Design of Bioacoustic Monitoring System Based Microcomputer Integrated with Cloud for Supporting Integrated Pest Management (IPM) In Precision Agricultural Production

Patrick Gani, Business development and marketing
Jaromansen Damanik, Programmes director
Andi Saputra Telaumbanua, Operational director

SUMMARY

Incidents of crop failure due to planthopper pests and rodents in East OKU on hundreds of hectares of rice farms in 2019 resulted in lost proceeds crop paddy farmers were high. The situation that has occurred has become a major problem for agricultural production. One of the efforts to prevent things such as well as efforts to increase food needs in the future is with the application of modern agricultural production systems adopting the concept of precision agriculture to minimize the impact of climate change outside as well as the limitations of land resources. The concept of precision agriculture will optimize management at the field level by considering aspects of plant physiology (suitability of the soil, plants, and water), suitability and protection of the environment (restrictions on the use of chemicals), and economic aspects (efficient use of resources). In addition, external factors that need to be considered in agricultural cultivation are the presence of plant pests.

One threat to increase crop production at this time is a pest attack. Loss of crop yields due to pest attacks can reach up to 100%, in severely damaged conditions. Control efforts carried out against pests are still based on the use of chemical pesticides. The idea to reduce and limit the use of chemical pesticides to control pests to reduce adverse side effects has long been discussed by world experts as well as in Indonesia. One of the ideas offered is the concept of integrated pest management (IPM), namely control with a rational combination system between the use of chemical pesticides and natural control and other means of control to control pest populations.

Integrated Pest Management (IPM) is a conception of thinking about controlling plant pests with a multidisciplinary ecological approach to managing pest and disease populations by utilizing various compatible control tactics in a coordinating management unit. Pest control on a narrow area can be done manually, but in a large area, a technology that can help monitor the pest is needed. This is necessary, so that potential crop production losses can be reduced so that the goal of the 12th SDGs can be achieved.

This IPM concept has become an environmentally sustainable national development program. This is because the eradication of conventional pests turned out to be ineffective and inefficient in controlling target pests and poses great risks to health and the environment. The revolution in the field of plant biotechnology in the 1990s has enabled farmers to choose GMO crops and involve them in IPM programs, but people are still unable to fully receive agricultural products from GMO crops. The technology currently developing for IPM is the use of bioacoustics to detect the types of insects that exist on a farm, pull (trap), and disrupt insect communication.

the BIAMON team believes that the use of pesticides is no longer needed in the future, because it can damage the soil and pollute the water, besides that the use of pesticides is also inefficient. therefore the solution from BIAMON is to use Bioacoustic to repel insects.

Bioacoustic comes from the word’s bio and acoustics, bio means life and Acustica means the study of vibration and sound. Bioacoustics is a mechanical change to gas, liquid, or solid which often causes sound waves. In communicating, humans and animals make sounds that can be understood by each other as information or signals. For example, a signal of an enemy attack so that a group of animals can avoid it. Likewise, when other life processes such as marriage, laying or giving birth, asking for help, stress, and happiness, each type of animal will generate vibrational sounds with a certain frequency and spectrum understood by the group.

Acoustic-based control can be one of the methods in integrated pest control. This method uses sound waves or signals in the form of vibrations for monitoring and studying the behaviour of insects that have existed since the beginning of 1900 [1]. Acoustic signals are effective for pulling (trapping), detecting, and disrupting insect communication. Sound waves with a frequency of 24 kHz, in general, can reduce the potential for bark beetles (*Dendroctonus frontalis*, and D. *brevicomis*) to arrive [2].

Acoustic signals produced by insects can be used as a source of information about their presence and behavior. [3] succeeded in detecting sago beetles (*Rhynchoporus ferrugineus*) which attack palm trees using ultrasonic sensors. [4] describe the detection of the infestation of cowpea beetle larvae (*Callosobruchus maculatus*) also through ultrasonic signals. Ultrasonic signals are produced by C. *maculatus* when consuming substrate and are captured by sensitive transducers at 40 kHz frequency.

One way to accelerate the achievement of SDGs, especially number 12 is to prevent and reduce crop losses due to plant pests through the use of acoustic signals. Problems encountered in observing acoustic signals produced by animals in the context of integrated pest control are supporting equipment factors that can facilitate data acquisition, data management, and species identification based on audio recordings (species identification). Also, of the many existing research results related to integrated pest control, there is still no linking the measurement data to cloud computing and the price is expansive. Therefore, we need a low-cost system that can be used to handle data acquisition and data management for small-medium scale research needs. The purpose of this study is to design microcomputer-based bioacoustics monitoring system that is integrated with the cloud to detect pests on agricultural land and testing the performance of a bioacoustics monitoring system for field observations compared to existing systems (ZOOM device).

The bioacoustic monitoring system (BIAMON) that has been made consists of three main components, namely: a solar panel, a microcomputer unit, and a microphone as a recorder and capture signal input for sound signals from animals and pests. The following are the results of the design tools that have been made, as in Figure 1.

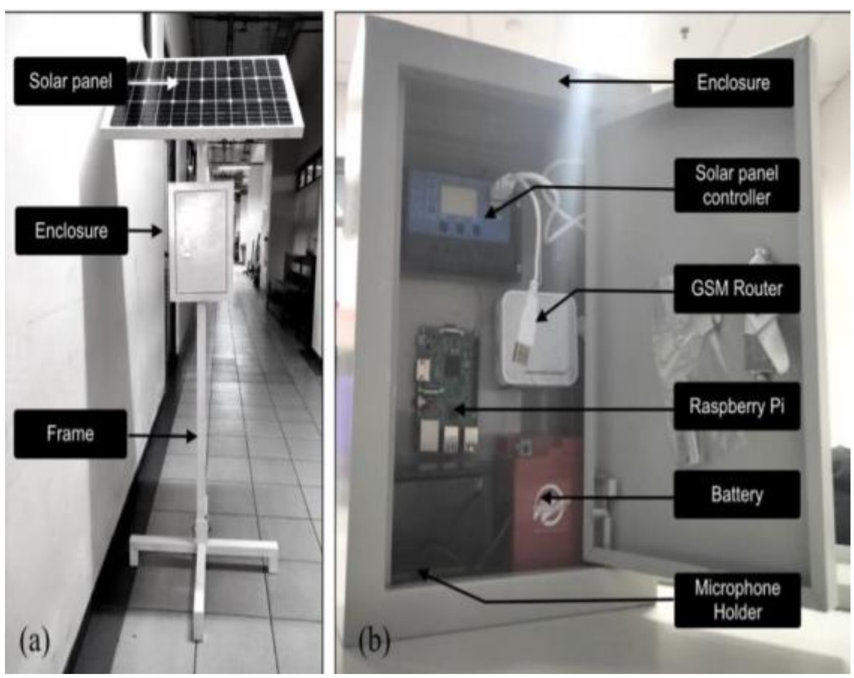


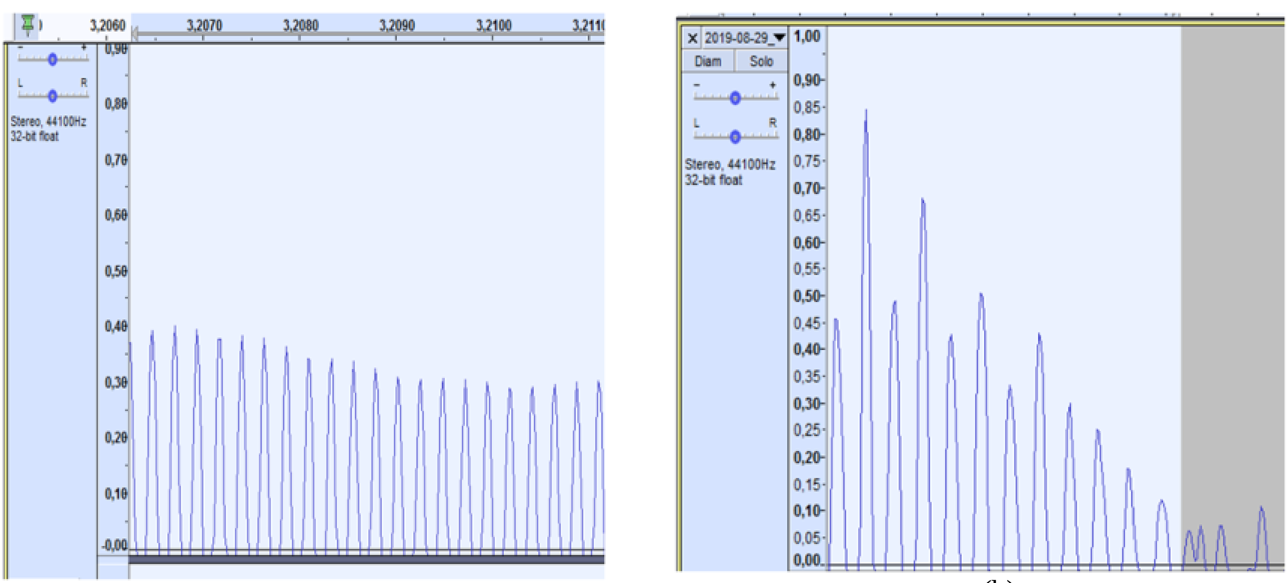
Figure 1. The results of the design of a bioacoustic monitoring system (BIAMON)

In this tool, the power used is sourced from the use of solar energy that is good and environmentally friendly. The solar panels installed on this device function to convert solar energy into electricity which is then flowed into the system. A tool in the form of a microphone mounted on the system functions as the receiver of signal data in the form of sound from the observed object. Microcomputers will send data to the cloud data storage system. The monitoring node cover uses material from a waterproof box so that during rainy weather it can still be used. The components arrangement tries to be optimized by the space and considering the aeration during the system operation. The enclosure is designed as waterproof for preventing the damages of electronics components by the high humidity in the tropical climate. These components are connected with an iron frame so that they can unite between solar panels and boxes. The last stage is to carry out the finishing process to ensure the final shape of BIAMON following the specified design and beautify the appearance with the Aerosol Paint.

In general, the mechanism or way of working of this BIAMON tool is first, the BIAMON device is installed in a field that wants to be reviewed, then the solar energy captured by the solar panel will be converted into electrical energy and flowed into the battery, then the current from the battery will turn on the Raspberry Pi microcomputer device. The next step is the microphone will capture the sound of the object being reviewed either in the form of the sound of insects or animals on a field every 5 minutes according to the programming of the Raspberry Pi microcomputer that we want.

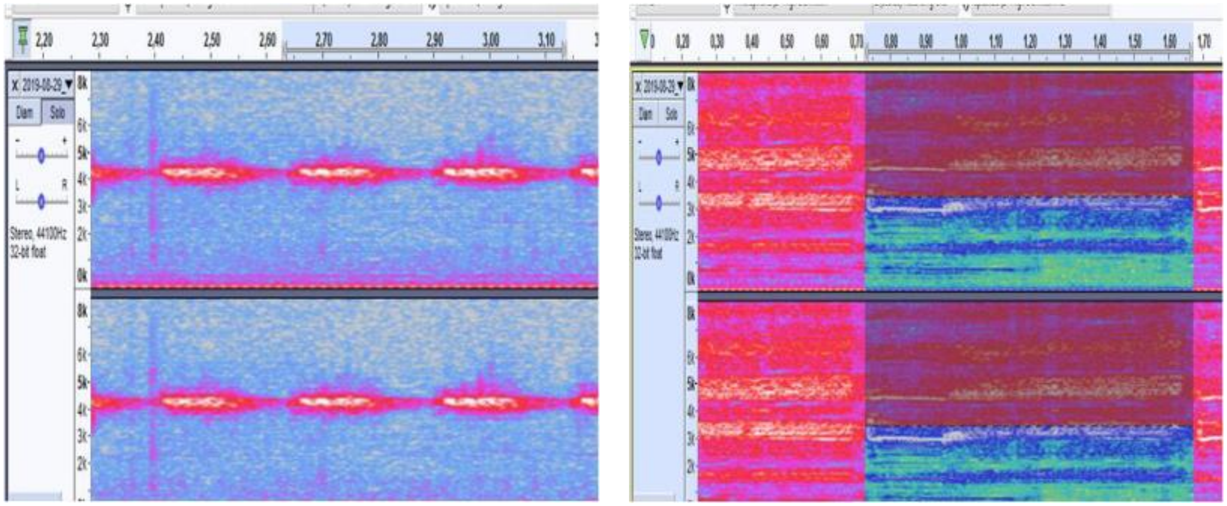
Then the observational data will be transferred to the Cloud Server @UGM data storage via GSM instead of an internet network server with a file name following the timestamp and WAV format. The system could manage the interval capturing by 10 minutes, and the recording duration about one minute resulting in a single WAV file with the size of 10 MB. For further analysis, the recorded file in directory can be downloaded from everywhere, every time, and data stored in the Cloud can be accessed by farmers, admins, users, or other web servers. Data analysed using the Audacity application to identify the frequency, amplitude, and decibels of the sound data generated. The performance test was conducted to ensure that the system can operate properly using power from solar panels and manages to record the surrounding sound at the laboratory scale.

Sound waves of animals and pests that have been recorded by the bioacoustic monitoring system (BIAMON), were analysed by Audacity software. This software functions to analyse the spectrum, frequency, decibels, and amplitude produced by animal sounds recorded by the device. The results of the analysis of the sound amplitude recorded by the instrument are presented in Figure 2. It was found that the deviation of the cricket amplitude was 0.4 and the Katydid was 0.85



(a) (b)

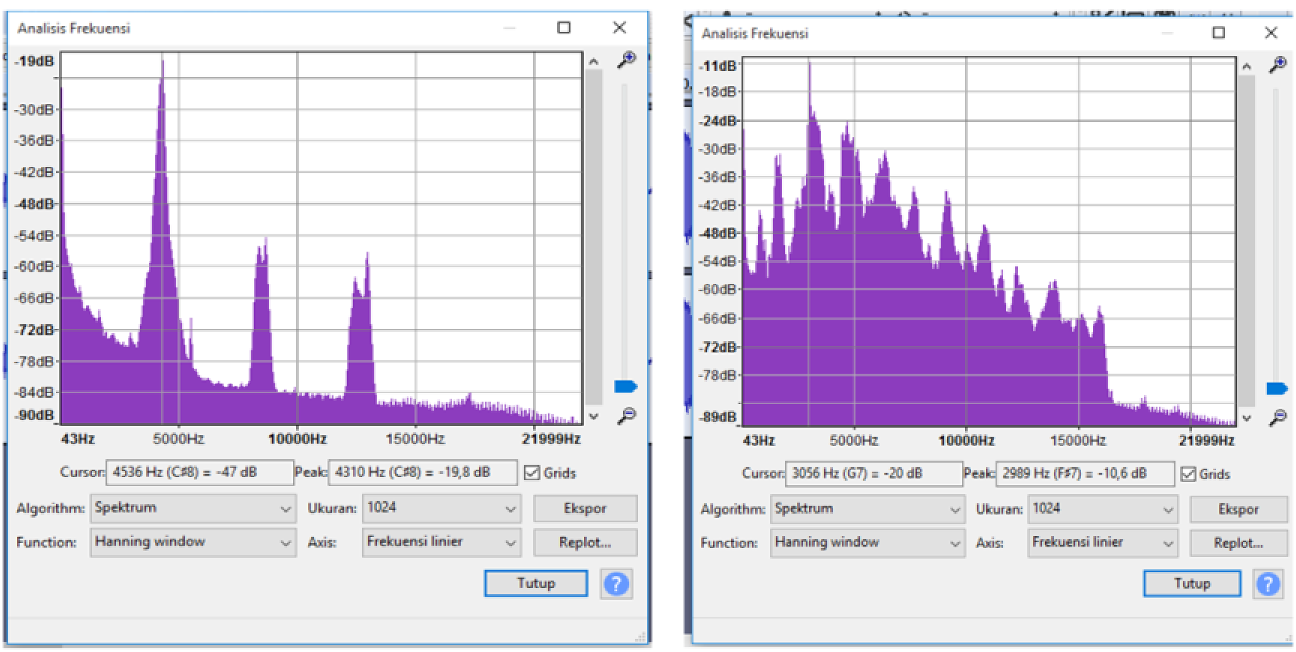
Figure 2. Sound amplitude analysis results released by Cricket (a) and Katydid (b)



(a) (b)

Figure 3. Sound spectrogram analysis results released by Cricket (a) and Katydid (b)

From the spectrum images obtained, the length of time the cricket produces "cricket" sound is 0.511 seconds, while katydid produces "ngik-ngik" sound is 0.947 seconds. Based on Figure 4, it is found that cricket frequencies are higher than katydid. The highest frequency of cricket sounds obtained was 4310 Hz and the sound of katydid was 2989 Hz. This result data then becomes a database for further observations, so that the system can directly analyse that the sound produced is a type of cricket and katydid.



(a) (b)

Figure 4. The results of the analysis of sound frequencies and decibels issued by Cricket (a) and Katydid (b)

The Figure 5 is a comparison chart of the lowest frequency of crickets from the measurement results of BIAMON with existing tools (ZOOM: tools that function the same as BIAMON, but the price is very expensive, not integrated with the cloud, and still using battery). The lowest reference frequency of crickets was obtained from the www.xeno-canto.org database of 3642.3 Hz. The accuracy of the results with the Mean Absolute Percentages of Error (MAPE) method shows that the percentage of errors measured by the lowest frequency of crickets with BIAMON is lower at 14.52% while the ZOOM is 15.80%.

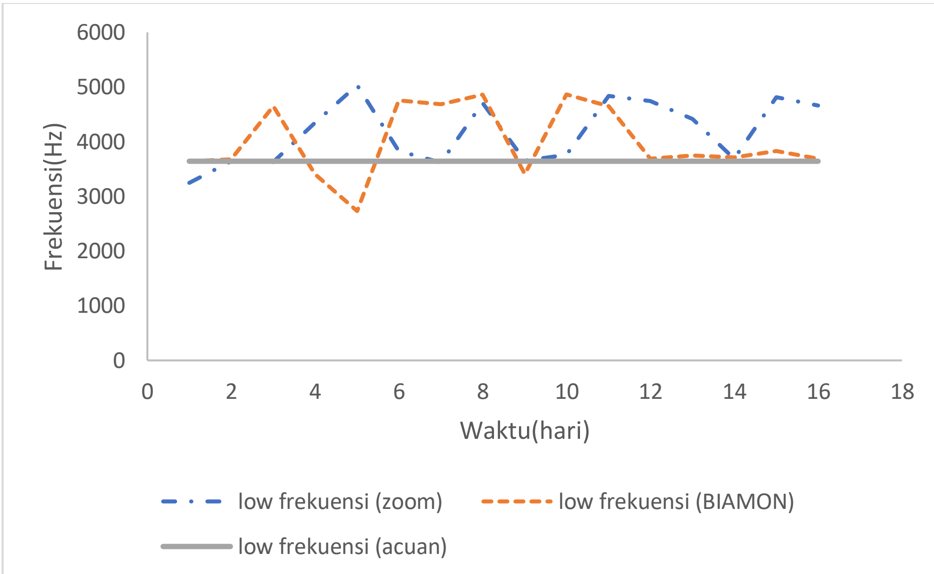


Figure 5. comparison chart of the lowest frequency of crickets from the measurement results of BIAMON with existing tools (ZOOM)

Likewise for the highest frequency measurement results of crickets, the accuracy of the test results with the Mean Absolute Percentages of Error (MAPE) method shows that the percentage of errors resulting from the highest frequency measurements of crickets with BIAMON is lower, namely 11.94% while the ZOOM tool is 12.13% (Figure 6). Thus, this BIAMON tool besides being connected to the cloud, the percentage of measurement error is smaller than similar devices namely ZOOM.

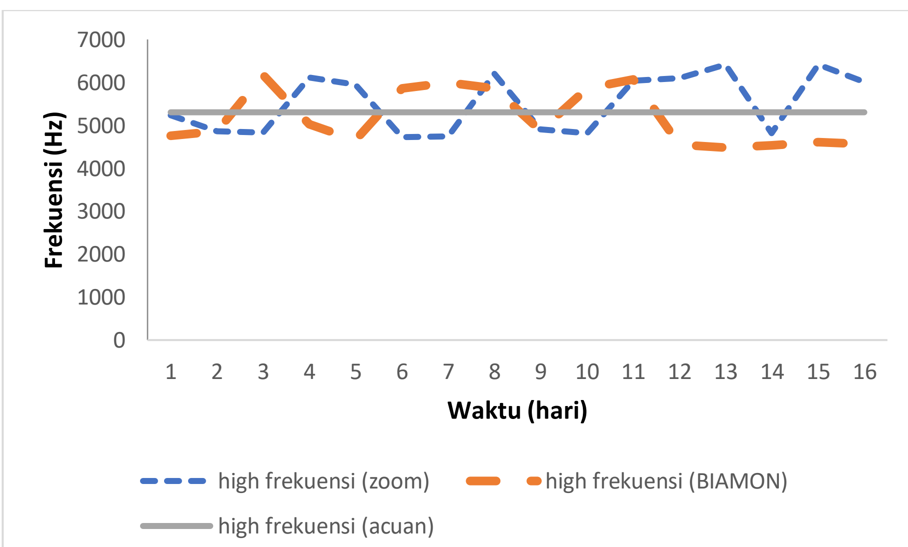


Figure 6. Comparison graph of the highest frequency of sound (*Gryllus assimilis*) from the measurement results of BIAMON and ZOOM instruments with reference frequencies

BIAMON also had won gold medal from 6th Southeast Asia Agricultural Engineering Student Paper Competition, also we will install our first prototype at Selopamioro Village, Bantul, Yogyakarta in early 2021. And will install 10 more by the end of 2021, as the instalment for BIAMON is completely free.

Future innovations will be able to make BIAMON repel pests that match the pests that are monitored and recognized by BIAMON, the method of repelling pests will use a frequency that will disturb the pests so that they will not get closer to farm land.

Acknowledgement

Authors wishing to acknowledge financial support from Ministry of Research, Technology and Higher Education of the Republic of Indonesia. Research Grants of Penelitian dan Pengabdian Inovasi Agroteknologi 2019 from PIAT UGM (No: 2447/UNI.P.III/PIAT/LT/2019. Also, the author would like to thanks Smart Agriculture Research group of Agricultural and Biosystems Engineering UGM for the support.

References

[1] Mankin, R 2011 '*Recent Developments in the use of Acoustic Sensors and Signal Processing Tools to Target Early Infestations of Red Palm Weevil in Agricultural Environments*'. *Florida Entomologist*, vol. 94, no. 4, hh.761-765.

[2] Aflitto & Hofstetter, NR 2014. '*Use of acoustics to deter bark beetles from entering tree materia*l', *Journal of Pest management science*, vol. 70, no. 12, hh.1808 –1814.

[3] Al-Manie, MA & MI Alkanhal 2007, '*Acoustic detection of the red date palm weevil*', *World Academy of Science, Engineering and Technology,* vol. 2, no.1, pp.160–163.

[4] Fatokun, CA, SA Tarawali, BB Singh, PM Kormawa, & M Tamo 2002, 'Challenges and opportunities for enhancing sustainable cowpea production', *Proceedings of the world cowpea conference III*, Nigeria.

[5] Nugroho, AP, Okayasu T, Hoshi T, Inoue E, Hirai Y, Mitsuoka M, & Sutiarso L 2016 'Development of a remote environmental monitoring and control framework for tropical horticulture and verification of its validity under unstable network connection in rural area', *Computers and Electronics in Agriculture*, vol. 12, no. 4, pp. 325-339.