Enhancing Chili Farming through IoT-Enabled Microclimate Monitoring

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Abstract. This research aims to design a microclimate monitoring system for chili plant cultivation using a microcontroller and Internet of Things (IoT) technology. The study addresses the issue of farmers' limited ability to monitor climate change. The proposed system consists of components such as the ATmega2560 microcontroller, Real Time Clock (RTC), Liquid Crystal Display (LCD), micro-SD Card, Arduino Ethernet Shield, DHT22 sensor, soil moisture sensor, infrared sensor, actuators, TP-Link router, modem, and Telkomsel GSM SIM card. The system records data every hour and sends it to a dedicated website. The research results show that the IoT-based monitoring system functions effectively, with 567 data points sent to the website with an accuracy rate of 94%. The cost of data transmission amounted to IDR 7086, and the data transmission speed to the LCD and the website was 1.5 minutes. The monitored data is displayed on the website Monitoringcabai.weebly.com. This research provides a valuable tool for farmers to make informed decisions about chili plant cultivation based on real-time microclimate data.

Keywords: Capsicum annum, Microclimate, IoT, Microcontroller.

1 Introduction

Horticultural cultivation is a pivotal subsector within agriculture, offering significant economic contributions [1]. Horticultural crops play a vital role in the income sources of farmers, trade, and labor absorption. In Indonesia, horticultural commodities can be categorized into four major groups: fruits, vegetables, medicinal plants, and ornamental plants [2], [3].

One of the standout commodities within horticulture is chili peppers, classified as fruit vegetables, which farmers extensively cultivate due to substantial domestic and international demand. The versatile role of chilies in food seasoning, food processing, and pharmaceuticals makes them susceptible to significant price fluctuations, presenting an attractive business opportunity [4].

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Chili plants belonging to the Capsicum annum family can be further categorized into two significant groups: large chilies (Capsicum annum), including red chilies, green chilies, and bell peppers, and small chilies (Capsicum frutescens), comprising white chili, green chili, and larger varieties known as "lombok japlak" [5].

To successfully cultivate chilies, precise care is essential to ensure optimal growth and prevent issues such as growth retardation or plant mortality. This involves considering microclimate conditions conducive to change, including temperature, sunlight intensity, air humidity, and soil moisture [6]. These microclimate factors have a direct influence on growth rates, pest and disease development, and overall plant health as they interact intimately with the plant and its surroundings, affecting variables like temperature, humidity, and soil moisture [7]

Farmers face significant challenges in monitoring climate changes, including uncertain fluctuations in temperature, humidity, and soil moisture, which can adversely affect plant growth and, by extension, the livelihoods of the farmers themselves [8]. Consequently, there is a pressing need for a monitoring system that can track microclimate changes to better support chili cultivation [9].

Monitoring systems are pivotal in automatic and real-time reporting of plant conditions [10]. They simplify agricultural land management, allowing secure data storage and remote access as needed.

Yahwe's research in 2016 [11] emphasizes the effectiveness of monitoring plant conditions based on soil moisture through microcontroller-based SMS. This approach proves invaluable for supervising and maintaining optimal plant conditions, effectively saving time and effort for plant owners. In our study, this monitoring system is implemented via a website, a technology commonly called the Internet of Things (IoT) [12].

The Internet of Things (IoT) is a transformative concept that extends the benefits of continuous Internet connectivity, making data sharing and global network access possible through embedded, always-active sensors [13]. IoT technology streamlines the monitoring and data collection of various variables, particularly in agriculture, proving particularly advantageous for countries with significant agricultural potential [14].

IoT technology for monitoring chili plant growth is poised to streamline remote and automated control of agricultural land and growth conditions. This transition from manual to computerized systems has the potential to significantly enhance efficiency, especially in regulating temperature, humidity, and soil moisture, ultimately supporting a thriving chili cultivation industry.

Specific objectives in this research include testing the chili monitoring data transmission system design by comparing the data accuracy between microSD and the website, calculating the cost and data quota consumption during data transmission, and comparing the data transmission speed from the LCD to the website.

2 Research Method

The equipment used in this research includes a personal computer, Arduino software, web browser software, ATmega2560 microcontroller, Telkomsel GSM SIM card, Real

Time Clock (RTC), MicroSD card, Arduino Ethernet Shield, 3.75G GSM Modem, TP-Link Router, USB connector, DHT22 sensor, soil moisture sensor, power supply, and writing tools. As for the materials, chili plants are used in the study.

2.1 Procedure

This research commences with the chili planting phase, followed by the programming of the equipment, the transmission of temperature, humidity, and soil moisture data to the website, monitoring the pump's activation status (on/off), data collection, and culminating in data analysis.

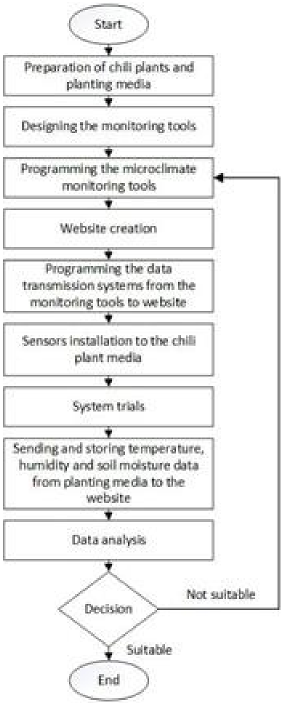


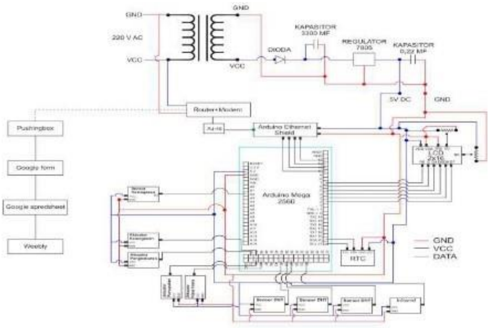
Fig. 1. Flowchart of enhancing chili farming through IoT-enabled microclimate monitoring

Design Criteria.
Based on a microcontroller, the chili plant monitoring system is designed to record data at one-hour intervals. Data transmission in this device is Internet of Things (IoT) based. The data the device records is processed through the microcontroller and then transmitted to Google Spreadsheet via Google Forms. Users can access the stored data using web browsers on a computer or smartphone by entering the designated website address.

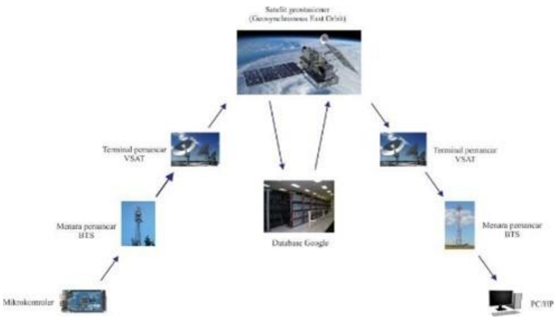
Data Transmission System.
In the data processing stage, after being received by the microcontroller, the subsequent step involves displaying the data on the LCD (Liquid Crystal Display) as an output.

Simultaneously, the data is transmitted using the Arduino Ethernet Shield, connected to a TP-Link router and a 3.75G modem with a GSM SIM card installed.

Functional Design.
In this research, a microclimate monitoring system for chili plant growth is designed using the Internet of Things (IoT) technology. Its primary purpose is to accurately record, securely store, and provide real-time display of microclimate monitoring data via a dedicated website.



(a)



(b)

Fig. 2. Schematic of the monitoring tool circuit (a) and data transmission flow system (b)

Data Analysis.
Research data is collected by a microcontroller at hourly intervals. Once gathered, the data is displayed on the LCD and transmitted to a website via the Internet. This data collection process spans 25 days, followed by an analysis that calculates the data quota, accuracy, and delivery speed. The analysis results are then presented in the form of tables and graphs.

a. The Amount of Internet Quota

The efficiency of the data retrieval process relies heavily on internet connectivity, as it involves transmitting data through the 3.75G Modem connected to a GSM SIM card. To determine which tool is economically viable with high productivity, it is essential to calculate the internet quota consumed during data collection. In this research, the quota calculation was performed manually, involving the verification of the quota used for each data transmission. The formula utilized for this quota calculation is as follows:

$$Amount\ of\ Internet\ Quota = \frac{Data\ consumption}{Data\ sent} \tag{1}$$

b. Data Accuracy

Data accuracy encompasses retrieving data initially recorded by the control system, which is subsequently stored on a micro-SD card displayed on both an LCD screen and a website. The data retrieval process involves saving or summarizing the data in a Google Spreadsheet, followed by keeping it in Google Drive in *.xls format. The recorded data is then sent to and displayed on the website. Ensuring the alignment of the recorded data with the transmitted data is crucial, necessitating a comparison to determine their appropriateness. The formula employed for calculating data accuracy is as follows:

$$Data\ Accuracy = \sum_{i=0}^{n}\left(\left(1 - \frac{Recorded\ data - Data\ sent}{Recorded\ data}\right) \times 100\%\right) \tag{2}$$

c. Data Delivery Speed

Delivery speed refers to the duration it takes for the system to transmit data through the internet network for display on the website. A stopwatch is employed during the data-sending process to calculate the data transmission rate from the microcontroller to both the LCD and the website. The Arduino program dictates data transmission at the 20th minute of every hour. When the LCD indicates the 20th minute, the stopwatch is initiated, running until the data is successfully sent to the website, and a notification is delivered via email. The formula used for calculating data transmission speed is as follows:

$$Delivery\ Data\ Speed = \sum_{i=0}^{n}\left(\frac{Sent\ time - Delivery\ time}{Number\ of\ observation}\right) \tag{3}$$

3 Result and Discussion

3.1 Automation and Data Accuracy

The chili farming control system is precisely engineered to showcase and log microclimate data about chili cultivation. This data encompasses date, delivery time, temperature, humidity, and soil moisture. These details are transmitted automatically and in real-time. All these components are integrated into a unified unit, each serving a distinct function. The automation system design and data collection outcomes are depicted in Fig. 3.

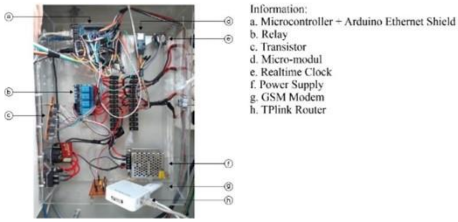


Fig. 3. Design of Data Automation System

3.2 Data Transmission System

The data transmission system involves transferring data from a source to a recipient using a computer or electronic media in real-time over the Internet. The data transmission system employs a web client method, where the microcontroller serves as the central controller for accessing a designated website address. This method, available on Arduino, requires the microcontroller to establish a connection with the targeted server, which, in this case, is Google. The Google applications utilized include Google Forms, Google Spreadsheet, and Google Drive.

Standard software cannot access Google Forms directly with an HTTPS address type in this transmission system. Hence, they must be redirected to another website using the Application Programming Interface (API) provided by Pushingbox. Each Google application used in this research has specific and interrelated tasks. These applications were chosen for their cost-effectiveness, offering free usage and a substantial data storage capacity of 15 gigabytes (GB).

In this study, Google Forms served as the data entry platform. The microcontroller was responsible for populating a form with inquiries about chili control data, encompassing temperature, moisture, humidity, pests, and pump status. Fundamentally, Google Forms operates by utilizing the POST HTTP request method. In simple terms, this method facilitates direct data transmission to the server upon submission without any data being exposed or visible in the URL address.

Fig. 4. Google Form window

Google Spreadsheets plays a vital role in processing and presenting the data sent from Google Forms. The data transmitted to Google Spreadsheet is organized into a table structure. This allows for flexibility in adjusting the number of rows and columns displayed in the Google Spreadsheet, accommodating customization to suit specific needs. For a visual representation, Fig. 5 illustrates the appearance of the Google Spreadsheet window in this research.

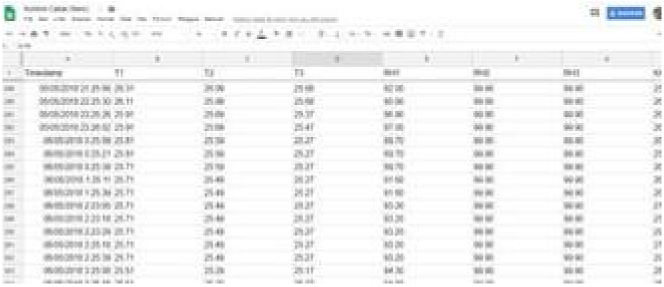


Fig. 5. Google Spreadsheet window

The website page includes a top opening link (Home), as illustrated in Fig. 6. Additionally, Monitoringcabai.weebly.com provides other page displays such as About and Contact.

Fig. 6. Website User Interface Monitoring Cabai Tep

The About page offers a visual representation and description of the object or tool, while the Contact page features the website owner's contact information, enabling visitors to reach out for inquiries. Accessing the Weebly application is convenient, as it is readily available for download on Playstore, making it accessible on smartphones.

3.3 Test of Data Transmission System

This research tested a data transmission system, which involved the integration of a microcontroller with a website to support the Internet of Things (IoT) system. The IoT system enables seamless data transmission from a source to a recipient without requiring physical interaction.

In this research, a router connected the microcontroller to the internet via a modem device. An active internet connection was essential to transmit data in real-time and online. The research plan entailed sending data at hourly intervals, with each data set promptly recorded on the micro-SD card and simultaneously sent to the website.

To ensure the implementation of the data transmission system aligns with the predetermined design criteria, various tests were conducted, encompassing quota calculations, data accuracy, and delivery speed assessments.

Calculating the Amount of Internet Quota.
The internet quota calculation in this monitoring aims to determine which tools are designed to be economically viable with high productivity. In this research, the chosen internet service provider is the Telkomsel brand. Telkomsel was selected as the service provider for the device, and based on the analysis conducted with OpenSignal software, it was found that the area where the Telkomsel provider's device is situated offers the best signal quality.

The calculation of the internet quota was conducted throughout the 25-day research period, commencing from the initial data transmission. Over these 25 days, 567 data transmissions were made to the website. These data transmissions occurred hourly, resulting in 24 daily transfers. It's important to note that 33 instances of data transmission errors or data that failed to be sent were observed during the study. The details of the data transmitted, and the associated internet quota usage can be found in Table 1.

Table 1. The amount of data sent.

Day	Data amount	Data price (IDR)
1	11	137
2	24	300
3	24	300
4	21	262
5	14	175
6	22	275
7	24	300
8	24	300
9	24	300
10	24	300
11	24	300
12	24	300
13	24	300
14	24	300
15	24	300
16	24	300
17	24	300

Day	Data amount	Data price (IDR)
18	24	300
19	24	300
20	24	300
21	24	400
22	24	300
23	19	237
24	24	300
25	24	300

After manually checking the daily usage of the internet quota, we can determine that the amount of data consumed each time it was sent, once every hour, was approximately 20 KB. In this research, 567 data entries were sent, which resulted in the consumption of about 11.34 MB, calculated using Equation 1.

Upon calculation, the total internet quota used over 25 days amounted to roughly 11.34 MB. The available allocation on the SIM card was 2 GB. Regarding cost, a 2 GB quota can be purchased for IDR 25,000. As shown in Table 1, the cost calculation for the quota used over 25 days amounted to approximately IDR. 7,086.

The Accuracy of Data Delivery.

The data displayed and recorded include the following information: date, time, temperature, humidity, moisture, as well as pump and pest trap statuses, as shown in Fig. 7 and Fig. 8.

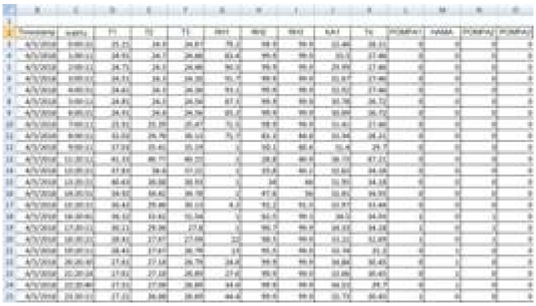


Fig. 7. Recorded data in microSD

In Fig. 7, the recorded data is displayed, presenting the sensor readings. The timestamp column indicates the date of data recording, while the time column displays the exact recording time. The columns labelled T1, T2, T3, and T4 represent temperature values, RH1, RH2, RH3, and KA1 indicate humidity and moisture values. The columns for pump 1, pump 2, and pump 3 show the moisture, mist, and fertilizer pump statuses, respectively. The displayed pump values are either 0 or 1, where 0 signifies that the pump is off, and one indicates that the pump is active. Upon comparing the data recorded on the MicroSD card with the data sent to the website (Fig. 8) and calculating the data accuracy, the results of this study indicate an accuracy of 94%. This figure aligns with the specified design criteria.

Fig. 8. Data sent to the website.

The Speed of Data Delivery.
The data transmission process in this research involves using a data transmission system implemented using the web client method. In this method, the microcontroller plays the role of the central controller. The microcontroller receives data collected from the sensor and is subsequently transmitted to Google Spreadsheet using the Arduino Ethernet Shield through the GET HTTP request method. The data stored in Google Spreadsheet is then made accessible on both the website and the Liquid Crystal Display (LCD) within the automation system tool.

The Liquid Crystal Display (LCD) in this study presents real-time temperature and humidity information that the microcontroller has processed. After processing, this data is sent to the website.

Measurements were conducted seven times at random intervals throughout the day (morning, afternoon, and evening) to assess the delivery speed to the LCD and the website.

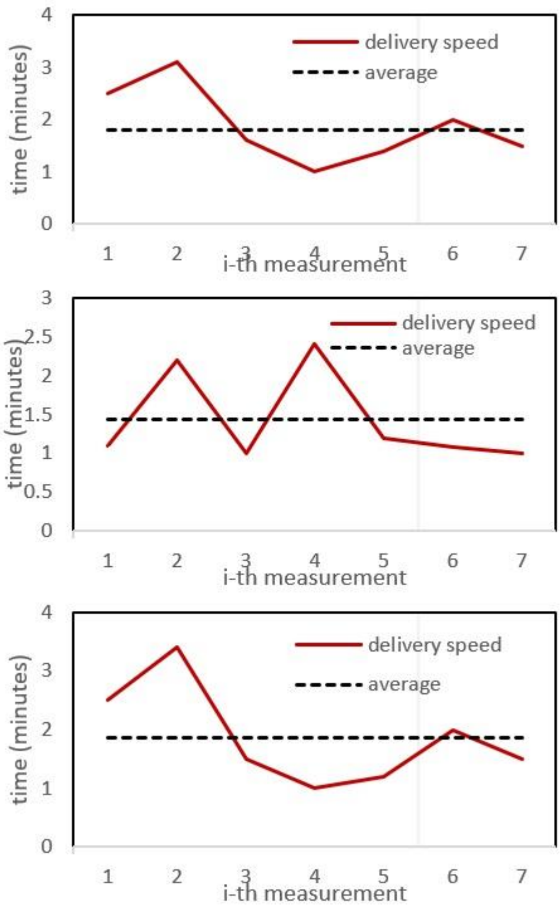


Fig. 9. Delivery speed in the morning (a), afternoon (b), and evening (c)

The testing of delivery speed from the microcontroller to both the LCD and website was conducted seven times at random intervals during morning, afternoon, and evening. The results showed that the average delivery times were 1.32 minutes in the morning, 1.43 minutes in the afternoon, and 1.86 minutes in the evening. Notably, there were differences in delivery speed, with the slowest delivery times occurring in the afternoon. Afternoon delivery speed was slightly slower than during the morning and evening. This variance could be attributed to increased users or heavier network traffic during the afternoon, potentially resulting in network instability.

It's important to acknowledge that delivery speed can be influenced by various factors such as geographical location, weather conditions, the devices used, and the surrounding building structures. An example of this is demonstrated in a study conducted by Pramecwari [15], which examined NetFlow for monitoring internet usage. That research highlighted the average speed of internet users on the Udayana University Campus, where the highest average rate was observed.

4 Conclusion

The Internet of Things (IoT) monitoring system has demonstrated its effectiveness in alignment with the predetermined design criteria. The successful transmission of 567 data entries to the website and remarkable data accuracy of 94% underscores the system's reliability. Additionally, data usage analysis revealed that these transmissions were efficient, consuming 11.34 MB of data and incurring IDR 7,086 in internet quota costs. Moreover, the system's delivery speed, averaging 1.5 minutes, ensures timely and responsive data transfer between the monitoring system and the website. The results of this study affirm the successful implementation of the IoT system, offering valuable insights for future applications and improvements.

References

1. C. Nuraini and A. Mutolib, ‘The sustainability analysis of red chili farming in Taraju District, Tasikmalaya Regency’, in IOP Conference Series: Earth and Environmental Science, Institute of Physics, 2023. doi: 10.1088/1755-1315/1133/1/012060.
2. K. Choudhary, P. Mishra, Dayanand, and V. Patni, ‘INFLUENCE OF ORGANIC FARMING ON VOLATILE COMPOUNDS IN METHANOLIC FRUIT EXTRACTS OF CHILI (CAPSICUMANNUUM L.)’, Journal of Microbiology, Biotechnology and Food Sciences, vol. 12, no. 3, 2022, doi: 10.55251/jmbfs.3545.
3. M. T. Sundari, Darsono, J. Sutrisno, and E. Antriyandarti, ‘Analysis of chili farming in Indonesia’, in IOP Conference Series: Earth and Environmental Science, IOP Publishing Ltd, Nov. 2021. doi: 10.1088/1755-1315/905/1/012046.
4. A. Haryanto et al., ‘Torréfaction to improve biomass pellet made of oil palm empty fruit bunch’, in IOP Conference Series: Earth and Environmental Science, 2021. doi: 10.1088/1755-1315/749/1/012047.
5. P. Pardian, E. Renaldi, A. Bustaman, T. Santoso, and D. Hardiawan, ‘Cabai Rawit (Capsicum frutescens L.) Value Chain: Agricultural Commodities Driving Inflation in Lombok Island’, IOP Conf Ser Earth Environ Sci, vol. 1211, no. 1, p. 012009, Jul. 2023, doi: 10.1088/1755-1315/1211/1/012009.
6. M. Telaumbanua, F. Kusuma Wisnu, A. Haryanto, S. Suharyatun, and A. Wahyudi, ‘Effect of Torrefaction Temperature on Physical Properties of Biopellet from Variant Biomass Waste’, 2022.
7. Handoko, DASAR PENYUSUNAN DAN APLIKASI MODEL SIMULASI KOMPUTER UNTUK PERTANIAN. Jurusan Geofisika dan Meteorologi, 1994.
8. W. Setiawati, N. Sumarni, Y. Koesandriani, A. Hasyim, TS. Uhan, and R. Sutarya, ‘Penerapan Teknologi Pengendalian Hama Terpadu pada Tanaman Cabai Merah untuk Mitigasi Dampak Perubahan Iklim (Implementation of Integrated Pest Management for Mitigation of Climate Change on Chili Peppers)’, 2013.

9. E. Said Mohamed, A. A. Belal, S. Kotb Abd-Elmabod, M. A. El-Shirbeny, A. Gad, and M. B. Zahran, 'Smart farming for improving agricultural management', Egyptian Journal of Remote Sensing and Space Science, vol. 24, no. 3. Elsevier B.V., pp. 971–981, Dec. 01, 2021. doi: 10.1016/j.ejrs.2021.08.007.
10. M. Telaumbanua, S. Triyono, A. Haryanto, and F. K. Wisnu, 'Controlled electrical conductivity (EC) of tofu wastewater as a hydroponic nutrition', Procedia Environmental Science, Engineering and Management, vol. 6, no. 3, 2019.
11. C. P. Yahwe, L. Isnawaty, and F.A, 'Rancang Bangun Prototype System Monitoring Kelembaban Tanah Melalui Sms Berdasarkan Hasil Penyiraman Tanaman', semanTIK, 2016.
12. B. B. Sinha and R. Dhanalakshmi, 'Recent advancements and challenges of Internet of Things in smart agriculture: A survey', Future Generation Computer Systems, vol. 126. Elsevier B.V., pp. 169–184, Jan. 01, 2022. doi: 10.1016/j.future.2021.08.006.
13. M. Telaumbanua, A. Haryanto, F. K. Wisnu, B. Lanya, and W. Wiratama, 'DESIGN OF INSECT TRAP AUTOMATIC CONTROL SYSTEM FOR CACAO PLANTS', Procedia Environmental Science, Engineering and Management, vol. 8, no. 1, 2021.
14.] R. Azhar, F. K. Wisnu, F. S. D. Kesumah, W. R. E. Putri, and R. A. Prasetya, 'State-space Implementation in Forecasting Carbon and Gas Prices in Commodity Markets', International Journal of Energy Economics and Policy, vol. 12, no. 3, pp. 280–286, May 2022, doi: 10.32479/ijeep.12894.
15. K. Tania Prameçwari, N. Putra Sastra, and D. Made Wiharta, 'NetFlow dalam Monitoring Penggunaan Internet', Teknologi Elektro, vol. 16, no. 03, 2017.