Economic Ergonomic Approach to Design an Optimal Manpower and Mechanization in Rice Production

Muanah¹, M F Syuaib² and Liyantono²

¹Graduate School of Bogor Agriculture University (IPB), Bogor, Indonesia
²Department of Mechanical and Biosystem Engineering, Faculty of Agricultural Engineering and Technology, Bogor Agriculture University, Indonesia

E-mail: muanahtmp@yahoo.com

Abstract. Productivity of manpower could be improved by considering the economic and ergonomic aspect. The ergonomic aspect (human factor) is required to design an optimal manpower, while in the economic aspect, the well being of manpower could be evaluated from the amount of received income based on their work capability. This research was conducted on February 2016 to January 2017 in Gapoktan Silih Asih rice field Cigombong, Bogor. This study aims to analyze the income of manpower based on current conditions, increasement of working hours and mechanization addition. The results showed that manpower income based on the current condition and ergonomic consideration was Rp 1,174,030/person.month, by increasing the working hours with ergonomic consideration the obtained income was Rp 1,766,204/person.month. The revenues were based on the existing work system even though the increasement of working hours have not provided optimal income due to low productivity. Therefore the results of analysis with the addition of selective mechanization, showed self-ownership machinery was more profitable the obtained income have more than the Bogor minimum wage standard of Rp 2,969,325/person.month.

1. Introduction
Rice production in the agricultural sector is one of the activities that absorb a lot of manpower. So that manpower conditions affect the productivity greatly. According to [1] which said that several factors that affect the productivity are the variable of wage suitability, work experience and expertise in work. But in this study, the focus was on the suitability of wages to obtain an optimal output. Wage is an acceptance or a compensation from employers to employees (manpower) on work or services that have been done [2].

Generally, in the wage agricultural sector between male and female manpower is different. Male manpower receives a higher wage than the female one. This is different from the wage system that used in the other sectors that is using a minimum wage standards. The minimum wage policy in Indonesia according to Gianie [3] policy is used to look at two aspects namely, (1) as a protection for workers to keep the value of received wage did not decrease in meeting the needs of daily living (2) as a protection for companies to maintain the manpower productivity. However, the policy in the agricultural sector has not been well realized, which caused the manpower’s income is still far from the minimum wage standard, while the risk of work is high. The amount of received income determines the welfare of a community. The higher per capita income of a society the higher of the prosperity level [4].
Therefore, based on the description above, in this study an economic ergonomic analysis was conducted. The Economic ergonomic is an ergonomic evaluation to get an optimal wage economically. So, the manpower in addition to the ergonomic conditions will also met an economical conditions (optimal wage) to support the welfare. This research aimed to: (1) to analyze the manpower income based on the existing work system with ergonomic approaches in the study location (2) to analyze the manpower income using scenario by increasing the working hours without changing the existing work systems and performing comparisons with the minimum wage standards, and (3) to analyze the manpower income with scenario of mechanization addition and comparing with the Bogor minimum wage standard.

2. Materials and methods

2.1. Data collection
This study used an ergonomic analysis result data including the number and the distribution of the ideal manpower. So the equipment and subject of research refered to the previous research conducted by [5] While the data of wage information of male and female manpower was obtained through a direct interview with the manpower or farmer.

2.2. Data analysis

2.2.1. Manpower’s Income Analysis
1. Manpower’s income analysis based on current condition
   From the number and distribution of existing manpower and data related to manpower’s wage, the manpower income could be determined by using Equation 1, then compared to the Bogor wage standard. The manpower’s income depends on the size of productivity called Human Power (HP). Human Power is the amount of daily worker needed for one crop season and one hectare of rice production. The output is measured by the manpower (person) and the area (ha).
   \[ HI = \frac{[T \times W]_m + [T \times W]_f}{HP} \]  
   Description :
   HI : Income per person (Rp/person.month)
   T : Duration of work (days/month)
   L : Manpower needs (person/ha)
   W : Manpower’s wage (Rp/day.person)
   m, f : Male and female manpower index
   HP : Human Power (person/ha)

2. Income analysis by increasing working hour (First Scenario)
   At the location of this study conducted manpowers work for 4.8 hours/day. Therefore, it can still be increased to 7 hours/day working hour. The increasement of the working hours was based on the standard working hours in Indonesia. The manpower’s income was calculated by Equation 1, where the wages is based on working hours and compared to the Bogor wage standard.

3. Income analysis with mechanization addition (Second Scenario)
   Based on the existing working system and the increasement of working hours that can not provide optimal income, so that in several work elements the mechanization was added. The addition of mechanization was conducted by selective method which means that the addition of mechanization was conducted on certain working elements based on the needs of existing workforce and with the considerable of available time. Therefore, from the addition of this mechanization, the manpower savings was obtained, then the difference in cost reduction from manpower savings to the machinery costs was an additional advantage of manpower.
3. Result and discussion

3.1. Manpower’s Number and Distribution
The economic ergonomic approach is the second stage of research after an ergonomic analysis. In ergonomic analysis, there is an ideal number and distribution of manpower to work on a series of rice production activities. Therefore, from the distribution with the resulting work output the amount of manpower’s income could be determined. The number and distribution of manpower based on the ergonomic approach reported by [5] can be seen in Table 1.

Based on work capacity and by using 120 days (4 month) per crop season, the rice production activities required a total manpower force of 2.32 persons consist of 1.85 male manpower and 0.47 female manpower on 100 work days (the minimum wage standard: 25 days/month). The value of 3.32 person/ha means average daily worker required for rice production on a hectare area of crop. From the needs of manpowers, the manpower productivity or called Human Power (HP) could be determined. The term of productivity in this study was obtained by dividing the work area output (ha) with manpower needed (person).

| Work Element              | Symbol | Required manpower (person.day/ha) |
|---------------------------|--------|-----------------------------------|
| Seedling**                | Se     | 13*                               |
| Tillage***                | Ti     | 56                                |
| Harrowing                 | Ha     | 9                                 |
| Transplanting             | Tr     | 22*                               |
| Fertilizing               | Fe     | 2                                 |
| Cutting                   | Cu     | 37                                |
| Paddy transporting        | Ev     | 15                                |
| Thressing                 | Th     | 38                                |
| Unhulled rice tranporting | Tp     | 9                                 |
| Drying                    | Dr     | 12*                               |
| Husking                   | Hs     | 9                                 |
| Polishing                 | Pl     | 4                                 |
| Grading                   | Gr     | 2                                 |
| Packaging                 | Pc     | 4                                 |
| Total                     |        | 232                               |

Information: *female manpower, **equivalent to provide the requirement of seeds for 1 m² of planting area; ***include hoeing the corners of rice field that was not processed by tractor, clean up and tidy up the rice field.

3.2. Manpower’s Income Analysis Using Current Condition
Manpower’s income in this study is a calculation result based on the amount of remuneration that has been applied in the research location. Where the current wage system is based on gender. Male manpower was Rp 50,000/day while the female manpower was Rp 35,000/day with average work time was 4.8 hours/day. Therefore, the calculation results using Equation 1 obtained Rp 1,174,030/person.month income (Table 2). The income was still lower than the Bogor regional minimum wage standard (Rp 2,960,325/person.month) of Bogor Regency in 2016.

Based on the existing work system, manpower income has not met the regional minimum wage standard. Therefore, the optimization was made based on two scenarios in which the existing work-
hours are not changed. The first scenario was applied on the same existing work-system but with extended working hour (from 4.5 hours became 8 hours as a daily standard); whilst the second scenario was apply with ‘selective mechanization’ to increase the daily work’s productivity due to increasing the daily wage. The optimization calculation revealed that the scenarios are rational to apply on a 100 ha area paddy field with 9 rotation of crops, so the number of labor expresses a daily routine of workers needed.

| Table 2. Manpower’s income based on current condition with the UMR standard |
|---------------------------------|------|
| Description                     | Amount |
| Required Manpower (person/ha)   | 2.32  |
| Manpower’s total cost (Rp/ha.month) | 2,723,750 |
| Average wage per person (Rp/person.month) | 1,174,030 |

3.3. Manpower’s Income Analysis by Optimizing Working Hours (Scenario 1)

Optimizing the working hours aimed to increase the working hours that have been applied which was 4.8 hours/day, then added to 7 hours/day in accordance to the provisions of working hours in Indonesia. One of the scenarios used in this study aimed to obtained an optimal income, then one way that was conducted was by optimizing the working hours.

Based on the analysis results by 7 working hours per day in a crop season required a total workforce of 1.44 people consisting of 1.16 men and 0.28 women manpowers. Increasement of working hours led to increased the work productivity to 0.69 ha/person because the manpower worked longer than the previous that was only 4.8 hours/day. The increase of working hours aimed to make the manpower more productive in order to get a standard wage. Which made the obtained revenue of Rp 1,766,204/person.month was bigger than before. Increasement of working hours without changing the existing work system proved not provide an income which in accordance to the Bogor minimum wage standards. The manpower income between male and female in this study was assumed to be the same because based on the results of the analysis proved that some elements of work are more productive if conducted by a female manpower, but also in labor regulations in Indonesia that the standard wage for male and female are not different (Table 3).

Therefore, to obtain the income according to the Bogor regional minimum wage, the second scenario must be conducted. The second scenario aimed to make a design by adding selective mechanization to the distribution of existing workforce, so the required manpower could be reduced but the work productivity could be improved to obtain the optimal results.

| Table 3. Manpower’s income based on the increasement of working hours (7 hours/day) |
|---------------------------------|------|
| Description                     | Amount |
| Required manpowers (person/ha)  | 1.44  |
| Manpower’s total cost (Rp/ha)    | 2,543,333 |
| Average wage per person (Rp/person.month) | 1,766,204 |

3.4. Analysis of Manpower’s Income with Mechanization Design (Scenario 2)

Based on the workflow that has already existed in gapoktan Silih Asih Cigombong Bogor, which was the place where this research was conducted, one crop season was counted into 134 working days. The results of the analysis showed that the seedling work element (Se) could be conducted simultaneously with the elements of tillage (Ti) and harrowing (Ha) on day-1 and day-14. In the first day, the seed distribution to the seedling area was conducted and the seed removal was conducted in the day of 14th. The work elements Se was conducted parallelly with land preparation (Ti and Ha) because they could be done such it was to optimize the work’s sequence. On the other hand, the other work elements had to be done in serial sequence, such as: planting was conducted after the tillage and harrowing and so on.
The workflow if conducted only in one round then in one growing season a lot of working time which is still left that can still be optimized was found. This optimization could be conducted by making a cluster with the longest working time limit on the nursery process takes 14 days, more details can be seen in Figure 1. Based on the analysis result that in one work cycle (one series of rice production activities) was divided into 9 clusters with the assumption of work area of 100 ha per crop season. In that cluster, if the works was still conducted manually with the available time, then the target capacity would not fulfilled, so the mechanization input on some work elements was required. In the second scenario with the addition of mechanization inputs selectively could increase the work productivity so that the income earned increased.

**Figure 1.** workflow of rice production activity per crop season (100 ha) with total work 134 days

|   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Se| Ti  | Ha  | Ti  | Ha  | Ti  | Se, Ha|  14 |
| Tr|     |     |     |     |     | 28   |     |
| Fe1|     |     |     |     |     | 42   |     |
| Fe2|     |     |     |     |     | 56   |     |
| Tp| Dr  | Hs, Pl| Gr, Pc|     |     | 70   |     |
|   |     |     |     |     |     | 84   |     |
|   |     |     |     |     |     | 98   |     |
|   |     |     |     |     |     | 112  |     |
| Cu, Ev, Th| | | | | | 126  |     |
|   |     |     |     |     |     | 134  |     |

**Figure 2.** workflow round cluster of rice productivity per crop season (134 work days) in 100ha

Generally, the total work capacity is the resultant of the engine capacity and the total cropping period. The capacity of farm machinery used in this calculation referred to [6] and [7]. In accordance to the observed cropping system, the time-sequence of cropping operations were 14 days of tillage, 5 days of planting, and 5 days of harvesting. So, according to the available time sequence, a walking-type tractor can till for 4.9 ha land area, whereas a riding-type tractor was equivalent for 9.8 ha. As for the planting work-element, a walking-type transplanter was capable for 1.75 ha, and a combine harvester was equivalent for 3.5 ha harvested area. The machine is optimally used if it able to work in one growing season on 9 clusters of 100 ha field area (Table 4).
Table 4. Comparison mechanization work capacity per crop season of rice production (total working time of 134 days)

| Mechanization               | Machinery capacity (ha/hour) | Limit of work hour (a) | Machinery work capacity ha/days | ha/(a) | ha/season |
|-----------------------------|------------------------------|-----------------------|--------------------------------|--------|----------|
| Walking-type Tractor        | 0.03*                        | 14                    | 0.2                            | 2.8    | 25       |
| Riding-type Tractor         | 0.1*                         | 14                    | 0.7                            | 9.8    | 84       |
| Walking-type Transplanter   | 0.05**                       | 5                     | 0.35                           | 1.75   | 42       |
| Combine Harvester           | 0.1*                         | 5                     | 0.7                            | 4.9    | 84       |

Source: *[6], ** [7], one days = 7 hour

Based on the number and distribution of manpower and the available time, the selective mechanization scenario was on 7 elements of work, such as: tillage, transplanting, cutting, transporting and threshing. The addition machinery in the scenario is economically advantageous to the labor wages. As Figure 2 shows that the total labor cost was relatively higher on the first scenario (without additional mechanization) compared to the second ones (with selective mechanization). The use of mechanization was eventually required to completing the tasks in such larger capacity in a given constrain of work time and sequence.

The use of mechanization inputs in this scenario was assumed to use the self-ownership and rental machinery. Each cost that must be spent for both can be seen in Table 5. In this study, costs on the self-ownership machinery used assumptions which was using variable costs that does not include fixed costs because the machine used is a donation machine from the government.

The required manpower due to mechanization addition reduced by 107 people in 100 ha of the crop season. The difference from the manpower requirement could be solved using mechanization. Comparison of total manpower and mechanization cost in the workday increasement and mechanization addition scenarios can be seen in Table 5. The difference of total cost was an advantage as additional income, the amount of profit can be seen in Table 6. The results show that monthly profit using a rental machinery was Rp 680,021/person.month. While the assumption of self-ownership machinery obtained a profit of Rp 1,196,595/person.month. Based on this, it can be concluded that using the self-ownership machinery is more profitable than using the rental machinery. This is because the cost incurred for the self-ownership machinery was less than the rental machinery. The results of this study were then compared to the standard of minimum wage (working for 7 hours/day or 25 days/month). While the previous working hours was 4.8 hours/day so it can still be optimized. Furthermore, the results of the analysis were compared to the standard of minimum wage with the same working hours.

Labour need on first scenario (increment of working hour) was 144 person not distributed yet smoothly every day (25 days/month). This was caused as practically labour need was different on every element (Table 1). Therefore, it needed to be done an optimization by additional mechanization. With this mechanization, work element that needs many labours can be finished in short time. Thus permanent labour need was 37 person in 100 hectare per crop season can be distributed smoothly to work every day.
Table 5. Total cost of manpower requirement (human and machinery) for rental and own machinery scenario per crop season 100 ha

| Description                       | Current Condition | Incremental working hour | Additional mechanization |
|-----------------------------------|-------------------|--------------------------|--------------------------|
| Rental machinery                  |                   |                          |                          |
| Required manpower (person)        | 193               | 144                      | 37                       |
| Manpower cost (thousand Rp)       | 907,917           | 1,017,333                | 258,125                  |
| Machinery cost (thousand Rp)      | 65,968            | 65,968                   | 553,168                  |
| Total (thousand Rp)               | 973,885           | 1,083,301                | 811,293                  |
| Own machinery                     |                   |                          |                          |
| Required manpower (person)        | 193               | 144                      | 37                       |
| Manpower cost (thousand Rp)       | 907,917           | 1,017,333                | 258,125                  |
| Machinery cost (thousand Rp)      | 27,813            | 27,813                   | 308,383                  |
| Total (thousand Rp)               | 935,729           | 1,045,146                | 566,508                  |

Table 6: Profit based on the difference of manpower cost with the increasement of working hour and additional mechanization

| Assumption of machinery usage     | 100 ha/crop season | ha/month |
|-----------------------------------|--------------------|----------|
| Rental machinery (Rp)             | 272,008,333        | 680,021  |
| Self-ownership machinery (Rp)     | 478,637,933        | 1,196,595|

3.5. Changes in Manpower Income with the Addition of Mechanization (Second Scenario)

Total income of manpower after the mechanization design can be seen in Table 7. A work round consisting of 9 clusters with the assumption of 100 ha per crop season proved to increase the income of manpower. The increase of manpower income was obtained from the difference between the manpower cost manually and the cost of using machinery. On the assumption showed that both of the rent machine and the self-ownership machinery could increase the revenue. Revenue of a rental machinery was lower if compared to the self-ownership machinery because the costs incurred of rental machinery was larger than the self-ownership machinery. In addition, the self-ownership machinery used a variable costs because it used a donation machinery from the government. Each income with the assumption that the income of rental machinery usage was Rp 2,446,225/person.month while the self-ownership machinery was Rp 2,962,799/person.month.

Based on these two assumptions, it can be concluded that the assumption by using the self-ownership machinery was more profitable compared to the rental machinery because the income earned already met the Bogor regional minimum wage standard. While the manpower income on assumption with rental machinery still below the Bogor regional minimum wage standard. This happened due to the cost of the existing rental machinery showed that the cost of the rental machinery with manpower costs was almost same, so that the addition of mechanization did not provide the optimum benefit for earning the Bogor regional minimum wage standard income.
### Table 7 Total income of manpower using additional mechanization

| Description                                      | Amount   |
|--------------------------------------------------|----------|
| Rental machinery                                 |          |
| Manpower income (Rp/person.month)                | 1,766,204|
| Additional income due to addition of machinery (Rp/person.month) | 680,021  |
| Total income (Rp/person.month)                   | 2,446,225|
| Own machinery                                   |          |
| Manpower income (Rp/person.month)                | 1,766,204|
| Additional income due to addition of machinery (Rp/person.month) | 1,196,595 |
| Total income (Rp/person.month)                   | 2,962,799|

*fix costs did not included due to the used machine was a donation from government

4. Conclusion

The result of the ergonomic approach analysis proved that the output of manpower based on the current condition with income of Rp 1,174,030/person.month has not met the Bogor regional minimum wage standard. Further analysis, the scenario by increasing the working hours without changing the existing work system was obtained income of Rp 1,766,204/person.month, where the income was not meet the Bogor regional minimum wage standard. Based on the second scenario analysis which was designing a mechanization with selective method proved to increase manpower income, but the addition of mechanization with the assumption of using a self-ownership machinery (Rp 2,962,799/person.month) was more profitable compared to the assumption of rental machinery (Rp 2,446,225/person.month) due to the obtained income with the self-machinery assumption has met the Bogor regional minimum wage standard.

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