengkil, Selangor, Malaysia
[4]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

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ABSTRACT

Hydroponics is the cultivation of plants by utilizing water without using soil which emphasizes the fulfillment of the nutritional needs of plants. This research has introduced smart hydroponic system that enables regular monitoring of every aspect to maintain the pH values, water, temperature, and soil. Nevertheless, there is a lack of knowledge that can systematically represent the current research. The proposed study suggests a systematic literature review of smart hydroponics system to overcome this limitation. This systematic literature review will assist practitioners draw on existing literature and propose new solutions based on available knowledge in the smart hydroponic system. The outcomes of this paper can assist future researchers by providing a guideline for user in highlighting approaches for the successful implementation of smart hydroponic system.

Corresponding Author:

Nur Ilyana Ismarau Tajuddin
Pusat Tamhidi, Universiti Sains Islam Malaysia
Nilai, Malaysia
Email: nur_ilyana@usim.edu.my

1. INTRODUCTION

Global climate changes and warming cause severe threats to water use and food security. Consequently, smart hydroponic systems are a promising direction to save water consumption in agricultural irrigation and develop sustainable agriculture [1]–[4]. Hydroponic is a planting method without using soil. “Hydro” in Greek means water and “ponos” means work. Hydroponics is a technique for growing plants in nutrients solutions (water containing fertilizers) with or without the use of artificial medium (sand, gravel, vermiculite, rockwool, perlite, peat moss, coir, or sawdust) to provide support [5]–[8]. So that in hydroponic, nutrients need to be given to plants, which is mineral water enriched by nutrients [9]–[12]. Hydroponics is a method of planting plants without using growing media from the soil. Hydroponics is soilless agriculture farming, which consumes less water and other resources as compared to the traditional soil-based agriculture systems [13]–[17]. Hydroponics involves the use of water as a medium for the cultivation of crops [18]–[20] and its make quality food in limited land [21]–[23]. A connected smart system will allow more people to access hydroponic growth. This will be achieved as the system will enable busy people to grow the food as it will take care of most of the aspects involved. Several recent reviews have been conducted on internet of things (IoT) solutions for smart agriculture, indicating that this research field always receives new contributions and continued advancement.

Current studies usually focus on the IoT, cloud platforms, network technologies, embedded system platforms, and mobile applications [23]–[29]. The authorized person can monitor the real-time status of a plant's growth from a distant location. Users can observe the key environmental indicators such as humidity, temperature, lighting intensity, and water level by the smartphone. The data will send to the application and displayed as required using a smartphone. The primary purpose of this study is to propose a systematic literature review of smart hydroponic system to shed some light on the research topic. Hydroponic basis signifies hydro = water and phonic = workmanship [1], [30]. Generally, a system of agricultural cultivation without using the land but water containing nutrient solutions. The cultivation of hydroponics is usually carried out in a greenhouse so that optimal plant growth is protected from the influence of elements outside like rain, pest disease, and climate. The benefits of hydroponics are: i) the guarantee of the success of plants in growing and producing, ii) the treatments and more controlled pest disorders being more practical, iii) the fertilizers are more productive, iv) more easily replacement the die plants with the new plants, v) reduces the labor costs, vi) plants can grow more rapidly, vii) the selling and production results of the plant are higher and sustain, viii) some types of plants can be cultivated out of season, ix) no risk of natural conditions, and x) the hydroponic plants can be carried out on anywhere and anytime [1], [31] as shown in Figure 1.

Figure 1. Hydroponic plant

Hydroponics can be considered the most acceptable option in areas with serious soil and water problems like soil-born pests, soil and water salinity, diseases, water, water shortage, and chemical residues in soil. One advantage of a hydroponics farm is lowered labor value because the farmer doesn't have to be compelled to prepare the watering, soil, and fertilization are mechanically engineered into the hydroponic farm [5], [32]. Since hydroponics farm is normally partially automated, it's more effortless to connected IoT to generate correct information and automate the farm [27], [33]–[35]. Gokul *et al.* [9] developed an android application to monitor the hydroponic system. This research can store sensor data in thing speak cloud. The sensors of pH, temperature, humidity, water level, and light intensity are used by integrating sensors and actuators to the microcontroller (ESP32). The maintenance and automatic observation are done by the intervention of IoT, which are used to transmit and retrieve information to the network, a mobile app is used to control the actuators, and the sensor data will be stored on thing speak cloud.

Hariono *et al.* [13] implemented data acquisition applications in an IoT-based hydroponic plant automation system using ESP8266. The system development method uses the waterfall method, which includes requirements analysis, system design, implementation, and testing. The results of data collection are displayed on the dashboard page in real time, so that the user can easily read them. The results of functional and effectiveness testing were satisfactory. Monitoring and control are done through the website. Deokar *et al.* [18] implements the hydroponic automation system and monitoring via the BLYNK application. This research aims to design the interface of an electronic circuit of sensors and actuators to a hydroponic system by using IoT-based automated hydroponic system for remote monitoring and control. As a result, the BLYNK application was more flexible and minimalist for monitoring use than the website one.

Prathima *et al.* [21] implements the hydroponic automation system. This research successfully makes a fully controlled and automatic hydroponic system with ESP32 and all sensors. This system is very suitable in all regions regardless of the environment and can be set up in a small space. Koge *et al.* [36] developed and monitoring of hydroponics using IoT. They also used the ESP8266 to sensor the water, temperature, pH, and light. As a result, the plant grows well using this approach without using soil. As a result, the rate of growing plants in a hydroponic system is much better than in the soil. Lakshmanan *et al.* [37] proposed to develop an automated intelligent hydroponic system using the IoT. This system can integrate the concept and functionality of IoT into the existing hydroponic system. The development of a user interface node for the node red, which is connected to the real-time sensor data, allows the user to successfully control, and monitor real-time data. Kularbphettong *et al.* [38] invented automated hydroponic system based on mobile application, IoT is a concept that aims to expand the benefits of continuously connected internet connectivity that allows us to connect machines, equipment, and other physical objects with network sensors and actuators to acquire data and manage their performance, thus enabling machines to collaborate and even act on newly acquired information independently and the initial idea of IoT was first raised by Kevin Ashton in 1999 in one of his presentations [12]. In this research, the researcher aspires to make it convenient and productive by operating IoT and mobile phones to monitor the automatic hydroponics vegetable system. This system can control plant growth's environmental factors: humidity, water, and temperature. This research integrated the components such as relay, arduino WeMos, pH sensor, and ultrasonic sensor module. As a result, the successful application of plants grown with hydroponic enhances pH sensor stability, and the system functions sufficiently.

Changmai *et al.* [39] invented smart hydroponic lettuce farm using the IoT. The study integrates components such as microcontroller device, Arduino Mega 2560 rev 3, water temperature sensor, DSI8D20, and others. The results reveal that lettuces from smart farms have around 36.59% higher weight, 17.2% more leaf, and 13.9% larger stem diameter than regular farms. The nitrate content of smart farm lettuces is also 8.24% better. IoT has recently been widely used in technology development. Communication between devices could be interpreted by using IoT. A lot of work could be reduced by using the hydroponic system so that plant treatment can be done flexibly [18]. IoT can easily monitor and control the hydroponic system, and all the required values can be appropriately maintained. The temperature, pH, water, humidity, and light intensity are applied by connecting with arduino [38], [39]. Based on explanations from previous researches, the researchers concluded that to cover the shortcomings of the hydroponic system can be overcome by building a simple system that can reduce maintenance costs and high production costs [21], [36], [37], [40]. The researchers attempted to apply a hydroponic system combined with the use of monitoring through the IoT based application, Arduino. Arduino was chosen because of low cost, easy programming, and open source of software and hardware. By utilizing the IoT concept in agriculture, farmers can easily monitor the agricultural condition and environment from anywhere. So, the system proposed in this research is an automated smart hydroponics system in Tamhidi, where this system will be able to implement the concept and functionality of IoT to the hydroponic system by using Arduino. The significance of hydroponics is providing a way for the average person to grow their plant without the need for soil.

Studies reveal that by 2050, food produced will increase to 70%, feeding 9.6 billion people, and is to be deployed in 525 million farms across the globe. Apart from sensing and monitoring, automation and regulation of hydroponic systems have resulted in the minimal human interface [38]. Considering that human world population will reach about 9 billion by the year 2050, it appears clear that food security is one of the pivotal themes of the new millennium and reasonably the most urgent challenge for the agricultural sector [39]. To satisfy the demand for food, world production will have to raise about 70% from 2007 levels. Additionally, since the world is becoming increasingly urbanized, 75% of the world population is projected to live in urban settlements [37].

2. METHOD

2.1. Planning

The researcher was conducted the systematic review using guidance from [40]–[44]. The review process consists three stages which are planning, selection, as well as extraction and execution. The planning stage activities specify specific research contexts, define reviewing protocols, and construct research questions. As shown in Figure 2, a researcher needs to identify the purpose and build the research question. Next, a review protocol is defined in this stage based on the research team's input, including researchers specializing. The issues related to the smart hydroponic system are selected as the primary context of the research in this review.

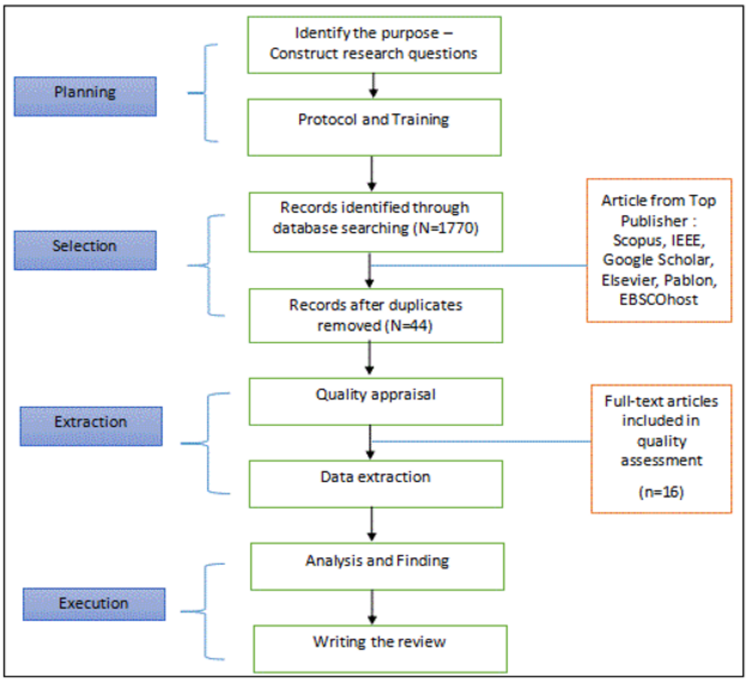

Figure 2. SLR processes adapt from Okoli and Schabram (2010) [41]

2.2. Selection

Searches are conducted in six leading electronic journal databases: Scopus, IEEE, Publon, Google Scholar, Elsevier, and EBSCOHost in the selection phase. A set of criteria for filtering the literature was established. As shown in Table 1, only literature from high-quality sources was used in this study according to specific criteria. Journals and conferences paper based on English-language peer-reviewed were chosen for this research, whereas dissertations, book reviews, conference papers, and books were excluded. The search was limited to articles published from 2017 until 2021. The following are the major contributions of the proposed research: i) to analyze the existing published materials on the hydroponic system and their presentation and ii) to analyze the study regarding smart hydroponic system.

Table 1. Criteria of article

No	Criteria	Inclusion	Exclusion
1	Focus on the article	Hydroponic plant	Articles that did not focus on hydroponic plant
2	Journal published	Top publisher/source: Scopus, IEEE, Pablon, Elsevier, Google Scholar	Journal and conference paper outside of the top publisher/source
3	Publication date	2017 onwards	Before 2017
4	Publication type	Journal, conference paper	Book chapters, technical reports, dissertations
5	Language	Journal article, conference paper was written in English	Other languages were not included

2.3. Extraction and execution

The authors analyzed the articles that met the above criteria for additional studies to meet the inclusion criteria for the review. At this stage, duplicate articles were removed. In addition, articles were reviewed for relevance, primarily based on the title and abstract. Completeness and advantages of data extraction were evaluated in terms of quality assessment. These four questions (Q1-Q4) are described in Table 2. Each question has only three answer options: yes=1; partially=0.5; and no=0. The characteristics of the literature and the results of the evaluation are described in the report phase and presented in the following section.

Table 2. Question descriptions

No	Item	Answer
Q1	Is there clear description of the aims and objectives of the investigation	Yes/No
Q2	Is the paper explained the method of analysis perttined and adequately?	Yes/No/Partially
Q3	Is the paper supported by primary data?	Yes/No
Q4	Is the paper explained the model structure in detail?	Yes/No/Partially

3. RESULT AND DISCUSSION

3.1. To analyze the existing published materials on the hydroponic system and their presentation

The existing published materials were analyzed based on the details given in this section. This was done to indicate the relevance of the current literature to the proposed research. Different types of analysis were performed to show in-depth detail of the existing. In the following stage, the abstract and brief content of the selected paper was evaluated. Forty-four relevant articles were then filtered by applying the quality assessment criteria. A total of 1770 references are considered relevant to this topic. Eventually, only 16 papers out of 44 (36.36%) were accepted for the data synthesis of evidence after conducting exclusion criteria. Table 3 indicates the overview of the quality assessment of the 16 papers (PD1-PD16) is considered for this review.

Table 3. Final set of articals selected for this study

ID	Sources	Year	Type of research	Publisher/sources	Type of article
PD1	[9]	2021	Empirical	Elsevier	Proceeding
PD2	[13]	2021	Empirical	Google Scholar	Journal
PD3	[18]	2021	Conceptual	Google Scholar	Journal
PD4	[5]	2020	Conceptual	Google Scholar	Journal
PD5	[21]	2020	Conceptual	Google Scholar	Journal
PD6	[36]	2020	Conceptual	Scopus	Journal
PD7	[37]	2020	Empirical	Scopus	Journal
PD8	[45]	2020	Empirical	Google Scholar	Journal
PD9	[38]	2019	Empirical	Scopus	Journal
PD10	[46]	2019	Conceptual	EBSCohost	Journal
PD11	[47]	2019	Empirical	IEEE	Conferences
PD12	[39]	2018	Empirical	IEEE	Conferences
PD13	[48]	2018	Empirical	IEEE	Conferences
PD14	[49]	2017	Empirical	IEEE	Conferences
PD15	[50]	2018	Empirical	Google Scholar	Journal
PD16	[51]	2018	Empirical	Publon	Conferences

Figure 3 shows the frequency of publication of smart hydroponic from 2017 until 2021. The data shows 3 papers from 2021, 5 papers from 2020, 3 papers from 2019, 4 papers from 2018 and 1 paper from 2017. Figure 4 shows the frequency of top publisher/source regarding the smart hydroponic system. Based on final set of articles selected for this study, 6 papers were extract from Google Scholar, 4 papers from IEEE, 3 papers from SCOPUS and 1 paper from Publon, Elsevier and EBSCOHost.

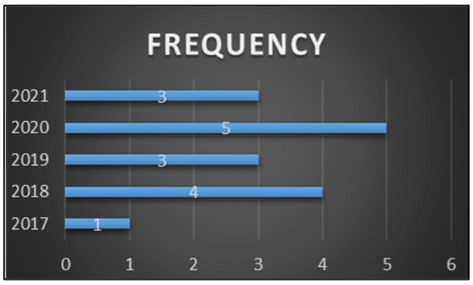

Figure 3. The frequency of publication of smart hydroponic

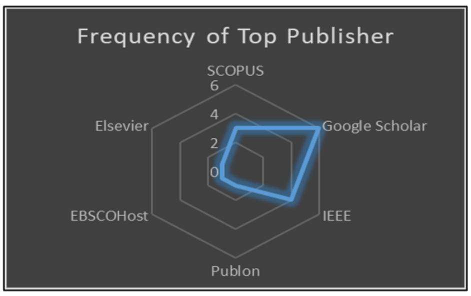

Figure 4. The frequency of top publisher

3.2. Quality assessment result

Table 4 shows the result of quality assessment based on quality assessment criteria. All papers have clear description of the aims and objectives of the investigation. 12 papers show the objectives of research is clear and method of analysis are explained in pertinent and adequately. 9 papers supporter by primary data and 13 papers were explained the model structure in detail. Table 5 exemplifies the filtering result of the quality assessment of all that paper that was classified as very good scores. 15 selected scored a very good quality scoring (3-4) with 93.34% and only 1 paper have a good quality score (2-3) with 6.66%.

Table 4. Quality assessment result based on sources and questions

Paper_ID	QS1	QS2	QS3	QS4	Total
PD1	1	1	1	1	4
PD2	1	1	1	1	4
PD3	1	1	0.5	0.5	3
PD4	1	1	1	1	4
PD5	1	1	0.5	0.5	3
PD6	1	1	1	1	4
PD7	1	1	1	1	4
PD8	1	1	1	1	4
PD9	1	1	1	1	4
PD10	1	1	1	1	4
PD11	1	0.5	0.5	1	3
PD12	1	0.5	0.5	1	3
PD13	1	0.5	0.5	1	3
PD14	1	0.5	0.5	1	3
PD15	1	0.5	0.5	0.5	2.5
PD16	1	1	1	1	4

Table 5. Quality assessment result summary

Quality scale	Very poor (<1)	Poor ($1- <2$)	Good ($2- <3$)	Very good ($3-4$)	Total
No. of papers	0	0	1	15	16
Percentages (100%)	0	0	6.66	93.34	100

3.3. To analyze the study regarding smart hydroponic system

Several studies on smart hydropnonic system can be found in the literature. The following subsections briefly present the results and discussion part of the paper. To answer this research question, the primary selected articles based on Table 6 lighted smart hydroponic system using IoT. Three papers developed automated hydroponic system based on mobile application. Five papers used ESP to sensor the water, temperature, pH, and light of hydroponic system and papers are integrate the components of arduino on smart hydroponic system. Based on explanations from previous researches, they used various technology in order to monitor the hydroponic plant effectively and efficient.

Table 6. The research regarding smart hydroponic system

References based on paper ID	Description
PD3, PD6, PD7, PD12	Smart hydroponic system using IoT
PD1, PD2, PD7	Developed utomated ydrophonic system based on mobile application
PD4, PD5, PD8, PD15, PD16	This research used ESP to sensor the water, temperature, pH and light of hydroponic system
PD3, PD12	This research is integrating the components of Arduino on smart hydroponic system

4. CONCLUSION

Smart hydroponic system enables farmers or users to monitor and control the plant growths. The development of IoT with the integration of a new technology platform help in agriculture. This article mainly focuses on the research of the smart hydroponic system, which can be implemented using IoT and various technology. The outcomes of this article can help future researchers by highlighting an approach of hydroponic for the successful implementation of smart hydroponic system.

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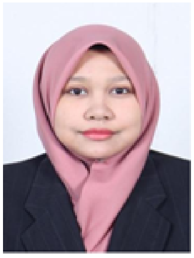
BIOGRAPHIES OF AUTHORS

Haifaa Jassim Muhasin holds her Ph.D. in a multi-level framework for efficient sensitive data transmission in cloud computing from Universiti Putra Malaysia (UPM) in Information Systems, Faculty of Computer Science and Information Technology, Malaysia. She holds her M.Sc. in Computer Science/Data Security from the Department of Computer Science and Information Technology, University of Technology, Baghdad, Iraq. She holds B.Sc. in Computer Science from the Faculty of Science, University of Baghdad, Iraq. Her current research interests are in data security, information systems, and cloud computing security. She is currently work as a senior lecturer in Department of Computer Science, Faculty of Education for Pure Science (Ibn-Al-Haitham), University of Baghdad, Iraq. She can be contacted at email: haifaajassim@yahoo.com or Haifaa.j@ihcoedu.uobaghdad.edu.iq.

Ali Yahya Gheni he holds his PhD from Universiti Putra Malaysia (UPM) in Information Systems, Faculty of Computer Science and Information Technology, Department of Software Engineering and Information Systems, Malaysia. He holds his MSc. from University College of Technology and Innovation (UCTI) in Information Technology Management, Department of Information Technology Management, Malaysia. He holds his BSc. in Computer Science from University of Baghdad, Department of Computer Science, Iraq. He is currently worked as a senior lecturer in University of Baghdad, Department of Co. Science. His research interest includes information systems, information technology management and software engineering. He can be contacted at email: ali.y.g@ihcoedu.uobaghdad.edu.iq.

Nur Ilyana Ismarau Tajuddin is a senior lecturer at Universiti Sains Islam Malaysia (USIM). She was PhD graduate at Universiti Putra Malaysia (UPM) in field of Information System. She has received his Master Degree in Management Information system from University Kebangsaan Malaysia (UKM), and Bachelor of Business in Computing from University Teknologi Mara (UiTM). She teaches business information system, business modeling, internet in practices, C++ programming, quantitative techniques. Her research interest includes knowledge management, management information systems, information technology strategic planning, performance measurement, entrepreneurship and Information ethic and policy. She can be contacted at email: nur_ilyana@usim.edu.my.



Nor Aziyatul Izni is a senior lecturer at the Centre of Foundation Studies, Universiti Teknologi MARA, Selangor Branch, Dengkil Campus. She has been awarded a Professional Technologist by the Malaysia Board of Technologists (MBOT) since November 2021. She graduated Bachelor of Applied Science (Honours) in Mathematical Modelling in 2012 and a Master of Science (Mathematics) in 2013 from Universiti Sains Malaysia (USM), Malaysia. She then completed her Ph.D. in 2019 from Universiti Teknologi Malaysia (UTM), Kuala Lumpur. Her research interests are primarily in the area of signal processing, applied statistical methods, applied mathematics, fusion algorithm, artificial intelligence as well as prediction and forecasting methods. She can be contacted at email: naizni@uitm.edu.my.

Yusmadi Yah Jusoh received the Ph.D. degree in System Science and Management from the National University of Malaysia (UKM) in 2008. Currently, she is an Associate Professor at Universiti Putra Malaysia (UPM), Faculty of Computer Science and Information Technology. Her research interest is in management information system, information system, information technology strategic planning, and software project management. Yusmadi is also a certified software tester and an academician at Department of Software Engineering and Information System, Faculty of Computer Science, and Information Technology, UPM since 1998. In 2008 she received her PhD in System Science and Management from UKM. She teaches software project management, team software project management, information systems, and management information systems. Her research interest includes software project management, information systems, performance measurement, and management information system. She can be contacted at email: yusmadi@upm.edu.my.

Khairi Azhar Aziz received the Bachelor of Computer Science in Software Engineering from Universiti Putra Malaysia in 2010. He holds a Master in Information System from the Universiti Kebangsaan Malaysia in 2017. Additionally, he graduated from Universiti Putra Malaysia (UPM) in 2023 with a Doctor of Philosophy (Information Systems). His research interests include information systems, e-commerce, knowledge management, software management, enterprise system aapplication, knowledge based system, software testing, information communication technology, and other IT-related topics. He was invited as presenter at the 9th International Conference on Information Management (ICIM2023) at the University of Oxford in Oxford, United Kingdom from the 17th to the 19th of March 2023. Additionally, he appointed as a reviewer and success contributor for the 10th International Conference on Information Management (ICIM2024) which be held from the 8th to the 10th of March 2024 at the University of Cambridge in Cambridge, United Kingdom. He was appointed as the Technical Committee for the 2024 6th Asia Conference on Machine Learning and Computing (ACMLC2024) in Bangkok, Thailand. He can be contacted at email: hairie_azdhar@yahoo.com.