The workload of rice harvester in Java Indonesia

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Abstract. This study aims to determine the workload of rice harvesters in different harvesting technologies and find ways to reduce the physical workload. The physical workload is shown by the magnitude of a worker's heart rate at work. The linear regression model is used to identify the independent variables that affect the workload dependent-variable. Heart rate and body temperature as the dependent variable are thought to be influenced by independent variables such as age, Body Mass Index, ambient temperature and humidity, and noise. Statistically the workload of workers in the manual harvest method is at the medium level, while the semi-mechanical and mechanical methods are at a low workload level. Factor that play a role in the physical workload of all harvesters is environmental temperature. To reduce the physical workload of manual workers by combining four alternative solutions, wearing red or blue clothes, using harvest tents, drink a lot, and using ergonomic tools.

1.Introduction.
Rice field area is a work area that contains a lot of work risks for farmers such as occupational health and safety issues. A number of conditions contribute to an increase in workload during the harvesting process. Standing long enough, unnatural posture, repetitive work, carrying heavy loads, and unsupportive environmental factors will cause health problems such as cardiovascular diseases if it lasts long enough [1]. Sloping paddy fields, muddy, far from access roads further increase the problem for harvesters. Harvesters always work all the time every day during the harvest period. This is related to poor health.

Many technological developments help humans to facilitate their work. The process of tillage using a hoe causes farmers to work hard until their working pulse reaches 161-176 beats / minute [2]. The use of tractors for tillage reduces the worker's heart rate to around 89-132 beats / minute [3]. This illustrates that changes in mechanization technology make the workload of farmers decrease from very high level of load, level 4-6 to high level, level 2-5 [4].

Workload is a number of efforts that must be spent by workers to do work that must be done in a certain period of time, can be done simultaneously or sequentially. Physiological workload relates to heart rate and energy requirements for work [5]. The harvesting process consists of 2 main activities namely cutting rice stalks and threshing rice grains [6]. Cutting rice stalks is done using a sickle, threshing rice grains can be done with traditional technology (manual), semi-mechanical and
mechanical. In the Special Province of Yogyakarta and parts of Central Java the harvest process on narrow land is done manually. Rice stems cut 25 cm from the base of the stem. The tip of the stem is slammed on the surface of a teak plank in the shape of a triangular prism. This manual threshing method is known as gepyok.

In semi-mechanical harvesting, threshing uses a hand thresher. The base of the rice stem is held by two workers' hands, the other end is directed at the rotating cylinder. The cylinder has nails on its surface to knock down grains of rice from rice stalks. Threshing can also be done with a power thresher machine. Rice grains will separate from the trunk when it exits the power thresher machine.

The introduction of technology and machinery can (i) minimize production costs, (ii) accelerate the completion of work, (iii) reduce yield losses and post-harvest [7]. At the level of mechanical technology, rice stalks are cut, threshed and cleaned in a combine harvester machine. For harvesters, accelerating the completion of work means reducing ergonomic risk. Ergonomic risks such as holding the material continuously, the body must bend, and be exposed to sunlight. Improvements to reduce physical workload can be done in work methods, work tools, work scheduling, and so on [8].

Preliminary research results in Sleman DIY in August 2018, harvesters need 252 hours to manually harvest 1 hectare of rice. Mini combine harvester needs 8.3 hours / ha. The standard KUBOTA D60 combine harvester machine at the Klaten location in Central Java takes 4 hours / ha. The research by [9], showed that the combine harvester machine had a harvest capacity of 5.05 hours / ha. The differences can be caused by many things, such as differences in land characteristics, operator capabilities, type of engine and so on.

2. Materials and Methods
2.1. Participants.
Participants are harvesting farmers who are observed by their workload. Participants are determined randomly. Participants are willing to be observed for 3 days at harvest. The study was conducted in Bantul and Sleman districts of Yogyakarta and Sukoharjo, Klaten, Central Java, in January - July 2019. The number of harvesting participants with manual harvest technology was 16 people, 20 participants were semi-mechanical and mechanized using mini combine harvester Q140R, HT12 and JAP001 were 10 participants.

2.2. Data analysis.
Harvester's physical workload in terms of the heart rate of the harvester's work. Data analysis using a multiple linear regression model was performed if the independent variables met all the classic assumption tests. The independent variable \((X_i)\) is age, body mass index, body temperature, ambient temperature and humidity, noise. Regression equation used:

\[
Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4
\]

Explanation :

- \(Y\) : dependent variable
- \(X_i\) : Independent variable \((i = 1, 2, 3, \ldots, k)\)
- \(a\) : intercept
- \(b\) : regression coefficient

Harvesting workloads with medium or higher heart rate should be sought to reduce the burden by modifying the independent variables that influence the percentage. Interventions for reducing workload are prepared in the form of recommendations that must be followed up with field research.
3. Result and Discussion

3.1. Harvester workload

Evaluation of the physiological workload by workers can be done by measuring the heart rate. This is done considering that the heavier the physical work of the worker the heavier the work of the heart which is indicated by the increasing heart rate. This heart rate is very easily influenced by mental load or ambient temperature. Heart rate remains the best choice because factors are easily measured and integrate all aspects of stress experienced by workers [10].

The results of observations of research variables for workers with manual, semi-mechanical and mechanical harvesting technology are listed in Table 1. Cardiovascular load (CVL) for manual and semi-mechanical harvesters has been investigated [11].

Table 1. Observation Result.

| Variable                  | Harvesting method | Manual | Semi-mechanical | Mechanical |
|---------------------------|-------------------|--------|-----------------|------------|
| Age                       |                   | 46.31 a| 55.65 b         | 45.00 a    |
| BMI                       |                   | 22.17 a| 23.30 b         | 21.89 a    |
| Heart Rate                |                   | 115.46 a| 96.43 b         | 95.10 b    |
| Body temperature          |                   | 36.13 a| 36.19 a         | 35.75 a    |
| Env. temperature          |                   | 32.14 a| 31.14 a         | 31.86 a    |
| Env. humidity             |                   | 73.78 a| 66.20 b         | 69.68 b    |
| Mental workload           |                   |       |                 | 68.39      |
| Noise                     |                   |       |                 | 98.56      |

Note: for each variable, the same letter after the number statistically shows that these two harvesting methods are not significantly different.

Variable heart rate manual harvesters differ from semi-mechanical and mechanical. Semi-mechanical and mechanical heart rates are not significantly different. Body temperature and ambient temperature did not differ for the three harvesting systems. Whereas the highest humidity for manual harvesting. The workload of the combine machine operator

Table 2. The Physical Workload of Harvester

| Harvesting technology | Variable          | Variable Independent | Multiple Linear Regression Equation | r   | Adj R² |
|-----------------------|-------------------|----------------------|-------------------------------------|-----|-------|
| Manual a              | CVL               | X₁ age, X₂ smoking habits, X₃ heart rate, X₄ env temperature | Y = 112.268 + 0.296 X₁ + 1.962 X₂ + 0.375 X₃ – 3.741 X₄ | 0.991 | 0.945 |
| Manual                | Body temperature  | age, heart rate, env. temperature, experience | Y = -47.816 + 0.031 X₁ + 0.021 X₂ + 2.057 X₃ - 0.016 X₄ | 0.945 | 0.853 |
| Semi mechanical a     | CVL               | X₁ age, X₂ smoking habits, X₃ heart rate, X₄ env temperature | Y = 177.175 + 0.472 X₁ - 6.554 X₂ + 1.237 X₃ - 1.025 X₄ | 0.977 | 0.911 |
| Mechanical            | CVL               | X₁ heart rate, X₂ env temperature | Y = -19.466 + 1.131 X₁ – 2.111 X₂ | 0.769 | 0.592 |
| Mechanical            | Heart rate        | BMI, body temperature, mental workload, noise, env. temperature | Y = 472.628 – 2.169 X₁ – 5.069 X₂ – 0.386 X₃ + 1.627 X₄ + 1.191 X₅ | 0.942 | 0.748 |

Source: a [11]
Table 2 shows the results of the linear regression analysis for manual, semi-mechanical and mechanical harvesting physical workloads. The independent variable for each test is a variable that passes the classic assumption test.

From the 5 linear regression models formed, one mechanical harvesting model has a strong correlation between the dependent variable CVL and the independent variable heart rate and ambient temperature. The other model has a very strong correlation with $r > 0.9$. Harvesting by manual method has a medium workload with a heart rate of 100-125 beats/minutes. Semi-mechanical and mechanical methods have relatively lower heart rates.

The high body temperature is caused by the activity that makes the heart work pumping blood. The activity causes the heart to respond (cardiovascular response) which makes blood vessels in the skin widen, increased blood flow, increased heat in internal organs and skin, increased heart rate which causes an increase in blood output from the heart [11]. Three reasons that cause the body can not cope with hot temperatures namely when (i) workers work in hot environments with high humidity, the body cannot reduce heat through sweating, (ii) insulation effects: the effects of clothing that inhibits evaporation, (iii) environmental conditions too so dehydrated [12].

Extreme environmental temperature and high humidity conditions cause the harvester’s body to increase in temperature. The limit of heat exposure received by workers is called the threshold limit values (TLV) [13]. Examples of usage as in Table 3.

| Arrangement of work-rest | Light Workload in °C | Medium Workload in °C | Heavy Workload in °C |
|--------------------------|----------------------|-----------------------|---------------------|
| Work continue            | 30.0 °C              | 26.7 °C               | 25.0 °C             |
| 75% work, 25% rest every hour | 30.6 °C              | 28.0 °C               | 25.9 °C             |
| 50% work, 50% rest every hour | 31.4 °C              | 29.4 °C               | 27.9 °C             |
| 25% work, 75% rest every hour | 32.2 °C              | 31.1 °C               | 30.0 °C             |

Rice harvesters work continuously without a specific rest period. Harvesters in manual systems with medium workloads have a heat exposure limit (TLV) of 26.7°C. This heat exposure limit is far lower than the actual solar heat exposure received by harvesters more than 8 hours a day at 31-32°C. Semi-mechanical and mechanical harvesters that have low workloads, TLV values are in the range of 30°C. The air temperature around the paddy fields is still 1-2°C higher than the TLV value.

For workers who work continuously for 1 hour, with a light workload, the heat exposure limit is 30°C. If there are interludes rest every hour, then exposure to heat can be higher. As a factor that affects the physical workload on all harvesting methods, the environmental temperature factor is an important thing to handle. The combination of work climate (temperature, humidity, air velocity and radiant heat) with the body’s metabolic heat can cause heat stress. Workers will sweat to cool the body. This causes excessive fluid loss called dehydration [13]. Harvesters must be able to be protected from extreme weather conditions. In harvesting using a combining machine, there is a noise factor that affects the workload of the operator. Another factor that cannot be included as a factor influencing operator workload is because it has not been properly measured, namely machine vibration.

### 3.2. Ergonomic Intervention
The independent variables that are important in each harvest technology are different. Environmental temperature is an environmental factor that contributes to workloads at all levels of harvest technology. To reduce the workload of manual harvesters, various methods are used. The first alternative is to wear red or blue cloth. The red and blue colors are shown to absorb very little ultraviolet radiation [14]. Second, use a harvest tent. Currently to reduce exposure to sunlight harvesters use simple tents made of tarpaulin and bamboo tied with rope. Third, harvesters consume a considerable amount of drinking water 1,800-2,400 cc to work for 4 hours to avoid dehydration [15].
Fourth use ergonomics gepyok [16]. Four alternative combination applications can optimize the workload of harvesters manually.

4. Conclusion
Each level of harvesting technology has a different workload, with the heaviest workload is manual harvesting using gepyok. The most contributing factor to the workload at all levels of harvesting technology is the ambient temperature. Efforts to reduce the workload of manual harvesters, by combining four alternative solutions, wearing red or blue clothes, using harvest tents, consuming a lot of drink, and using ergonomic gepyok tools.

Acknowledgements
We would like to Acknowledgments the financial support from UGM Research Grant RTA 2019, Rekognisi Tugas Akhir No. 2129/UNI/DITLIT/DIT-LIT/LT/2019.

5. References
[1] Karasek and Theorell,1990 dalam Niu, S., 2010, Ergonomics and Occupational Safety and Health : an ILO Perspective, Applied Ergonomics 41 pp 744-753.
[2] Nag, P.K., and C.K. Pradhan, 1992, Ergonomics in the Hoeing Operation, *International Journal of Industrial Ergonomics* 10 (1992) pp 341-350.
[3] Sutami, E., B Purwantana, and GT Mulyati, 2018. Analisis Beban Kerja Operator Traktor Roda Dua pada Pengolahan Tanah di Lahan Sawah, Skripsi FTP UGM Yogyakarta
[4] Kroemer, K., H. Kroemer, K. Kroemer-Elbert, 2004, Ergonomics: How to Design for Ease and Efficiency (New Jersey: Prentice Hall)
[5] Guastello, 2014, *Human Factors Engineering and Ergonomics* (New York: CRC Press)
[6] Sucipta, I.N., 2009, *Agro Ergonomi Dasar-dasar Ergonomi di Bidang Pertanian*, (Denpasar: Udayana University Press)
[7] Sulaiman, A.A., 2018, *Indonesia Menuju Lumbung Pangan Dunia 2045*, Kuliah Tamu Mentri Pertanian Republik Indonesia (Yogyakarta: Fakutas Pertanian Universitas Gadjah Mada 12 Maret 2018)
[8] Mulyati, G.T., M Maksum, B Purwantana, and M Ainuri, 2019, Ergonomic Risk Identification for Rice Harvesting Worker, *Proc. The 3rd Int. Symp. on Agriculture and Biosystem Engineering*, Makassar, Indonesia.
[9] Nugraha, S., 2012, *Inovasi Teknologi Pascapanen untuk Mengurangi Susut Hasil dan Mempertahankan Mutu Gabah/Beras di Tingkat Petani*, Buletin Teknologi Pascapanen Pertanian Vol 8 (1).
[10] Iridiastadi and Yassierli, 2014, *Ergonomi Suatu Pengantar* (Bandung: PT Remaja Posdakarya.)
[11] Sanders, M.S. and E J McCormick (1993), *Human Factors in Engineering and Design* (7td ed) (New York, England: McGraw-Hill)
[12] Oborne, D.J., (1995). *Ergonomic at Work, Third Edition* (England: John Wiley and Sons)
[13] Suma’mur, P.K, 2009, *Higiene Perusahaan dan Keselamatan Kerja*, (Jakarta: CV Haji Mas Agung. Jakarta.
[14] Anonim, 2009, *Menghindari Panas Matahari ? Pakai Saja Baju Biru dan Merah*, https://detik.com/health.
[15] Huda, A.I. and T Suwandi, 2018, Relations Between Workload and Consumption of Drinking Water With Dehydration In Workers Of Tofu Factory, *https://e-journal.unair.ac.id*, ©2018 IJOSH. Open access under CC BY NC-SA license doi: 10.20473/ijosh.v7i3.2018.310–320
[16] Sa’diyah, N., M Maksum and GT Mulyati, 2019, Reducing MSDs and Physical Workload of Manual-Harvesting Peasant, *Proc. of the 5th Int. Conf. on Science and Technology (ICST 2019)*, Yogyakarta.