Wireless Sensor Network for Monitoring Rice Crop Growth

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Abstract — For observation of rice plants continuously against climatic influences of rice plants in the vegetative stage, reproductive stage, ripening stage by measuring the pH level, temperature, soil moisture using the technology of *Wireless Sensor Network (WSN)*. The purpose of this study to monitor climate effects on the growth of rice plants with the technology *Wireless sensor network (WSN)*. The design and implementation of WSN based on *Zigbee*_platform and Arduino with observation method involve monitoring the change of indicator of each sensor node, distance parameter, delay parameter on each rice growth. Testing the performance of WSN through parameter *RSSI (receive signal strength indicator)* between the end device and the coordinator through software applications *XCTU* do at every stage of rice growth. Test results at a distance of 100 meters obtained the average value of RSSI in the vegetative stage of -80.40 *dBm*, at the reproductive stage of -83.72 *dBm*, and at the ripening stage of -84.44 *dBm*. The WSN implementation, testing using cluster tree topology is done at a different time. The test is performed between the sensor node to the node coordinator in the topology of the cluster tree in different areas. The result of the measurement of data delivery delay is 312*ms* for the area of 1 hectare of rice field at 120 days of age with the node number of 7 units. Furthermore, with the node number 7 units, 376*ms* for the paddy field with 2 hectare area. The results of WSN implementation experiments on 2 hectares of rice farming area can provide real time information so as to contribute in agriculture when there is a change of climatic conditions or sudden pest diseases that affect the results of rice crop productivity and food security.

Keywords—WSN, Zigbee Platform, Arduino, Topologi cluster tree, RSSI.

I. INTRODUCTION

The tropical climate to be one of the main factors to be considered in determining the timing and pattern of planting season[1]. Most rice plants are particularly vulnerable to the effects of climatic and weather conditions such as temperature, humidity, pH and pests of rice plants[2]. Classification of rice plant growth includes seedling stage, vegetation stage, reproduction stage and ripening stage[3]. Changes in climate and irregular weather conditions need to be monitored daily in the field to provide information in real time, thereby reducing the work load of farmers[4],[5]. Previous studies have designed the WSN in one stage of rice growth by using point to point topology[4],[5] and star topology[6] to monitor changes in climatic conditions. So in this study the proposed design and implementation tools WSN technology with the observation method using a cluster topology tree. Implementation is used to monitor three stages of rice plant growth on climatic factors and the influence of pests with climate indicators. Where these indicators include: temperature, pH, soil moisture, so it is useful for farmers in an effort to ensure food security.

II. WIRELESS SENSOR NETWORK

2.1 WSN to monitor rice growth

Wireless sensor networks have been widely used in industry, civil applications, and agricultural environments. A wireless sensor network consists of a small sensor has a transceiver that collaborate to disseminate information between the sensor nodes in an area with power consumption and lower costs. WSN architecture between the sensor network is as follows [7]:

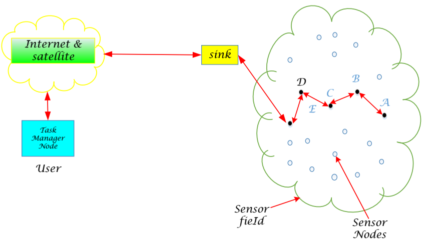

Figure 1. WSN architecture[7]

A sensor mote [8] consists of four main units, namely, data acquisition unit, a memory unit and data processing, communication unit and the power unit. Block components in wireless sensor network are shown in figure 2.

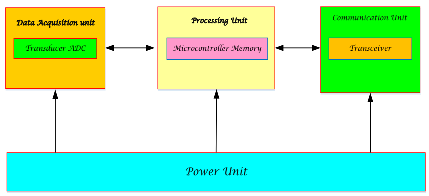

Figure 2. Component block WSN[8]

2.2 Zigbee

ZigBee [9] is based on the IEEE 802.15.4 specification for a suite of high level communication protocols that are used to create a personal area network (PAN) to power a small radio, low power, low bandwidth requirements. Zigbee provides multihop routing and functionality for radio packet based protocols. Figure 3. Comparison of different wireless communication standards.

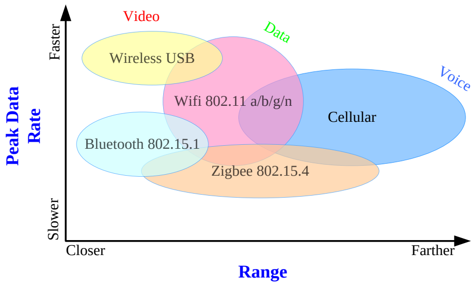

Figure 3. Comparison of wireless communication standards [9]

There are several network topologies used[10],[9] such as star, mesh and clustter tree in figure 4. In Zigbee [10] described some concept of physical devices RFD and FFD. A device can be a full function device (FFD) or reduced function device (RFD). RFD can be used for simple applications where the device does not need to transmit large amounts of data and must communicate only with certain FFD. FFD can work in general as PAN coordinator, router or as a simple device. It can communicate with either another FFD or RFD.

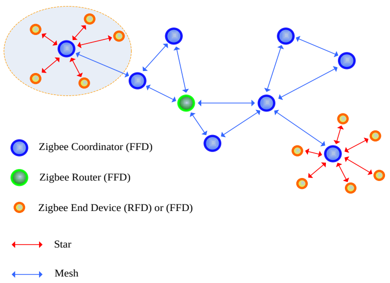

Figure 4. Network Structure IEEE 802.15.4 / ZigBee [10]

2.3 RSSI

In this study, ranging technique *RSSI (receive signal strength indicator)* used to determine the distance between the transmitter and receiver. One of the shadowing models in support of RSSI is in the equation 2.1[11],[12]:

$$\overline{Pr}(d)_{dBm} = [Pr(d_0)]_{(dBm)} - 10\, n \log\left(\frac{d}{d_0}\right) \ldots\ldots\ldots\ldots\ldots(2.1)$$

do is a reference distance of 1 meter. So to know the distance measurement in outdoor environment can be used equation 2.2[11].

$$RSSI(d)_{dBm} = [Pr(d)]_{(dBm)} = A - 10\, n \log d \ldots(2.2)$$

Where *A* is the strong received signal within 1*m* with *dBm* units.

2.3 Rice growth

In this study rice growth includes several stages [13],[14]:

a. Stage vegetative and the feasibility of planting area.

At this stage the condition of the paddy field has not been planted. Where farmers do soil processing first. Parameter values ideal acid at pH between (4.0-7.0) was conducted to determine the feasibility of planting area. In lowland rice plants have temperatures around 23 ° -27 ° C with an altitude of 0-650 mdpl.

b. Reproduction phase

The reproductive phase or often also called the generative phase is the phase in which the rice plants begin to appear panicles.

c. Ripening phase

The ripening phase is the phase in which the rice crop is ready to be harvested.

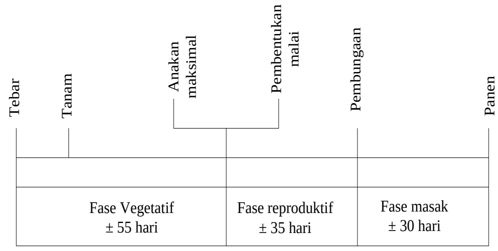

Figure 5. Rice growth phase [13]

III. DESIGN SYSTEM WSN

The design of monitoring system on rice growth in WSN network is done before rice planting season begins until harvest time. The survey was conducted in a land area of rice plants cropping pattern changed. Where the rice crop research sites located at coordinates : S 6.5149°, E 107.7783°. In Figure 6. Is the coordinate point of the study.

Figure 6. Research location

A. *Design System*

To support the performance of WSN to monitor the growth of the rice plant system design. The system model created follows the Zigbee platform protocol[9]. The hardware in the research consists of radio module xbee series 2, Arduino, shield board module, DHT11 sensor, pH sensor, soil moisture sensor and power supply with output voltage ± 5 volts. Each sensor node will send data to the router and the router forwarding to the coordinator. Figure 7 is a model of the proposed design system.

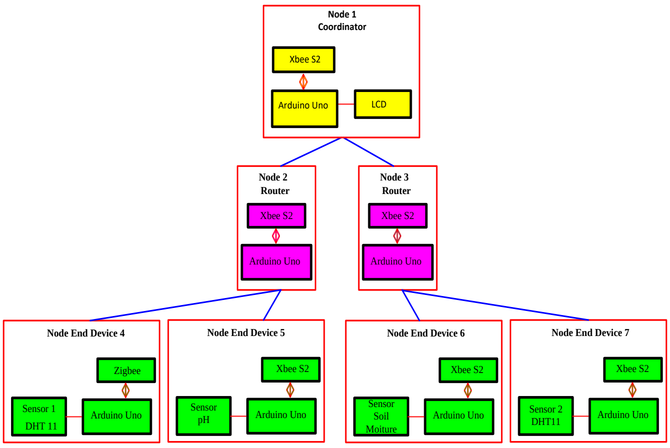

Figure 7. Proposed system model

B. *Topology*

1. Pair topology
   The use of pair topology is done on test 1 to find the distance between nodes[15].
2. Cluster tree topology
   Topology used in this research is cluster tree topology.

This topology is used to determine the time of receipt of data at the coordinator and the extent to which a node can reach the area of paddy fields. In the cluster tree topology used 7 nodes with the following explanation:

a. Node 1 is coordinator
b. Nodes 2 and 3 are routers
c. Nodes 4,5,6 dan 7 are end device

Router nodes is 100 meters from the coordinator. Node end devices is 100 meters from the router. Node 1 is the first device that consists of an Arduino, XBee series 2, shield board, LCD power supply. Nodes 2 and 3 are devices 2 and 3 consisting of xbee series 2 modules and power supply. Node 4 is the device 4 consists of an Arduino, XBee series 2, shield boards, sensor DHT11. Node 5 is a 5 device consisting of Arduino, xbee series 2, shield board, pH sensor. Node 6 is a 6 device consisting of Arduino, xbee series 2, shield board, DHT11 sensor and Node 7 is the device 7 consists of an Arduino, XBee series 2, shield board, soil moisture sensor.

The cluster tree topology is used in the 2nd test because it is sufficient for the wide coverage of 2 hectares of paddy fields.

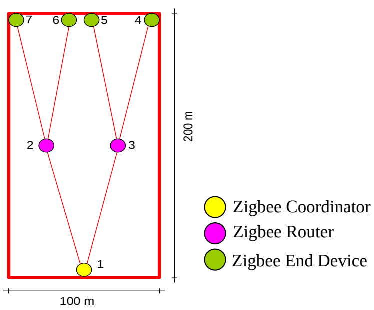

Figure 8. Cluster tree topology

In wireless sensor network research to monitor rice growth using XCTU softaware. The following is explained about the tests performed:

a. Testing 1: To obtain distance parameters Xbee network testing between the coordinator with the end device / router point to point first. The purpose of this test is to know the extent to which each node can communicate with different distances to get the value of *RSSI (receive signal strength indicator)*. Further testing is done[15] using a star topology with pairing and on / off method where the coordinator and router are connected first and then the router is brought to some point until the router can't communicate with the coordinator. After that the router is connected to the end device. Testing is planned in every growth of rice plants.

b. Testing 2: To obtain Delay parameters and monitoring indicators used sensor node cluster topology tree. The purpose of this test is to determine the data transmission time of each sensor node to the recipient at the coordinator node and to monitor several indicators of climate change include pH level, temperature, soil moisture. The distance between Zigbee Coordinator, Zigbee Router, Zigbee End Device about 100 meters. The area of the delay parameter measurement is between 1 hectare and 2 hectares at 120 days of rice plant age with the number of nodes 7 units. While the area of research for monitoring indicators of each sensor node about 2 hectares with the number of nodes 7 units.

IV. TEST RESULT AND ANALYSIS

4.1 Result of design

The design of the node consists of 7 units. In Figure 9. is the result of design coordinator node that serves as the data recipient of each node.

Figure 9. Result and design node coordinator

4.2 Test results of distance parameters

In testing the XBee network obtained RSSI value to determine the received signal strength at different distances. Distance measurements taken between nodes from 5 meters to 100 meters. The sampling time of the RSSI data is every 5 meters with 50 samples of observational data in 20 measurements. So we get 1000 data of RSSI observation to different distance. In Figure 10. Shows the result of testing the distance parameter against RSSI.

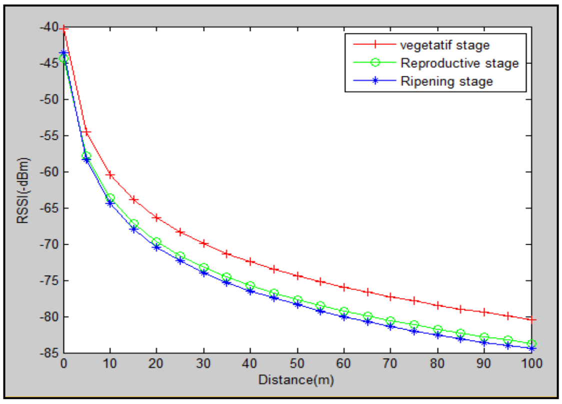

Figure 10. RSSI curve to the distance at vegetative stage, reproductive stage, ripening stage.

The relationship of measuring the distance parameter to RSSI for the monitor of rice plants is to know the maximum range of each node. In figure 10, the RSSI value changes as a result of different rice growth altitudes [13] thus affecting the value of RSSI. The measurements were taken from the average result of RSSI at 100 meters. At the vegetative stage the height of the rice plant averaged ± 60cm, where RSSI is -80.40 dBm, at the reproductive stage the height of the rice plant is approximately ± 90cm, the RSSI value becomes -83.72 dBm, at the ripening stage the height of the rice plant has started meeting and fruiting with a height of about ± 100cm so that the value of RSSI of -84.44 dBm. This proves that the further the distance the node decreases the signal strength received.

4.3 *Test results parameter delay and monitoring indicators of each sensor node.*

The purpose of the delay parameter measurement is to see how far the delay parameters affect the different area. Measurements were made at the time of each sensor node sends the data to the coordinator. To get the delay used the latest delivery time difference with the previous time. During this time the four sensor nodes transmit data simultaneously to the coordinator node and the data received on the coordinator are stored in the tools record in *XCTU software*. The sample data taken in the measurement is every one minute with the span of time for 10 minutes.

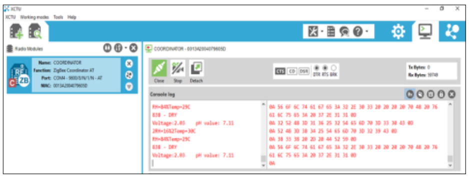

Figure 11. Sensors nodes test results on XCTU software

Table 1. Data stored in the xctu tools record.

```
04-15-2018 14:18:46.458,-,AT,"COORDINATOR,0013A2004079605D,ZigBee Coordinator AT,20A7,COM4 - 9600/8/N/1/N,0"

04-15-2018 14:18:46.735,122,RECV,566F6C746167653A322E3033202020207048207661 6C75653A20372E31310D0A
04-15-2018 14:18:46.983,123,RECV,566F6C746167653A322E303320202020704820766 16C75653A20372E3131
04-15-2018 14:18:46.987,124,RECV,0D0A566F6C746167653A322E30332020202070482076616C75653A20372E31310D0A52483D3539255465 6D703D33
04-15-2018 14:18:46.988,125,RECV,33430D0A566F6C746167653A322E30332020202070482076616C75653A20372E31310D0A
04-15-2018 14:18:46.988,126,RECV,3252483D31302532546 56D703D3336430D0A
04-15-2018 14:18:47.314,127,RECV,383339202D20445259 0D0A
04-15-2018 14:18:47.365,128,RECV,566F6C746167653A322E30332020202070482076616C75653A20372E31
```

In Figure 11. The data stored in the tools record in the xctu software is still in hex form, so to see the sensor node data in the conversion to char. In table 1. During data transmission of each sensor node there is a delay of data reception time on the coordinator. Data transmission by the sensor node, although each sensor node time of data delivery has been set for 1 second. In figure 12, we get the result of delay measurement on different area. Distance of each node between coordinator, router, end device each 100 meters, 120 days of rice age with an area of 1 hectare and 2 hectares with a duration of observation 10 minutes.

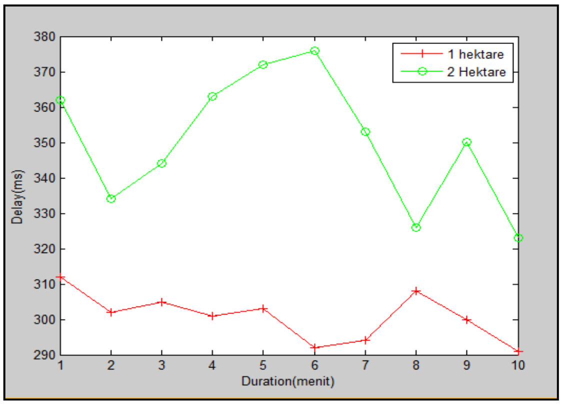

Figure 12. Graph delay with an area of 1 hectare and 2 hectares

The delay relationship to the different area of the area to know the connectivity and the delay of the data transmitted. While the relation of delay on climate monitoring is to get real time field information data. In addition, the information data is also useful to anticipate the sudden onset of pest diseases that affect rice crops. In figure 12. Shows the delay change on a 2 hectare area of 376*ms* and a 1 hectare area of 312*ms*. On the network side the coordinator will continue to communicate with other node sensors even though one of the node sensors is off. But the disadvantage is that when one of the router nodes is dead the sensor data node is not sent. Routing the cluster tree network in this study is different from the static dynamic mesh topology.

Furthermore, testing the indicators of each sensor node with different methods of monitoring at different times. Measurement time is done from morning at 09.00-10.00 AM, noon at 01.00-02.00 PM, afternoon at 04.00-05.00 PM. Sample observation data taken every 5 minutes in 1 hour during 15 days of measurements at three stages of rice growth.

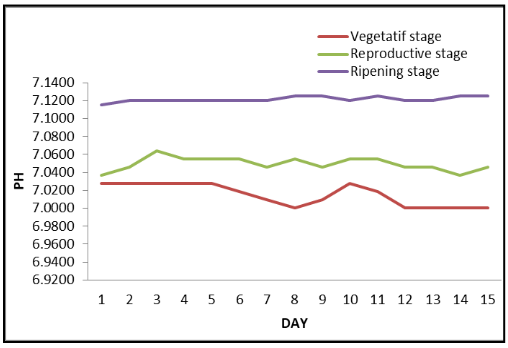

Figure 13. Graph of pH at the vegetative, reproductive, ripening stage

In Figure 13. Shows monitoring results at three stages of rice plant growth. At the vegetative stage and the reproduction stage the pH value is still stable that is between 7.0-7.06. While at the ripening stage pH value becomes up to 7.1.

1. The results of testing the temperature and soil moisture indicators at the vegetative stage

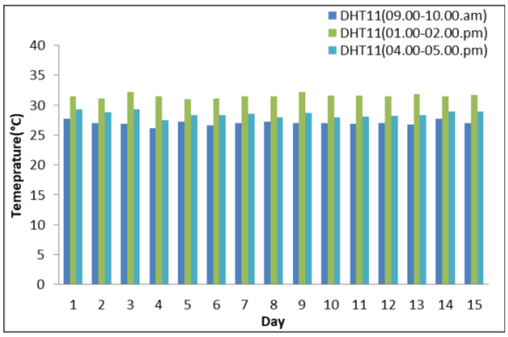

Figure 14. Graph of temperature of the first sensor

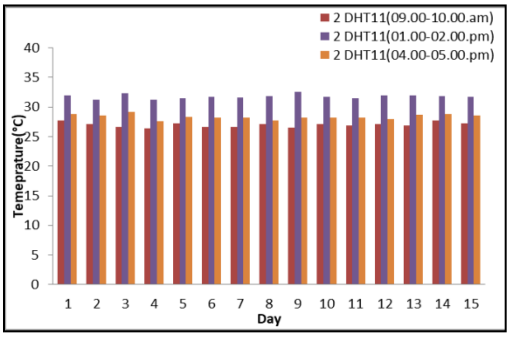

Figure 15. Graph of temperature of the second sensor

Figure 14. Indicates temperature changes at the vegetative stage, where temperatures are below 33°C. Weather conditions are sunny. Figure 15. Indicates temperature changes at the reproductive stage, where the temperature is below 33°C.

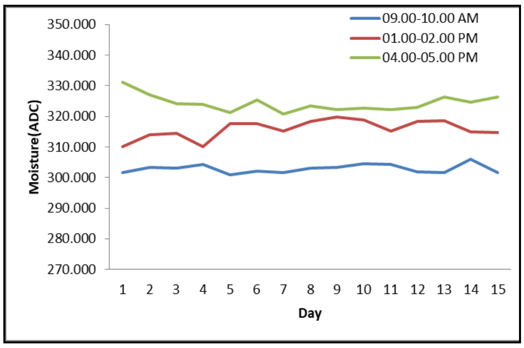

Figure 16. Graph of soil moisture

Since soil moisture sensors are categorized as follows: 0-369 conditions "water", 370-599 "humid" conditions and 600-1000 in "dry". In Figure 16. Indicate the soil moisture changes at the vegetative stage, where the conditions of rice plants are still inundated so that the sensor will read "water".

2. The test results of monitoring indicators of temperature, soil moisture at reproductive stage.

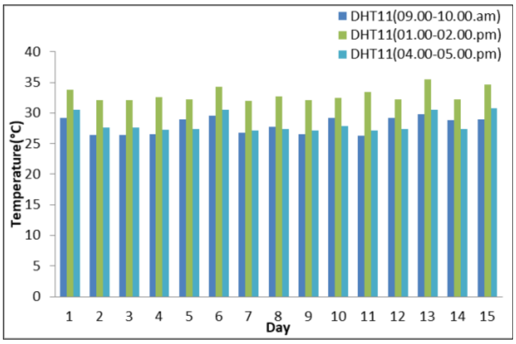

Figure 17. Graph of temperature of the first sensor

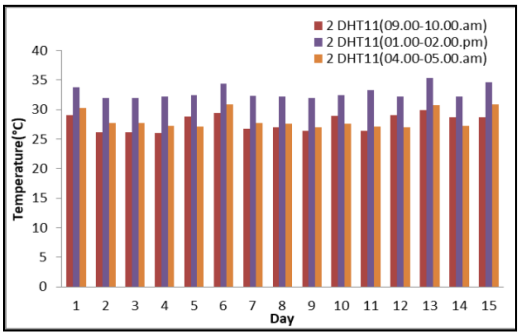

Figure 18. Graph of temperature of the second sensor

Figure 17. Indicates temperature changes at the reproductive stage, where the temperature is still below 34°C. Figure 18. Indicates temperature changes at the reproductive stage, where the temperature is still below 34°C.

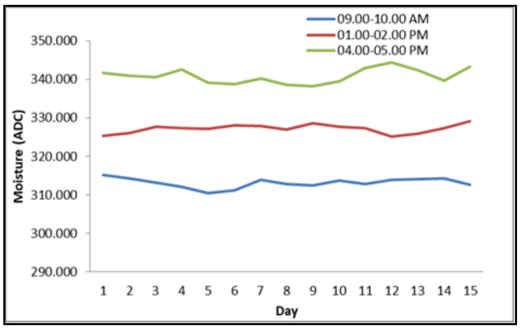

Figure 19. Graph of soil moisture

In Figure 19. Indicates the change in soil moisture at the reproductive stage, where the condition is still wet the sensor indicates "water".

3. The test results of monitoring indicators of temperature, soil moisture at this stage of ripening.

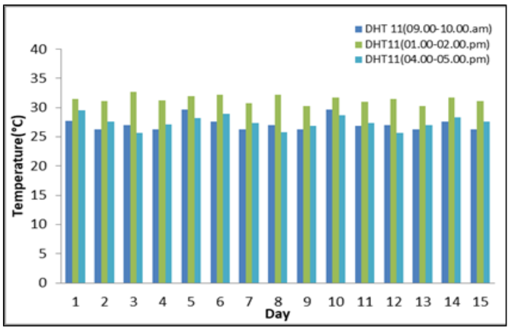

Figure 20. Graph of temperature of the first sensor

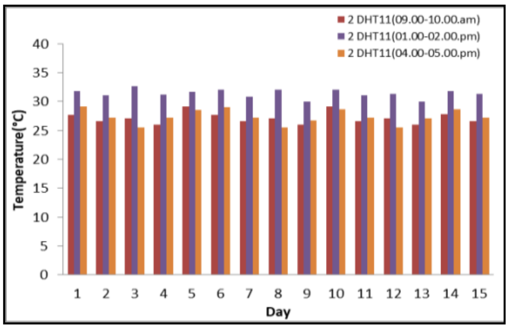

Figure 21. Graph of temperature of the second sensor

Figure 20. Indicates temperature changes at the ripening stage, where the temperature is below 33°C. Figure 21 shows the temperature change at the ripening stage, where the temperature is below 33°C.

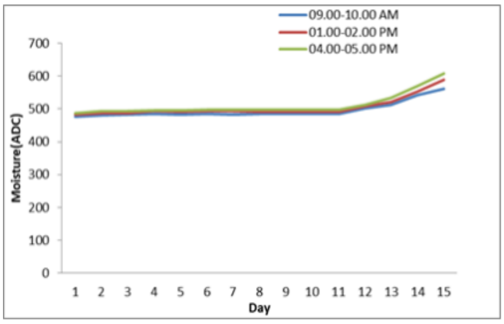

Figure 21. Graph of soil moisture

Figure 20. Indicates the soil moisture change from humid to dry conditions. At this stage the rice plant approaches the harvest time, so the condition of the soil is allowed to dry.

V. Conclusion

From the results of WSN research to monitoring the growth of rice plants based on Zigbee and Arduino using cluster tree topology, the device is able to reach an area of approximately 2 hectares of rice fields. In the network also occurs data transmission delay on a 1 hectare area of 312 *ms*, while on a 2 hectare area of 376 *ms*. The ability of nodes at a distance of 100 meters has a mean value of different RSSI due to the influence of the height of varied rice plants. Wireless sensor network technology with cluster tree topology can help in anticipating the effects of climate change at an unstable planting area, so as to reduce the workload of farmers.

Referensi

[1] A. Fadholi, D. Supriatin, S. Meteorologi, D. Amir, S. Meteorologi, and F. Kaisepo, "Sistem pola tanam di wilayah priangan berdasakan klasifikasi iklim oldeman 1," vol. 12, pp. 56–65, 2012.

[2] H. G. Goh, H. Y. Lee, C. F. Leong, C. S. Kuek, S. Yue, And K. H. Kwong, "Practical Implementation Of Self-Powered Wireless Sensor Networks For Paddy Field Monitoring,"Pp. 2–7.

[3] V. Anbumozhi, E. Yamaji, and T. Tabuchi, "Rice crop growth and yield as influenced by changes in ponding water depth , water regime and fertigation level," vol. 37, 1998. [7] M. A. Miskam, I. A. Rahim, O. Sidek, and M. Q. Omar, "Deployment of Wireless Water-Quality Monitoring System at Titi Serong Paddy Crop Field , Malaysia," pp. 19–20, 2013.

[4] M. A. Miskam, I. A. Rahim, O. Sidek,"Deployment of Wireless Sensor Network at Titi," no. I4ct, pp. 30–35, 2014.

[5] M. A. Miskam, Inzarulfaisham Abd Rahim, O. Sidek, and M. Q. Omar, "Deployment of Wireless Water-Quality Monitoring System at Titi Serong Paddy Crop Field , Malaysia," pp. 19–20, 2013.

[6] Santoshkumar, Udaykumar R.Y, "Development of WSN System for Precision Agriculture", Department of Electrical and Electronics Engineering National Institute of Technology Karnataka, Surathkal,India santoshkumar777@yahoo.com, Department of Electrical and Electronics Engineering National Institute of Technology Karnataka, Surathkal, India udaykumarry@yahoo.com, IEEE Sponsored 2nd International Conference on Innovations in Information Embedded and Communication Systems, ICIIECS 2015

[7] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci,"Wireless sensor networks: a survey, Computer Networks 38 (2002) 393–422

[8] T. Kalaivani, A. Allirani, and P. Priya, "A survey on Zigbee based wireless sensor networks in agriculture," TISC 2011 - Proc. 3rd Int. Conf. Trendz Inf. Sci. Comput., no. i, pp. 85–89, 2011.

[9] Drew Gislasson, "Zigbee Wireless Sensor Networks," pp. 1–427, 2007.

[10] S. Tadakamadla, "Indoor local positioning system for zigbee, based on RSSI," Mid Sweden Univ., p. 60, 2006.

[11] Zhang Jianwu, Zhang Lu, "Research On Distance Measurement Based On RSSI Of Zigbee", College Of Communication Hangzhou Dianzi University Hangzhou,China, ISECS International Colloquium On Computing, Communication, Control, And Management, 978-1-4244-4246-/09/IEEE 2009.

[12] O. G. Adewumi, K. Djouani, and A. M. Kurien, "RSSI based indoor and outdoor distance estimation for localization in WSN," Proc. IEEE Int. Conf. Ind. Technol., pp. 1534–1539, 2013.

[13] Yuli Surya Fajar,"Penelitian Irigasi Hemat Air Pada Budidaya Tanaman Padi Dengan Metode Sri (*System Of Rice Intensification*) Di Daerah Irigasi Ciramajaya, Desa Salebu, Kecamatan Mangunreja, Kabupaten Tasikmalaya, Jawa Barat",Skripsi IPB,2008.

[14] Heni Hariyani,"Evaluasi Status Hara Kalium Pada Tanah Sawah Di Pulau Jawa", Skripsi IPB tahun 2017.

[15] Koko Joni, Risanuri Hidayat, Sujoko Sumaryono, "pengujian protokol ieee 802.15.4 /zigbee di lingkungan *outdoor".*Jurusan Teknik elektro dan Teknologi Informasi Universitas Gadjah Mada Yogyakarta, Seminar Nasional Informatika 2012 (semnasIF 2012) ISSN: 1979-2328 UPN "Veteran" Yogyakarta, 30 Juni 2012.