Tarjih: Agribusiness Development Journal. Volume 05 Number 01 (2025) Page: 91-100
DOI: https://doi.org/10.47030/tadj.v5i01.922

e-ISSN: 2798 - 0782
Tarjih: Agribusiness Development Journal
Journal Homepage: https://jurnal-umsi.ac.id/index.php/agribisnis

Transformation of Modern Agriculture through Agricultural Mechanization in Indonesia

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Received : May 6, 2025
Revised : June 23, 2025
Published: June 30, 2025

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ABSTRACT

Agricultural mechanization is one of the important components for modern agriculture in achieving sustainable food self-sufficiency targets. In fact, advances in mechanization technology will make agriculture triumphant, so that Indonesia as the world's food barn can be realized. This study aims to see how the development of innovation-based agricultural mechanization, as well as how the efficiency of agricultural products in the application of agricultural mechanization. The government through the Ministry of Agriculture has created many works to build mechanization 4.0, including (1) rice seed spreading drones, (2) rice planting robots, (3) autonomous tractors, and (4) integrated harvesting plus tillage machines. These four agricultural machines can be a solution for Indonesian farmers in running a modern farming business. The government, through the Ministry of Agriculture, has distributed agricultural machinery assistance in an effort to help farmers. The use of rice transplanter (transplanting machinery) can save 30 percent of planting costs compared to conventional planting methods. Nationally, the cost of planting that can be saved reaches Rp 8.6 trillion every year. Weeding tools, the use of weeding machines is three times faster than conventional methods with a savings value of Rp 7 trillion in weeding costs. The use of tractors for soil cultivation can also reduce the use of conventional labor with faster operationalization. The use of agricultural machinery, both pre- and post-harvest, is a driving force for accelerating the process of increasing production and farming efficiency so that farmers get greater benefits.

Keywords: *Mechanization, Agriculture, Farmers, Indonesia*

INTRODUCTION

The transformation of the economy (Loizou et al., 2019) and employment (Lu, 2009) between sectors has often been inconsistent and has placed agriculture in an important position (Chandra and Diehl, 2019). In simple terms this can be seen from the contribution of the agricultural sector in the national economy and the number of workers employed in agriculture (Suryana, 2008). In 1957 the contribution of agriculture in Indonesia and South Korea to their respective economies was 56 percent and 41 percent (Yang and Mei, 2017). After 45 years later, the contribution of agriculture to the economy in both countries decreased to 17 percent and 4 percent (Wang et al., 2019). At the same time the number of people working in agriculture in both countries changed at very different rates. In 1957 the number of people working in agriculture in South Korea and Indonesia was 70 percent and 61 percent respectively (Skobelev et al., 2019). By 2002 these figures were 12 percent and 44 percent respectively (Pingali, 2007). Based on these data, it can be seen that in Indonesia, for every 1 percent reduction in agricultural GDP, only 0.43 percent of the labor force leaves agriculture. Compare this with South Korea which achieved a very rapid transformation rate in employment (Yang and Mei, 2017), where every 1 percent reduction in agricultural GDP the number of workers leaving agriculture reached 1.56 percent. As a result, the remaining labor

force in agriculture in South Korea in 2002 was only 12 percent.

From the simple comparison above, it can be seen that economic transformation (Irawan, 2005) and employment (Ahmad, 2016) in Indonesia are not in line, so it can be said that the agricultural development cake continues to shrink and is contested by many farmers (Eryürük et al., 2019). Thus, it is certain that agricultural businesses will continue to be marginalized (Grace, Husak and Bogle, 2014) because they are dominated by small farmers or smallholders (Mamun, Nusrat and Debi, 2011).

Meanwhile, the transformation of agriculture towards modernization is characterized by the character of an industrial society with high productivity characteristics, efficient use of natural resources and technology, and able to produce by producing quality outputs and high added value (Huttunen, 2019; Kansanga et al., 2018). In other words, modern agriculture can be a form of farming system with very diverse product specialization, higher use of tradeable inputs, and has practiced a more efficient farm management system (Lu, 2009 Takeshima, Hatzenbuehler and Edeh, 2020). One of the characteristics of modern agricultural practices is the intensive and efficient use of agricultural mechanization (Van Loon et al., 2020; Eryürük et al., 2019).

Agricultural mechanization is one of the important components for modern agriculture (Abdi et al., 2010; Ulusoy, 1976; Huttunen, 2019) in achieving sustainable food self-sufficiency targets (Ahmad, Ali M.S.S & Rahmadanih, 2017). Even advances in mechanization technology will make agriculture triumphant (Olmstead and Rhode, 2014), so that Indonesia as the world's food barn can be realized. Advances in mechanization can encourage youth to plunge into the fields to become farmers. Youth have the ability to innovate or make new breakthroughs, so that they can optimize and awaken idle land and tidal land. In the past, young people did not want to go to the fields, but now many become farmers while carrying tractors and sometimes talking on cell phones. Therefore, if the youth are engaged, Indonesia is optimistic about becoming the world's food barn and realizing the nawa cita of building the country from the periphery.

In modern agriculture (Kansanga et al., 2018), farmers are active as role holders by utilizing technology and information (Yang and Mei, 2017; Wang et al., 2018, 2019; Rudnick et al., 2019) . The success of modern agriculture depends on the linkages between business actors, access to resources, technology, management, investment, markets, and government policy support. According to Dohm (2005), the development of modern agriculture is not only how farmers use the latest technology in sustaining increased productivity of agricultural businesses, but more importantly it is how agricultural activities are managed as a successful business (Fitzgerald et al., 2019; Eryürük et al., 2019; Abdi et al., 2010).

The urgency of agricultural modernization is based on the argument that food sovereignty can only be achieved if the productivity and efficiency of agricultural production increases (Pingali, 2007; Olmstead and Rhode, 2014; Qiao, 2017; Loizou et al., 2019). Modernization is expected to be the key to increased production and efficiency of labor, time, and costs (Olmstead and Rhode, 2014; Qiao, 2017; Fitzgerald et al., 2019; Loizou et al., 2019; Wang et al., 2019). In the concept of modern agriculture currently developed by the government, farmers as the main actors are also encouraged to be able to control upstream to downstream. They must add value to the products they produce. Thus, new labor can be absorbed and save millions of farmers in rural areas to remain prosperous.

Another important thing towards modern agriculture is that the government also intensifies mechanization and continues to encourage the development of various agricultural technologies and innovations. Efforts to intensify mechanization are pursued through increased provision of agricultural machinery assistance as well as training and mentoring. The development of technology and innovation is done through adaptive research to answer the needs in the field.

Modern agricultural development must remain environmentally friendly which ensures the sustainability of production (Collins and Fairchild, 2007; Mamun, Nusrat and Debi, 2011; Ely, Geall and Song, 2014; Ali and Suleiman, 2016; Vergragt et al., 2016; Pradhan et al., 2017) . In this context, modern agriculture is basically an agricultural business that utilizes the latest technology that is appropriate to the agroecology and socio-economy of farmers, productive, efficient, and profitable for farmers (Griggs, 2011; Yang and The, 2011; DING et al., 2015). The use of superior varieties of seeds, fertilizers, pesticides, herbicides, irrigation arrangements, the use of agricultural machinery at various stages of the production process to the processing of crops are the characteristics of modern agriculture in the production subsystem (Clark, 2007; Fedrigo and Tukker, 2009; Kang et al, 2013; Alho, 2015; Vittersø and Tangeland, 2015; Eltholth et al., 2015; Margarido and Santos, 2015; Ali and Suleiman, 2016; Lukman et al., 2016; Gebreyes, 2017; Pradhan et al., 2017) . The application of green revolution technology in wetland rice cultivation is a representation of modern agriculture for Indonesian rice farmers, despite the limited use of farm machinery. Modern agriculture has been convincingly proven to provide food for 250 million Indonesians with limited land area. However, it is a concern and should be studied in the context of modern agricultural development in Indonesia, how to develop agricultural mechanization based on innovation, and how the efficiency of agricultural products in the application of agricultural mechanization.

RESEARCH METHODS

Research Design

The research is literature study research by reviewing analyzing articles, reports and related literature agricultural management using agricultural mechanization in Indonesia. The results of this literature review will be used to identify how the development of innovation-based agricultural mechanization, as well as how the efficiency of agricultural products in the application of agricultural mechanization.

RESULTS AND DISCUSSION

Development of Innovation-Based Agricultural Mechanization

The application of agricultural mechanization in farming activities is one form of agricultural transformation towards modernization which is characterized by high productivity, efficiency, and produces quality outputs and high added value (Pingali, 2007; Lu, 2009; Abdi et al., 2010; Huttunen, 2019; Van Loon et al., 2020) . In the last four years, the Ministry of Agriculture has produced technological innovations in horticulture, livestock, plantations, agricultural mechanization, and other supporters such as biotechnology, mapping, fertilization, and post-harvest agriculture (Ministry of Agriculture, 2019c) .

In general, agricultural mechanization can also be defined as the application of engineering science in developing, organizing, and controlling the operation of agricultural production processes (Olmstead and Rhode, 2014) . The scope of agricultural mechanization develops in line with technological developments and agricultural modernization (Loizou et al., 2019; Van Loon et al., 2020) . Agricultural mechanization aims to increase labor and land productivity and reduce production costs. The use of agricultural machinery in the production process is intended to increase efficiency, effectiveness, productivity, yield quality, and reduce the workload of farmers. Therefore, optimal utilization of available land needs to be supported by a good agricultural mechanization system. Technology-based agricultural development (innovation) is a stage in responding to the challenges of the industrial revolution 4.0 . This is clear evidence that future agricultural development is increasingly responding to the development of modern technology. In this context, mechanization not only plays a role in improving production quality and saving costs, but also in improving the welfare of farmers and realizing Indonesia as the world's food barn.

Mechanization technology innovation is the key to the success of national agriculture. In this case, modern agricultural automation technology plays an important role in supporting the development of agricultural commodity products. Modern mechanization technology is developed to the fullest, including private seed production institutions and farmer groups.

The government through the Ministry of Agriculture has created many works to build mechanization 4.0, including (1) drone seed spreader rice , (2) rice planter robot, (3) autonomous tractor, and (4) integrated harvest plus tillage machine. These four agricultural machines can be a solution for Indonesian farmers in running modern farming businesses (Ministry of Agriculture, 2019) .

The seed dispersal drone is capable of dispersing seeds for one ha of land within 1 hour. Its capacity reaches 50-60 kg per ha. The seed spreading drone works independently according to the pattern or flow that has been made on the android device and is guided by GPS. The drone is also capable of resume operation, so that the delayed operation can be resumed automatically to avoid overlap. The drone battery can operate for 20 minutes with a maximum carrying capacity of 6 kg of rice seeds (Ministry of Agriculture, 2019a) .

The rice planting robot functions to plant rice seedlings in paddy fields. This robot is able to communicate through the *Internet of Things* (IoT) via GPS and work independently. The rice planting robot can communicate via GPS. The performance specifications of the rice planting robot are 30 cm planting width, six planting rows, working speed of 2 km per hour with a working width of 1.8 m, working capacity of 0.36 ha per hour or 3 hours per ha (Ministry of Agriculture, 2019a) .

Autonomous tractor or unmanned 4-wheel tractor controlled by an IoT-based navigation system. This tool can perform tillage according to the planning map using GPS. While rice harvesting machines integrated with tillage are able to carry out two activities at once, namely harvesting rice and cultivating the soil with rotary (Ministry of Agriculture, 2019a) .

According to Ministry of Agriculture, (2019b) autonomous tractor is the latest innovation produced through its organ Balai Besar Pengembangan Mekanisasi Pertanian (BBP Mektan). This autonomous *four-wheel* tractor uses a GPS navigation system based on *Real Time Kinematics* (RTK). This unmanned tractor functions to cultivate land using a 4-wheel tractor with a steering system that can be controlled automatically. This autonomous tractor can also do tillage according to the planning map with an accuracy of 5-25 cm. The control system on the

tractor consists of steering, gas, gear, brake, and clutch controls. For tillage applications using implements and PTO control. The novelty of this engineered four-wheel autonomous tractor can be seen from the development of a modular-based RTK Base *Rover* navigation system (not a brand of telemetry equipment such as Leica or Trimble), so that it can be self-produced at low cost. In addition, there is also a communication system between the tractor and *base station* with TCP/IP protocol with 2.4 or 5 GHz *wireless* media, the availability of *command control* to control the tractor in the form of parameters with text format through a serial *interface*.

Other advantages and novelties of autonomous tractors are the availability of a modular *controller* design that can be transferred to other tractors, simple i 2c protocol-based intermodular sensor and actuator communication standards, mapping applications that can be used for tillage in different locations, and the availability of control actuators with simpler systems. If this latest technological innovation has been adopted and mass-produced by agricultural machinery companies, it can be utilized to increase the efficiency and effectiveness of farming efforts so as to increase production and farmers' welfare.

Currently, more *advanced* technology is needed, namely digital technology. One of the collaborations that can be carried out between BB Mektan and PT Yanmar DieselIndonesia is to implement *smart assists* for agricultural machinery, especially on-farm such as tractors, *combine harvesters*, and transplanters. With smart assist, users (farmers) can check the area of land being cultivated at that time in real time, the number of tractors working, as well as the duration of work of the equipment attached to the smart assist. Thus this digital technology can predict when fast moving components should be replaced.

Figure 1. Rice transplanting robot
(Source: BB Padi, 2019)

Figure 2. Autonomous tractor
(Source: Badan Litbang Pertanian, 2018)

Improved Agricultural Machinery Assistance

Along with the free market or trade globalization, the flow of goods including agricultural products will be freer and easier to enter Indonesian territory. This will pose a threat to local farmers and potentially lead to national food dependence on foreign production. The key to facing trade globalization is production efficiency. The threat can be faced with three micro steps (Khaeron, 2017), namely: (1) increasing production in order to meet national food needs, (2) increasing production cost efficiency so that agricultural products have price competitiveness, and (3) improving the quality of competitive products.

All these steps are inseparable from the successful implementation of modern agricultural technology. Through government policies that prioritize siding with farmers, including significantly increasing the facilitation of agricultural machinery assistance, has shifted the position of agricultural businesses from traditional systems to modernization.

Modernization of agriculture can also be seen in the use of better and more effective cultivation methods, the application of agricultural machinery with appropriate technology, starting from land processing, harvesting and post-harvest handling, the use of superior seeds, appropriate and sufficient fertilization, the use of more qualified agricultural human resources, and the efficient use of natural resources, especially irrigation water, so that environmental balance is maintained. Modernization also covers post-harvest aspects such as harvesting methods, processing of products and making modern and safe packaging, efficient trade systems, and continuously improving government policies that are conducive to agricultural business activities.

Based on the Technical Guidelines for Procurement and Distribution of Agricultural Machinery Assistance of the Directorate General of PSP of the Ministry of Agriculture (2018), the types of assistance include two- and four-wheeled tractors, water pumps, *cultivators*, rice planting tools, *excavators*, *hand sprayers*, corn planting tools, and rice harvesting tools. The assistance is provided to farmers through farmer groups in various

agricultural centers. With the use of these agricultural machines, farmers can utilize technology to shorten the time and process of cultivating crops and harvesting simultaneously.

In the 2010-2014 period, the number of agricultural machineries distributed was less than 50,000 units and in the 2014-2018 period increased to 429,413 units (Warta Ekonomi, 2019). The amount of agricultural machinery assistance in 2014 reached 12,501 units, then increased to 56,785 units in 2016, and almost tripled to 148,804 units in 2017. In 2018, agricultural machinery assistance was recorded at 126,942 units.

Compared to the number of synthetic agricultural machinery in 2013 which only reached 7,633 units, the number or distribution of mechanization in the 2014-2018 period increased to 421,780 units or increased by 5,526 percent. In 2019, in the context of the development and application of agricultural mechanization, the distribution of agricultural machinery is still in process, which is targeted at 61,879 units.

The massive assistance of agricultural machinery to farmers since the end of 2014 has raised the level of use of Indonesian agricultural mechanization. The level of mechanization is the usability of agricultural machinery to the area covered. According to the Agricultural Research and Development Agency (2018), in 2015 the level of Indonesian agricultural mechanization only reached 0.5 HP per ha, then in 2016 and 2017 it became 0.83 HP and 1.18 HP respectively. In 2018 the level of agricultural mechanization increased by 236 percent to 1.68 HP per ha. Therefore, a significant increase in the level of agricultural mechanization is a leverage point in increasing the modernization of Indonesian agriculture. As an illustration, the level of agricultural mechanization in 2015 in developed countries such as the United States has reached 17 HP and Japan 16 HP per ha. While in Malaysia 2.4 HP, Thailand 2.5 HP, and Vietnam 1.5 HP per ha.

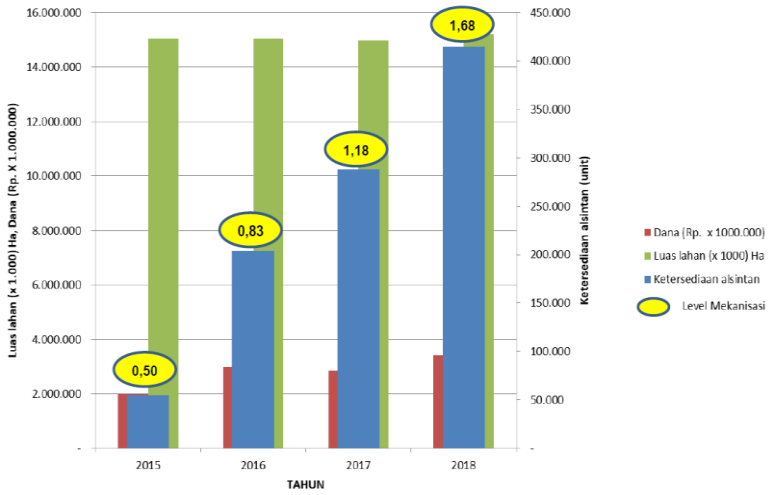

Figure 3. Development of agricultural mechanization level in Indonesia 2015-2018 (Source: Badan Litbang Pertanian, 2018).

The estuary of increased agricultural machinery assistance is to increase the production of agricultural commodities that are more competitive. The savings in production costs are expected to increase farm profits. This is a source of incentive for increasing agricultural production at large.

Agricultural Production Efficiency

According to DG PSP (2019), agricultural modernization through the use of agricultural machinery has significantly increased the productivity of food commodities and the income of farming families. The use of agricultural machinery at every stage of production, harvest, and post-harvest activities saves the cost of tillage, planting, weeding, and harvesting because most of the labor has been replaced by faster and more efficient machinery. Agricultural modernization can also encourage people's interest, especially the younger generation, to enter the world of farming. Initially, farming was considered a job that did not provide adequate incentives, was muddy, exposed to the sun, and relied more on muscles. The implementation of mechanization 4.0 in the agricultural sector makes the farming process more efficient because it can reduce production costs and increase productivity and competitiveness.

The implementation of agricultural mechanization technology can increase production by 10 percent, reduce harvest loss by 10.2 percent, and save production costs by 40 percent. Before the existence of planting tools, planting activities cost around Rp 2 million per ha. The use of mechanization reduces planting costs to Rp 1 million per ha. Thus, from 600 million ha of agricultural land throughout Indonesia, farmers can save up to Rp 16

trillion per planting season (Ditjen PSP, 2019).

Without mechanization, harvesting activities for 1 ha of land takes 25 days, while the use of agricultural machinery only takes 3 hours with a harvesting cost of Rp 2 million per ha per season. Agricultural mechanization can also save rice yield losses of 10.2 percent or the equivalent of 7 million tons of rice. The use of mechanization technology reduces harvesting costs to Rp 1 million per ha per season (Table 1). Economic analysis shows that the cost of manual rice production, especially for tillage, planting, harvesting, and post-harvesting is Rp 6,500,000 per ha per season. The use of mechanization technology saves production costs by 40 percent to IDR 3,600,000 per ha per season (DG PSP, 2019).

Table 1. Comparison of time and cost of conventional and modern (mechanized) rice cultivation

Description	Conventional farming	Modern agriculture
Time to harvest	25 days	3 hours
Harvest cost (IDR/ha/season)	2.000.000	1.000.000
Production cost (IDR/ha/season)	6.500.000	3.600.000

Source: DG PSP (2019).

Kariyasa's study (2018) shows that the acceleration of agricultural mechanization has an impact on various aspects: (1) saving farming costs; (2) increasing rice productivity; (3) saving costs and increasing production to compensate for the decline in prices received by farmers so that NTP continues to rise; (4) lifting the status of farmers from poor to prosperous; (5) saving the use of labor and increasing added value so that agricultural labor productivity increases.

Farming costs that can be saved through agricultural modernization, starting from tillage, seed sowing, planting seedlings, weeding, and harvesting reach 30.9 percent. The reduction in rice farming costs with agricultural modernization reached Rp 2.28 million per ha per season compared to farming without mechanization.

Table 2. Potential Cost Savings from Farm Modernization (Ha/season)

Activity Type	Conventional Agriculture	Modernization of Agriculture	Savings	
			Rp	%
Land Processing	1.600.000	1.200.000	-400.000	-25,0
Sowing to Planting	1.720.000	1.100.000	-620.000	-36,0
Weeding	1.200.000	510.000	-690.000	-57,5
Harvest	2.857.125	2.285.700	-571.425	-20,0
Total	7.377.125	5.095.700	-2.281.425	-30,9

Source: Kariyasa (2018)

The increase in productivity that can be achieved from the implementation of agricultural mechanization reaches 33.83 percent, which comes from planting seedlings using a transplanter, harvesting using a combine harvester, and creating efficiency in the use of farming inputs.

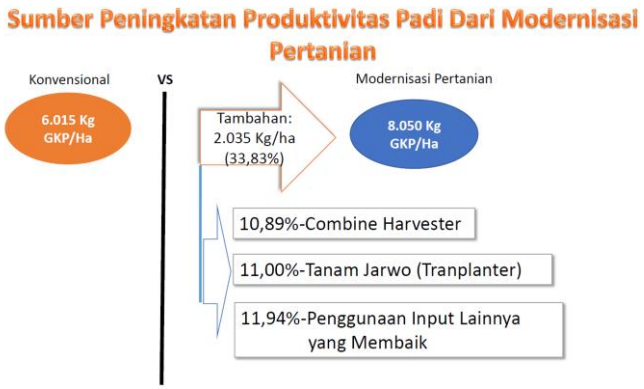

Figure 4. Source of increasing rice productivity with farm modernization in 2018 (Source: Kariyasa, 2018).

Meanwhile, another impact of agricultural modernization is that there are additional cost savings and production increases that can compensate for the decline in prices received by farmers. The study results show that during January-May 2018 and 2019, although output prices fell, due to cost efficiency and increased production, the Farmer Exchange Rate (NTP) continued to rise. In January 2018, the NTP value was 103.06 and in January 2019 it increased to 103.32. In May 2018, the NTP value was 101.61 and in May 2019 it increased to 102.61.

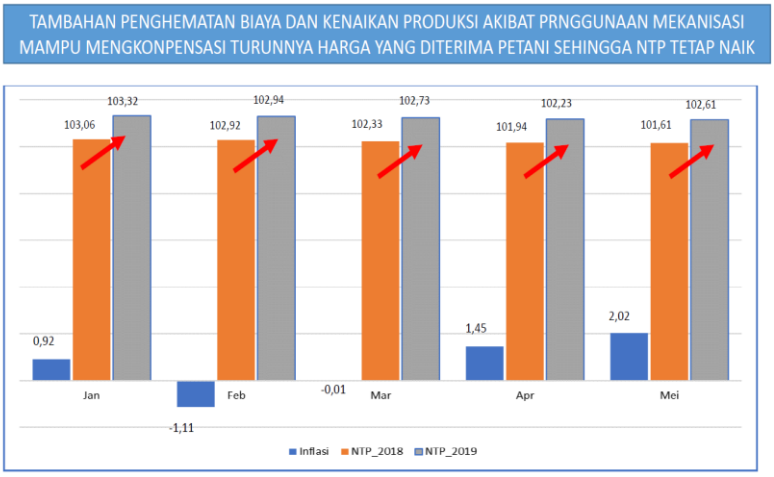

Figure 5. The incremental impact of cost savings and production increases with the use of mechanization technology on NTP
(Source: Kariyasa, 2018)

The additional cost savings and increase in production due to the use of mechanization can compensate for the decline in price increases received by farmers, thus lifting the status of farmers from poor to prosperous. The data shows that the use of mechanization technology has an impact on increasing food production, leading to price stability and lower inflation. The use of agricultural mechanization also reduces farming costs, which in turn improves farmers' welfare. Based on the results of the analysis, it appears that during the 2014-2018 period food inflation fell by 67.74 percent, while the value of the Farmer Business Exchange Rate (NTUP) rose by 5.45 percent and the NTP rose by 0.42 percent.

The results of a study by Hermanto et al. (2016) in Cianjur District, West Java, showed that the existence of agricultural mechanization assistance increased rice farming productivity by 5.4 percent. This is due to the acceleration of planting so that the plants grow simultaneously.

Table 3. Analysis of rice farming business per ha before and after the mechanization assistance program

No.	Item	Before the program	After the program	Change (%)
1	Productivity (Kg/ha)	5.600	5.900	5,4
2	Labor (IDR/ha)	6.446.000	6.254.000	-3,07
3	Farming input (IDR/ha)			
	-Seed	300.000	300.000	0,00
	-Pesticides	350.000	350.000	0,00
	-Fertilizer	780.000	780.000	0,00
	Total farm inputs	1.430.000	1.430.000	0,00
4	Other expenses	100.000	100.000	0,00
5	Total cost (IDR/ha)	7.976.000	7.784.000	-2,47
6	Total revenue (IDR/ha)	20.160.000	21.240.000	5,08
7	Total income (IDR/ha)	12.184.000	13.456.000	9,45
8	B/C ratio	1,53	1,73	2,34
9	R/C ratio	2,53	2,73	3,34

Source: Hermanto et al. (2016).

This condition is also supported by the availability of water that suits the needs of plants and reduced attack intensityhama . In addition, farmers were also able to save on land processing costs by 3.07 percent. As a consequence, production costs were reduced by about 2.5 percent and farmers' income increased by 9.45 percent.

CONCLUSION

Modernizing agriculture through the development of mechanization is a necessity because it can overcome the problem of labor shortages and at the same time reduce yield losses during harvest. The government through the Ministry of Agriculture has created many works to build mechanization 4.0, including (1) rice seed spreading drones, (2) rice planting robots, (3) autonomous tractors, and (4) integrated harvesting plus tillage machines. These four agricultural machines can be a solution for Indonesian farmers in running a modern farming business. The government, through the Ministry of Agriculture, has distributed agricultural machinery assistance in an effort to help farmers. The use of rice transplanter (transplanting machinery) can save 30 percent of planting costs compared to conventional planting methods. Nationally, the cost of planting that can be saved reaches Rp 8.6 trillion every year. In weeding, the use of weeding machines is three times faster than conventional methods with a savings value of IDR 7 trillion in weeding costs. The use of tractors for soil cultivation can also reduce the use of conventional labor with faster operationalization. The use of agricultural machinery, both pre- and post-harvest, is a driving force in accelerating the process of increasing production and farming efficiency so that farmers get greater benefits.

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