Ergonomics study on pivot-type trailer operation for two-wheeled tractor on sloping land

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Abstract. The operation of the pivot type trailer on a two-wheeled tractor on flat land shows that it is more ergonomic than conventional trailers, but for testing on sloping land it has never been tested. Therefore, this study aims to analyze ergonomics, especially the operator's workload on the operation of a pivot-type trailer on a two-wheeled tractor on a sloping land. The calculation of the operator's workload is based on heart rate measurements, where three operators have their heart rate data taken during the activity of operating a two-wheeled tractor in pulling a trailer. The workloads analyzed are qualitative and quantitative workloads. The results showed that the operation of conventional trailers for land slopes of 0°, 10°, and 30° respectively showed IRHR values of 1.23, 1.24, and 1.31 or the level of work "light", "light", and "light". While using a pivot type trailer, the IRHR values are 1.20, 1.27, and 1.55 or the work levels are “light”, “light”, and “medium”. The average energy consumption rate of operating a conventional trailer is 2.54 kcal/hour.kg-bb (kilocalories per hour per operator's weight), while using a pivot type trailer 2.60 kcal/hour.kg-bb. The high level of operator workload is largely determined by the skill of the operator in operating the trailer, which requires training in its operation. This causes the operator's workload to operate on pivot type trailers higher than conventional trailers. However, from the aspect of operator comfort and safety, pivot-type trailers are superior, especially when turning.

1. Introduction
Agriculture for the Indonesian people is the most important sector, but agriculture is part of culture as well as the lifeblood of some people. Therefore, it is not an exaggeration to say that the progress of this nation's progress is highly dependent on success in developing and maintaining this sector properly. Agriculture in Indonesia today is inseparable from technology and mechanization. The application of mechanization in agriculture will certainly be very beneficial, namely it can increase productivity, quality, and shorten working time.

Palm oil is a raw material used for intermediate and downstream industrial groups [1]. The area of oil palm plantations in Indonesia reaches 14.32 million ha. The details are large plantations of 8.51 million hectares with oil palm production of 26.57 million tons. This shows that from year to year there has been an increase in terms of the area of oil palm plantations, with the increase in the area of oil palm plantations, it is certain that every activity inside and outside the oil palm plantation area also
increases. A two-wheel tractor is a tractor powered by a diesel (or gasoline) motor supported by two wheels (usually there is an additional 1 small wheel on the back). These tractors are generally used for working in paddy fields, or on moist or wet and not too dry land by small-scale family farms with narrow plots of land [2].

In addition, this two-wheeled tractor can also be used as a means of transporting agricultural products on agricultural land if a transport trailer is used. Previously the means of transportation used on agricultural land was a wheelbarrow using human power, this tool certainly has limitations and is very difficult to use, especially with difficult trajectories and unequal land slopes.

Based on Nugraha [3], on flat land (0% land slope) the forward speed of the rickshaw is 5.38 km/hour and on uphill land (4.34% land slope) the forward speed of the non-motorized rickshaw is 4.63 km/hour, this of course will take time. which will also produce a large workload and consume a lot of energy, it is found that the average energy consumption required by rickshaw operators is 4080 kcal/day during working hours. This value is close to the upper limit of energy allowed for heavy work which is ± 4800 kcal/day [4]. This will certainly reduce work effectiveness and increase operator fatigue at work.

The use of two-wheeled tractors in transporting agricultural products, namely by using a trailer, is still very minimal, because there are difficulties in its operation. Two-wheel tractors do not yet have the right design for a trailer so they are still considered less ergonomic. According to Nafchi et al. [5], regarding the operation of a two-wheel tractor towed with a trailer, it was stated that the design of the two-wheel tractor steering handlebar on the tractor body has a weakness when it is used to tow a trailer. When the tractor is running on an uneven surface, the steering handlebar will also move up and down from the operator's control position following the movement of the tractor body. In addition, when the tractor turns, the handlebar of the tractor moves away from the operator's control position because the handlebar has turned following the tractor body while the trailer has not turned.

These problems will certainly affect the operator's workload so that it has an impact on the operator's work productivity. Therefore, it is necessary to design a trailer that can be controlled easily without placing excessive workload on the operator. Dhafir et al. [6] have designed a pivot-type trailer to overcome the problems of conventional trailers on two-wheel tractors. In ergonomic and technical testing, the pivot type trailer shows better than conventional trailers on sloping land, but the operator's workload measurement has never been carried out on the sloping land. Therefore, in this study, we will compare the operator's workload between pivot type trailers and conventional trailers on sloping land.

At first glance, the workload of using a conventional trailer with a pivot trailer may be the same as the workload, however, every implement that is replaced and every modification made will result in a different workload [7]. The purpose of this study was to analyze and compare the operator's workload on the operation of conventional trailers with pivot type trailers using two-wheel tractors on oil palm land, especially on sloping land.

2. Materials and methods

2.1. Time and place

This research was conducted in October 2020 in an oil palm plantation in Gampong Jalin, Jantho City, Aceh Besar District, Aceh Province. Meanwhile, data processing is carried out at the Laboratory of Agricultural Equipment and Machinery, Agricultural Engineering Study Program, Syiah Kuala University, Banda Aceh.
2.2. Tools and materials
The tools used in this research are two-wheel tractor Yanmar brand model TF 85-MLY with a power of 8.5 DK/2200 rpm, dimensions of length 2640 mm, width 765 mm, height 1060 mm, weight 251 kg and tractor wheel tread distance of 840 mm. The trailer used is an assembled conventional trailer with a length of 1200 mm, a width of 900 mm, a height of 300 mm, a trailer wheelbase of 1080 mm and a wheel size of 175/70 R13 as well as a pivot trailer with a length of 1200 mm, a width of 900 mm, a height of 350 mm, trailer wheelbase 1080 mm and tire wheel size 175/70 R13. The measurement tools used are Heart Rate Monitor (HRM), stopwatch, digital metronome, handycam, meter, scale, waterpass, 18 MP digital camera. The materials used are diesel oil, palm FFB, batteries and stationery.

2.3. Test procedure
This research implementation method uses quantitative descriptive analysis method which describes, explains, or summarizes various conditions, situations, or various research variables according to events as they are which can be photographed, interviewed, observed, and which can be disclosed through documentary materials.

In this study, preparations were made in advance in the form of field observations to determine a representative research place or location, adjust the appropriate data collection location according to the research objectives, determine the subject, and treatment, as well as the slope of the land and the length of the track to be used, including: (1) trajectory: flat land, land slope 10°, land slope 30°; (2) operation: straight, turn 45° and turn 90°; (3) trailer load: full load of palm fresh fruit bunches (FFB). Then take initial data including anthropometric data collection, steptest calibration, and recording heart rate data on tractor operating activities with trailers.

The subjects used in this study were two-wheeled tractor operators consisting of 3 (three) adult males. The selected operator sample is close to the anthropometric secondary data of the Indonesian people.

2.3.1. Basal Metabolic Energy (BME) Measurement. One of the commonly used methods to determine the BME value is to calculate body dimensions (body surface area), which can then be converted into oxygen volume (VO2). In the metabolic oxidation equation, it is known that each liter of oxygen (O2) consumption through respiration is equivalent to the generation of 5 kcal of energy. The body surface area can be calculated using the Du'Bois equation [7].

\[
A = H^{0.725} \times W^{0.425} \times 0.007246 \quad (1)
\]

Where :

- \(A\) = Body surface area (m2)
- \(H\) = body height (cm)
- \(W\) = body weight (kg)

Based on the calculation of body area using this equation, BME (equivalent to VO2) can be determined using the conversion table [7].

2.3.2. Quantitative Workload Measurement. Data collection begins with taking heart rate measurement calibration data using the step test (ST) method, step test calibration using the Heart Rate Monitor (HRM). The rhythm of the pace of the steps measured at a frequency of 20, 25, and 30 cycles/minute, the ST movement follows the rhythm of the metronome. Then the Work Energy Cost (WEC) for each ST cycle can be calculated using the equation :

\[
WEC_{ST} = \frac{w \times g \times 2f \times h}{4.2 \times 10^3} \quad (2)
\]
Where:

\[ WEC_{ST} = \text{Work Energy Cost during the step test (kcal/min)} \]
\[ n = \text{repetition} \]
\[ g = \text{acceleration of gravity (9.8 m/s}^2) \]
\[ f = \text{step test frequency} \]
\[ h = \text{step test bench height (m)} \]
\[ 4.2 = \text{unit calibration factor from Joules to calories} \]

In order to obtain the objectivity of the heart rate (HR) value, for each object observed the ST calibration results must be normalized in order to obtain a more objective HR value. Normalization was performed by comparing the relative HR at ST (HR_{STn}) to HR at rest. This comparison value is also known as IRHR (Increase Ratio of Heart Rate).

\[ IRHR_{\text{step test}} = \frac{HR_{ST}}{HR_{rest}} \] (3)

A graph is made to see the correlation to the increase in \( WEC_{ST} \) which has an equation of function:

\[ Y = aX + b \] (4)

where: \( Y = IRHR \) dan \( X = WEC \) (kcal/min)
\[ a \text{ and } b = \text{constanta} \]

Then to find the IRHR value when operating the tractor using the same method as the IRHR step test. That is by comparing the heart rate when operating the tractor (HR Work) with the heart rate at the initial rest (HR Rest).

\[ IRHR_{\text{step test}} = \frac{HR_{ST}}{HR_{rest}} \] (5)

The subject's IRHR value when operating the tractor is entered into the subject's equation as 'Y' so that the 'X' value is obtained as work energy consumption at work (work WEC). Furthermore, the Total Energy Cost (TEC) can be calculated by adding up the energy needed to work WEC and the energy needed to support the minimal physiological functions of the BME body, described in the following equation:

\[ TEC = WEC + BME \] (6)

where:
\[ TEC = \text{Total Energy Cost (kcal/min)} \]
\[ WEC = \text{Work Energy Cost (kcal/min)} \]
\[ BME = \text{Basal Metabolic Energy (kcal/min)} \]

The workload received by each subject will be influenced by their body weight, so to minimize the effect of weight, it must be eliminated by dividing the TEC value by the subject's body weight, described in the following equation:

\[ TEC' = \frac{TEC}{w} \] (7)

where: \( TEC' = \text{Total Energy Cost per Weight (cal/kg.min)} \)
\[ w = \text{body weight (kg)} \]
2.3.4. **Qualitative Workload Measurement.** Qualitative workload measurement can be determined by looking at the level of a person's workload based on the IRHR value at work, this value can be seen in the table of job categories based on the IRHR by Syuaib [7].

3. **Results and discussion**

The operation of the tractor to pull the trailer is carried out by 3 different operators, figure 1 shows the operation of the tractor using a conventional trailer, while figure 2 shows the operation of the tractor using a pivot type trailer.

In the figure 1, it can be seen that the conventional trailer has a weakness when turning, where the tractor handlebar is out of the operator's control when turning. While in figure 2, the trailer used is a pivot type trailer, which has added wheels under the operator's seat, which makes it easier for the operator to maneuver the tractor, especially when turning.

![Figure 1](image1.png)

**Figure 1.** The Operation of a two-wheel tractor for pulling conventional trailers.

![Figure 2](image2.png)

**Figure 2.** The Operation of a two wheel tractor tractor for pulling a pivot type trailer.

3.1. **Basal Metabolic Energy (BME) Measurement**

The first step in calculating the workload is to measure BME, by measuring BME it will be known the energy consumption required by the subject to carry out his minimal physiological functions. The following are the results of measuring body dimensions and BME for each subject (table 1).
Table 1. Anthropometric characteristics and BME values of each subject.

| Subject   | Sex | Age (Years) | Weight (Kgs) | Height (cm) | A (m²) | VO2 | BME (kcal/min) |
|-----------|-----|-------------|--------------|-------------|--------|-----|----------------|
| Operator A| Male| 35          | 70           | 162         | 1.763  | 218 | 1.09           |
| Operator B| Male| 21          | 65           | 171         | 1.776  | 219 | 1.095          |
| Operator C| Male| 21          | 60           | 171         | 1.717  | 212 | 1.06           |

BME = Basal Metabolic Energy; A = Body surface area; VO2 = volume of oxygen

The results show that there is a correlation between body dimensions and BME. Table 1 shows that Operator C has a body dimension of 1,717 m² so that the BME is 1.06 kcal/minute, the wider body dimension are operator B with a value of 1,776 m² so that the BME is 1.095 kcal/minute. This shows, the wider the dimensions of a person’s body, the greater the energy needed to carry out the functions of the body’s organs.

3.2. Measurement of IRHRST, WEC_ST, IRHR Work and WEC Work

To determine the relationship between heart rate and increased workload, a Step Test (ST) calibration was carried out. Each subject has different characteristics and different physiological abilities (cardiovascular and muscle fiber abilities). So that each graph of heart rate measurement is also different. Figure 3 shows an overview of the results of KST measurements for each operator.

Figure 3. Results of step test heart rate measurement.

The results of the Step Test Calibration heart rate measurement show that there is a general graphic pattern, namely an increase in heart rate often with an increase in the level of load given in the form of a step test frequency.

The WEC_ST value, which is the subject’s energy consumption value for the body’s metabolic processes and doing work, needs to be calculated to make graphs and power equations with IRHR values. While the WEC_ST value can be calculated using the power principle approach. Where, when doing the step test the subject is assumed to be walking up the stairs carrying a load of his own weight.
Table 2. IRHR and WEC<sub>ST</sub> values of subjects in the step test calibration.

| Subject     | ST1 (20 cycle/min) | ST2 (25 cycle/min) | ST3 (30 cycle/min) |
|-------------|--------------------|--------------------|--------------------|
|             | IRHR (kcal/min)   | IRHR (kcal/min)   | IRHR (kcal/min)   |
| Operator A  | 1.35               | 1.54               | 1.70               |
| Operator B  | 1.65               | 1.9                | 2.05               |
| Operator C  | 1.44               | 1.63               | 1.82               |

ST1 = Step Test 1; ST2 = Step Test 2; ST3 = Step Test 3; IRHR = Increase Ratio of Heart Rate; WEC<sub>ST</sub> = Work Energy Cost during Step Test.

The relationship between WEC<sub>ST</sub> and IRHR is then plotted in a graph as shown in figure 4. Each subject has its own slope of the graph that represents the increase in IRHR against the increase in the WEC<sub>ST</sub> value. From the graph, it can be seen that the steeper the slope of the line, the greater the change in the IRHR value to changes in the level of workload.

Figure 4. Correlation graph of WEC<sub>ST</sub> and IRHR<sub>ST</sub> operators.

The IRHR is measured from the subject's heart rate when working with the same calculation method as the IRHR during the step test. Work IRHR is used to calculate the amount of Work Energy Cost in work activities by entering the work IRHR value into the calibration equation. To find out the work energy released by the subject (WEC) on tractor operating activities, it is done by inputting the IRHR value for the activity into the IRHR<sub>ST</sub> and WEC<sub>ST</sub> correlation equation.
Table 3. Calibration and WEC equations on flat land.

| Subject    | Calibration Equation | IRHR Work | WEC (kcal/min) |
|------------|----------------------|-----------|----------------|
| Operator A | \( y = 0.5972x + 0.0466 \) | 1.32 P, 1.29 C | 2.13 P, 2.09 C |
| Operator B | \( y = 0.784x + 0.0623 \)  | 1.12 P, 1.03 C | 1.35 P, 1.23 C |
| Operator C | \( y = 0.7446x + 0.0484 \) | 1.25 P, 1.17 C | 1.62 P, 1.51 C |

IRHR = Increase Ratio of Heart Rate; WEC = Work Energy Cost during work

Table 4. Calibration and WEC equations on land with a slope of 10°.

| Subject    | Calibration Equation | IRHR Work | WEC (kcal/min) |
|------------|----------------------|-----------|----------------|
| Operator A | \( y = 0.5972x + 0.0466 \) | 1.28 P, 1.33 C | 2.07 P, 2.15 C |
| Operator B | \( y = 0.784x + 0.0623 \)  | 1.20 P, 1.15 C | 1.45 P, 1.39 C |
| Operator C | \( y = 0.7446x + 0.0484 \) | 1.24 P, 1.25 C | 1.60 P, 1.62 C |

IRHR = Increase Ratio of Heart Rate; WEC = Work Energy Cost during work; P = pivot type trailer; C = conventional trailer

Table 5. Calibration and WEC equations on land with a slope of 30°.

| Subject    | Calibration Equation | IRHR Work | WEC (kcal/min) |
|------------|----------------------|-----------|----------------|
| Operator A | \( y = 0.5972x + 0.0466 \) | 1.33 P, 1.30 C | 2.16 P, 2.10 C |
| Operator B | \( y = 0.784x + 0.0623 \)  | 1.29 P, 1.15 C | 1.56 P, 1.39 C |
| Operator C | \( y = 0.7446x + 0.0484 \) | 1.30 P, 1.22 C | 1.68 P, 1.57 C |

IRHR = Increase Ratio of Heart Rate; WEC = Work Energy Cost during work; P = pivot type trailer; C = conventional trailer

The results of measuring heart rate when using a tractor (IRHR Work) on flat land with a pivot trailer are 1.12–1.32, and with a conventional trailer 1.03–1.29, so that by entering this value into the equation (as \( y \)), the energy released by the subject is obtained (WEC) at work (tractor driving) is 1.35 – 2.13 kcal/min with pivot trailers and 1.23 – 2.09 kcal/min with conventional trailers.

On land with a slope of 10° the working IRHR with pivot trailers is 1.20 – 1.28, and with conventional trailers 1.15-1.35, with energy expended at 1.45 – 2.07 kcal/min on pivot trailers and 1.39 – 2.15 kcal/min on a conventional trailer. While on land with a slope of 30°, the working IRHR on pivot trailers is 1.30 – 1.33, and on conventional trailers it is 1.15-1.30 with energy expended at 1.56 – 2.16 kcal/minute on pivot trailers and 1.39-2.10 kcal/minute on conventional trailers.

The WEC value of the pivot trailer and conventional trailer if we average it is 1.70 kcal/min for the entire slope of the land. So if we refer to the average working hour of the Indonesian people, which is 7 hours/day (Undang-Undang No. 13 Tahun 2003 Pasal 77), the WEC value obtained is 102 kcal/hour and 714 kcal/day during working hours. This value is still far low when compared to the transportation of palm oil using a wheelbarrow. According to Nugraha [3], the average energy consumption required for wheelbarrow operators is 4080 kcal/day during working hours. This value is also close to the upper limit of energy allowed for heavy work, which is ± 4800 kcal/day [4].

3.3. Qualitative and quantitative workload

Qualitative workload analysis was conducted to see the level of workload level relative to the physiological condition of the subject. While the quantitative workload to see the amount of energy
released by the subject at work. Tables 6 and 7 show the results of qualitative and quantitative analysis of operators on flat land using pivot type trailers and conventional trailers. Tables 8 and 9 show the results of qualitative and quantitative analysis of operators on land with a slope of 10° using pivot type trailers and conventional trailers, while tables 10 and 11 show the results of qualitative and quantitative analysis of operators on land with a slope of 30° using pivot type trailers and conventional trailers.

Table 6. Qualitative and quantitative workloads on the operation of a two-wheel tractor for pulling pivot type trailer on flat land.

| Subject | Body Weight (kg) | IRHR Work (pulse/min) | Workload | BME (kcal/min) | WEC (kcal/min) | TEC (kcal/min) | TEC' (kcal/kg.hours) |
|---------|-----------------|-----------------------|----------|----------------|----------------|----------------|-------------------|
| Operator A | 70 | 1.32 | medium | 1.09 | 2.13 | 3.22 | 2.76 |
| Operator B | 65 | 1.12 | light | 1.10 | 1.35 | 2.45 | 2.26 |
| Operator C | 60 | 1.25 | medium | 1.06 | 1.62 | 2.68 | 2.68 |
| Average | 65 | 1.23 | light | 1.08 | 1.70 | 2.78 | 2.57 |

IRHR = Increase Ratio of Heart Rate; BME = Basal Metabolic Energy; WEC = Work Energy Cost during work; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight

Table 7. Qualitative and quantitative workloads on the operation of a two-wheel tractor for pulling conventional trailers on flat land.

| Subject | Body Weight (kg) | IRHR Work (pulse/min) | Workload | BME (kcal/min) | WEC (kcal/min) | TEC (kcal/min) | TEC' (kcal/kg.hours) |
|---------|-----------------|-----------------------|----------|----------------|----------------|----------------|-------------------|
| Operator A | 70 | 1.29 | medium | 1.09 | 2.09 | 3.18 | 2.72 |
| Operator B | 65 | 1.03 | light | 1.10 | 1.23 | 2.32 | 2.15 |
| Operator C | 60 | 1.18 | light | 1.06 | 1.51 | 2.57 | 2.57 |
| Average | 65 | 1.16 | light | 1.08 | 1.61 | 2.69 | 2.48 |

IRHR = Increase Ratio of Heart Rate; BME = Basal Metabolic Energy; WEC = Work Energy Cost during work; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight

Table 8. Qualitative and quantitative workloads on the operation of a two-wheeled tractor on land with a slope of 10°.

| Subject | Body Weight (kg) | IRHR Work (pulse /min) | Workload | BME (kcal/min) | WEC (kcal/min) | TEC (kcal/min) | TEC' (kcal/kg.hours) |
|---------|-----------------|-----------------------|----------|----------------|----------------|----------------|-------------------|
| Operator A | 70 | 1.28 | medium | 1.09 | 2.07 | 3.16 | 2.71 |
| Operator B | 65 | 1.20 | light | 1.10 | 1.45 | 2.54 | 2.35 |
| Operator C | 60 | 1.24 | light | 1.06 | 1.60 | 2.66 | 2.66 |
| Average | 65 | 1.24 | light | 1.08 | 1.71 | 2.79 | 2.57 |

IRHR = Increase Ratio of Heart Rate; BME = Basal Metabolic Energy; WEC = Work Energy Cost during work; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight
The total energy that must be expended by the operator (TEC) in the activity of driving a tractor is the sum of the energy that must be expended for work activities (WEC) with energy for body metabolic activities (BME). So, based on the calculation results, the TEC is 2.45 – 3.22 kcal/minute on pivot type trailers and 2.32 - 3.18 kcal/minute on conventional trailers (for flat land), 2.54 – 3.16 kcal/minute on pivot type trailers and 2.48 - 3.24 on conventional trailers. (land with a slope of 10°), and 2.66 – 3.25 kcal/min on a pivot type trailer and 2.48 - 3.19 on a conventional trailer (land with a slope of 30°).

The results of the qualitative analysis show that the average working IRHR on pivot type trailers is between 1.12 – 1.32 and on conventional trailers between 1.03 - 1.29 (for flat land) , and on sloping land 10° on pivot type trailers between 1.20 – 1.28 and on conventional trailers between 1.15 -1.33, while on land with a slope of 30° on pivot type trailers between 1.29 – 1.33 and on conventional

Table 9. Qualitative and quantitative workload on the operation of a two-wheel tractor for pulling conventional trailers on land with a slope of 10°.

| Subject | Body Weight (kg) | IRHR Work (pulse /min) | Workload | BME (kcal /min) | WEC (kcal /min) | TEC (kcal /min) | TEC' (kcal /kg.hours) |
|---------|------------------|-------------------------|----------|----------------|----------------|----------------|---------------------|
| Operator A | 70 | 1.33 | medium | 1.09 | 2.15 | 3.24 | 2.78 |
| Operator B | 65 | 1.15 | light | 1.10 | 1.39 | 2.48 | 2.29 |
| Operator C | 60 | 1.25 | medium | 1.06 | 1.62 | 2.68 | 2.68 |
| Average | 65 | 1.24 | light | 1.08 | 1.72 | 2.80 | 2.58 |

IRHR = Increase Ratio of Heart Rate ; BME = Basal Metabolic Energy ; WEC = Work Energy Cost during work ; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight

Table 10. Qualitative and quantitative workloads on the operation of a two-wheel tractor to pull a pivot trailer on land with a slope of 30°.

| Subject | Body Weight (kg) | IRHR Work (pulse/min) | Workload | BME (kcal/min) | WEC (kcal/min) | TEC (kcal/min) | TEC' (kcal/kg.hours) |
|---------|------------------|------------------------|----------|----------------|----------------|----------------|---------------------|
| Operator A | 70 | 1.33 | medium | 1.09 | 2.16 | 3.25 | 2.78 |
| Operator B | 65 | 1.29 | medium | 1.10 | 1.56 | 2.66 | 2.45 |
| Operator C | 60 | 1.30 | medium | 1.06 | 1.68 | 2.74 | 2.74 |
| Average | 65 | 1.31 | medium | 1.08 | 1.80 | 2.88 | 2.66 |

IRHR = Increase Ratio of Heart Rate ; BME = Basal Metabolic Energy ; WEC = Work Energy Cost during work ; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight

Table 11. Qualitative and quantitative workloads on the operation of a two-wheel tractor for pulling conventional trailers on land with a slope of 30°.

| Subject | Body Weight (kg) | IRHR Work (pulse /min) | Workload | BME (kcal/min) | WEC (kcal/min) | TEC (kcal/min) | TEC' (kcal/kg.hours) |
|---------|------------------|-------------------------|----------|----------------|----------------|----------------|---------------------|
| Operator A | 70 | 1.30 | medium | 1.09 | 2.10 | 3.19 | 2.74 |
| Operator B | 65 | 1.15 | light | 1.10 | 1.39 | 2.48 | 2.29 |
| Operator C | 60 | 1.22 | light | 1.06 | 1.57 | 2.63 | 2.63 |
| Average | 65 | 1.22 | light | 1.08 | 1.69 | 2.77 | 2.55 |

IRHR = Increase Ratio of Heart Rate ; BME = Basal Metabolic Energy ; WEC = Work Energy Cost during work ; TEC = Total Energy Cost; TEC' = Total Energy Cost per body weight
trailers between 1.15-1.30, so that by referring to the workload table on flat land activities with an average work of 'light' for pivot and conventional trailers, on land with a slope of 10° the average working is 'light' for both trailers, and on land with a slope of 30° it is 'medium' for pivot type trailers and for conventional trailers it is 'light'.

Body weight is an additional burden that the subject must spend when working, so to find out the actual energy (TEC') released by each subject in climbing activities, that is by dividing TEC by body weight. So the total work energy per body weight (TEC') on a pivot type trailer is 2.57 kcal/kg.hour and on a conventional trailer it is 2.48 kcal/kg.hour for flat land, and on a sloped land 10° the TEC' value on the pivot type trailer is 2.57 kcal/kg.hour and on the conventional trailer it is 2.58 kcal/kg.hour, then on a 30° slope the TEC' value obtained on the pivot type trailer is 2.66 kcal/kg.hour and on a conventional trailer is 2.55 kcal/kg.hour.

The slope of the land is very influential on the workload of the operator, where the greater the slope of the land will increase the workload on the operator as shown in figures 5 and 6, especially on the pivot type trailer. According to Visano et al. [8], the topography of the land is part of the working environment for oil palm harvesting. The work environment can put an additional burden on workers. So it can be said that the topography of the land is part of the workload of oil palm harvesters. In line with the results of the analysis Nurjannah [9], which has a positive correlation, it is known that the relationship between land and worker fatigue is unidirectional. This means that if the topography of the land is high, the fatigue of workers is also high.

![Figure 5. Relationship between land slope and (a) IRHR ; (b) WEC.](image)

![Figure 6. Relationship between land slope and (a) TEC ; (b) TEC'.](image)
From the previous discussion, it can be seen that the operator's workload in the operation of pivot type trailers tends to be greater than that of conventional trailers, this is largely determined by the skills of the operator in operating the trailer, which requires training in its operation [10-13]. However, from the aspect of operator comfort and safety, pivot-type trailers are superior, especially when turning [6].

4. Conclusions

Qualitative workload levels show the average working IRHR on pivot type trailers between 1.12 – 1.32 and on conventional trailers between 1.03-1.29 (flat land), on land with a slope of 10° for pivot type trailers between 1.20 – 1.28 and on conventional trailers between 1.20 – 1.28 1.15-1.33, while on land with a slope of 30° on pivot type trailers between 1.29 – 1.33 and on conventional trailers between 1.15-1.30, so that by referring to the workload table on flat land activities with an average work of 'Light' for pivot type trailers and conventional, on land with a slope of 10° the average working is 'Light' for both trailers, while on land with a slope of 30° it is 'Medium' for pivot type trailers and for conventional trailers it is 'light'. Meanwhile, the quantitative workload level shows that the total work energy per body weight (TEC') on the pivot type trailer is 2.57 kcal/kg.hour and on the conventional trailer it is 2.48 kcal/kg.hour for flat land, on 10° sloping land the TEC' value on the pivot type trailer is 2.57 kcal/kg.hour and on the conventional trailer it is 2.58 kcal/kg.hour, while on a 30° slope the TEC' value obtained on the pivot trailer is 2.66 kcal/kg. hour and on a conventional trailer it is 2.55 kcal/kg.hour. The slope of the land affects the workload of each operator at work, this is shown in the IRHR table with WEC, where every increase in the slope of the land affects the operator's workload so that the higher the IRHR will be directly proportional to the WEC value.

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