Performances of Multifunctional Farming Bulldozer in Indonesia

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Abstract. Farming bulldozer (FB) is a heavy-duty machine made by Komatsu designed explicitly for multipurpose operations in broad land types, from extremely dry to wet/swamplands. FB is a bulldozer but uses a wider crawler so that its Ground Pressure (GP) is about half compared to 4W tractor. The tested FB was D21PL-8 type having GP 0.19 kg/cm², Flywheel HP 32.4 kW 44 PS@2450 rpm, Operating Weight 4815 kg. Attached with associated implements, FB can do land clearing and leveling, land plowing and harrowing, soil puddling, subsoil draining, direct seeding, and harvesting. Tested fields are in the provinces of West Java (wet/dryland), South Sumatra (wetland), South Kalimantan (wetland), South Sulawesi (dry/wetland), West Papua (dry/wetland) and East Nusa Tenggara (dryland). In general, FB can do precise leveling in a range of ±15mm in 0.15-ha tested paddy field. Worktime for plowing continued with puddling is 4.97 hours/ha and harrowing continued with puddling is 5.15 hours/ha while for hand tractor in both cases is more than 13 hours/ha. It means FB can reduce work time up to 60%. In term of yield, there is no significant difference with hand tractor, which ranges from 6 t/ha to 7 t/ha. In conclusions, FB can do many tasks of land cultivations, cover a wider area of any land types, reduce labor numbers and cost, and increase planting intensity. Further testing to find the optimal size of land, operation and maintenance costs and impacts on the economy, society, and environment are still underway.

1. Introduction

The success of paddy cultivation in extensive paddy fields (>100 ha) on wetlands or swamplands primary lays on the flatness of the land surface that will determine how the water level distributes uniformly over the area [1] [2]. Uneven water levels will cause the plants to grow unequally and give adverse effects on yields and the quality of rice [3] [4]. Some seeds even may sink and will not grow as expected. A too large area may make this target is difficult or impossible to achieve. The too small area may not be practical to use farm-machinery and cannot be feasible financially. It is essential then to determine the optimum size and shape of the paddy field that meets both technical and financial feasibilities. This size will depend on many things, such as the environmental biophysics of the locality, the size of farm-machineries, and the management system to be applied [5]. Japan has introduced 30 m
width to 100 m length as a national standard for consolidated paddy fields [6]. Other countries, however, may be difficult to adopt it and have many different sizes to be called optimum [7].

According to the geophysics, Indonesia has various types of paddy fields from small-size contoured fields mainly in sloping lands to extensive size fields primarily in wetlands/swamplands\(^1\). Most of the small size can only be managed manually or supported with bulls. Some capable of operating hand-tractors. Heavy farm-machineries such as four-wheel tractors and combined harvesters can be seen now operating in many places, whether drylands and wetlands [8].

Regarding those paddy fields swamplands, farm-machineries often face problems on their mobility due to the low bearing capacity of deep soil layers with high water content. On the other sides, it is tough to drain the water due to these paddy fields commonly lay on lowlands that are occasionally influenced by the sea tide and consists of clay content with low water permeability [9]. These paddy fields indeed need farm-machineries having less ground pressure, so that capable of moving around without risking to further soil compaction. For this purpose, a Swamp Dozer or Farming Bulldozer (FB) has been designed to move freely and adequately can cover a full area of paddy fields in the wetlands or swamplands\(^2\). Differed with a common bulldozer, the farming bulldozer has a full shoe width and equipped with PTO to draw many types of implements for land preparations.

Until this time, this machine is not yet available in the market but still underway development. Performance tests, whether in the laboratory in Japan and fields in some places in Indonesia, are still underway. Previously, the Rice Research Institute of Ishikawa Prefecture, Japan has used FB with the results were able to perform land leveling with ±15 mm-deviation, stable growth of seedlings, and 5%-yield increment. Besides the 3 points linkage, the FB here was also equipped with ICT Machine Control using GPS and capable using associated implements to perform broader works such as soil plowing, land leveling, water leveling, soil puddling, bullet mole draining and v-ditch direct seeding (Figure 1).

\[\text{Figure 1. Farming Bulldozer with various types of implements}\]

In Indonesia, since 2017 FB currently has been tested in West Java, South Sumatra, South Kalimantan, South Sulawesi, West Papua, and East Nusa Tenggara. This paper is to report results of the testing of FB type DL21L-8 conducted in the Rice Research Center belongs to the Ministry of Agriculture located in Sukamandi District, Subang Regency, West-Java Province, Indonesia. The FB was used here for land preparation started from land leveling, plowing, harrowing, and water leveling.

In some cases, it also was used to cut ridges so that the tested paddy fields sized in a relatively equal width and length. Comparisons with the current practices were undertaken to see differences, especially in terms of field capacity, work-time, costs, and effects to the yields. Moreover, fertilizer treatments were carried out to see the effects of dosage differences on the yields.

2. Methodology
Komatsu designs farming Bulldozer (Figure 2), especially to cultivate farmlands having the low bearing capacity that is not possible to operate hand tractors and 4-wheel tractors. The primary purpose is to enhance the workability under severe conditions of swamplands or wetlands naturally flooded with water most of the time and layered with deep clayey soils.

\(^1\) http://ricepedia.org/indonesia. Accessed 10/06/19
\(^2\) https://www.youtube.com/watch?v=z3uJI8zpDI. Accessed 10/06/19.
There are 3-point links, coupler, rear PTO, which is the standard equipment for various farming works such as land leveling, soil plowing, and soil puddling. In general, FB used in this testing was D21PL-8 that has Flywheel Horsepower 32.4 kW (44 PS)/2450 rpm, Operating Weight of Canopy 4815 kg and Ground Pressure 0.19 kg/cm². Appendix 1 shows the specification of the FB D21PL-8.

Figure 3 shows the experimental design comprising 3 methods with 9 blocks each about 0.15 ha in size. Method1 used FB equipped with rotary and blade in 3 blocks (No.1, 2 and 3), Method2 used rotary and harrow in 3 blocks (No.4, 5 and 6), Method3 (Current1) was the current work using hand tractor by surfing (the operator was sitting) in 3 blocks (No. 7, 8 and 9). Every block sized in 0.15 ha. Moreover, also, Method4 (Current2) used hand tractor by walking in 1 block (No. 10). The Current1 and Current2 here were used as the control for comparisons. Rotary was used for plowing and crushing, the blade was used for leveling, and harrow was used to puddling and leveling at the same time.
There were 3 different treatments for fertilization. Block No. 1, 4, and 7 were treated with 60%. Block No. 2, 5, and 8 with 80%, and Blocks No. 3, 6, and 9 with 100% dosages compared to the current practice. Fertilization was carried out manually while rice transplanting was used a transplanter. Plant maintenance was used as currently practiced. Yield in every block was measured in 4 plots sized in 2 m x 2 m. Other measured variables were the numbers of panicle and grain, the percentage of full grain and grain weight.

3. Results and Discussions
Hand tractor (Current 1) is commonly used to prepare paddy fields operated by workers hired from the surrounding area. The four-wheel tractor is not familiar here mainly due to limited budgets and skilled operators. Hand tractor is not operable when the soil is dry and too hard. That why water must flow before the land preparation, which consumes lots of irrigation water. The preparation includes soil plowing, puddling, and land/water leveling with the blade. These works completed in 13 days with a total cost about $170 per hectare.

While Method 1 and Method 2 were not so different in each other taking 3 days to complete the whole tasks with a total cost $195 per hectare. FB is operable any time independent on the soil dryness and can save irrigation water. Using rotary, FB can shred the paddy remnants from previous cultivation and mixed with the soil. Blade then was used to level the land. Harrow or blade both can level the water surface without any significant differences in the results. It means using rotary and blade is sufficiently useful for land preparation.
Figure 4. Land surfaces as results of land leveling by hand tractor and farming bulldozer

Figure 4 shows land surfaces after leveled by Current 1 compared with that of Method 1 and Method 2. The colors indicate the soil level from the surface of the water ponding on the land. Plots No. 1, No. 2 and No. 3 were the results by Method 1, Plots No. 4, No. 5 and No. 6 by Method 2 and Plots No. 7, No. 8 and No. 9 by Current 1. The highest-level scale is 5 cm, and the lowest scale is -5 cm. The greener is the flatter. While Current 1 resulted in undulating soil surface with 60%-66% flatness, Method 1 and Method 2 produced similar results with green color covered most of the lands and attained 97%-99% flatness.
Figure 5 shows the times needed by Method 1 and Method 2 with that by Current 1 as the control. Method 1 and Method 2 each spent 4.97 hours and 5.15 hours while HT as the control spent 13.54 hours to finish the works. It means there are a reduction of 62% and 63% out of the work time by Current 1. In other locations, Current 1 may spend more than 30 hours per hectare for the three works. While, Current 1 needed 3 kinds of works (Ploughing, Puddling, and Finishing), method 1 and method 2 needed only 2 kinds of works which are plowing and puddling by bland or by the harrow. Work time per hectare by Method 1 and Method 2 are still less compared to plowing by Current 1, which is 5.94 hours.

Figure 6. Steps for land preparation by farming Bulldozer compared with Hand Tractor.
Figure 6 shows steps for land preparation by Method1 and Method2 compared with that by Current1. As mentioned earlier, Current1 spent 13 days to prepare the lands with the initial step to fill the land with water (1 day), then waiting for about 2 days to start ploughing (1 day), then wait for 3 days for incubation, then water filling again (1 day), then wait for 2 days, then puddling (1 day) while FB1 and FB2 can do all those steps for less than 3 days. Here, plowing finishes in a half day then continued with water filling, and border maintaining and water/soil leveling. Thus, Method1 and Method2 can save time 10 days. This simulation has considered drops of efficiency due to the larger cultivated area.

Treatments of NPK dosage of 100%, 80%, and 60% showed no significant effects on the yields based on Current1, Method1, and Method2. The yields varied from 6.02 t/ha to 6.78 t/ha of dried paddy. In the average, one plant produced 10 panicles consisting 127 grains out of which 87% was filled with weight 22.8 g/1000 grains. Reducing NPK dosage up to 60% would give a favourable implication to rationale the production costs.

4. Conclusions

Compared to hand tractor, Farming Bulldozer can reduce 10 days of land preparations from 13 days to 3 days (77%). While hand tractor needs more than 13 hours, the bulldozer needs about 5 hours to finish soil plowing, soil puddling, and water leveling. While hand tractor produced 66%, farming bulldozed resulted in more than 97% of soil flatness. The different uses of machinery and treatment of NPK dosage gained no effect on yields. Though the cost per hectare is a little bit higher, the farming bulldozer can accelerate land preparation and cover a broader area that cannot be reached or done by hand tractor.

5. References

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Acknowledgments
Authors wishing to acknowledge the management of Rice Research Institute belongs to the Ministry of Agriculture located in Sukamandi, Subang, West-Java for all assistance given and to the Komatsu Indonesia for lending the farming bulldozers and giving all valuable supports.

6. Appendices

Appendix 1. Specification of Farming Bulldozer DL21PL

| Specification                  | Value         |
|-------------------------------|--------------|
| Operating weight (kg)         | 4815         |
| Flywheel Power (HP/rpm)       | 44/2450      |
| Max Drawbar Pull (kN)         | 43.8         |
| Travel Speeds:                |              |
| 1 Forward/Reverse (km/h)      | 2.3/2.5      |
| 2 Forward/Reverse (km/h)      | 4.1/4.5      |
| 3 Forward/Reverse (km/h)      | 6.8/7.4      |
| Turning Radius (m)            | 2.4          |
| Dimensions (mm)               |              |
| Overall Length                | 4320         |
| Overall Width (with Blade)    | 2150 (2490)  |
| Overall Height                | 2450         |
| Length of Track on Ground     | 1820         |
| Track Gauge                   | 1450         |
| Shoe Width                    | 700          |
| Ground Clearance              | 340          |
| Engine:                       |              |
| Model                         | KOMATSU 4D94LE-2ZAD |
| Type                          | Direct Injection |
| Piston Displacement (L [oo])  | 3.053 (3053) |
| Blade:                        |              |
| Type                          | Straight Tilting Blade Hydraulics |
| Width (mm)                    | 2450         |
| Height (mm)                   | 590          |
| Max Lift/Drop (mm)            | 840/380      |
| Max Tilt Adjustment (mm)      | 320          |
| UC:                           |              |
| Type                          | Swamp Shoe   |
| No of Rollers Carrier/Track Rollers | 1/6         |
| HYD:                          |              |
| Max Oil Pressure (MPa)        | 15.2         |
| Discharge Flow (L/min)        | 59           |
| Tank:                         |              |
| Coolant (L)                   | 10           |
| Fuel Tank (L)                 | 60           |
| Engine Oil (L)                | 7.3          |
| PTO:                          |              |
| Clutch Type                   | Wet Type Multi-plate |
| Rotational Speed/Engine Speed | 540/2018     |