Towards sustainable agricultural mechanization in Indonesia

A conceptual model of innovation technology

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Innovation towards modern agriculture is characterized by increasing productivity, efficiency, quality and added value of agricultural produce. As a process towards this modern agriculture, traditional rice culture in Indonesia has moved significantly from manual practices to a certain level of mechanized farming. However, historical evidences of Indonesian rice mechanization indicate that the process is relatively slow when compared with other Asian countries. This is related to the existence of infrastructure, institutional, technological capacity, cultural endowment and farmers' empowerment in assessment technology and information. A certain path called a sustainable path needs to be identified during the development plan. This path would indicate the level of mechanization that is suitable to technology, institution, infrastructure and bio-economic environment.

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Introduction

Increase productivity through intensification, reduce post-harvest losses, increase added value and maintain the quality of farm product – these are the multiple objectives of farm mechanization in Indonesia. In addition to these, the overall goals of farm mechanization are to increase the welfare of farm households and create employment opportunities in the rural areas. All of these may not be achieved by a single strategy, such as increasing the number of machinery used for farm production. They will need a long-term strategy to re-energize rural development as a whole, which will enable farmers to improve their capacity to adopt a technology suitable for running their farm business efficiently. Farm mechanization includes not only the use of machines – like tractors, irrigation pumps, threshers or rice mill – but also the cultural changes, and the processes of invention, innovation, adoption and commercialization of technology.

Small farm mechanization system development in Indonesia started with

material transfer in the year of 1950, followed by design transfer in 1970 and then capacity transfer beginning in 1980 (Handaka, 2003). It was in line with the development stages of rice cultivation in Indonesia (Ananto and others, 2004), which are identified as the period before the green revolution (1950-1970) and after the green revolution (1970-1990). The failures and successes in these stages have provided the new orientation needed for sustainable development.

The next development phase will be more complex and competitive for the country, since global changes in information technology and economy will have an impact on national capacity in generating, adopting, adapting and delivering the best-suited technology for the benefit of the farmers.

General situation in Indonesian agriculture

Agriculture in Indonesian economic development

Indonesia has a large population of about 220 million (2003), of which 62 per cent lives in Java Island, which occupies only 7 per cent of the total land area. The agricultural sector accounts for a large portion of population with low income. The ratio of agricultural income to non-agricultural income is about 1:6.

The relative share of agriculture in GDP fell from about 32 per cent in the mid-1970 to about 25 per cent in the mid-1980, while the relative share of agricultural employment in the total labour force depleted from about 67 per cent in the early 1970s to 55 per cent in the early 1980s. The aggregate performance of the agricultural GDP at present is good, although not spectacular. The sector employs the largest share (45 per cent) of Indonesia's labour and its contribution to the GDP is the second largest (17 per cent), though far below those in the 1970s and 1980s.

Largely, agriculture plays a crucial role in contributing to the major socio-economic development objectives – GDP growth, employment, improved nutrition and food security, poverty alleviation, and the balance of payment.

As part of a structural transformation process, the government in 2004 launched a programme to revitalize agriculture through (a) increased food security system, (b) agri-business development, and (c) improved welfare of farmers. Increased food security system includes increased food production through crop intensification, land development for rice and other food crops, irrigation efficiency, optimum use of farm machinery, and reduction of post-harvest losses. Agri-business development entails product diversification, quality achievement and development of industry in rural areas. These are supported by quality human resource development for extension, education and training. Financial aid will be created to facilitate small farmer's access to credit.

Data on the growth in production of rice (the staple food grain in Indonesia) are provided in Table 1. It can be seen that, during 1999-2003, the average rice yield increased from 4.25 t/ha to 4.54 t/ha. Production of rice (and other agricultural commodities) has increased quite surprisingly. For instance, rice production increased by about 4.7 per cent in 2007 and is expected to increase further up to 5 per cent in 2008. It is among the highest yield in Asia, which reflects the level of rice intensification in the country.

Statistical data on the land ownership and household incomes (Siregar, 2006) indicated that farm households were the lowest income group, and consisted of more than 44 per cent of total households. Among the farmers, landless farmers and households with less than 0.5 ha land had disposable incomes of US$250 and US$300, respectively. Farm households with landholding from 0.5 ha to 1.0 ha and more than 1.0 ha had incomes of US$350-US$400. Non-agriculture households had incomes between US$400 and US$500, while the urban households had income more than US$900/year.

The income differences between these household groups provide the best socio-economic indicator set for stressing the need for technological innovation, adoption and utilization. This shows the importance of considering the socio-economic condition of the country in selecting the level of mechanization technology. Choosing technology based on the economic scale of society is very important, so that one doesn't end up with a premature technology.

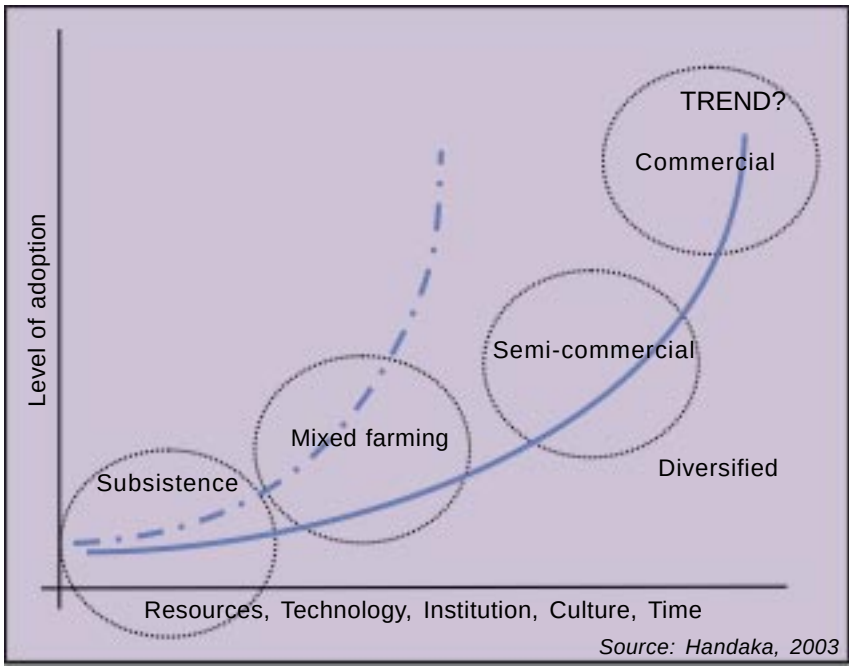
The data, however, also indicate some contradictory facts. The use of farm machinery – such as power tiller and portable thresher – is increasing rapidly in densely populated areas – Java, Sulawesi and Bali islands, for example – where the infrastructure such as irrigation and transportation are far better than in the other islands. Another indication is that the shift in the harvesting labour contract system has also influenced the use of post-harvest machinery. Therefore, a more specific technology innovation process for mechanization should be put into the development planning agenda of the country. What will be the structure of technology innovation in the global economic development climate? Global economy has strongly affected the choice of technology for small farms through free trade, information and competition. Even in a developing nation like Indonesia, the market has already opened up. Hence, Indonesia must decisively address sustainable farm mechanization to avoid what is called premature mechanization.

Table 1: Rice harvest area, production and productivity

Year	Harvest area (million ha)	Production (million tonnes)	Productivity (t/ha)
1999	11.96	50.87	4.25
2000	11.79	51.90	4.40
2001	11.50	50.46	4.39
2002	11.52	51.49	4.47
2003	11.49	52.14	4.54

Source: Central Bureau of Statistics, 2003

Figure 1: Evolutionary process of farming system and farm mechanization



Source: Handaka, 2003

The evolutionary process of farm mechanization

Historical evidence of farming system development in Indonesia points to the need of analysis of the evolutionary process of farm mechanization technology. Figure 1 shows the evolutionary process of mechanization technology in the country. A farm system moves from the subsistence to the commercial farm stage along a sustainable path. The development stages illustrate the technology adoption capacity that moves from one stage to another, influenced by variables such as infrastructure, cultural endowment, resources endowment, institutional arrangement, technology innovation, economy and cultural behaviour. The farm system's capacity to improve productivity is dependent upon its capacity to adopt, adapt and manage technology, institution, capital and other resources.

Government intervention in this process could facilitate the change or provide conditions that help accelerate the evolution. The intervention, however, could also precipitate premature mechanization if not properly planned (non-sustainable path). For example, subsidy for lowering the price of machinery and the large quantity of machinery supplied to farmers as aid – with minimal assistance in the selection, implementation and training for use of that machinery – would create an unsustainable development problem.

There are some critical issues that need to be worked out by the decision makers, researchers, scientists, farm mechanization professionals and the users of farm machinery. Do the small farmers really need mechanization? What will be the mechanization system suitable for them? How should it be developed? What conditions are required for adopting and implementing mechanization? Answers to these are necessary for small farm mechanization aimed at the revitalization of the agricultural sector.

At the first stage, the subsistence stage, farm mechanization is just beginning. No machinery is needed for any kind of farm work at this stage. It exists in remote and less developed areas when technology, infrastructure, institution, information and culture are isolated. It happens if communication between a village and the market is closed or limited, for example, in a transmigration area. This situation will change if the isolation is ended, and communication develops step by step and the market works.

If the farmers feel any additional income or profit can be made by using machinery, they will adopt only the machinery for land preparation but also those for post-harvest processing, through innovation process. This will spread from the individual farmer to the community, the region and the nation via the market. The changes will move up from the subsistence to the mixed, diversified and commercial farming systems, and then farm mechanization will follow this path of development (Table 2). In Figure 1, moving from the solid line towards the dotted line indicates the rapidity of these changes. If it is needed, then such changes should be encouraged. In this evolutionary process, the government could also encourage the development by facilitating mechanization process, but this policy must be designed without any distortion of the market mechanism to avoid premature mechanization (Hayami and Kawagoe, 1989).

Innovation process of farm machinery

Importance of innovation

There are several definitions for innovation, but for the purpose of this article we will take one that is related to rural economic development. Innovation is processes that take place when knowledge, technology or information is made available and is put to use in socially progressive and economically productive ways by a group of linked actors (organizations/individuals) in rural areas. It demands the capacity to access, adapt and apply knowledge to specific contexts, and to learn and evolve continuously (Raina, 2007). Accordingly, innovation in rural and agricultural development is a system, consisting of many components, that deal with the process of change in rural areas. The intricacy of innovation system was depicted as a process of crossing the "Darwinian seas" separating the continent of invention from the continent of successful innovation and commercialization (Juma and others, 2001).

Table 2: Evolutionary Process of farm mechanization related to farming system stages

Variables	Farming stages			
	Subsistence	Mixed	Semi-commercial	Commercial
Seed input	On farm production, farmer-to-farmer exchange	On farm production, farmer-to-farmer exchange, some purchase	Frequent purchase	Permanent purchase (annually)
Farm worker	Family workers	Partly hired labour	Mostly hired labour	Hired labour and specialist
Output utilization	All consumed for the whole family	Mostly consumed and partly sold	Sold at the local market or nearby market	Commercially sold to the big market
Product diversification	Limited	Mostly simple diversification for the family	Already diversified but in small part	Specific product and highly for commercial market
Institutional set-up	Local and traditional information; farmer to farmer	Use local market and limited information	Local and regional institution set up, farm association built, market available	Full market orientation; financial backing by farmer's bank or investment
Mechanization level	Limited with simple tools	Mostly manual and simple tools with the help of animal power	Small mechanization with limited capacity for selected work	Use mechanization for any kind of work that is suitable

Source: Handaka, 2005

At present, the important feature of Indonesian agriculture is the reducing poverty in rural areas through increasing productivity, efficiency, quality and added value of farm produce. Indonesia achieved self-sufficiency in rice production in 1984. But currently, although rice yield has increased to 5.2 t/ha, the country is importing rice to maintain price stability.

Innovation has played a lead role in generating technologies – such as new varieties of grains, legumes and other crops – suitable for prevailing economic conditions. However, the sustainability of the innovation still depends largely on how the nation will put the agenda of research and development (R&D) in agriculture as the primary driver of innovation. R&D in agriculture is very rare, and almost non-existent in the private sector: most of it is conducted by public research institutes, including state universities. Kremer and Zwane (2003) indicated that private R&D investment in Indonesia was only 0.1 per cent of the GDP.

Empirical evidences of farm mechanization in Indonesia

The simplest way to measure the need of farm mechanization is the increase in the number machinery in use. It is not easy to collect this data, but the National Bureau of Statistics has collected the data formally, beginning in the middle of 1980 (Table 3).

More than fifty per cent of power tillers are located in Java, even though Java is the most densely populated area. Among four provinces in Java Island, the West Java province has the largest number of power tillers; however, the number of threshers is too small when compared with other provinces. Even though this province has the highest level of intensive rice cultivation, supported by the large irrigation facilities. Other provinces with increasing number of farm machinery are South Sulawesi, West Sumatera and Aceh.

The use of water pump is connected with ground water availability. A study on the development of ground water for productive farming in East Java (Abi Prabowo and others, 2002) indicated that the utilization of water pump has (a) enabled farmers to increase income by increasing number

Table 3: Use of selected farm machinery in Indonesia (1999-2003)

Machinery	1998	1999	2000	2001	2002	Ann. growth (per cent)
Hand tractor	84,178	86,944	99,304	86,644	103,446	6.0
Pesticide applicator	1,642,686	1,760,543	n.a.	1,562,217	n.a.	3.4 [b]
Irrigation pump	117,340	166,030	190,013	215,774	216,643	17.5
Thresher [a]	370,426	375,299	388,609	340,654	347,658	-1.68
Dryer	5,778	5,798	6,238	7,117	5,045	-1.8
Rice mills	43,071	42,816	45,402	39,996	46,123	2.2

a. Estimated number consist of 30 per cent power thresher and 70 per cent manual thresher including pedal

b. Data of the period 1997-2001

Source: Central Bureau of Statistics (1999-2004)

of crops, (b) increased the awareness of the farmers on the degradation of quality and quantity of water availability, (c) changed farmers orientation from protective irrigation (using water for protecting crop) to productive irrigation (using water to secure the productivity of the land and added value of the farming system).

In 1980, at least 97 per cent of the total rice produced was being processed using machinery, including small, medium and large rice milling machines. Tjahyohutomo (2003) had reported that small rice mill produced the lowest milling recovery of 55.7 per cent. The medium rice mill showed a recovery of 59.7 per cent, while the large rice mills recovered 61.5 per cent of the rice milled. The quality of rice was also reflected by the level of milling machines: the larger the machine, the better the quality.

At the same time, there was significant growth of mobile rice milling machines in rural areas. Thousands of such machines were demanded by small rural households, especially those who harvested only 100-200 kg. The reason was very simple – quick service and reasonable cost. But the problem was that this machine was low in quality and milling recovery. The increasing number of the machine, which was performing "illegal" milling, caused problem for the regular millers; it caused a fall in the number of small, stationary rice mills.

Small-scale post-harvest mechanization has developed remarkably. As a tropical country, Indonesia produces several types of grains and legumes as important secondary food crops. Common problems that affect both grain and legume production are high post-harvest losses, relatively low quality and low status in food safety. Grains and legumes are susceptible to the mycotoxin contamination that poses a health risk. To address these problems, the government at all levels has supported the farmer, particularly in the field of post-harvest technology, by conducting R&D, training and extension activities. As a consequence, the growth of post-harvest mechanization has been faster than that of pre-harvest mechanization. For instance, in groundnut production, the usage of pre-harvest machinery such as small planters, cultivator and ridgers are very rare. In contrast, usage of post-harvest machinery has been common even at the village community level. The use of small machinery such as peanut sheller, dryer and grader indicate that the trend would increase in the near future.

Innovation systems

Many factors have contributed to make the need of agricultural technology different between the developing and the developed countries. In general, the capacity of agricultural research to contribute to agricultural produce is relatively low in developing countries like Indonesia (Kremer and Zwane, 2003). This weakness may contribute to the gap between the developed countries and developing countries in the field of production, quality and added value. The factors that contribute to the technological gap are economical growth, development of science and technology, infrastructure and the political will of the government.

Innovation systems in rural agriculture involve the process of change in rural areas, and this involves beliefs, values and institutional aspects, and some others that are not hardware or physical product. Innovation systems involve several sources of knowledge and skills, continuous cycles of learning and change among the actors of innovations, and enabling institutional arrangements put on the process (Raina, 2007).

Mechanization strategy

Some parameters should be carefully considered in developing farm mechanization in Indonesia. According to the social economic condition indicated by Siregar (2006) in the previous section, two approaches may be applied in considering a historical evidence, and also the progress in innovation technology and the development in farm machinery industry. First, a selective approach that should be applied to the region or area that is still in the stage of development process or an area where cost of labour is low. Second, a progressive approach that takes competitive market as a key factor for development, and usually applied in the case of post-harvest processing of agricultural products that need high quality standards. In any case, farm mechanization must be designed after a feasibility study and a pilot project. A working map or reference map of the indicated farm mechanization zone also needs to be developed.

Conclusion

Modern agriculture is characterized by high productivity, efficient use of natural and technological resources, adequate product quality and quantity as demanded by the market, and competitive pricing of the product. It is a continuous process that is required to improve the performance of farming systems, facilitating the transformation from the subsistence to commercial farms.

Farm mechanization in Indonesia is a process of technological evolution. It is one of the inputs required to improve the modernization process. It has a strategic role in the dynamic transformation from the subsistence to modern farm. That role comprise: (a) increasing production and productivity, (b) increasing the efficiency of the process and natural resource utilization, (c) improving the quality and added value of the agricultural produce, and (d) increasing the income of farm households.

Government could play a critical role in facilitating extension, training and education needed for competitive human resources development, contributing directly or indirectly to build the needed infrastructure (road, irrigation facilities, electrification, etc.). Farm mechanization should be developed based on market mechanism. In special cases, government could play an important role by providing assistance through cheap credit, but only for a fixed, short period. The government could also encourage the development process by enhancing mechanization development, but this policy must be designed without any distortion of market mechanism, to avoid premature mechanization. Farm mechanization in Indonesia must be strategically developed through three

fundamental steps: a feasibility study, pilot projects and development.

Small to medium mechanization will coninue to dominate the future prospect of farm mechanization in the country. Post-harvest mechanization for processing agricultural products will be strongly needed in the rural industrial processes, and it will be more rapidly adopted by the farmers since the nature of its contribution to the beneficiary is more significant than pre-harvest mechanization.

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