

Strengthening The Competitiveness and Eco-Efficiency of SMEs in Thailand

Market Assessment Of Mechanization Potential For Cassava Production



Prepared for

gtz

Thai-German Partnership
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EXECUTIVE SUMMARY

AgriSource was commissioned by GTZ to conduct a market assessment of mechanization potential for cassava production. The study was conducted in February and March 2007 by field studies in the major eastern and north eastern cassava production provinces, using in depth discussions with producers, service suppliers, research institutions and universities.

Cassava production, a major crop in Thailand, is faced with a major constraint of low income while at the same time being faced with increasing production costs.

Labor costs for harvesting and fertilizing & weed control are the two highest cost items in cassava production (Table 1.1). Labor costs are likely to continue to increase due to increasing daily rates, in part associated with the continual movement of labor from the agricultural sector into the non-agricultural sector.

To address labor issues, the introduction of mechanization can provide a possible solution. With efficient machines, labor requirements can be greatly reduced and harvesting efficiency can be greatly increased. In addition, with effective technology and an efficient market for contract harvesting, the current price paid for harvesting services is likely to decrease. Reductions in overall harvesting costs will help to reverse the current production increase trend and keep root production costs under control. In addition, the freshness and quality of harvested roots can be improved. With higher quality roots, farmers can get relatively higher prices. Mechanized harvesting will also assist in root supply during the dry season when lifting is difficult due to hard soil conditions.

Thus, this research and study has been focused on mechanized harvesting to:

- assess the current cassava machinery and mechanized service markets
- identify and develop raw intervention concepts

Field Survey Indications

Mechanized harvesting costs are cheaper than manual harvesting costs. According to AgriSource's field survey, average traditional manual harvesting costs are 1,563 to 1,807 baht/rai or 287 to 448 baht/ton (Table a). Meanwhile, the mechanized harvesting cost is in the range of 1,123 to 1,615 baht/rai or 228 to 267 baht/ton.

Table a: Cassava Harvesting Costs, February-March 2007

Province	Average Yield	Traditional Manual Harvesting		Machanization Harvesting	
	(tons/rai)	(baht/ton)	(baht/rai)	(baht/ton)	(baht/rai)
Nakhon Ratchasima	4.93	317.10	1,563.30	227.73	1,122.74
Chonburi & Rayaong	6.04	287.25	1,734.99	267.45	1,615.39
Khon Kaen, Kalasin & Maha Sarakham	4.03	448.27	1,806.52	no m/c used	no m/c used

Source: AgriSource Survey, Feb-Mar 2007



Result of Mechanized Harvesting Modeling Comparison

Lower Operating Costs Compared to Manual Harvesting

Mechanized harvesting modeling cost analysis in this report is based on research by agricultural engineering specialists at Kasetsart and Khon Kaen Universities (see references). The analysis finds that mechanized operating cost in different assumptions is lower than traditional manual harvesting costs. The traditional manual harvesting cost in 2006 was 517 baht/rai at a yield of 3.375 tons/rai, according to the Office of Agricultural Economics. Meanwhile, large-scale mechanized harvesting costs 207-243 baht/rai (Table b) at a diesel price of 23 baht/liter. Small-scale mechanized harvesting costs 185-206 baht/rai.

Table b: Summary of Mechanized Harvesting Costs & Break-Even-Point Using Various Assumptions.

Assumption	Total Fixed Cost	Total Variable Cost	Total Operating Cost	Break-Even-Point
	(baht/rai)	(baht/rai)	(baht/rai)	Harvested Area (rai)
I. Buy only large digger	24.74	199.23	223.98	64.38
II. Buy brand new large scale tractor & digger	44.16	199.23	243.40	120.77
III. Buy second-hand large-scale tractor & digger	31.08	176.25	207.32	82.72
IV. Buy only small digger	16.98	181.75	198.73	44.64
V. Buy both brand new small-scale tractor & digger	24.22	181.75	205.97	65.67
VI. Buy second-hand small tractor and a digger	19.83	165.55	185.38	52.87

Note: 1. Break-even-point is calculated to find the mechanization harvesting area per year where the mechanization harvesting cost is equal to the traditional manual harvesting cost.

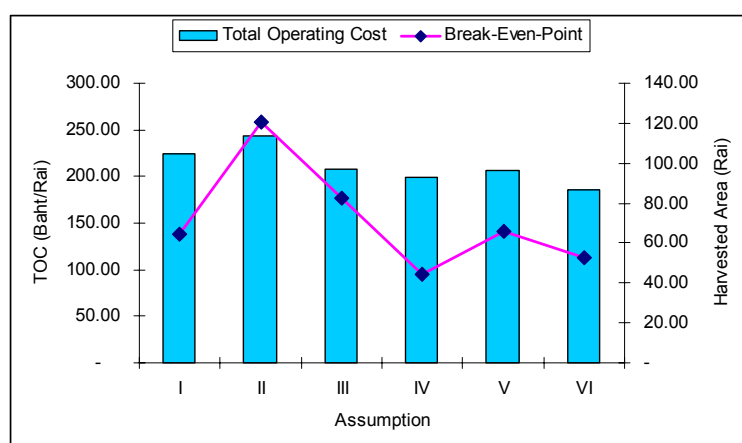
2. Traditional manual harvesting cost is 516.67 baht/rai in 2006, according to Office of Agricultural Economics

Total operating costs of the mechanized harvesting in this analysis varies depending upon investment alternatives and funding sources. A sensitivity analysis based on increasing the diesel price to 30 and 35 baht per liter indicated that mechanized harvesting maintained its cost advantage over traditional labor methods.

The break-even-point for investment on a new large tractor and digger in assumption II is 121 rai annually (Table b). Meanwhile, the break-even-point for investment on a new small-scale tractor and digger in assumption V is 66 rai annually.



Chart a: Mechanized Operating Cost and Break-Even-Point



Payback Period & Return on Investment

If a farmer investing in mechanized harvesting machinery wants to get payback within five years with a 20 percent return on investment, he has to harvest 1,495 rai/year for a new large tractor with digger (assumption II) and 655 rai/year for a new small tractor with digger (assumption V) (Table c).

Table c: Five Year Payback Period

Assumption	Total Harvested Area	Working Days (8 hrs/day)	Investment (Baht)	Net Income (Baht)	Return on Investment (%)
I. Buy only large digger	48.65	2	20,000	4,003	20.01
II. Buy brand new large scale tractor & digger	1,495	72	920,000	183,903	19.99
III. Buy second-hand large-scale tractor & digger	534	26	420,000	83,934	19.98
IV. Buy only small digger*	40	3	7,000	4,769	68.12
V. Buy both brand new small-scale tractor & digger	655	57	350,000	69,976	19.99
VI. Buy second-hand small tractor and a digger	288	25	187,000	37,408	20.00

*Note: Farmer owning small tractor and buying a digger will get 68.12% return on investment and have a payback period only 1.47 years if he only uses for his own land.

An opportunity exists to expand using cassava harvesting machinery from the current low usage of less than 15 percent of total farmer numbers. Technology for cassava harvesting machinery is already available. However, a number of operations are needed to be done manually including stem selection for seeding, separating individual roots from its mass, and truck loading.

Current machinery systems have a potential to reduce manpower used, harvesting time and operation costs, while increase working efficiency. However, suitable machinery, functional and economic usage need to be defined on a case by case basis due to a numbers of factors which will effect using the machinery in the field. Local factor such as rainfall and farm conditions need to be taken into consideration during plan formulation. The development of a suitable field operation schedule is an essential step during plan formulation.



Advantages and Disadvantages of Cassava Mechanized Harvesting

Advantages	Disadvantages
Better working capacity compared to manual harvesting (Large-scale 2.61, small-scale 1.43, manual 0.037 rai/hour)	Constraint when working in short length and odd shaped with short length and not able to work in the rainy season.
Increasing labor productivity.	Requiring skill labor to operate and maintain farm tractor.
Lowering total production cost of cassava.	Suitable cassava variety with consistent size should be considered for highest working efficiency.
Able to harvest in dry season.	Large-scale harvesting machine still requires a significant labor force.
Increasing farm tractor utilization if farmers or service providers already occupie.	Unable to work continually if the cassava field has lots of weed.
Flexible to work in variable row space from only 766 mm.	
Decrease in harvesting loss and damage	
Opportunity for good time management to get good price and deliver fresh quality cassava roots.	

Opportunities and Constraints Facing Suppliers

Opportunities	Constraints
Labor force issues because of labor movement from the agricultural sector to the non-agricultural sector.	Farmers have limited funds for investment in plantations because cassava is a low income crop.
Demonstrating mechanized harvesting benefits and efficiency would motivate farmers and service providers interest, especially in the upper northeastern area.	Large down payment required for tractor and machinery purchase.
Availability of small-scale harvesting machine provides more opportunity to small and medium farmers.	Most of farmers do not know about the benefit and efficiency gains with mechanized harvesting.
More finanancial institutins giving loans to the agricultural sector.	Increasing diesel price
Strong baht currency would lower the cost of imported tractor and fuel	



Intervention Opportunities

1. Building Awareness and Transferring Information about Mechanized Harvesting Benefits
2. Financing Machinery Purchases
3. Financing Cassava Production Inputs
4. Training and Demonstration Plots for Improved Cassava Management
5. Building Awareness and Transferring Information about Soil Analysis and Nutrient Requirements
6. Cassava Field Day
7. Field Trials of Combine Harvester and Further R&D of Harvesting Equipment



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1. Introduction

1.1 Project Background

The Thai-German Program for Enterprise Competitiveness (T-G PEC) is a joint undertaking of the Thai and German governments. The goal of the program is to improve the competitiveness and eco-efficiency of Thai enterprises in selected sectors. The program has two components: business and financial services and eco-efficiency services. Under each component, there are several projects which implement interventions aimed at improving the competitiveness of selected small and medium enterprise (SME) sectors. The above mentioned project falls under the Business and Financial Services Component.

The purpose of the project is to promote the competitiveness of small and medium enterprises (SME) in Thailand's tapioca industry, particularly near the tapioca starch producers and farmers level. SMEs benefiting from this project initially will include small commercial farmers, traders in agro-enterprise value chains, as well as processors, distributors and exporters.

The project will influence SME competitiveness through improving the market for business, financial, and eco-efficiency services. The program divides services into two categories. The first is public benefit services coming from the Government of Thailand or from Business Membership Organizations. These services include national, regional or sectoral competitiveness strategies; or improved policies, laws, regulations, and information. The second category is private benefit services. These may be delivered either as stand-alone services, such as accounting, financial services, certification and testing, or as services embedded within SME business transactions in sector-based value chains. These services include knowledge, information, and advice which are invaluable to enhancing SME competitiveness.

The programme influences competitiveness and the service market through interventions. Interventions are a set of activities linked by a common purpose and aimed at influencing some change at both the enterprise and service provision levels. The programme defines an intervention as:

Any significant allocation of programme resources (manpower or money) invested in a well-defined "sub-project" of a partner which is aimed at enhancing the competitiveness of SMEs through either: stimulating the demand for services from SMEs; improving the ability of the partner to provide better services (public or private) to SMEs; or improving the policy, legal or regulatory framework conditions for SMEs

Each intervention therefore has to have clear indicators for a sub-sector's competitiveness (either productivity, business performance, innovations, or sustainable production processes) and must have a set of indicators that show some change in the service market, usually through some recorded change in supply or demand (awareness, understanding and usage) from SMEs for that service.

1.1.1 The Importance of Mechanization in Cassava Production

Root supply will be a critical factor that restricts the industry's growth potential. With limited available planting area, increasing productivity is the only way to increase supply. However, the margin for farmers has to be sufficient to prevent farmers switching to other crops. Although future root prices are expected to stabilize, costs also have to be kept under control.

Table 1.1: Thailand Cassava Production Cost, 2003-2006

Baht/ Rai					
Items	2003	2004	2005	2006	2006 (%)
1. Fixed Cost	333.97	333.97	333.97	333.97	11.74
Land rent	324.34	324.34	324.34	324.34	11.40
Depreciation	9.63	9.63	9.63	9.63	0.34
2. Variable Cost	1,954.02	2,015.45	2,197.33	2,510.93	88.26
<i>2.1 Labor Costs</i>	<i>1,149.78</i>	<i>1,206.98</i>	<i>1,324.89</i>	<i>1,529.29</i>	<i>53.76</i>
Land preparation	289.88	293.08	325.11	377.42	13.27
Planting	133.79	136.58	162.22	181.83	6.39
Fertilizing & Weeding control	340.17	346.59	403.75	453.37	15.94
Harvesting	385.94	430.73	433.81	516.67	18.16
<i>2.2 Material Costs</i>	<i>617.53</i>	<i>624.21</i>	<i>719.14</i>	<i>806.46</i>	<i>28.35</i>
Stems	182.91	204.69	224.83	240.52	8.45
Fertilizers	286.43	272.21	321.70	371.54	13.06
Herbicides	135.15	134.27	159.57	180.44	6.34
Fuel & Lubricant	6.71	6.71	6.71	7.37	0.26
Agriculture Materials & Parts	4.66	4.66	4.66	4.85	0.17
Equipment Maintenance	1.67	1.67	1.67	1.74	0.06
<i>2.3 Interest Expense</i>	<i>186.71</i>	<i>184.26</i>	<i>153.30</i>	<i>175.18</i>	<i>6.16</i>
3. Total Production Cost (Baht/Rai)	2,287.99	2,349.42	2,531.30	2,844.90	100.00
4. Production Cost (Baht/kg)	0.75	0.74	0.98	0.84	-
5. Yield/Planted Area (kg/Rai)	3,064	3,173	2,596	3,375	-

Source: Office of Agriculture Economics (Updated Feb 19, 2007)

As seen Table 1.1, labor costs for harvesting, and fertilizing and weed control are the greatest cost items in cassava production, followed by both land preparation and fertilizer. The cost of labor is likely to continue to increase due to labor shortages, especially for harvesting, which is labor intensive. Labor shortage is also one of the major constraints perceived by stakeholders. The situation is getting worse during the rainy season, leading to roots rotting in the ground in some soil types, if they are not harvested on time due to insufficient labor. In contrast during the dry season, root lifting by hand is affected by hard dry soils, affecting root supply to processors.



To address this problem, the introduction of mechanized harvesting can provide a possible solution. With efficient machines, labor requirements can be greatly reduced and harvesting speed can be greatly increased. This has the potential to provide a solution to the rotten roots problem during the rainy season and harvesting difficulties during the dry season. In addition, with effective technology and an efficient market for contract harvesting, the price paid for harvesting services is likely to decrease. This will help to reverse the current trend and keep root production costs under control. In addition, the cleanliness and quality of harvested roots can be improved. With higher quality roots, farmers can get relatively higher prices.

1.2 Objectives of the Study

The objective of this project is to assess two major markets concerning cassava production mechanization and the identification and development of raw intervention concepts. The first is the machinery market. The other is the service market related to mechanization in cassava production, such as contract harvesting, machine rental, and other related tasks.

1.2.1 The Machinery Market

For the machinery market, the study should address the following:

- A capacity assessment of major cassava machinery suppliers and research institutes.
- An assessment of available machines in the market in terms of:
 - Technical Capability, Capacity and Performance.
 - Investment, Operating and Maintenance Costs and ROI.
 - Advantages and Disadvantages over others.
- Major constraints and opportunities facing suppliers.

1.2.2 The Service Market

In this section, the purpose is to assess the current usage and utilization of mechanization in cassava production and to identify the constraints and limitations in the service market. The study has to address the following:

- Current usage and utilization of mechanized services in each category: fee based service providers (e.g. contract harvesters), machine rental businesses or embedded services provided in the value chain.
- An assessment of the number and capacity of services providers in each category.
- Farmers' preferences and demands for each service category.
- Major market constraints and opportunities for each service category.

1.2.3 Identification of Raw Intervention Ideas

The final objective of this assignment is to identify the market and development of raw intervention ideas. The study has to address the following:

- For each of major constraint and opportunity, what are the possible market interventions that can address the issues, whether in terms of demand creation, capacity building or improvement of regulatory environments



2. The Machinery Market

General Farm Machinery Market

The farm machinery market is a competitive market with many suppliers. However, price competitiveness is not used as the main strategy because suppliers would rather compete with better after sales service and availability of parts. The market is likely to continue to grow along with increasing farm machinery usage indicated by the Office of Agricultural Economic report (Table 2.1). In 2005, use of farm tractors was 235,387 units with growth rate of 7.40 percent from the previous year. This growth is consistent with growth trend occurring over the previous five years

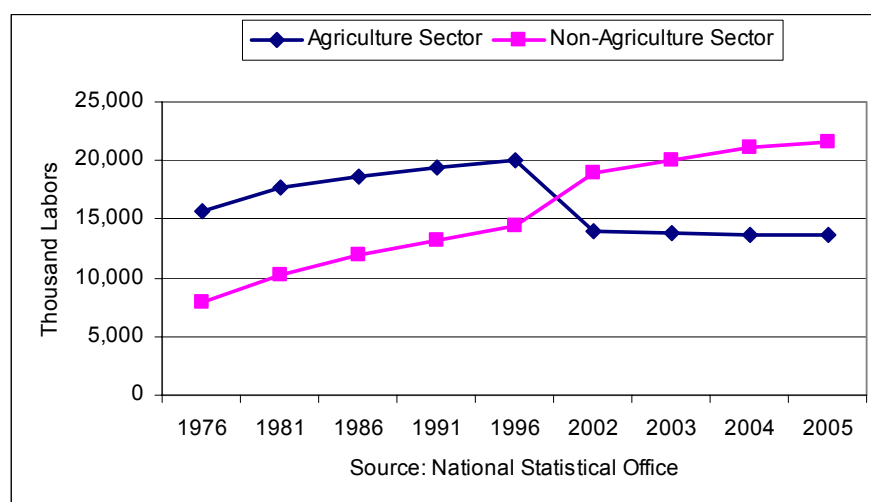
Table 2.1: Thailand Farm Machinery Usage, 2001-2005

Machinery	Units					Growth Rate (%)
	2001	2002	2003	2004	2005	
Two-wheel Walking Tractors	2,040,074	2,065,004	2,090,239	2,115,782	2,141,637	1.22
Farm Tractors	176,939	190,026	204,081	219,176	235,387	7.40
Water Pumps	1,466,833	1,432,499	1,398,969	1,366,224	1,334,245	(2.34)
Sprayer Machines	473,764	483,978	494,413	505,073	515,962	2.16
Manual Sprayer	1,341,327	1,224,108	1,117,133	1,019,507	930,412	(8.74)
Threshing Machine	54,146	53,804	53,464	53,126	52,791	(0.63)

Source: Collected by Bureau of Agricultural Economic Research, Office of Agricultural Economic

The farm machinery market is expected to continue to grow as the agricultural sector labor force decreases and moves into the non-agricultural sector (Chart 2.1).

Chart 2.1: Agricultural and Non-Agricultural Labor Force, 1976-2005



In addition, leasing services provided by a leading tractor supplier “Siam Kubota” will help boosting market growth, though it is not easy to get credit. John Deere has also recently entered the tractor and machinery leasing market. In the future, only agricultural machinery suppliers with enough capital will survive.



Cassava Mechanical Lifter Market

The cassava mechanical lifter or digger market is highly competitive. There are low barriers to entry for new entrants because the capital investment is not high. In addition, it uses simple techniques. Each producer's product is differentiated by design, shape, and quality. With a number of players in the market, the cassava digger producers cannot set high prices compared to others.

The competition is not high, as the cassava digger usually is not the manufacturer's only major product. They usually produce and supply several kinds of agricultural equipment such as weed sprayer, seed planting machines, corn combines, furrowing tools, etc. This agricultural equipment is produced and sold seasonally along with seasonal crops such as sugarcane, rice, corn, and cassava. The market does not compete by pricing but rather by maintaining their products quality and image.

2.1 Capacity Assessment of Major Cassava Machinery Suppliers and Research Institutes

2.1.1 Machinery Suppliers

Major cassava machinery suppliers include local agricultural engineering shops producing agricultural implements such as cassava diggers or tractor implements (i.e. 3 disc plough, 7 furrow disc plough, and rotary slashers for weeding), and tractor suppliers. Large numbers of suppliers are available throughout the country. However, these suppliers are not directly involved in any major research and development of new generation cassava harvesting machines.

Local Agricultural Engineering Shop

Without suitable implements, farm tractors are unable to utilize their full potential. Today, there are over a hundred types of implements available for virtually all types of farming applications. Most of these implements are widely used in Europe and America. Most of these implements, however, are quite expensive and some of them are not suited for Thailand's applications. In Thailand the most favored implements include the front blade dozer, 3-disc plough, 7-disc harrow plough and rotary slashers.

Local Thai engineering shops are good at copying and adapting the original implements at a cheaper price and more suited to the local farm environment and farmers' needs. Different models of cassava digging implements have been copied from the original pattern created by Thailand's famous universities including the Department of Agriculture Office, Kasetsart University, and Khon Kaen University. The engineering shops producing cassava diggers are generally in the major cassava producing provinces such as Chonburi, Nakhon Ratchasima, Sa Kaeo, Chaiyaphum, Chachoengsao, and Prachinburi.

Most of them are small factories with less than 10 workers, located in community areas with convenient transportation available. These local engineering shops sometimes face problems with a lack of skilled labor. According to AgriSource



interviews, some workers are local farmers who have finished planting and are waiting for harvest. They usually go back to work on their own farms for planting and harvesting.

An owner of agricultural engineering shop in Sa Kaeo said that he had used his own capital for the initial investment of only 500,000 baht. The investment included 25 percent for purchasing land, 25 percent for building construction, 20 percent for tools and equipment, and the remaining 30 percent was for business cash flow.

Cassava digger customers include local and nearby cassava farmers owning tractors and tractor service providers. Cassava diggers are mostly made to order and sold on a cash basis with the price ranging between 6,500-8,000 baht for diggers suitable for small tractors (20-30 HP) and 18,000-20,000 baht large tractors (>60 HP). Ready to use diggers can be found in Nakhon Ratchasima, the major cassava planting area of Thailand. Digger shapes and designs are effectively similar, however this may vary slightly in different areas due to various factors such as soil, cassava variety, or even tractor driver's and harvester's preferences.

Photo 1: Cassava Digger for Small Tractor (20-30 HP) Produced by Kijtavorn Kanchang, Nakhon Ratchasima Province



Photo 2: Cassava Digger for Big Tractor (>60 HP) Produced by Lert Engineering, Chonburi Province



Photo 3: Cassava Digger for Big Tractor (>60 HP) Produced by Kijtavorn Kanchang, Nakhonratchasima Province



Photo 4: Lert Engineering Shop, Chonburi



According to AgriSource interviews, digger lifetime, for big tractors, is expected to be 5-10 years. Diggers for small tractors were developed later and have a replaceable plate. Through plate rotation the plate will usually last approximately 120 rai, depending on soil conditions.

The following are the local engineering shop producing cassava diggers:

Ouan Engineering Shop, Nakhonratchasima	044 864205
Hia Kai Kijtavorn Kanchang, Nakhonratchasima	044 389167
Kok-Hin-Tang, Chaiyaphoom	057 683214
Lert Engineering Shop, Chonburi	038 485224

Tractor Suppliers

Major tractor suppliers are Ford, Kubota, Hinomoto, and several used tractor importers. Ford is a leader in large tractors while Kubota seems to control the majority of the small tractor market.

The tractor market is competitive and is capital intensive. Imports of second-hand tractors appear to generate good margins so there are quite a number of importers and distributors. Competition is based on a strategy of quality and after-sale-services rather than pricing. Only one supplier (Kubota) has offered a leasing installment program. This has recently been copied by John Deere.



Ford Tractor

Over 90 percent of second hand large tractors in Thailand are Ford. Thai farmers choose second-hand Ford tractors because of strength, easily accessible parts, economics, and good resale value. The largest supplier of Ford second hand tractors and spare parts in Thailand was Mit Alai Tractor Co., Ltd. However an abundance of small second hand Kubota tractors has resulted in Mit Alai Tractor ceasing their sales of second hand tractors. The company is still selling new Fords for cash only without a leasing or installment payment service. Several other second hand Ford importers and suppliers in major provinces are still available such as Chonburi Mueangthong, and Chonburi Tractor.

In Thailand, available second-hand Ford models include 5000, 5600, 6600, 7600, 6610, 6700, 7700, and 6640. A major advantage for the Ford tractor family model 5000, 5600, 6600, 7600, 6610, 6700 and 7700 is that most parts are compatible with each other. The parts are not too expensive and are readily available throughout Thailand.

Ford 6600 and 6610 are probably the most popular and most widely used large tractor in Thailand. Because of its versatility and durability, this tractor can work in almost all farming applications. Ford 6600 comes with 78HP engine, was manufactured between 1976 -1982, and is available with power-assisted steering.

Ford 6610 is powered by an 85 HP engine and is available in both 2WD and 4WD models. Imported models also available in both constant mesh and synchromesh gearboxes.

Prices of second hand Ford tractors are ranged between 300,000-500,000 baht without any implements. Farmers usually have to modify and recondition these second-hand tractors before using. In addition, farmers have to buy basic implements such as a rear blade, and 3 disc and 7 disc ploughs, that cost about 30,000-34,000 baht.

The main disadvantage of buying a second hand tractor is the non availability of leasing services. Second hand tractors are sold on a cash only basis. As a result, only wealthy farmers can afford to buy. Ford tractors are recognized as powerful and high work efficiency tractors.

John Deere

Kamol Industry Co., Ltd., an agent of John Deere in Thailand was established in 1989 with a registered capital of 15 million baht. Its business includes sales, engineering design, after sales service, and installation and manufacturer of body parts for tractors and trucks. The company has 240 workers and 60 staff.



The company has just joined with KTB Leasing to offer a no-collateral loan to John Deere equipment buyers with a 30 percent down payment. Interest rates are set at a flat rate of 6 to 6.75 percent, or equal to an effective rate of 12 to 13 percent per year.

Term payments range from one to three years. Monthly or quarterly payment terms are offered, with flexibility to match farmer cash flows.

KTB Leasing hopes to sign up 200 to 300 clients and offer leases of 200 million baht under the Kamol Industry arrangement. More financing options for clients will help expand the company's sales potential.

According to Managing director Kamol Surangsuriyakul, the company had annual sales of around one billion baht, with John Deere equipment accounting for 30 to 40 percent of total sales. The price for a Deere tractor ranges from 500,000 to 1,000,000 baht.

John Deere tractors are not as popular as Ford because parts are not as available and are expensive.

Siam Kubota

The favorite small tractor for small to medium scale farmers is Kubota, produced by Siam Kubota Industrial Company Limited. It is the first Thai small diesel machine producer with moderate technology from Japan.

Siam Kubota Industrial Co., Ltd, an integrated leader in agricultural machinery is a joint venture company between Kubota Cooperation (51 percent), the Siam Cement Public Company (10 percent), Marubeni Cooperation (4.74), and Minsin Machinery Company (4.26 percent). The company started operation in 1978. Its current registered capital is 208 million baht with over 800 employees.

Siam Kubota offers a diverse range of product lines including span diesel engines, walk-behind tractors, riding tillers, tractors, combine harvesters, rice transplanters, and other implements.

Available models of Kubota tractor are B2410 (24 HP), L2808 (28 HP), L3408 (34 HP), M5000, M9000, M1055 (105 HP) with prices ranging from 295,000 – 1,095,000 baht. Most farmers using Kubota tractors use small tractors ranging from 20-30 HP, due to their economic prices and lower diesel consumption, compared to bigger tractors over 30 horsepower.

The company established Siam Kubota Leasing Company Limited in 2006, providing leasing and credit services. This leasing service provides more opportunity to small-medium farmers and tractor rental service providers for buying a tractor. However, farmers still have to pay the first installment, or down payment, which can be as high as 100,000 baht. This is lot of money for poor and small farmers who struggle to accumulate this amount.



According to AgriSource interviews, most tractor rental service providers are truck owners providing transportation service delivering cassava roots to mills, brokers, and wealthy farmers whom own or rent big plots of land (>100 rai). Some of them have borrowed money from BAAC for buying new tractors and equipment. Loans from BAAC are not that easy with the bank requiring personal guarantees or land title deeds as collateral.

2.1.2 Research Institutes

The Department of Agricultural, Kasetsart University, Khon Kaen University, CIAT, and TTDI have all been involved in research and development of cassava harvesting machines for over 20 years ago. As a result, local engineering shops producing agricultural equipment in major cassava planting areas received technology transfer during 1997-1999. Following this, local engineering shops in major cassava planting areas adapted and produced several models of cassava diggers for hitching to tractors. However, the use of mechanized cassava harvesting throughout the country has been estimated at less than 10 percent of total planting area, based on AgriSource interviews.

There appears to be benefit for partnerships between universities and research institutes and private industry to further research and develop efficient small-scale mechanization for cassava management.

Kasetsart University and The Department of Agriculture

In the past, tractors were only used prior to planting for land preparation. The Department of Agricultural Office and Kasetsart University began researching appropriate mechanization for harvesting in 1974. Their results showed that mechanized harvesting could reduce production costs by 90 baht per rai. However, the R&D on cassava harvesting equipment was stopped by the second oil crisis in 1979.

All national economic and social development plans have focused on economic growth, specifically in the non-agricultural sector. As a result, labor from the agricultural sector has gradually moved to the non-agricultural sector due to higher incomes (see Table 2.2). Scarcity of agricultural labor occurs in some areas, while other areas have not yet faced the problem. However, most of farmers are currently from the old generation as the new generation mostly prefer to work in factories or gain higher education rather than work in the field. Major labor problems are anticipated in the near future.

As a result, the Department of Agriculture, in cooperation with Kasetsart University, led by Tanya Kietiwat started research and development on mechanized cassava harvesting again from 1991-1993. A cassava digger with only one beam was found to be the most suitable for cassava harvesting in Thailand.



From 1991-1993, three prototypes of cassava diggers were tested and evaluated. The first prototype was built from a pattern received from CIAT (Centro Internacional de Agricultura Tropical). Second was the cassava digger that the Faculty of Agricultural Engineering developed in 1974. Third was a farmers' harvesting machine designed and developed by a tractor garage in Rayong province, which was mostly used in Rayong and Prachinburi province.

Results from the testing indicated that the cassava harvesting machine designed by the Faculty of Agricultural Engineering had highest working efficiency at an average of 4.11 rai per hour. The one designed by CIAT achieved 4.05 rai per hour, and the farmers design only 2.82 rai per hour. Meanwhile, the occurrence of broken roots from the Faculty of Agricultural Engineering was least at 10.96 percent, CIAT 11.95 percent, and farmers' design 20.15 percent (see Table 2.2).¹

Table 2.2: Capability Comparison of DOA, CIAT, and Farmer Machine, 1991-1993

Capability	DOA*	CIAT	FARMER
	(60-70hp)	(60-70hp)	(60-70hp)
Field Capacity:			
- Rai/Hour	4.11	4.05	2.82
- Rai/Day (8 hours/day)	32.88	32.4	22.56
Working Efficiency (%)	78.8	77.29	69.33
Broken Roots (%)	10.96	11.95	20.15
Roots Leaving under Ground	8.62	13.13	15.69
Pull Power/Area (Newton/cm ²)	1.89	2.04	2.14

Source: Department of Agriculture Office, Ministry of Agriculture and Cooperatives

Note: * DOA developed in 1974

In 1997, the Department of Agricultural Office, the Department of Agriculture Extension, Kasetsart University, and Thailand Tapioca Development Institute (TTDI) had realized the impending labor scarcity problems in cassava farming. Thus, they had promoted the use of cassava harvesting machines with the aim of addressing the labor scarcity problem as well as reducing production costs. They arranged an efficiency contest for cassava harvesting machines to look for the best one. Finally, they found that a machine with one beam and three nails produced by Jittakorn Steel Shop in Sa Kaeo, called "JK", was the best one. They had promoted this "JK" design to cassava farmers during the 1997/98 crop. The Department of Agriculture Extension (DOAE) launched the "Cassava Production Development Project" aimed at increasing production and market capability. As part of the project, DOAE distributed 10 JK harvesting machines to 10 farmer groups in Chachoengsao, Sa Kaeo, Chonburi, and Rayong for trial from October 1997 to September 1998. Energy consumption, maintenance costs, and working capacity information were collected as seen in Table 2.3.

¹ Tanya Kietwat, Sukri Numtasukhon, and Anan Balnalung, 1993, Cassava Harvesting Machine Research & Development, Division of Agricultural Engineering, Department of Agriculture Office

Table 2.3: Field Capacity of “JK” Cassava Harvester with 60HP Tractor

Field Capacity & Area Harvesting	Trial No.			Average
	1	2	3	
Width & Length of Land (m x m)	20 x 80	20 x 80	20 x 80	20 x 80
Harvesting Area (Rai)	1	1	1	1
Working Capacity (Rai/Hour)	2.63	2.7	2.66	2.66
Diesel Consumption (Litre/Hour)	6.59	10.54	7.85	8.33
Loss from Unharvesting Roots in the Ground	3.94	1.49	1.38	2.27

Source: TTDI, 1997

Dr.Sakda Intaravichai & Dr.Thanya Kietwat
Faculty of Agricultural Engineering

From January 1998 to December 2000, Dr.Sakda Intaravichai, Dr.Thanya Kietwat, and Dares Kitiopas did a cassava harvesting machine development project with support from the Thailand Tapioca Development Institute (TTDI). The project aimed to add working efficiency and remove constraints from available cassava harvesting machines. Several designs of cassava harvesting machines were produced and sold by local engineering shops in the major cassava planting area but were not acceptable or well-known by farmers. The major causes of farmer unacceptability were the following constraints, occurring in different planting areas with different soils and machine designs:

- The existing harvesting machine could not work continuously because it still required some labor to remove the cassava roots out of the tractor pathway, otherwise the tractor would run over and brake the roots.
- Weed infestations in the planting area made working conditions difficult for the machine, which lead to a high harvesting loss percentage. In addition, it was time consuming to take weeds away from the digger and beam.
- Some of the machines were poorly designed and fabricated. This lead to difficulties for the tractor maintaining the correct track and digger alignment. The problem was created because the available machine did not have a land side.

“K.72” a vibrating cassava digger was designed in 1998²and developed to overcome those constraints. It’s used a vibration technique passing along digger plate/disc plough. The application of a vibration mechanism makes a better soil shatter that leads to lower draft requirement as well as better working efficiency.

K.72, a vibrating cassava digger is attached to the three point linkage of a 60-80 HP tractor. The vibration is generated by an unbalanced weight driven by the power take off (pto).

According to Dr.Sakda, the field performance test revealed that with the use of the vibrating mechanism, K.72’s draft requirement was reduced by 30 percent. Moreover, the vibrating cassava digger yielded 29 percent higher field capacity,

² Dr.Sakda Intaravichai, Faculty of Agricultural Engineering, Kasetsart University

⁴ Bank for Agriculture and Agricultural Cooperatives



and 15 percent less fuel consumption when compared with the cassava digger without the vibration mode. In addition, the tractor was more easily controlled for harvesting. The field loss was about three percent. From cost estimations, it was calculated that the break-even point for using the vibrating cassava digger occurred when the harvesting operation area was 60 rai.

Primary evaluation indicates the machine has a working capacity of 3.12 rai per hour with an average working efficiency of 80.75 percent, and lost non harvested roots remaining in the ground of 7.48 percent. The K.72 cassava harvesting machine can reduce cassava harvesting cost by 80 baht per rai. These savings require re-calculation as the diesel price has increased from about 13 baht per liter in 2000 up to about 23 baht per liter in February 2007.

A patent has been applied for a under the name of Kasetsart University and the TTDI, who supported the research, for the K.72.

According to Dr.Sakda's interview, a cassava root truck loading machine prototype has also been designed and developed, however more research is required in capacity evaluation. Research was stopped due to lack of funding resources.

Khon Kaen University

Development of Cassava Harvesting with Cassava Diggers By Dr.Seri Wongpichet and Group

Department of Agricultural Engineering, Faculty of Engineering.

Associate Professor Dr.Seri Wongpichet developed two models of cassava diggers for use with small and big tractors. KKKU46 model needs a tractor with over 60HP, while KKKU48 needs a 20-30HP tractor.

KKKU48 was demonstrated to cassava farmers in Nakhon Ratchasima province in 2005. However, the research was experimental and done only in small land plots. No data about fuel consumption was collected due to funding limitations. Several bigger plots in different areas should be done, collecting fuel consumption data.

In addition, he also researched and built a prototype cassava harvester using a walk behind tractor However, detail on working capacity and efficiency is not available yet as it's still experimental and restricted by financial problems.

KKKU 46 Model

The traditional manual cassava harvesting process has a low capacity and high labor cost. Intensive labor is used for root lifting, cutting individual roots from the root mass, and loading on trucks. This project was aimed to develop improved performance of the harvesting process to address the labor problem. The experimental method and the work study were used to collect data from each development step. Planting conditions in the northeast region was the basis for this development.



A suitable method for plot preparation, cassava digger prototype (KKU 46), and the suitable method for dug root collection and cutting were found in 2003. These methods could increase the performance of the cassava harvesting process, both in field capacity and output quality. The labor cost was decreased about 100 baht per rai.

KKU 46 digger was designed for hitching with big tractor (>60 HP). It can be used in the cassava fields with row spacing over 1,000 mm.

Table 2.4: Comparison of KKU 46 Cassava Harvesting Machine with Traditional Labor Harvesting

Field Capacity	Labor Harvesting	KKU 46 Harvesting
1.Working Capacity (Rai/labor-hour):	0.028	0.067
- Cassava Tree Cutting & Land Preparation	-	0.142
- Root Digging	0.041	2.082
- Dug Roots Collecting & Cutting	0.092	0.137
2.Loss from Remaining Roots Underground (%)	7.800	-
3.Loss from Broken Roots (%)	2.100	8.500

Note:

- 1.Trial in 200 m² for Labor harvesting and 800 m² for KKU 46 Machanize Harvesting
- 2.Sandy clay with 4.9% wb moisture, KU 50 variety, Yield 5.9 ton/rai
- 3.Length between furrow 1,110 mm., Length between cassava trees 899 mm
- 4.Dug cassava roots unconveying value 0%

KKU 48 Model

This study's aim was to develop mechanized cassava harvesting using small 20-30 HP tractors. It was designed for cassava harvesting with row spacing smaller than 1,000 mm. This row spacing was mostly used by cassava farms, especially in infertile soil, which is not suited for big tractors. By testing the cassava digger which factories or other researchers developed, the prototype was drawn. It was designed constructed and tested. The KKU48 cassava digger has a field capacity of approximately 1.45 rai/man-hour. This is faster than the traditional labor harvesting by about 39 times and the traditional cassava digger by 32 percent. The harvesting loss was less than 0.6 percent which was lower than the traditional labor harvesting about 5.1 percent. This prototype worked well in the cassava field that had row spacings from 766-1,000 mm, without trampling losses.

According to Professor Seri, KKU 48 mechanized cassava harvester can be used with a 20-30 HP tractor and can reduce labor cost by 100 baht/rai. Trial fields were in Amphur Dan-koon-tod, Nakhon Ratchasima province.



2.2 Machinery Market Assessment

2.2.1 Technical Capability, Capacity and Performance

Cassava Harvesting Machinery from the Department of Agricultural

According to Department of Agricultural Office (DOA), they have undertaken research which found that traditional labor harvesting in eastern region can harvest 0.3 tons/person/day over eight working hours. Meanwhile, using mechanized harvesting with a 60 HP tractor and a one beam-three nail cassava digger can harvest 21.28 rai per day (8 hours). The mechanized harvesting speed is a lot faster than traditional labor harvesting so cassava farmers are able to sell their production at the right time when prices are good.

DOA found that farmers using mechanized harvesting could meet the break-even-point if they used the mechanized harvester for five crops with an average harvesting area at 47.35 rai per crop and the mechanized harvesting service cost was set at 170.30 baht per rai. This means that the cassava farmer using mechanized harvesting should have an average harvesting area at least 47.35 rai per crop. In addition, DOA found when harvesting a 47.35 rai per crop, the harvesting service needed to be charged at 99.30 baht per rai to break-even. Adding this mechanized harvesting cost (99.39) with cost of labor for root collecting and loading on trucks at 369.40 baht per rai, the total harvesting cost would cost 468.70 baht per rai compared to 586.53 baht per rai of the traditional labor harvesting cost.

Cassava Harvesting Machine by Khon-Kaen University

As mentioned above, Dr.Seri Wongpichet of Khon-Kaen University has developed two models of cassava harvesting machine: KKU46 and KKU48. Comparisons of capacity for KKU46 and KKU48 with existing cassava harvesting machines are shown in Tables 2.5 and 2.6.

Working capacity of KKU48-the small mechanized (22 HP) is 1.23 rai/man-hour while KKU46-the large mechanized harvesting (60-80HP) is able to work 2 rai/man-hour. Loss of cassava roots left in the ground for KKU46, and KKU48 are 0.60, and 0.50 percent respectively.



Table 2.5: Technical Capability of Cassava Harvesting Machine Using Small and Large Tractors

Details	Farmers' Small Tractor	Farmers' Big Tractor	KKU 46
	(20-30 HP)	(>60 HP)	(>60 HP)
Dimension and Capacity			
1. Width of Digger (m.m.)	530.00	708.00	560.00
2. Average Digging Width (m.m.)	635.00	1,051.00	975.00
3. Average Digging Depth (m.m.)	182.00	261.00	259.00
4. Average Digging Speed (km/hr)	3.26	4.54	4.85
Working Capacity			
1. Field Capacity			
- Working Capacity (Rai/Man-Hour)	1.23	1.97	2.00
- Speed Efficiency (%)	73.40	68.00	69.30
2. Cassava Digging Capacity (Quantity)			
- Quantity of Easy Dug Cassava (%)	67.00	86.00	87.80
- Quantity of Difficult Dug Cassava (%)	29.70	13.60	11.60
- Length of cassava roots moving from digging line (m.m.)	-	755.00	645.00
3. Loss: Cassava Roots Left in the Ground (%)	3.30	0.40	0.60

Source: Dr.Seri Wongpichet, Faculty of Engineering, Khon Kaen University

Note: Trial Factors include

- Rayong 5 variety, radial of roots or average width and depth =229 x 186 mm.
- Distance between cassava trees 550 mm., Distance between rows 1,110 mm.
- Cassava yield 1,981.3 kg./rai.
- Soil type: Clay sandy soil with 2.5%wb moisture
- Land area 1,643 m²

Table 2.6 shows comparison of small-scale tractor farmers produced digger and KKU48 with traditional manual harvesting. KKU48 has field capacity of approximately 1.43 rai/man-hour. This is faster than traditional manual harvesting by about 39 times. In addition, the harvesting loss of roots left in the ground was less than 0.6 percent which is lower than the traditional manual harvesting of approximately 5.1 percent.

Table 2.6: Comparison of Farmer Small Tractor, K KU 48 and Traditional Labor Harvesting, 2005

Working Result ¹	KKU 48	Farmers' Harvesting Machine	Traditional Labor Harvesting
	Small Tractor	Small Tractor	
	(22 HP)	(22 HP)	
Dimension and Capacity			
1. Width of Digger (m.m.)	560.00	530.00	-
2. Average Digging Width (m.m.)	678.00	600.00	-
3. Average Digging Depth (m.m.)	222.00	191.00	-
4. Average Digging Speed (km/hr)	2.60	2.37	-
Working Capacity			
1. Field Capacity			
- Working Capacity (Rai/Hour), (Rai/Man-Hour)	1.43	1.08	0.037
- Speed Efficiency (%)	70.50	68.00	-
2. Cassava Digging Capacity (Quantity)			
- Quantity of Easy Dug Cassava (%)	10.40	8.40	5.60
- Quantity of Difficult Dug Cassava (%)	89.60	91.60	94.40
- Length of cassava roots moving from digging line (m.m.)	10.10	7.60	-
3. Loss: Cassava Roots Left in the Ground (%)	0.50	0.80	5.60

Source: Dr.Seri Wongpichet, Faculty of Engineering, Khon Kaen University

Note: 1. Trial Factors include

- Rayong 5 variety, radial of roots or average width and depth =225 x 209 mm.
- Distance between cassava trees 606 mm., Distabnce between rows 943 mm.
- Cassava yield 3,751 kg./rai.
- Soil type: Clay sandy soil with 1.18%wb moisture
- Land area 1,600 m² in Nakhon Ratchasima province.

Advantages of K KU 48 Compared To Farmers Machine and Traditional Labor Harvesting:

- Increased working capacity at 1.43 rai/man-hour comparing to farmers' harvesting machine at 1.08 rai/man-hour, and traditional labor harvesting at only 0.037 rai/man-hour
- Better capability in harvesting difficult dug cassava with loss of cassava roots under ground at less than 0.6 percent
- Able to harvest cassava roots with row spacing between 766-1,000 mm.

Capability Comparison of Current Existing Cassava Harvesting Machine

The capability of current cassava harvesting machines available in the market are compared with traditional manual harvesting in Table 2.7. Please note that field trials were done in different environments and constraints such as soil type, cassava varieties, yield, weeding burden, and other factors. Working speed is not the only major factor, but loss from broken and roots leaving in the ground should be considered as well.



Table 2.7: Cassava Harvesting Machine Capability Comparison with Traditional Harvesting

Capability	Farmer ¹ 1993	Lert Engineering	Kijtavorn	JK ³	K.72	KK48	Traditional Manual Harvesting ³
	(60-70HP)	(60-80HP)	(60-70HP)	(60-80HP)	(60-80HP)	(20-30HP)	
Field Capacity:							
- Rai/Hour-Labor	2.82	2.50	2.85	2.66	2.50	1.43	0.037
- Rai/Day (8 hours/day)	22.56	20.00	22.80	21.28	20.00	11.44	0.296
Working Efficiency (%)	69.33	71.74	79.98	80.79	n.a.	70.50	n.a.
Fuel Consumption (Litres/hr)	n.a.	n.a.	n.a.	8.33	3.82	n.a.	0
Broken Roots (%)	20.15	n.a.	n.a.	n.a.	n.a.	8.50	2.1
Roots Left in the Ground	15.69	16.31	3.64	2.27	3.16	0.50	5.6

Source: Department of Agriculture Office, Ministry of Agriculture and Cooperatives

Samart Boonarj, Kasetsart University, Design & Development of A Tractor Mounted Cassava Root Collector, 2000

Note: 1. This model was developed in 1983 approximately.

2. JK model produced by Jitakorn Steel Engineering with three nails on a beam.

3. According to Dr. Seri Wongpichet and Camnueng Watyotha, Faculty of Engineering, Khon Kaen University

2.2.2 Investment, Operating and Maintenance Costs and ROI

Traditional Manual Harvesting Cost

According to Department of Agricultural Economics, labor harvesting cost in 2006 was **516.67 baht/rai or 153 baht/ton** compared to 433.81 baht/rai or 167 baht/ton in 2005 (see Table 1.1). Labor harvesting costs per ton were reduced as a result of yield increasing to 3.375 tons/rai in 2006 from 2.596 tons/rai in 2005.

Investment, Operating, and Maintenance Cost

If a cassava harvesting machine is used, the operation & maintenance and investment costs are estimated as following:

- Price of digger for large-scale tractor 20,000 baht
- Price of digger for small-scale tractor 7,000 baht
- Digger useful life 2,500 hours or 5 years
- Loan interest rate 9.75 percent (Based on BAAC⁴ lending rate for new customers however existing customer with good record of payment will get the minimum rate 7.5 percent)
- Interest on Investment 3.25 percent (Based on BAAC fixed deposit rate)
- Diesel fuel price 23 baht/liter
- Labor cost 120 baht/day (8 hours)
- Tractor driver cost 250 baht/day (8 hours)
- Large-scale machine capacity 2.61 rai/hour (Average field capacity of current machines used including Lert Engineering, Kijtavorn, JK, and K.72, see Table 2.8)
- Small-scale machine capacity 1.43 rai/hour (Based on KKU.48 developed by Dr. Seri Wongpichet and Kamnueng Wathayota/ Khonkaen University)
- Fuel consumption 7.84 liters/hour for tractor 60-80HP⁵
3.92 liters/hour for tractor with less than 35HP

⁵ Dr. Sakda Intaravichai & Dr. Thanya Kiatwat, 1999, The Comparison of Cassava Root Harvesting between Manual and Machine Harvester



- Lubricant expense 10 percent of fuel consumption
- Repairs and maintenance cost of tractor and digger is averaged at 1.2 percent of purchased price divided by 100 working hours³
 - New large-scale tractor (60-80HP) 900,000 baht (10 year lifetime)
 - Second-hand large tractor (60-80HP) 400,000 baht (5 year lifetime, price in the market is in the range of 300,000-500,000 baht)
 - New small-scale tractor (Kubota L2808 4WD, 28HP) 343,000 baht (10 year lifetime)
 - Second-hand small tractor 150,000 baht (5 year lifetime, second-hand tractor with engine power less than 35HP is selling at 90,000-200,000 baht)
 - Traditional manual harvesting cost 516.67 baht/rai, according Office of Agricultural Economics

Various assumptions are compared to look for the best alternative with lowest total operating cost, as follows:

- ▣ Assumption I: Farmer has existing large tractor and considers buying a digger.
- ▣ Assumption II: Farmer will buy both new large tractor and cassava digger.
- ▣ Assumption III: Farmer will buy second-hand large tractor (60-80 HP) and cassava digger.
- ▣ Assumption IV: Farmer has existing small tractor and will buy a digger.
- ▣ Assumption V: Farmer will buy a new small tractor and cassava digger
- ▣ Assumption VI: Farmer will buy a second-hand small tractor and cassava digger

Total Operating Cost

Consequently, the total cost can be obtained from the following equation:

$$\text{TCM} = \text{TFC} + \text{TVC}$$

Where:

- TCM = Total operating cost for mechanized harvesting
- TFC = Total fixed cost
- TVC = Total variable cost

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

According to Dr.Sakda Intaravichai of Kasetsart University, calculation of break-even-point of cassava harvesting machine shall use following formula⁶:

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

⁶ Dr.Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester

Where:	F_t	=	Fixed cost (baht/year)
	A_t	=	Machine usage cost (baht/rai)
	A	=	Harvested area (rai/year)
	$R \& M$	=	Repairs & maintenance cost (baht/hour)
	F	=	Fuel cost (baht/hour)
	O	=	Lubricate Oil (baht/hour)
	L_0	=	Driver rate (baht/hour)
	L_1	=	Labor rate (baht/hour)
	C_t	=	Machine working capacity (rai/hour)

Details on calculations for total operating costs on assumptions I to VI are shown in the Appendix Note section.

Total operating cost of cassava harvesting mechanized with large tractor under Assumption I, II, and III is in the range of 207-243 baht/rai (Table 2.8).

Total operating costs and investment on a cassava digger for an existing small tractor, a new small tractor and digger, and a second-hand tractor and digger under Assumption IV, V, and VI is shown in Table 2.9.

Table 2.8: Total Operating Cost and Break-Even-Point For Assumptions I, II, and III

New investment	Assumption I		Assumption II		Assumption III	
	Large-Scale Digger		New Large Tractor & Digger		Second-Hand Large Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a.Digger Depreciation Cost	3,600	2.76	3,600	2.76	3,600	2.76
b.Tractor Depreciation Cost	81,000	20.69	81,000	20.69	72,000	18.39
c.Interest Expense & Interest on Investment for Digger	1,690	1.30	1,690	1.30	1,690	1.30
d.Interest Expense & Interest on Investment for Tractor	-	-	76,050	19.42	33,800	8.63
Total Fixed Cost	86,290	24.74	162,340	44.16	111,090	31.08
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a.Repair and maintenance cost for digger	2.40	0.92	2.40	0.92	2.40	0.92
b.Repair and maintenance cost for tractor	108.00	41.38	108.00	41.38	48.00	18.39
c.Fuel expense	180.32	69.09	180.32	69.09	180.32	69.09
d.Lubricant expense	18.03	6.91	18.03	6.91	18.03	6.91
e.Driver expense	31.25	11.97	31.25	11.97	31.25	11.97
f.Labor cost	180.00	68.97	180.00	68.97	180.00	68.97
Total Variable Costs	520.00	199.23	520.00	199.23	460.00	176.25
Total Opeating Costs		223.98		243.40		207.32
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		64.38		120.77		82.72

Assumption I: Farmer has existing large tractor and buys a digger.

Required additional investment is only the cassava digger for the large-scale tractor.

With the assumption that the farmer has to borrow money from BAAC to buy a digger, he can get loan for 80 percent of the digger price (16,000 baht) with an



interest rate at 9.75 percent, as they are a new customer (only current customer having good record of payment can get minimum retail rate (MRR) at 7.5 percent). As a result, the loan interest expense is included in the fixed costs as well as interest on investment for the down payment paid by the farmer at 3.25 percent based on BAAC current fixed deposit interest rates (12 months).

A new Ford 6610 tractor is used in this assumption as Ford is most popular large tractor among farmers according to AgriSource survey and study.

Assumption I, an investment on a cassava digger for hitching with an existing large-scale tractor with loan from BAAC would have a total operating cost at 224 baht/rai. This includes fixed costs of 25 baht/rai and variable costs of 199 baht/rai.

The mechanized harvesting area per year must be 64.38 rai to meet break-even-point where machine usage cost is equal to traditional manual harvesting cost.

Assumption II: Farmer will buy both new large tractor and cassava digger.

Assuming the farmer has to borrow money from BAAC to buy a tractor and digger, he can get a loan at 80 percent of the tractor and digger price (900,000 baht & digger 16,000 baht respectively) with interest rate at 9.75 percent, in the case where they are a new customer (only current customer having a good payment record can get the minimum retail rate (MRR) at 7.5 percent). Meanwhile, the total installment period is generally 5 years according to AgriSource's interviews. As a result, the loan interest expense is included in the fixed cost as well as interest on investment for the down payment paid by farmer at 3.25 percent based on BAAC current fixed deposit interest rate (12 months).

A new Ford 6610 tractor is used in this assumption as Ford is the most popular large scale tractor among farmers according to AgriSource survey and study.

Assumption II, a new large-scale mechanized harvesting with a BAAC loan at 9.75 percent interest rate has total operating cost at 243 baht/rai. This includes fixed costs of 44 baht/rai and variable costs of 199 baht/rai.

The mechanized harvesting area per year must be 120.77 rai to meet break-even-point where machine usage cost is equal to traditional manual harvesting cost.

Assumption III: Farmer will buy second-hand large tractor (60-80 HP) and cassava digger.

The assumption is that the farmer has to borrow money from BAAC to buy a second-hand tractor (60-80HP) and digger, he can get loan for 80 percent of the tractor and digger price (320,000 baht & 16,000 baht respectively) with an interest rate at 9.75 percent in the case where they are a new customer (only current customers having a good record of payment can get the minimum retail rate (MRR) at 7.5 percent). Meanwhile, the total installment period is generally 5 years according to AgriSource's interviews. As a result, the loan interest expense is



included in the fixed cost as well as interest on investment for the down payment paid by farmer at 3.25 percent based on BAAC current fixed deposit interest rate (12 months).

Assumption III, investment on a second-hand large-scale tractor and a digger with a BAAC loan at 9.75 percent interest rate has total operating cost at 207 baht/rai. This includes fixed costs of 31 baht/rai and variable costs of 176 baht/rai.

The mechanized harvesting area per year must be 82.72 rai to meet break-even-point where machine usage cost is equal to traditional manual harvesting cost.

Table 2.9: Total Operating Cost and Break-Even-Point For Assumptions IV, V, and VI

New investment	Assumption IV		Assumption V		Assumption VI	
	Small-Scale Digger		New Small Tractor & Digger		Second-Hand Small Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a.Digger Depreciation Cost	1,260	1.76	1,260	1.76	1,260	1.76
b.Tractor Depreciation Cost	30,870	14.39	30,870	14.39	27,000	12.59
c.Interest Expense & Interest on Investment for Digger	592	0.83	592	0.83	592	0.83
d.Interest Expense & Interest on Investment for Tractor	-	-	15,534	7.24	9,975	4.65
Total Fixed Costs	32,722	16.98	48,256	24.22	38,827	19.83
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a.Repair and maintenance cost for digger	0.84	0.59	0.84	0.59	0.84	0.59
b.Repair and maintenance cost for tractor	41.16	28.78	41.16	28.78	18.00	12.59
c.Fuel expense	87.86	61.44	87.86	61.44	87.86	61.44
d.Lubricant expense	8.79	6.14	8.79	6.14	8.79	6.14
e.Driver expense	31.25	21.85	31.25	21.85	31.25	21.85
f.Labor cost	90.00	62.94	90.00	62.94	90.00	62.94
Total Variable Costs	259.90	181.75	259.90	181.75	236.74	165.55
Total Opeating Costs		198.73		205.97		185.38
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		44.64		65.67		52.87

Assumption IV: Farmer has existing small tractor and will buy a digger

Required additional investment is only the cassava digger for the small tractor.

The assumption is that the farmer has to borrow money from BAAC to buy a digger, he can get loan at 80 percent of the digger price (7,000 baht) with interest rate at 9.75 percent as they are a new customer (only current customers having a good payment record can get the minimum retail rate (MRR) at 7.5 percent). As a result, the loan interest expense is included in the fixed costs as well as interest on investment for the down payment paid by farmer at 3.25 percent based on the BAAC current fixed deposit interest rate (12 months).

A new Kubota small tractor with 28HP and 4 wheel drive is used in this assumption as small Kubota tractors are the most popular among farmers, according to AgriSource's surveys.



Assumption IV, an investment on a digger for hitching with an existing small tractor would have a total operating cost of 224 baht/rai. This includes fixed costs of 17 baht/rai and variable costs of 199 baht/rai.

The mechanized harvesting area per year must be 44.64 rai to meet the break-even-point where machine usage cost is equal to traditional manual harvesting cost.

Assumption V: Farmer will buy a second-hand small tractor and cassava digger

Using the assumption that a farmer has to borrow money from BAAC to buy a digger, he can get loan at 80 percent of the digger price (7,000 baht) with an interest rate at 9.75 percent as he is a new customer (only current customers having a good payment record can get the minimum retail rate (MRR) at 7.5 percent). As a result, the loan interest expense is included in the fixed costs as well as interest on investment for the down payment paid by farmer at 3.25 percent based on BAAC current fixed deposit interest rate (12 months).

Meanwhile, a new Kubota small tractor with 28HP and 4 wheel drive is used in this assumption, as the small Kubota tractor is most popular among farmers according to AgriSource's surveys. Kubota Leasing interest rate is 7.5 percent with 60,000 baht down payment and installments over four years. The farmer has to pay 7,311 baht/month (Appendix Table 6: Siam Kubota Leasing Service)

Assumption V, total operating costs for a new small tractor and digger, with a loan from Kubota Leasing is 206 baht/rai. This includes fixed costs of 24 baht/rai and variable costs of 206 baht/rai.

The mechanized harvesting area per year must be 65.67 rai to meet the break-even-point where machine usage cost is equal to traditional manual harvesting costs.

Assumption VI: Farmer will buy a second-hand small tractor and cassava digger

The assumption is that a farmer has to borrow money from BAAC to buy a tractor and digger, he can get loan at 80 percent of the digger price (7,000 baht) with interest rate at 9.75 percent as he is a new customer (only current customers having a good payment record can get the minimum retail rate (MRR) at 7.5 percent). As a result, the loan interest expense is included in the fixed costs as well as interest on investment for the down payment paid by farmer at 3.25 percent, based on BAAC current fixed deposit interest rate (12 months).

According to AgriSource's study and survey, a second-hand tractor with less than 35HP price is in the range of 90,000-200,000 baht. In this assumption, a price of 150,000 baht is used.

Assumption VI, total operating costs for a second-hand small tractor and digger with a BAAC loan is 185 baht/rai. This includes fixed costs of 20 baht/rai and variable costs of 165 baht/rai.

The mechanized harvesting area per year must be 52.87 rai to meet the break-even-point where machine usage cost is equal to traditional manual harvesting costs.

Comparison of Mechanized Operating Cost

Assumption VI, buying a second hand small tractor and digger has the lowest total operating cost at 185.38 baht/rai with 52.87 rai of harvesting area per year to meet the break-even-point (Table 2.10).

Meanwhile, assumption II, buying a new large tractor and digger has the highest total operating cost at 243.40 baht/rai with 120.83 rai of harvesting area per year to meet the break-even-point.

Table 2.10: Farmers' Total Operating Cost and Break-Even-Point

Assumption	Total Fixed Cost	Total Variable Cost	Total Operating Cost	Break-Even-Point
	(baht/rai)	(baht/rai)	(baht/rai)	Harvested Area (rai)
I. Buy only large digger	24.74	199.23	223.98	64.38
II. Buy brand new large scale tractor & digger	44.16	199.23	243.40	120.83
III. Buy second-hand large-scale tractor & digger	31.08	176.25	207.32	82.72
IV. Buy only small digger	16.98	181.75	198.73	44.65
V. Buy both brand new small-scale tractor & digger	27.60	181.75	209.35	75.52
VI. Buy second small tractor and a digger	19.83	165.55	185.38	52.87

Note: 1. Break-even-point is calculated to find the mechanization harvesting area per year where the mechanization harvesting cost is equal to the traditional manual harvesting cost.

2. Traditional manual harvesting cost is 516.67 baht/rai in 2006, according to Office of Agricultural Economics

- **Return of Investment (ROI):**

Investment in mechanized cassava harvesting can be done by two major groups, which include farmers and service providers.

Investment by Farmers

According to Office of Agricultural Economics, 30.59 percent or 464,956 households planted 10-20 rai of cassava in 2005 (Chart 2.2). However, it would be difficult for these poor farmers to afford farm mechanization, unless they were growing additional areas of other crops. Thus, this report assumes that farmers with planted areas of greater than 40 rai would be able to afford farm mechanization.



Chart 2.2: Thailand Household's Cassava Planted Area, 2005

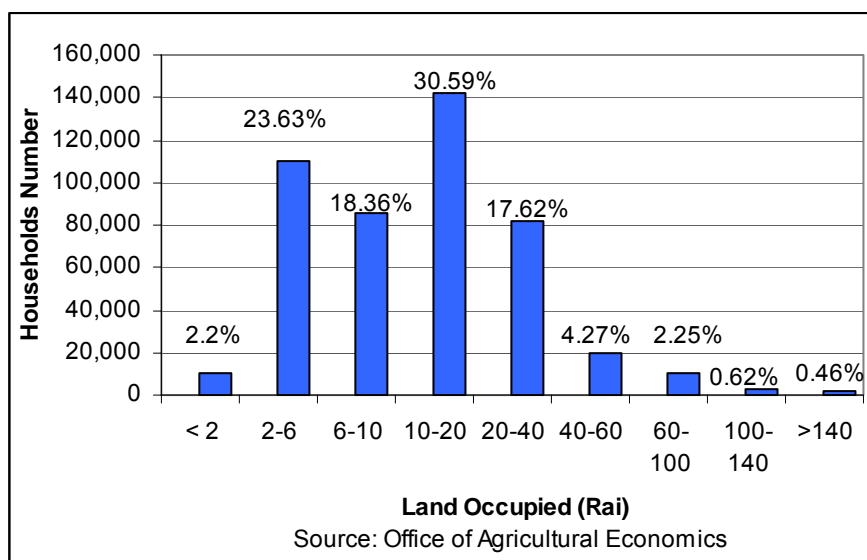


Table 2.11: Farmers' Investment, Total Operating Cost, and Saving & Income from Using Mechanized Harvesting

	Assumption					
	I	II	III	IV	V	VI
Manual Harvesting Cost (baht/rai)	516.67	516.67	516.67	516.67	516.67	516.67
Mechanized Operating Cost:						
- For Their Own Field (baht/rai) ³	223.98	243.40	207.32	198.73	205.97	185.38
- For Service Provider (baht/rai) ⁴	155.01	174.43	138.35	135.79	143.03	122.44
Income:						
- Savings from using m/c harvesting (baht/rai)	292.69	273.27	309.35	317.94	310.70	331.29
- Service to other casava farmers (baht/rai.)	300.00	300.00	300.00	250.00	250.00	250.00
Investment:						
- Digger (baht)	20,000	20,000	20000	7,000	7,000	7,000
- Tractor (baht)	-	900,000	400000	-	343,000	150,000

Note: 1. Service fees for large-scale mechanization in assumption I, II, & III is 300 baht/rai

2. Service fee for small-scale mechanization in assumption IV, V, & VI is 250 baht/rai.

3. Farmers have to pay labor for root collecting, cutting, and loading onto truck.

4. Labor cost for collecting, cutting, and loading is paid separately by farmers, mechanized cassava harvesting service providers pay only tractor drivers.

As shown in Table 2.11, cassava farmers will save money in investing and using mechanization for harvesting their own fields instead of using traditional manual harvesting as well as earning from servicing their neighbors as follows:

- Assumption I: If a farmer already has a large-scale tractor and he adds a 20,000 baht investment for a digger, his benefit is saving 292.69 baht/rai from using mechanized harvesting on his own land compared to manual harvesting. If he provides a harvesting service to others, he would also gain 145 baht/rai.

- Assumption II: If a farmer invests in a new large tractor and digger totaling 920,000 baht, his benefit is saving 273.27 baht/rai from using mechanized

harvesting on his own land compared to manual harvesting. If he provides a harvesting service to others, he would also gain 126 baht/rai.

- Assumption III: If farmer invests in a second-hand large tractor and a digger totaling 420,000 baht, his saving is 309.35 baht/rai from using mechanized harvesting compared to manual harvesting. If he provides a harvesting service to others, he would also gain 162 baht/rai.
- Assumption IV: If farmer already has a small tractor and he adds a 7,000 baht investment on a digger. Then, his saving is 317.94 baht/rai from using mechanized harvesting compared to manual harvesting. If he provides a harvesting service to others, he would also gain 114 baht/rai.
- Assumption V: If farmer invests in a new small tractor with a digger totaling 350,000 baht, his benefit is a 310.70 baht/rai saving from using mechanized harvesting compared to manual harvesting. If he provides a harvesting service to others, he would also gain 107 baht/rai.
- Assumption VI: If farmer invests in a second-hand small tractor with a digger totaling 157,000 baht, his benefit is a 331.29 baht/rai saving from using mechanized harvesting compared to manual harvesting. If he provides a harvesting service to others, he would also gain 128 baht/rai.

Return on Investment, Payback Period and Required Harvesting Area to Meet Break-Even-Point

If farmer investing in mechanized harvesting utilizes the machinery on his own land and also provides services to his neighbors at a rate of 300 baht/rai for large tractors and 250 baht/rai for small tractors, then his return on investment will come from both savings from using mechanized harvesting on his own field and earnings from service providing to his neighbors.

Again, trialing different harvesting areas are done in Assumption I-VI.

Assumption I: Farmer having existing large tractor (60-80HP) and buying a cassava digger

Farmer invests about 20,000 baht for digger hitching with a large tractor with 60-80HP. He harvests 40 rai of his land, and also provides service to his neighbors at 300 baht/rai for additional income. Thus, the farmer needs to harvest at least 48.65 rai per year totally, to get payback in five years and return on investment at 20.01 percent. That means he has to provide mechanized harvesting service to others of at least 16.5 rai per year and work three days per year (Table 2.12).

If he harvests totally 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai per year, his return on investment will high as 710, 1,077, 1,435, 2,160, 2,881, and 3,613 percent respectively with a payback period of only 0.36-1.68 months.



Table 2.12: Return on Investment and Payback Period for Farmer's Owning a Large Tractor with Additional Investment on Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)						
	48.65	1,000	1,500	2,000	3,000	4,000	5,000
Working Days/Year (8 hours/day)	2	48	72	96	144	192	239
Total Income:	14,303	299,708	450,718	599,708	899,708	1,198,931	1,500,374
- Save from using m/c harvesting on his own field 40 rai (baht/yr.)	11,708	11,708	12,718	11,708	11,708	10,931	12,374
- Service to other casava farmers (baht/year)	2,595	288,000	438,000	588,000	888,000	1,188,000	1,488,000
Total Operating Expense (baht/year)	10,300	157,771	235,277	312,783	467,795	622,808	777,820
Net Income (baht/year)	4,003	141,937	215,441	286,925	431,912	576,123	722,554
Investment (baht)	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Return on Investment (%)	20.01	709.68	1,077.20	1,434.62	2,159.56	2,880.62	3,612.77
Payback Period (Year)	5.00	0.14	0.09	0.07	0.05	0.03	0.03

Note: 1. Farmer own 40 rai of cassava field and a 60-80HP tractor
 2. Digger price is 20,000 baht with 5 years lifetime
 3. Cassava mechanized harvesting service fee is 300 baht/rai
 4. Harvesting capacity 2.61 rai/hour

Assumption II: Farmer buying a new large tractor and a cassava digger.

Farmer invests a total of 920,000 baht for a new tractor with engine power 60-80HP and a digger.

If he wants to get payback in five years, he has to use the equipment a total of 1,495 rai per year or about 72 days, based on field capacity at 2.61 rai/hour. Meanwhile, he will get a 20 percent return on investment (Table 2.14).

If he harvests totally 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai per year, his return on investment will be about 13, 20, 27, 41, 54 and 68 percent respectively with a payback period of 1.47-7.56 years (see Table 2.13)

Table 2.13: Return on Investment and Payback Period for Farmer Buying a New Large Tractor and Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)						
	1,495	1,000	1,500	2,000	3,000	4,000	5,000
Working Days (8 hours/day)	72	48	72	96	144	192	239
Total Income:	447,431	298,931	448,931	598,931	898,931	1,198,931	1,498,931
- Savings from using m/c harvesting on his own field 40 rai (baht/year)	10,931	10,931	10,931	10,931	10,931	10,931	10,931
- Service to other casava farmers (baht/year)	436,500	288,000	438,000	588,000	888,000	1,188,000	1,488,000
Total Operating Expense (baht/year)	263,528	177,187	264,400	351,614	526,042	700,470	874,898
Net Income (baht/year)	183,903	121,744	184,530	247,317	372,889	498,461	624,033
Investment (baht)	920,000	920,000	920,000	920,000	920,000	920,000	920,000
Return on Investment (%)	19.99	13.23	20.06	26.88	40.53	54.18	67.83
Payback Period (Year)	5.00	7.56	4.99	3.72	2.47	1.85	1.47

Note: 1. Farmer own 40 rai of cassava field and buying a brand new 60-80HP tractor
 2. Digger price is 20,000 baht with 5 years lifetime
 3. Cassava mechanization harvesting service fee is 300 baht/rai
 4. Tractor (60-80HP) price is 900,000 baht with 10 years lifetime
 5. Farmer needs to buy new digger at year six at the same price
 6. Harvesting capacity 2.61 rai/hour



Assumption III: Farmer buys second-hand large tractor (60-80 HP) and cassava digger.

If farmer buys a second hand tractor and a cassava digger priced at 400,000 baht and 20,000 baht, he has to harvest a total of 534 rai per year in order to get payback at year five with a 20 percent return on investment (Table 2.14). Therefore, he has to provide a mechanized harvesting service over at least 494 rai per year.

If he harvests totally 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai per year, his return on investment will be about 38, 57, 76, 115, 153 and 192 percent respectively with a payback period of 2.64, 1.75, 1.31, 0.87, 0.65 and 0.52 years respectively.

Table 2.14: Return on Investment and Payback Period for Farmer Buying a Second-Hand Large Tractor and Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)						
	534	1,000	1,500	2,000	3,000	4,000	5,000
Working Days (8 hours/day)	26	48	72	96	144	192	239
Total Income:	160,574	300,374	450,374	600,374	900,374	1,200,374	1,500,374
- Savings from using m/c harvesting on his own field 40 rai (baht/year)	12,374	12,374	12,374	12,374	12,374	12,374	12,374
- Service to other cassava farmers (baht/year)	148,200	288,000	438,000	588,000	888,000	1,188,000	1,488,000
Total Operating Expense (baht/year)	76,640	141,113	210,290	279,467	417,820	556,174	694,528
Net Income (baht/year)	83,934	159,261	240,084	320,907	482,553	644,200	805,846
Investment (baht)	420,000	420,000	420,000	420,000	420,000	420,000	420,000
Return on Investment (%)	19.98	37.92	57.16	76.41	114.89	153.38	191.87
Payback Period (Year)	5.00	2.64	1.75	1.31	0.87	0.65	0.52

Note: 1. Farmer own 40 rai of cassava field and buys a second-hand 60-80HP tractor
 2. Digger price is 20,000 baht with 5 years lifetime
 3. Cassava mechanized harvesting service fee is 300 baht/rai
 4. Second-hand tractor (60-80HP) price is 400,000 baht with 5 years lifetime
 5. Farmer needs to buy new digger at year six at the same price
 6. Harvesting capacity 2.61 rai/hour

Assumption IV: Farmer already has existing small tractor and buys a digger.

If farmer already has a small tractor (>35HP) and buys a digger at 7,000 baht and uses the mechanized only on his own land 40 rai, he will get payback at 1.47 years with a 68 percent return on investment (Table 2.15).

If he harvests totally 1,000, 1,500, 2,000, 3,000, and 4,000 rai per year, his return on investment will be about 1,634, 2,450, 3,266, 4,895 and 6,527 percent respectively with a payback period of only 0.24-0.72 months.



Table 2.15: Return on Investment and Payback Period for Farmer Buying a Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)					
	40	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	3	87	131	175	262	350
Total Income:	12,718	252,718	377,718	502,718	752,560	1,002,560
- Savings from using m/c harvesting on his own field 40 rai (baht/year)	12,718	12,718	12,718	12,718	12,560	12,560
- Service to other cassava farmers (baht/year)	-	240,000	365,000	490,000	740,000	990,000
Total Operating Expense (baht/year)	7,949	138,306	206,200	274,095	409,883	545,672
Net Income (baht/year)	4,769	114,412	171,517	228,623	342,677	456,889
Investment (baht)	7,000	7,000	7,000	7,000	7,000	7,000
Return on Investment (%)	68.12	1,634.45	2,450.25	3,266.04	4,895.39	6,526.98
Payback Period (Year)	1.47	0.06	0.04	0.03	0.02	0.02

Assumption: 1. Farmer own 40 rai of cassava field and a small-scale tractor(<35)

2. Digger price is 7,000 baht with 5 years lifetime
3. Cassava mechanization harvesting service fee is 250 baht/rai
4. Mechanization harvesting capacity 1.43 rai/hour

Assumption V: Farmer buying a brand-new small-scale tractor and a digger.

If farmer invests in a new small tractor (<35HP) and a digger totaling 350,000 baht, he has to use the mechanized harvesting over 655 rai per year to get payback in 5 years with a 20 percent return on investment (Table 2.16).

If he harvests totally 1,000, 1,500, 2,000, 3,000, and 4,000 rai per year, his return on investment will be about 31, 46, 61, 92, and 122 percent respectively with a payback period of only 0.82-3.27 years.

Table 2.16: Return on Investment and Payback Period for Farmer Buying a New Small Tractor and a Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)					
	655	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	57	87	131	175	262	350
Total Income:	166,178	252,428	377,428	502,428	752,428	1,002,428
- Savings from using m/c harvesting on his own field 40 rai (baht/year)	12,428	12,428	12,428	12,428	12,428	12,428
- Service to other cassava farmers (baht/year)	153,750	240,000	365,000	490,000	740,000	990,000
Total Operating Expense (baht/year)	96,202	145,547	217,061	288,576	431,605	574,635
Net Income (baht/year)	69,976	106,881	160,367	213,852	320,823	427,794
Investment (baht)	350,000	350,000	350,000	350,000	350,000	350,000
Return on Investment (%)	19.99	30.54	45.82	61.10	91.66	122.23
Payback Period (Year)	5.00	3.27	2.18	1.64	1.09	0.82

Assumption: 1. Farmer own 40 rai of cassava field

2. Digger price is 7,000 baht with 5 years lifetime
3. Mechanized cassava harvesting service fee is 250 baht/rai
4. Tractor (34HP) price is 343,000 baht with 10 years lifetime
5. Farmer has to buy new digger at year six at the same price
6. Mechanization harvesting capacity 1.43 rai/hour

Assumption VI: Farmer buys a second-hand small-scale tractor and cassava digger

If farmer invests in a second small tractor and a digger totaling 187,000 baht, he has to harvest over 288 rai per year in order to get a 5 year payback period with a 20 percent return on investment (Table 2.17).

If he harvests totally 1,000, 1,500, 2,000, 3,000, and 4,000 rai per year, his return on investment will be about 69, 103, 137, 205, and 273 percent respectively with a payback period of only 0.37-1.46 years.

Table 2.17: Return on Investment and Payback Period for Farmer Buying a Second-Hand Small-Scale Tractor and a Cassava Digger

Harvesting his own land 40 rai	Total Harvested Area/Year (rai/year)					
	288	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	25	87	131	175	262	350
Total Income:	75,127	253,252	378,252	503,252	753,252	1,003,252
- Savings from using m/c harvesting on his own field 40 rai (baht/year)	13,252	13,252	13,252	13,252	13,252	13,252
- Service to other casava farmers (baht/year)	61,875	240,000	365,000	490,000	740,000	990,000
Total Operating Expense (baht/year)	37,718	124,955	186,174	247,393	369,830	492,268
Net Income (baht/year)	37,408	128,296	192,078	255,859	383,421	510,984
Investment (baht)	187,000	187,000	187,000	187,000	187,000	187,000
Return on Investment (%)	20.00	68.61	102.72	136.82	205.04	273.25
Payback Period (Year)	5.00	1.46	0.97	0.73	0.49	0.37

Assumption: 1. Farmer own 40 rai of cassava field

2. Digger price is 7,000 baht with 5 years lifetime
3. Mechanized cassava harvesting service fee is 250 baht/rai
4. Second-hand small tractor (34HP) price is 180,000 baht with 5 years lifetime
5. Farmer has to buy new digger at year six at the same price
6. Mechanization harvesting capacity 1.43 rai/hour

Investment by Pure Service Providers

Return on Investment, Payback Period and Required Harvesting Area to Meet Break-Even-Point

If a service provider invests in the harvesting machine, and provides services to cassava farmers at rate of 300 baht/rai for a large tractor and 250 baht/rai for a small tractor. Then, his return on investment will come from providing services to the farmers. However, return on investment and payback period depends upon several variable factors such as fuel price, labor daily rate, and harvesting area per year.

Again, trialing different harvesting areas is done in Assumption I-VI.

Assumption I: Service provider has a large tractor (60-80HP) and buys a cassava digger

If the service provider has a tractor with 60-80HP, buys a cassava digger and provides a mechanized harvesting service to cassava farmers over 27.6 rai at 300



baht/rai, they will get 19.99 percent return on investment with a five year payback period (Table 2.18).

If he provides service to farmers at 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai/year, he will get return on investment of 725, 1,087, 1450, 2,175, 2,900 and 3,625 percent with only 0.03-0.14 year payback period.

Table 2.18: Return on Investment and Payback Period for Service Provider Having a Large-Scale Tractor and Buying a Cassava Digger

Harvested Area/Year (rai)	27.6	1,000	1,500	2,000	3,000	4,000	5,000
Working Days/Year (8 hours/day)	1	48	72	96	144	192	239
Services Income	8,280	300,000	450,000	600,000	900,000	1,200,000	1,500,000
Total Operating Expense (baht/year)	4,278	155,012	232,518	310,025	465,037	620,049	775,061
Net Income (baht/year)	4,002	144,988	217,482	289,975	434,963	579,951	724,939
Investment (baht)	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Return on Investment (%)	20.01	724.94	1,087.41	1,449.88	2,174.82	2,899.75	3,624.69
Payback Period (Year)	5.00	0.14	0.09	0.07	0.05	0.03	0.03

Note: 1. Digger price is 20,000 baht with 5 year lifetime

2. Cassava mechanized harvesting service fee is 300 baht/rai

3. Harvesting capacity 2.61 rai/hour

Assumption II: Service provider buys a new tractor with 60-80HP and a cassava digger

If this service provider harvests 1,465 rai/year or working 70 days/year, he will get 20 percent return on investment with a 5 year payback period (Table 2.19).

If he provides service to farmers at 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai/year, he will get a return on investment of 14, 20, 27, 41, 55, and 68 percent with 1.47-7.33 year payback period.

Table 2.19: Return on Investment and Payback Period for Service Provider Buying a New Large-Scale Tractor and a Cassava Digger

Harvested Area/Year (Rai)	1465	1,000	1,500	2,000	3,000	4,000	5,000
Working Days (8 hours/day)	70	48	72	96	144	192	239
Services Income	439,500	300,000	450,000	600,000	900,000	1,200,000	1,500,000
Total Operating Expense (Baht/Yr.)	255,537	174,428	261,642	348,856	523,283	697,711	872,139
Net Income (Baht/Yr.)	183,963	125,572	188,358	251,144	376,717	502,289	627,861
Investment (Baht)	920,000	920,000	920,000	920,000	920,000	920,000	920,000
Return on Investment (%)	20.00	13.65	20.47	27.30	40.95	54.60	68.25
Payback Period (Year)	5.00	7.33	4.88	3.66	2.44	1.83	1.47

Note: 1. Digger price is 20,000 baht with 5 year lifetime

2. Cassava mechanized harvesting service fee is 300 baht/rai

3. Tractor (60-80HP) price is 900,000 baht with 10 year lifetime

4. Farmer needs to buy new digger at year six at the same price

5. Harvesting capacity 2.61 rai/hour



Assumption III: Service provider buys a second-hand tractor with 60-80 HP and a cassava digger.

If the service provider harvests 520 rai/year (25 working days) for his clients, he will get 20 percent return on investment with a five year payback period.

Meanwhile, if he provides a harvesting service up to 1,000, 1,500, 2,000, 3,000, 4,000, and 5,000 rai, the rate of return on investment will be 38, 58, 77, 115, 154, and 192 percent respectively with a payback period of 2.60, 1.73, 1.30, 0.87, 0.65 and 0.52 years respectively.

Table 2.20: Return on Investment and Payback Period for Service Provider Buying a Second-Hand Tractor with Engine Power 60-80HP and a Cassava Digger

Harvested Area/Year (Rai)	520	1,000	1,500	2,000	3,000	4,000	5,000
Working Days (8 hours/day)	25	48	72	96	144	192	239
Services Income	156,000	300,000	450,000	600,000	900,000	1,200,000	1,500,000
Total Operating Expense (Baht/Yr.)	71,944	138,354	207,531	276,708	415,062	553,416	691,769
Net Income (Baht/Yr.)	84,056	161,646	242,469	323,292	484,938	646,584	808,231
Investment (Baht)	420,000	420,000	420,000	420,000	420,000	420,000	420,000
Return on Investment (%)	20.01	38.49	57.73	76.97	115.46	153.95	192.44
Payback Period (Year)	5.00	2.60	1.73	1.30	0.87	0.65	0.52

- Note: 1. Digger price is 20,000 baht with 5 year lifetime
 2. Cassava mechanized harvesting service fee is 300 baht/rai
 3. Tractor (60-80HP) price is 900,000 baht with 10 year lifetime
 4. Farmer needs to buy new digger at year six at the same price
 5. Harvesting capacity 2.61 rai/hour

Assumption IV: Service provider owning a tractor with engine power less than 35HP and buying a digger

If the service provider provides harvesting services of only 12.25 rai/year, he will get 20 percent return on investment with a 5 year payback period.

If he provides services up to 1,000, 1,500, 2,000, 3,000 and 4,000 rai/year, the return on investment will be at 1,632, 2,447, 3,263, 4,895 and 6,526 percent respectively with a payback period of only 0.24-0.72 months.



Table 2.21: Return on Investment and Payback Period for Service Provider Having a Small Tractor (<35HP) and Buying a Cassava Digger

Harvested Area/Year (Rai)	12.25	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	1	87	131	175	262	350
Services Income	3,063	250,000	375,000	500,000	750,000	1,000,000
Total Operating Expense (Baht/Yr.)	1,663	135,789	203,683	271,577	407,366	543,154
Net Income (Baht/Yr.)	1,399	114,211	171,317	228,423	342,634	456,846
Investment (Baht)	7,000	7,000	7,000	7,000	7,000	7,000
Return on Investment (%)	19.99	1,631.59	2,447.39	3,263.18	4,894.77	6,526.37
Payback Period (Year)	5.00	0.06	0.04	0.03	0.02	0.02

Note 1. Digger price is 7,000 baht with 5 year lifetime

2. Cassava mechanized harvesting service fee is 250 baht/rai

3. Mechanization harvesting capacity 1.43 rai/hour

Assumption V: Service provider buys a new tractor with engine power less than 35HP and a digger

If the service provider provides harvesting services totaling 654 rai/year, he will get a 20 percent return on investment with a 5 year payback period.

If he provides services up to 1,000, 1,500, 2,000, 3,000, and 4,000 rai/year, the return on investment will be at 31, 46, 61, 92, and 122 percent respectively with a payback period of 0.82-3.27 years.

Table 2.22: Return on Investment and Payback Period for Service Provider Buying a New Small Tractor and a Cassava Digger

Harvested Area/Year (Rai)	654	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	57	87	131	175	262	350
Services Income	163,500	250,000	375,000	500,000	750,000	1,000,000
Total Operating Expense (Baht/Yr.)	93,541	143,029	214,544	286,058	429,088	572,117
Net Income (Baht/Yr.)	69,959	106,971	160,456	213,942	320,912	427,883
Investment (Baht)	350,000	350,000	350,000	350,000	350,000	350,000
Return on Investment (%)	19.99	30.56	45.84	61.13	91.69	122.25
Payback Period (Year)	5.00	3.27	2.18	1.64	1.09	0.82

Assumption: 1. Digger price is 7,000 baht with 5 year lifetime

2. Mechanized cassava harvesting service fee is 250 baht/rai

3. Tractor (34HP) price is 343,000 baht with 10 year lifetime

4. Farmer has to buy new digger at year six at the same price

5. Mechanized harvesting capacity 1.43 rai/hour

Assumption VI: Service provider investing both a second-hand tractor with engine power less than 35HP and cassava digger

If a service provider buys a second-hand small tractor and cassava digger, he will get a 20 percent return on investment with a 5 year payback period if he harvests 293 rai/year (Table 2.23).

If he provides services up to 1,000, 1,500, 2,000, 3,000, and 4,000 rai/year, the return on investment will be 68, 102, 136, 205 and 273 percent respectively with a payback period of 0.37-1.47 years.

Table 2.23: Return on Investment and Payback Period for Service Provider Buying a Second-Hand Small Tractor and a Cassava Digger

Harvested Area/Year (Rai)	293	1,000	1,500	2,000	3,000	4,000
Working Days (8 hours/day)	26	87	131	175	262	350
Services Income	73,250	250,000	375,000	500,000	750,000	1,000,000
Total Operating Expense (Baht/Yr.)	35,874	122,438	183,656	244,875	367,313	489,750
Net Income (Baht/Yr.)	37,376	127,562	191,344	255,125	382,687	510,250
Investment (Baht)	187,000	187,000	187,000	187,000	187,000	187,000
Return on Investment (%)	19.99	68.22	102.32	136.43	204.65	272.86
Payback Period (Year)	5.00	1.47	0.98	0.73	0.49	0.37

- Assumption: 1. Digger price is 7,000 baht with 5 year lifetime
 2. Mechanized cassava harvesting service fee is 250 baht/rai
 3. Second hand Tractor (34HP) price is 180,000 baht with 10 year lifetime
 4. Farmer has to buy new digger at year six at the same price
 5. Mechanized harvesting capacity 1.43 rai/hour

2.2.3 Advantages and Disadvantages

Advantages of Mechanized Cassava Harvesting

- Mechanized harvesting has better working capacity compared to traditional manual harvesting. Large-scale machinery can harvest 2.61 rai/hour, and small-scale can do 1.43 rai/hour. Meanwhile, manual harvesting can do only 0.037 rai/hour.
- Increasing labor productivity. Field working capacity of current farmers' cassava harvesting machinery with 22 and 60 HP tractors are 1.08 and 1.97 rai/man-hour respectively compared to the traditional labor harvesting at only 0.037 rai/man-hour (Table 2.24).⁷ This allows cassava farmers to sell their production at the right time, price, root quality, and match truck availability. This can reduce losses occurring from starch percentage and weight reduction when traditional labor harvesting may not be able to fulfill truck delivery (12 tons for 6 wheel truck and 25 tons for 10 wheel truck).
- Lowering total production costs. Mechanized harvesting cost/rai is cheaper compared with the traditional manual harvesting cost at 516 baht/rai. At

⁷ Wongpichet S. & Watyothin C., Development of Cassava Digger which Hitched with Small Tractor, 2003 & 2005

current diesel prices of 23 baht/liter, large-scale harvesting machines (60-80HP) have a total operating cost of only 207-224 baht/rai (including labor cost for roots collecting, separating from its mass, and loading). Meanwhile, small-scale harvesting machines (<35HP) have total operating costs of only 187-206 baht/rai. The mechanized harvesting cost is still lower than the manual harvesting even when diesel price increases up to 35 baht/liter (Table 2.25).

- Mechanized harvesting can be done during the dry season when traditional labor harvesting cannot be undertaken because of hard soil conditions.
- Using mechanized harvesting would increase tractor utilization if a farmer already has a tractor.
- The current harvesting machines can work well in the field with flexible row spacing from 766 to 1,000 mm, according to Professor Dr.Seri Wongpichet of Khon Kaen University.
- Considerable decrease of harvesting losses and damage (roots left in the ground).
- Continuous supply to the market and processing plants with fresh cassava roots



Table 2.24: Comparison of Working Capacity and Harvesting Cost of Traditional Harvesting Method and Current Mechanized Method

Working Result ¹	Harvesting Machine ¹	Harvesting Machine ²	Traditional Labor Harvesting ¹
	Small Tractor	Big Tractor	
	(22 HP)	(>60 HP)	
Dimension and Capability			
1. Digger Width (mm)	530.00	708.00	-
2. Average Digging Width (mm)	600.00	1,051.00	-
3. Average Digging Depth (mm)	191.00	261.00	-
4. Average Digging Speed (km/hr)	2.37	4.54	-
Working Capacity			
1. Field Capacity			
- Working Capacity (rai/hour), (rai/man-hour)	1.08	1.97	0.037
- Speed Efficiency (%)	68.00	68.00	-
2. Cassava Digging Capacity (Quantity)			
- Quantity of Easy Digging Cassava (%)	91.60	86.00	94.40
- Quantity of Difficult Digging Cassava (%)	7.60	13.60	-
3. Loss: Cassava Roots Left in the Ground (%)	0.80	0.40	5.60
4. Harvesting Cost (baht/ton)	122-242 Baht/Ton ³	150-270 Baht/Ton ⁴	153 Baht/Ton ⁵

Source: Dr.Seri Wongpichet, Faculty of Engineering, Khon Kaen University

Note:

1. Trial Factors include

- Rayong 5 variety, radial of roots or average width and depth =225 x 209 mm.
- Distance between cassava trees 606 mm., Distance between rows 943 mm.
- Cassava yield 3,751 kg/rai
- Soil type: Clay sandy soil with 1.18%wb moisture
- Land area 1,600 m²

2. Trial Factors include

- Rayong 5 variety, radial of roots or average width and depth =229 x 186 mm.
- Distance between cassava trees 550 mm., Distance between rows 1,110 mm.
- Cassava yield 1,981.3 kg/rai
- Soil type: Clay sandy soil with 2.5%wb moisture
- Land area 1,643 m²

3. Including labor cost for roots collecting and loading into truck., Source: AgriSource Interview in Nakhon Ratchasima

4. Including labor cost for roots collecting and loading into truck, Source: AgriSource Interview in Chonburi & Rayong

5. Including labor cost for roots collecting and loading into truck, Source: Office of Agricultural Economic/ 2006 Annual Report



Table 2.25: Cassava Harvesting Machine Operating Cost at Various Diesel Prices

Total Operating Cost of Cassava Harvesting Machine (baht/rai)			
Diesel Price	23 baht/litre	30 baht/litre	35 baht/litre
Assumption I. Buy only large digger	224	247	264
Assumption II. Buy new large tractor & digger	203	267	283
Assumption III. Buy second-hand large tractor & digger	207	230	247
Assumption IV. Buy only small digger	199	219	234
Assumption V. Buy new small tractor & digger	206	227	241
Assumption VI. Buy second-hand small tractor & digger	187	206	221

Disadvantages of Mechanized Cassava Harvesting

- The harvesting machine is constrained when working in field layouts that have short lengths, on sloping land, and may not be able to work in the rainy season because of difficulty of tractor movement on wet soil.
- Require skilled labor to operate and maintain tractors and harvesting machines.
- Suitable cassava varieties should be considered to get the highest working efficiency. Consistent size, width and length of roots allows working efficiency and speed.
- Large-scale harvesting machine still needs labor of at least 12 people per day as it is a three stage process; first-mechanized lifting of the roots, second first team with 4 people walk after the tractor to remove cassava roots from furrow and accumulate in heaps, and third another team with 8 people cutting individual roots from their mass and loading into the truck. Lower labor levels are required for small tractor harvesting.
- The harvesting machine cannot work continually if the cassava field has lots of weed (Photo 5).
- Some roots remaining in the ground (Photo 6), although considerably less than traditional methods.



Photo 5: Cassava Harvesting Machine Work Obstructed by Weeds

Photo 6: Roots Remaining in the Ground



Photo 5



Photo 6

2.3 Major Constraints and Opportunities Facing Suppliers

Constraints

- Farmers have limited money invested in their plantation as cassava is a low income crop. Most investment money is from cooperatives loans, with an interest rate of 8.5 percent/year. A farmer with a 2-person guarantee can not get more than 50,000 baht loan. A farmer with collateral can get only half of the appraised cost or not more than 400,000 baht.
- Although growth is expected in the tractor market due the availability of the Kubota and John Deere leasing services, farmers still need large amount of cash for a down-payment. The down payment for a small tractor is 60,000 baht and 100,000 baht for a large tractor. Installment payments are required every month which is difficult for farmers because of the seasonal nature of their income.
- Most cassava farmers have no idea about mechanized harvesting benefits and efficiency so they do not trust the working capacity and efficiency of the mechanized harvesting.
- Increasing fuel price would increase mechanized operating costs.

Opportunities

- Mechanization tends to have more become more involved in agriculture as the labor force in the agricultural sector has continued to move into the non-agricultural sector.

Labor force problems are likely to happen in north-eastern and eastern areas as young people prefer to work in factories rather than in the fields. Normally, cassava farmers have to avoid harvesting during the rice and sugarcane harvesting period (November-January). Otherwise, they have to pay higher daily wages. Wages for rice and sugarcane harvesting are as high as 200-240 baht per day compared to the normal cassava daily rate of 120-140 baht.

Only wealthy to medium income farmers or transport service providers can gather sufficient numbers of either local or foreign labor. Local poor labor usually borrows money from wealthy/large farmers so they're forced to pay back either in cash or laboring. Meanwhile, foreign labor demands for housing, transport, and some other living benefits which small farmers cannot afford.

- There is potential that farmers and service providers in the northeast will be interested in using mechanized cassava harvesting if they have opportunity to observe the actual field work. Using mechanized harvesting with small tractors (<30 HP) has slowly spread out in Nakhon Ratchasima over the last two years, due to its harvesting capability in dry season combined with technology transfer by Professor Dr.Seri Wongpichet of Khon Kaen University. Small-scale mechanization requires less investment compared to large scale.
- Availability of small scale, flexible mechanization for reducing labor-intensive tasks provides more opportunity to small-medium farmers for mechanery investment, as labor costs are rising to the level of justifying the investment. In the past, mechanized developed for cassava was only appropriated for large commercial plantations.
- Financial institution and leasing companies are interested in financing for farmers' investment on farm mechanization.
- A strong baht would lower cost of imported tractors and fuel price.



3. The Service Market

The purpose of this section is to assess the current usage and utilization of mechanization in cassava production and to identify the constraints and limitations in the service market. The study has to address the following:

3.1 Current Usage and Utilization of Mechanization in Cassava Production

AgriSource Field Survey

This field survey focused on the major cassava production areas including Chonburi, Rayong, Nakhon Ratchasima, Khon Kaen, Maha Sarakham, and Kalasin.

During the field survey, usage of mechanization in cassava farms was found in Chonburi, Rayong, and Nakhon Ratchasima province. There is no mechanized harvesting usage in Khon-Kaen, Maha Sarakham, and Kalasin, though they use mechanization for land development and preparation.

Chonburi and Rayong have used mechanization in cassava fields for the last 7-8 years while Nakhon Ratchasima had used the mechanized harvesting for only two years (first crop in 2005/06, and this year 2006/07 will be the second crop).

Please note that the survey focused on cassava farmers experienced in using mechanized harvesting. These also knew the current manual harvesting costs and labor situation in their surrounding areas.

Chonburi and Rayong Provinces

In Chonburi and Rayong, large-scale mechanization (tractor with 60-70HP) is mostly used. Of those using mechanization, utilization is high, including land preparation, weeding, and harvesting. Most of the farmers interviewed in these provinces owned or rented big plots of land and usually plant both cassava and sugarcane at the same time. They also use the mechanization for sugarcane farming where the utilization is higher compared to cassava farming, because the nature of the cassava plant, size and shape of roots that restricts easy mechanization.

In addition, large-scale cassava mechanized harvesting still is labor-intensive because of the three stage harvesting process; first mechanized lifting of the cassava roots, second about 4 people are needed to remove the roots from the furrow otherwise the tractor will run over and break the roots, and third another 8 labors remove the individual roots from the root mass and load into a six-wheel truck (containing 10-11 tons). More labor is required if a ten-wheel truck (16-18 tons) is used for delivery. Mechanized harvesting still reduces the total labor requirement and increases productivity. Some farmers owning large-scale harvesting machines have stopped using the machine for harvesting because they have been forced to by foreign laborers who want to get higher payments from the number of working days or by harvesting weight. If farmers insist on



using mechanized harvesting instead of manual harvesting, they will not have labor which they require for accumulating roots, cutting and loading. Some of these farmers have turned back to using manual harvesting, even though the cost is higher.

Current mechanized harvesting service costs in Chonburi and Rayong province is charged at 23-25 baht/ 70 kg, this includes labor costs for root collecting and truck loading (see Table 3.1). Delivery costs are charged separately at 130 baht/ton. Some service providers charge 31 baht/100 kg, this includes labor cost for root collecting and truck loading as well as delivery to the processor. Some service providers charge at 300 baht/ rai for mechanized harvesting, labor for root collecting and truck loading with separate charges for delivery depending on distance.

Average mechanized harvesting service rate in Chonburi and Rayong province are about 267 baht/ton or 1,615 baht/rai with an average harvested area of 164 rai/farmer, and a 6.04 ton yield.

Use of mechanized harvesting in Rayong is currently less than 20 percent of the total crop, according to Mr.Somdej Jitsom, leader of Rayong Cassava Farmers Group. Most of the cassava farmers using mechanized harvesting are the large farmers who invest in their own harvesting machinery and employ tractor drivers. As a result, these farmers have gained benefits by reducing production costs from savings occurring from the utilization of mechanization compared to manual harvesting.

Photo 7: Large Scale Cassava Harvesting Machine

Photo 8: Labor Collecting and Separating Cassava Roots



Photo 7



Photo 8



Table 3.1: Mechanized Harvesting Service Cost in Chonburi and Rayong Provinces, 2007

Chonburi & Rayong Province	Harvested Area	Yield	Total Production	Tractor	Mechanization Harvesting Service Rate	Labor Root Collecting & Loading	Cassava Delivery Cost
Farmer/Amphur	(rai)	(tons/rai)	(tons)	(HP)	(baht)	(baht)	(baht/ton)
Mr.Nikom1/ A.Nongyai, Chonburi	200	8.4	1,680	60-80HP	23 baht/ 70 kg including labor for root collecting & loading		130
Mr.Nikom2/ A.Nongyai, Chonburi	400	4.9	1,960	60-80HP	23 baht/ 70 kg including labor for root collecting & loading		130
Mr.Tanant/ A.Nongyai, Chonburi	150	7	1,050	60-80HP	22 baht/ 70 kg including labor for root collecting & loading		130
Mr.Somdej/ A.Pluakdaeng, Rayong	300	4.5	1,350	60-90HP	300 baht/rai	13 baht/ 70 kg	130
Mr.Dusit/ A.Pluakdaeng, Rayong	25	10	250	60-80HP	25 baht/ 70 kg including labor for root collecting & loading		130
Ms.Kham/ A.Banchang, Rayong	20	4	80	60-80HP	31baht/100 kg including root collecting & delivery		
Mrs.Kguan/ A.Banchang, Rayong	50	3.5	175	60-80HP	31baht/100 kg including root collecting & delivery		
Average	164	6.04	935	60-90HP	267.45 baht/ton 1,615.39 baht/rai		130

Source: AgriSource Field Survey, February-March 2007



Table 3.2: Traditional Manual Harvesting Cost in Chonburi and Rayong Province

Chonburi & Rayong Provinces	Harvested Area	Yield	Total Production	Labor rate	Cassava Delivery Cost	Cassava Price	Current Harvesting Method
Farmer/Amphur	(rai)	(ton/rai)	(tons)	(baht)	(baht/ton)	(baht/kg)	
Mr.Nikom1/ A.Nongyai, Chonburi	200	8.4	1,680	12 baht/70 kg (=171 baht/ton)	130	1.5	m/c
Mr.Nikom2/ A.Nongyai, Chonburi	400	4.9	1,960	12 baht/70 kg (=171 baht/ton)	130	1.34	m/c
Mr.Tanant/ A.Nongyai, Chonburi	150	7	1,050	120 baht/day plus snack, drink, & transportation	130	1.3	m/c
Mr.Somdej/ A.Pluakdaeng, Rayong	300	4.5	1,350	13 baht/70 kg (=186 baht/ton)	130	1.3	m/c
Mr.Dusit/ A.Pluakdaeng, Rayong	25	10	250	130 baht/day plus meals, snack & transportation	130	1.4	m/c
Ms.Kham/ A.Banchang, Rayong	20	4	80	31baht/100 kg including root delivery (310 baht/ton)		1.3	Manual
Mrs.Kguan/ A.Banchang, Rayong	50	3.5	175	31baht/100 kg including root delivery (310 baht/ton)		1.3	Manual
Average	164	6.04	935	287.25 baht/ton* 1,734.99 baht/rai	130	1.35	

Source: AgriSource Field Survey, February-March 2007

Note: Labor working capacity is 0.037 rai/man-hr.

Nakhon Ratchasima

Cassava farmers in Nakhon Ratchasima have started using mechanized harvesting over the last two years, according to AgriSource's interview. Some have just started using mechanized harvesting for the first crop this year. There was cooperation in the research and development of a vibrating cassava digger by Kasetsart University (Dr.Sakda Intaravichai), Department of Agriculture (Dr.Thanya Kiatiwat), and TTDI (at research station in Dan-khun-tod, Nakhon Ratchasima) in 1999. Publications about the "K.72"-vibrating cassava digger during July-September 1999 can be found in The Thai Tapioca Trade Association 1999 Year Book, Thairat Newspaper, Krungthep Turakij Newspaper, and Farmer Technology. There are no recent publications.

Currently, small-scale mechanized harvesting (20-35HP tractor) is mostly used due to smaller land holdings compared to cassava farming in Chonburi and Rayong. In addition, Kubota, the leading small tractor supplier of has offered a good deal with a promotion program and long term installment program. Meanwhile, other suppliers including new and second hand large tractors do not have such a good offer, they are only selling on a cash basis.



According to the AgriSource survey, the small-scale mechanized harvesting requires less labor compared to the large one because working speed and capacity are lower. It requires only about 6-7 labor/machine compared to 12-15 required by the large-scale teams.

In addition, this small-scale mechanization requires only two stages process, first mechanized lifting of the cassava roots; second remove the individual roots from the root mass and loading into six-wheel truck. Some operators choose to put a third step of collecting the roots into heaps before cutting. (Photo 10)

Photo 9: Small Cassava Harvesting Machine in Nakhon Ratchasima

Photo 10: Labor Gathering and Separating Cassava Roots



Mechanized service providers in Nakhon Ratchasima charge 150-250 baht/rai. Cassava farmers have to pay separately for root collecting, truck loading, and delivery to processors. Labor costs for root collecting and truck loading is charged at 150 baht/ton or 120-150 baht/day. Normally, the mechanized service providers are the labor organizers or leaders who provide transport for the labor. The average mechanized harvesting service cost in Nakhon Ratchasima is about 228 baht/ton or 1,123 baht/rai (Table 3.3). Meanwhile, the traditional manual harvesting cost is about 317 baht/ton or 1,563 baht/rai (see Table 3.4).



Table 3.3: Mechanized Harvesting Service Cost in Nakhon Ratchasima, 2007

Nakhon Ratchasima Province	Harvested Area	Yield	Total Production	Tractor	Mechanization Harvesting Service Rate	Labor Root Collecting & Loading	Cassava Delivery Cost
Farmer/Amphur	(rai)	(tons/rai)	(tons)	(HP)	(baht)	(baht)	(baht/ton)
Ms.Chantha/ A.Sikiew	32	5.00	160	34HP	150 baht/rai	150 baht/ton	150
Mr.Inta/ A.Sikiew	30	5.00	150	34HP	150 baht/rai	150 baht/ton	150
Mr.Boontham/ A.Sikiew	300	5.00	1,500	34HP	150 baht/rai	150 baht/day	100
Mr.Vichian/ A.Muang	300	10.00	3,000	never use	Don't know	Don't know	130
Mr.Somchai/ A.Sikiew	20	4.00	80	28HP	200 baht/rai	150 baht/ton	150
Mr.Sam/ A.Jakaraj	24	4.37	105	34HP	180 baht/rai	120 baht/day	150
Mr.Samruay/ A.Jakaraj	5	5.00	25	28HP	180 baht/rai	120 baht/day	150
Mr.Sang/ A.Sungnuean	5	3.00	15	28HP	250 baht/rai	150 baht/ton	150
Mr.Sakorn-Service Provider/ A.Sungnuean	15	3.00	45	28HP	250 baht/rai	150 baht/day	150
Average	81	4.93	564	28-34HP	38.33 baht/ton 189 baht/rai	189.40 baht/ton, 933.74 baht/rai	142
Total Harvesting Cost					227.73 baht/ton	1,122.74 baht/rai	

Source: AgriSource Field Survey, February-March 2007

Note: Labor working capacity for root collecting and loading is 0.074 rai/man-hr. with the assumption that the capacity will be double compared to manual harvesting at 0.037 rai/man-hr.

Table 3.4: Traditional Manual Harvesting Cost in Nakhon Ratchasima Province

Nakhon Ratchasima Province	Harvested Area	Yield	Total Production	Labor rate	Cassava Delivery Cost	Cassava Price	Current Harvesting Method
Farmer/Amphur	(rai)	(tons/rai)	(tons)	(baht)	(baht/ton)	(baht/kg)	
Ms.Chantha/ A.Sikiew	32	5.00	160	200 baht/ton	150	1.3	m/c 1st crop
Mr.Inta/ A.Sikiew	30	5.00	150	200 baht/ton	150	1.32	m/c
Mr.Boontham/ A.Sikiew	300	5.00	1,500	150 baht/day	100	1.3	m/c
Mr.Vichian/ A.Muang	300	10.00	3,000	150 baht/ton in rainy season, 220 baht/ton in dry season	130	1.3	Manual
Mr.Somchai/ A.Sikiew	20	4.00	80	170 baht/ton	150	1.28	m/c
Mr.Sam/ A.Jakaraj	24	4.37	105	120 baht/day	150	1.2	m/c
Mr.Samruay/ A.Jakaraj	5	5.00	25	120 baht/day	150	1.2	m/c
Mr.Sang/ A.Sungnuean	5	3.00	15	300 baht/ton	150	1.3	m/c
Mr.Sakorn (Service Provider)/ A.Sungnuean	15	3.00	45	150 baht/day	150	1.35	m/c
Average	81	4.93	564	317.10 baht/ton* 1,563.30 baht/rai	142	1.28	

Source: AgriSource Field Survey, February-March 2007

Note: Labor working capacity is 0.037 rai/man-hr.



Kasetsart University Field Survey

According to a research survey in Chachoengsao, Prachinburi, Sa Kaeo, Chonburi, and Rayong done by Sompong Sriprang⁸ in 2001, most farmers investing in cassava harvesters (digger) already have their own tractor with an average planting area of 145 rai (Table 3.5). These farmers have used cassava harvesting machines on their own land for approximately 21.68 percent of total working hours in cassava harvesting. The remaining 78.32 percent of total working hours were as service providers for other nearby farmers.

Table 3.5: Cassava Harvested Area of Farmers Owning Tractors and Cassava Harvester in Eastern Thailand, 1997/98

Farmer Group	Total Harvested Area of the Group	Harvested Area of Farmers Occupying Cassava Harvesting Machine
	(Rai)	
Chachoengsao:		
Moo 6 A.Plangyao	200.00	60.00
Moo 8 A.Sanamchaikat	500.00	200.00
Moo 6 A.Phanomsarakram	1,200.00	300.00
Moo 13 A.Ta-trakieb	500.00	130.00
Prachinburi:		
Moo 13 A.Srimahapoh	450.00	60.00
Moo 5 A.Srimahosop	400.00	20.00
Srakaew:		
Moo 5 A.Wangnamyen	500.00	50.00
Moo 8 A.Tapraya	600.00	80.00
Chonburi:		
Moo 2 A.Nongyai	900.00	300.00
Rayong:		
Moo 6 A.Banchang	945.00	250.00
Total	6,195.00	1,450.00
Average	619.50	145.00

3.1.1 Fee Based Service Providers

Fee based service providers include contract buyers, harvesting service providers, and full range services providers. Mechanized cassava service providers are found in Chonburi, Rayong, Chachoengsao, Nakhon Ratchasima, and Prachinburi.

Contact buyers usually buy the cassava roots in situ, then harvest with their own staff. They estimate the number of tapioca plants and sample the weight of roots from several plants. Cassava farmers will get paid about 2,000-4,000 baht per rai.

⁸ Sompong Sreeprang 2001, A Feasibility Analysis of the Investment on Cassava Diggers in Eastern Region of Thailand



Harvesting and delivery expenses are included and deducted from the purchasing price. Contract buyers use their experience and skill for estimating yields.

Contract buyers may be wealthy farmers that have pickups or trucks, labor, and possibly harvesting machines for harvesting the cassava roots. Currently, only some of them are using mechanized harvesting. Again, those in the eastern region use big scale mechanization (tractor over 60 HP) and those in the central and north-eastern areas mostly use small-scale mechanization (<34 HP). These contract buyers normally have their own trucks for delivering cassava roots and other crop production.

Harvesting and transport service providers will do both harvesting and delivery to starch mills, brokers, and chippers. Sometimes, owners of the mechanized harvester and trucks are different people but they group together and have a team of labor to provide the services. They usually charge separately for harvesting and delivery but sometimes these service charges may be linked together. Small-scale mechanized harvesting is charged at 150-250 baht per rai while large-scale mechanized harvesting is charged at 300-360 baht per rai. Root delivery service costs range from 100-150 baht per ton depending on distance.

Some tractor owners drive themselves while some employ drivers. Tractor drivers get paid 250 baht/day or 10 percent of the total tractor service fee. Normally, tractor drivers work only half a day in the morning, otherwise the roots may be left overnight as workers cannot remove the roots from its mass and load the truck at the same speed as the harvesting machine can lift.

Planting, weeding, and harvesting service providers are founded in Chonburi and Rayong where cassava farms on average are bigger than other parts of Thailand. Some clients using these kind of services are millers who own big plots of land and want to plant their own cassava for supplying their own starch mills. Some are wealthy farmers who rent big plots of land from institutions, companies, or Bangkok owners at cheap annual rate for long-term specific periods. These service providers have a full range such as cheap foreign labor teams, tractors with a full range of implements, including cassava diggers, and trucks. One service providers in Chonburi disclosed that he charges a starch miller 2,500 baht/rai for cassava cultivation including land preparation, stems, planting, and weeding. Harvesting is charged separately at about 2,000 baht/rai with yield of approximately 6 tons/rai. He mentioned that he can charge a bit lower for farmers or cassava fields with lower yields. Both machinery and manual labor are used for cultivation, depending on season, as it is difficult for tractor to work in the field during the rainy season.

3.1.2 Machine Rental Business

Tractor rental for agricultural farming was not been found during the survey. Currently machine rental businesses rent machines, equipment, and tools to the construction industry only.



3.1.3 Other Embedded Services Provided

There are no mechanized embedded services provided in the cassava farming sector.

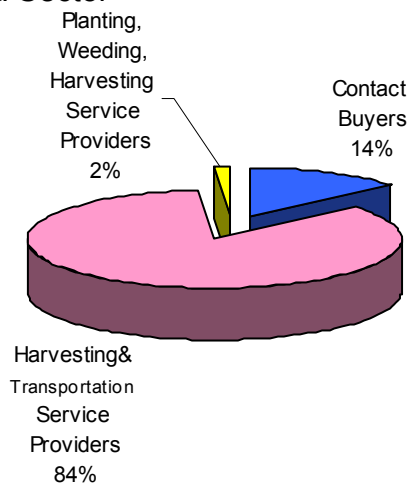
However, non-mechanized services are found. Large-scale cassava farmers in Chonburi are a leading, forward thinking group who try different ways of crop production such as planting different cassava varieties to find a suitable variety for their land, applying different fertilizers both chemical and non-chemical including chicken manure and bio-fertilizer, and crop rotation. Some of them have bought all the chicken manure from nearby farms for using both on their farm and selling to other small farmers with better returns and yield improvement.

Some large-scale cassava farmers also sell stems to other farmers, which gives better returns, instead of selling only roots for processing.

3.2 Assessment of the Number and Capacity of Service Providers (in each category)

According to AgriSource interviews, harvesting and transportation service providers are about 84 percent of the total service providers, following by contact buyers at 14 percent and whole cultivation service providers 2 percent (Chart 3.1). These are best estimates based on field survey findings, which were limited by time.

Chart 3.1: Estimated Proportion of Contact Buyers, and Other Service Providers in the Cassava Sector



According to AgriSource field survey and interviews, mechanized harvesting service providers are available in eastern, central, and lower north-eastern (Nakhon Ratchasima) provinces.

The use of large-scale mechanized harvesting in the east is mostly used by large farmers, or less than 20 percent of the cassava farmers in the region. Most of these large scale farmers do not use service providers but they have invested in their own mechanization.

Some harvesting service providers were found in Nakhon Ratchasima during the survey, but none were found in the upper northeast like Kalasin, Khon Kaen, Maha Sarakham and Roi-et.

The current transportation service providers are expected to be capable of additional investment on cassava harvesting machinery by borrowing from the Bank of Agriculture and Agricultural Cooperatives.

Generally mechanized service providers cooperate with transport service providers who have labor teams. Sometimes, these service providers (harvesting and transportation) are the same.

Working capacity for harvesting machines is about 2.61 rai/ hour for large-scale and 1.43 rai/hour for small-scale machines.

3.3 Farmers Preferences and Demand

Contract Buyers

Old farmers without any younger generation living-in prefer to sell their cassava roots to contract buyers. They are not interested in how the contract buyers will harvest as they already received their money. Use of cassava harvesting machines would benefit the contract buyers rather than farmers. Unless, the contract buyers shares the lower operating costs benefit with the farmer.

If harvesting and transport service providers are available, farmers prefer to use these services rather than contract buyers, due to higher returns.

Harvesting and Transport Service Providers

Cassava farmers prefer to deliver to processors at the right time, which is when the processor's buying prices are high. Those farmers using mechanized harvesting have realized the timing benefit as well as the harvesting cost benefits. Meanwhile, most cassava farmers using manual harvesting do not realize the benefit from mechanized harvesting both in timing and cost savings; some of them do not realize the reliability, capacity and efficiency of harvesting machines.

Generally, the harvesting team and transportation service provider will coordinate schedules themselves, if they are different teams. Meanwhile, the farmers also prefer the service providers to do it this way, as it's convenient for them.

Small farmers cannot afford the high investment for the tractor. If they use the mechanized harvesting service, they will pay a total of 369 baht/rai for the total large-scale mechanized harvesting package or 313 baht/rai for the small-scale package. This is still cheaper when compared to manual harvesting at 517 baht/rai.



If the small cassava farmers can establish a cooperative or group for investing in a machine and employ a driver, a lower service fee is possible. Hence, their cassava production costs will be lower.

Planting/ Weeding/ Harvesting Service Providers

Full cultivation service providers are preferred for large-scale farmers with yields above the national average, rather than small to medium scale farmers with average or below average yields.

This full cultivation service is found in the eastern region. Some land owners unable to do the cultivation by themselves prefer to rent out their land getting a known annual rent income rather than use this kind of service or try to grow themselves.

3.4 Major Market Constraints and Opportunities

Table 3.6: Major Market Constraints and Opportunities for Service Providers Using Cassava Harvesting Machines

Constraint	Opportunity
Increasing diesel price will raise their service cost.	Continually movement of labor force from the agricultural sector to non-agricultural sector
Decreasing cassava planting area due to low root prices over the last two years.	Current cassava farm owners in the northeast are old generation without young generation relatives living-in
Require skilled driver, and people to provide repairs and maintenance for tractor.	Able to harvest at correct time for better prices and starch quality
Mechanization cannot be used during the rainy season.	Decreasing interest rates would allow them to borrow money and invest at lower interest expense.
Generally small plots of land for cassava farming would add more transportation cost to them while losing business opportunities if they have only one tractor and labor team.	Kubota Leasing has good offer with four year payment period at 6-7.5%.
Cassava farmers where mechanized harvesting is available don't use because they do not realize the timing and cost saving benefits compared to the manual harvesting.	Other financial institutions such as BAAC and KTB Leasing are providing long-term payment periods with flexible payments of monthly/quarterly/six monthly/annual matching farmers income.
Cassava farmers in upper north-east have no idea on mechanized harvesting; How is it works, efficiency and output capacity gains, and its improvements when compared to the traditional manual harvesting.	Strong baht currency may result in decreasing imported tractor prices as well as parts and fuel price.

4. Interventions

Target Area:

Upper North-Eastern provinces

Target Groups:

- Existing general agricultural service suppliers
- Existing manual cassava harvesters
- Cassava root transporters
- Large key farmers
- Mills

Key Constraints for the Interventions to Address:

- Information on cassava management including mechanized harvest methods and economic benefits and
- Finance



4.1 Building Awareness and Transferring Information About Mechanized Harvesting Benefits

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Educate current and potential equipment end-users and stimulate them to purchase harvest equipment	Cargill Siam Starch Mill, Maha Sarakham; Asia Modified Starch Company, Kalasin; Khon Kaen University, Engineering Faculty	<ol style="list-style-type: none"> 1. Raise participants' awareness about benefits of mechanized harvesting 2. Identify financial resources for purchasing machinery 3. Identify end-users who are willing to participate 	1. Identify financiers, starch mills, and equipment owner-operators willing to participate and determine their requirements	<ol style="list-style-type: none"> 1. Schedule seminars for target group members at the two host mills 2. Develop presentation materials showing economic analysis and graphic displays of mechanized harvesting 3. Identify and invite participants to attend the seminars 4. Follow up with participants after the seminars 	<ol style="list-style-type: none"> 1. Number of participating mills and equipment suppliers 2. Number of attendees at the seminars 3. Number of attendees interested in purchasing machinery 4. Number of mechanized harvesters operating as a result of the seminars

4.2 Financing Machinery Purchases

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Establish financing options that stimulate purchase of mechanized harvesting equipment	BAAC; commercial banks; tractor leasing companies; Cargill Siam Starch, Maha Sarakham; Asia Modified Starch, Kalasin	<ol style="list-style-type: none"> 1. Provide triangular contracts between financing organizations, starch mills, and equipment users to facilitate purchase of harvesting machinery 2. Establish concessional financing rates and privileges for early adopters of harvesting machinery 3. Establish long term supply agreements between mills and producers 	<ol style="list-style-type: none"> 1. Willingness of mills and suppliers to enter long term supply agreements for mutual benefit 2. Desire by BAAC and private sector financiers to support the cassava sector and mechanized harvesting 3. Producers and harvest service providers willing to change current harvesting techniques 	<ol style="list-style-type: none"> 1. Identify the most suitable tractors and diggers for mechanized cassava harvesting 2. Facilitate protocols that support and collateralize triangular agreements between financiers, starch mills, and equipment owner-operators 3. Hold seminars to introduce financing options, mechanized harvesting concepts, and benefits 	<ol style="list-style-type: none"> 1. Number of financiers, starch mills, and equipment owner-operators participating 2. Concessional interest rates achieved and resulting savings to equipment users 3. Number of triangular agreements undertaken and related volume of roots-starch.

4.3 Financing Cassava Production Inputs

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Remove financial constraints restricting input usage for cassava production	BAAC; Cargill Siam Starch, Maha Sarakham; Asia Modified Starch, Kalasin; fertilizer and chemical suppliers	<ol style="list-style-type: none"> 1. Increased root yield per rai and profitability for root producers 2. Improved harvest timing and resulting starch quality 3. More consistent root delivery to mills 4. Sustainable production through improved nutrient usage 	<ol style="list-style-type: none"> 1. Willingness of mills and input suppliers to enter long term supply agreements for mutual benefit 2. Desire by BAAC and private sector input suppliers to support the cassava sector through better provision of crop inputs 3. Desire of root producers to improve production efficiency 	<ol style="list-style-type: none"> 1. Identify optimum crop inputs and publicize to root producers 2. Establish relationships with input suppliers 3. Facilitate protocols that support and collateralize triangular agreements between input suppliers, starch mills, and root producers 	<ol style="list-style-type: none"> 1. Number of participating farmers, input suppliers, and starch mills 2. Number of triangular contracts and total value of loans 3. Increased root yield and improved timeliness of deliveries to mills 4. Improved financial returns for farmers and starch mills

4.4 Training and Demonstration Plots for Improved Cassava Management

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Improve management standards and capabilities of cassava root producers	1. Suranaree University of Technology, School of Crop Production Technology, Nakhon Ratchasima	1. Improve cassava root yield and quality delivered to starch mills	1. Willingness of starch mills, input suppliers, and farmers to partner for mutual benefit	1. Identify best practices for cassava management using locally adapted varieties, proper fertilizer and weed control, and mechanized harvesting	1. Number of farmers participating in field days and demonstrations
	2. Starch mills	2. Improve starch yields	2. Available resources at Suranaree University	2. Identify and establish demonstration plots	2. Improved awareness by producers of best management practices
	3. Crop input suppliers	3. Increase producer profitability	3. Available land for demonstration trials	3. Organize seasonal producer seminars to transfer information and technology	3. Number of field days and demonstrations
	4. Khon Kaen University Analysis Lab	4. Promote sustainable crop management techniques		4. Design and produce handouts and other information transfer systems	4. Increased yields and quality
		5. Establish and improve crop production record systems among farmers			5. New varieties identified as suitable for specific areas

4.5 Building Awareness and Transferring Information About Soil Analysis and Nutrient Requirements

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
1. Optimize nutrient requirements for cassava and raise production efficiency	1. Cargill Siam Starch, Maha Sarakham; Asia Modified Starch, Kalasin; Sanguan Wongse Industries, Nakhon Ratchasima; other starch mills willing to participate	1. Educate farmers to test their soil and stimulate them to purchase correct fertilizer	1. Identify capacity and operating standards of KKU soil lab	1. Establish supply chain for soil samples and recommendations	1. Development of nutrient recommendation standards for different soil types
2. Educate farmers about soil nutrient requirements and stimulate them to test soil and purchase correct nutrients	2. Khon Kaen University Soil Analysis Lab	2. Identify nutrient application needs to ensure adequate application	2. Evaluate current sample supply and recommendation procedures	2. Expand KKU lab capacity to meet increased demand (staff, training and equipment)	2. Number of farmers participating
		3. Increase root yields, quality, farm profitability	3. Willingness of starch mills to participate collecting samples and disseminating results to growers	3. Develop soil test recommendation standards specifically for cassava	3. Number of soil tests and recommendations
		4. Timely return of soil analysis results and recommendations by soil labs		4. Farmer-oriented education programs to ensure understanding of lab results and recommendations	4. Increased yield and root quality
		5. Promote sustainable land use		5. Link with BAAC to make testing an incentive for financing new loans	
		6. Link with BAAC for soil analysis promotion and in-kind fertilizer loan agreements			

4.6 Cassava Field Day

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Technology transfer of cassava management	<ol style="list-style-type: none"> 1. Participating mill to host the event, eg Cargill Siam Starch, Maha Sarakham 2. Other private mills 3. Cassava input suppliers 4. Thailand Tapioca Development Institute 5. Other industry stakeholders 	<ol style="list-style-type: none"> 1. Display latest management techniques, equipment, and related technology 2. Increase root yields and producer profitability 3. Promote sustainable crop management techniques 	<ol style="list-style-type: none"> 1. Willing partners to host and sponsor the event 2. Site large enough for demonstration plots, harvesting trials, exhibitor display stands, etc 3. Exhibitors prepared to participate in the event and develop field demonstration sites and booths 	<ol style="list-style-type: none"> 1. Develop theme and plans related to technology transfer 2. Identify host partner and site 3. Establish demo plots for new cassava varieties, equipment, etc 4. Advertise the field day widely through upper northeast region 5. Transport assistance to bring producers from cassava production areas 	<ol style="list-style-type: none"> 1. Number of attendees related to technology transfer 2. Number of exhibitors 3. Increased awareness of management practices

4.7 Field Trials of Combine Harvester and Further R&D of Harvesting Equipment

Goal	Implementing Partners	Targets	Pre-requisites	Key Implementation Steps	Measurement Criteria
Develop harvesting technology that reduces field labor	<p>1. Kasetsart University, Agricultural Engineering Faculty</p> <p>2. Khon Kaen University, Agriculture Engineering Faculty</p>	1. Develop a combine root harvester and related equipment that will cut labor use and improve farm profitability and efficiency	<p>1. Evaluate commercial viability of existing combine root harvester</p> <p>2. Identify additional machinery requirements for the cassava production</p>	<p>1. Advanced field testing in multiple locations</p> <p>2. Identify existing and future market potential for harvester and other machinery</p> <p>3. Facilitate partner search to assist with project funding</p> <p>4. Facilitate commercial engineering firm for commercial production</p>	<p>1. Commercial production of machinery</p> <p>2. Numbers of machines and field trials</p> <p>3. Number of private partners assisting in R&D</p>

5. Conclusion

According to AgriSource field survey and study, mechanized cassava harvesting is currently being used and slowly being adopted by cassava farmers in Chonburi, Rayong, Chachoengsao, Prachinburi and Nakhon Ratchasima.

Average traditional manual harvesting costs in the survey area is in the range of 1,563-1,807 baht/rai or 287-448 baht/ton (Table 5.1). Meanwhile, mechanized harvesting cost is in the range of 1,123-1,615 baht/rai or 228-267 baht/ton. These survey figures should not be considered as a basis for the whole country due to a limits sample size and field survey area.

These survey figures indicate that mechanized harvesting costs are cheaper than the traditional manual harvesting cost.

Table 5.1: Summary of Cassava Harvesting Cost in Field Survey, February-March 2007

Province	Average Yield	Traditional Manual Harvesting		Machanization Harvesting	
	(tons/rai)	(baht/ton)	(baht/rai)	(baht/ton)	(baht/rai)
Nakhon Ratchasima	4.93	317.10	1,563.30	227.73	1,122.74
Chonburi & Rayaong	6.04	287.25	1,734.99	267.45	1,615.39
Khon Kaen, Kalasin & Maha Sarakham	4.03	448.27	1,806.52	no m/c used	no m/c used

Source: AgriSource Survey, Feb-Mar 2007

Result of Mechanized Harvesting Cost Analysis

The mechanized harvesting cost analysis in this report is based on research and studies from agricultural engineering specialists Kasetsart and Khon Kaen Universities (see references). The analysis finds that mechanized operating costs in all the assumptions are lower than traditional manual harvesting costs. The traditional manual harvesting cost in 2006 was 517 baht/rai at yield of 3.375 tons/rai, according to the Office of Agricultural Economics. Meanwhile, the large-scale mechanized harvesting cost range from 207-243 baht/rai (Table 5.2) at a diesel price of 23 baht/litre. Small-scale mechanized harvesting costs range from 185-206 baht/rai.

Table 5.2: Summary of Mechanized Harvesting Cost & Break-Even-Point in Different Assumptions. Diesel Price 23 Baht/Liter.

Assumption	Total Investment	Total Fixed Cost	Total Variable Cost	Total Operating Cost	Break-Even-Point
	(baht)	(baht/rai)	(baht/rai)	(baht/rai)	Harvested Area (rai)
I. Buy large digger	20,000	24.74	199.23	223.98	64.38
II. Buy new large tractor & digger	920,000	44.16	199.23	243.40	120.77
III. Buy second-hand large tractor & digger	420,000	31.08	176.25	207.32	82.72
IV. Buy small digger	7,000	16.98	181.75	198.73	44.64
V. Buy new small tractor & digger	350,000	24.22	181.75	205.97	65.67
VI. Buy second-hand small tractor and a digger	157,000	19.83	165.55	185.38	52.87

Note: 1. Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

2. Traditional manual harvesting cost is 516.67 baht/rai in 2006, according to Office of Agricultural Economics

Total operating cost of mechanized harvesting at increasing diesel prices, 30 and 35 baht/liter are also lower than manual harvesting cost as shown in Appendix Tables 3.1, 3.2, 4.1, and 4.2.

Payback Period & Return on Investment

If a farmer investing in mechanized harvesting wants to get payback within five years with a 20 percent return on investment, he has to harvest 1,495 rai/year and 655 rai/year for an investment on a new large-scale tractor with a digger (assumption II) and small tractor with a digger (assumption V) respectively (Table 5.3).

Table 5.3: Five Years Payback Period

Assumption	Total Harvested Area	Working Days (8 hrs/day)	Investment (baht)	Net Income (baht)	Return on Investment (%)
I. Buy large digger	48.65	2	20,000	4,003	20.01
II. Buy new large tractor & digger	1,495	72	920,000	183,903	19.99
III. Buy second-hand large tractor & digger	534	26	420,000	83,934	19.98
IV. Buy small digger*	40	3	7,000	4,769	68.12
V. Buy both new small tractor & digger	655	57	350,000	69,976	19.99
VI. Buy second-hand small tractor and a digger	288	25	187,000	37,408	20.00

*Note: Farmer owning an existing small tractor and buying a digger will get 68.12% return on investment and have a payback period of only 1.47 years if he just uses for his own harvest

Thus, there is an opportunity to expand mechanized cassava harvesting from the current levels of less than 15 percent total harvested area. Technology for mechanized cassava production is already available. However, a number of operations need to be done manually such as stem selection for seeding, separating individual roots from its mass, and truck loading.

Current available machinery has the potential to reduce manpower requirements, harvesting time and operation costs while increasing working efficiency. However, with suitable machinery, functional and economic usage needs to be found on a case by case basis, due to a numbers of factors will affect machinery field usage. Local factors such as rainfall and farm conditions need to be taken into consideration during plan formulation. The development of a suitable field operations schedule is an essential step in plan formulation.

Intervention Opportunities

1. Building Awareness and Transferring Information About Mechanized Harvesting Benefits
2. Financing Machinery Purchases
3. Financing Cassava Production Inputs
4. Training and Demonstration Plots for Improved Cassava Management
5. Building Awareness and Transferring Information About Soil Analysis and Nutrient Requirements
6. Cassava Field Day
7. Field Trials of Combine Harvester and Further R&D of Harvesting Equipment



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Appendix Tables:

Appendix Table 1: Thailand Tapioca Planted Area, Production, Yield and Farm Gate Price, 1989-2005

Year*	Planted Area ('000 rai)	Harvested Area ('000 rai)	Production ('000 ton)	Yield/planted area (kg/ rai)	Yield/Harvested area (kgs/rai)	Farm Gate Price (baht/kg)	Farm Income (mill. baht)
1988/89	10,136	9,957	24,264	2,394	2,437	0.53	12,860
1989/90	9,562	9,297	20,701	2,165	2,227	0.71	14,698
1990/91	9,323	8,960	19,705	2,114	2,199	0.82	16,158
1991/92	9,323	9,066	20,356	2,183	2,245	0.77	15,674
1992/93	9,100	8,988	20,203	2,220	2,248	0.60	12,122
1993/94	8,817	8,642	19,091	2,165	2,209	0.70	13,364
1994/95	8,093	7,782	16,217	2,004	2,084	1.16	18,812
1995/96	7,885	7,676	17,388	2,205	2,265	0.91	15,823
1996/97	7,907	7,690	18,084	2,287	2,352	0.71	12,840
1997/98	6,694	6,527	15,591	2,329	2,389	1.31	20,424
1998/99	7,200	6,659	16,507	2,293	2,479	0.83	13,701
1999-2000	7,406	7,068	19,064	2,574	2,697	0.61	11,629
2000/01	6,918	6,558	18,396	2,659	2,805	0.87	16,004
2001/02	6,224	6,176	16,868	2,710	2,731	1.05	17,712
2002/03	6,435	6,386	19,717	3,064	3,087	0.93	18,337
2003/04	6,757	6,608	21,440	3,173	3,244	0.80	17,152
2004/05	6,524	6,162	16,938	2,596	2,749	1.33	22,528
2005/06	6,933	6,693	22,584	3,257	3,375	1.29	29,134
2006/07F	7,431	7,131	25,288	3,403	3,546	1.07	27,058

Source: Office of Agricultural Economics, Ministry of Agriculture & Co-Operative
Thailand Tapioca Trade Association

Note: 6.25 Rai = 1 Hectare

*2005/06 Crop: October 2006-September 2007

Update: Feb 19, 2007

Appendix Table 2: Diesel Price

Year	Annul Average Price (Baht/Litre)	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
1996	8.64	8.34	8.39	8.50	8.46	8.43	8.36	8.33	8.44	8.62	9.05	9.25	9.50
1997	9.53	9.41	8.86	8.76	8.89	8.75	8.45	8.48	9.02	9.94	11.09	11.16	11.49
1998	9.21	11.79	11.06	10.12	9.80	9.70	8.90	8.80	8.50	8.45	8.41	7.77	7.26
1999	8.97	7.61	7.29	7.89	8.50	8.54	8.34	8.94	9.14	10.24	10.20	10.29	10.65
2000	12.91	11.11	11.58	12.4	11.41	11.37	12.62	13.16	13.69	14.24	14.76	14.71	13.87
2001	13.44	13.54	13.24	13.14	14.07	14.54	14.44	13.86	14.10	13.56	13.18	12.24	11.39
2002	13.11	11.47	11.83	12.29	13.10	13.46	12.92	12.79	13.09	13.89	14.59	13.89	13.94
2003	14.08	14.65	14.87	14.79	14.66	14.01	12.83	13.86	13.64	13.49	13.75	14.08	14.39
2004	14.55	14.08	14.59	14.59	14.59	14.59	14.59	14.59	14.59	14.59	14.59	14.59	14.59
2005	19.93	14.59	14.74	16.06	18.19	18.19	19.25	22.37	22.90	23.83	23.79	22.94	22.25
2006	25.59	24.17	24.40	25.35	26.30	26.74	27.34	27.74	27.54	26.06	24.24	23.84	23.34
2007	23.08	22.77	23.12	23.34									

Source: Ministry of Energy

Appendix Table 3.1: Mechanized Cassava Harvesting Operating Cost If Diesel Price is 30 Baht/Liter (Assumption I, II & III)

New investment	Assumption I		Assumption II		Assumption III	
	Large-Scale Digger		New Large-Scale Tractor & Digger		Second-Hand Large-Scale Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a. Digger Depreciation Cost	3,600	2.76	3,600	2.76	3,600	2.76
b. Tractor Depreciation Cost	81,000	20.69	81,000	20.69	72,000	18.39
c. Interest Expense & Interest on Investment for Digger	1,690	1.30	1,690	1.30	1,690	1.30
d. Interest Expense & Interest on Investment for Tractor	-	-	76,050	19.42	33,800	8.63
Total Fixed Cost	86,290	24.74	162,340	44.16	111,090	31.08
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a. Repair and maintenance cost for digger	2.40	0.92	2.40	0.92	2.40	0.92
b. Repair and maintenance cost for tractor	108.00	41.38	108.00	41.38	48.00	18.39
c. Fuel expense	235.20	90.11	235.20	90.11	235.20	90.11
d. Lubricant expense	23.52	9.01	23.52	9.01	23.52	9.01
e. Driver expense	31.25	11.97	31.25	11.97	31.25	11.97
f. Labor cost	180.00	68.97	180.00	68.97	180.00	68.97
Total Variable Cost	580.37	222.36	580.37	222.36	520.37	199.38
Total Operating Cost		247.11		266.53		230.45
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		64.42		120.82		82.77

Note: Cassava digger lifetime is 5 years or 2,500 hours according to Dr. Sakda Intaravichai. Book value 10%

Digger price: large 20,000 baht, small 7,000 baht

Brand new tractor: large-scale (60-80HP) 900,000 baht, small-scale (<35HP) 343,000 baht, Lifetime 10 years

Second-hand tractor: large-scale 400,000 baht, small-scale 150,000 baht, Lifetime 5 years

BAAC loan interest rate 9.75%, Ford Kubota Leasing interest rate 7.5%

BAAC fixed deposit interest (12 months) 3.25%

Mechanization capacity: Large-scale 2.61 rai/hour, small-scale 1.43 rai/hour

Repair & Maintenance cost is averaged at 1.2% of purchased price for every 100 working hours according to Dr. Sakda Intaravichai/ Kasetsart University

Fuel price 30 baht/litre

Fuel consumption rate: large-scale mechanization 7.84 litres/hour, small-scale 3.82 litres/hour

Lubricant expense = 10% of fuel expense

Driver wage 250 baht/day (8 working hours)

Labor rate 120 baht/day (8 working hours), Required 12 mans/day for large-scale mechanization, 6 mans/day for small-scale mechanization

Appendix Table 3.2: Mechanized Cassava Harvesting Operating Cost If Diesel Price = 30 Baht/Liter (Assumption IV, V & VI)

New investment	Assumption IV		Assumption V		Assumption VI	
	Small-Scale Digger		New Small-Scale Tractor & Digger		Second-Hand Small-Scale Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a.Digger Depreciation Cost	1,260	1.76	1,260	1.76	1,260	1.76
b.Tractor Depreciation Cost	30,870	14.39	30,870	14.39	27,000	12.59
c.Interest Expense & Interest on Investment for Digger	592	0.83	592	0.83	592	0.83
d.Interest Expense & Interest on Investment for Tractor	-	-	15,534	7.24	9,975	4.65
Total Fixed Cost	32,722	16.98	48,256	24.22	38,827	19.83
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a.Repair and maintenance cost for digger	0.84	0.59	0.84	0.59	0.84	0.59
b.Repair and maintenance cost for tractor	41.16	28.78	41.16	28.78	18.00	12.59
c.Fuel expense	114.60	80.14	114.60	80.14	114.60	80.14
d.Lubricant expense	11.46	8.01	11.46	8.01	11.46	8.01
e.Driver expense	31.25	21.85	31.25	21.85	31.25	21.85
f.Labor cost	90.00	62.94	90.00	62.94	90.00	62.94
Total Variable Cost	289.31	202.31	289.31	202.31	266.15	186.12
Total Operating Cost		219.30		226.54		205.95
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		44.68		65.71		52.91

Note: Cassava digger lifetime is 5 years or 2,500 hours according to Dr.Sakda Intaravichai. Book value 10%

Digger price: large 20,000 baht, small 7,000 baht

Brand new tractor: large-scale (60-80HP) 900,000 baht, small-scale (<35HP)343,000 baht, Lifetime 10 years

Second-hand tractor: large-scale 400,000 baht, small-scale 150,000 baht, Lifetime 5 years

BAAC loan interest rate 9.75%, Ford Kubota Leasing interest rate 7.5%

BAAC fixed deposit interest (12 months) 3.25%

Mechanization capacity: Large-scale 2.61 rai/hour, small-scale 1.43 rai/hour

Repair & Maintenance cost is averaged at 1.2% of purchased price for every 100 working hours according to Dr.Sakda Intaravichai/ Kasetsart University

Fuel price 30 baht/litre

Fuel consumption rate: large-scale mechanization 7.84 litres/hour, small-scale 3.82 litres/hour

Lubricant expense = 10% of fuel expense

Driver wage 250 baht/day (8 working hours)

Labor rate 120 baht/day (8 working hours), Required 12 mans/day for large-scale mechanization, 6 mans/day for small-scale mechanization

Appendix Table 4.1: Mechanized Cassava Harvesting Operating Cost If Diesel Price is 35 Baht/Liter (Assumption I, II & III)

New investment	Assumption I		Assumption II		Assumption III	
	Large-Scale Digger		New Large-Scale Tractor & Digger		Second-Hand Large-Scale Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a.Digger Depreciation Cost	3,600	2.76	3,600	2.76	3,600	2.76
b.Tractor Depreciation Cost	81,000	20.69	81,000	20.69	72,000	18.39
c.Interest Expense & Interest on Investment for Digger	1,690	1.30	1,690	1.30	1,690	1.30
d.Interest Expense & Interest on Investment for Tractor	-	-	76,050	19.42	33,800	8.63
Total Fixed Cost	86,290	24.74	162,340	44.16	111,090	31.08
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a.Repair and maintenance cost for digger	2.40	0.92	2.40	0.92	2.40	0.92
b.Repair and maintenance cost for tractor	108.00	41.38	108.00	41.38	48.00	18.39
c.Fuel expense	274.40	105.13	274.40	105.13	274.40	105.13
d.Lubricant expense	27.44	10.51	27.44	10.51	27.44	10.51
e.Driver expense	31.25	11.97	31.25	11.97	31.25	11.97
f.Labor cost	180.00	68.97	180.00	68.97	180.00	68.97
Total Variable Cost	623.49	238.89	623.49	238.89	563.49	215.90
Total Operating Cost		263.63		283.05		246.97
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		64.45		120.85		82.80

Note: Cassava digger lifetime is 5 years or 2,500 hours according to Dr.Sakda Intaravichai. Book value 10%

Digger price: large 20,000 baht, small 7,000 baht

Brand new tractor: large-scale (60-80HP) 900,000 baht, small-scale (<35HP)343,000 baht, Lifetime 10 years

Second-hand tractor: large-scale 400,000 baht, small-scale 150,000 baht, Lifetime 5 years

BAAC loan interest rate 9.75%, Ford Kubota Leasing interest rate 7.5%

BAAC fixed deposit interest (12 months) 3.25%

Mechanization capacity: Large-scale 2.61 rai/hour, small-scale 1.43 rai/hour

Repair & Maintenance cost is averaged at 1.2% of purchased price for every 100 working hours according to Dr.Sakda Intaravichai/ Kasetsart University

Fuel price 35 baht/litre

Fuel consumption rate: large-scale mechanization 7.84 litres/hour, small-scale 3.82 litres/hour

Lubricant expense = 10% of fuel expense

Driver wage 250 baht/day (8 working hours)

Labor rate 120 baht/day (8 working hours), Required 12 mans/day for large-scale mechanization, 6 mans/day for small-scale mechanization

Appendix Table 4.2: Mechanized Cassava Harvesting Operating Cost If Diesel Price = 35 Baht/Litre (Assumption IV, V & VI)

New investment	Assumption IV		Assumption V		Assumption VI	
	Small-Scale Digger		New Small-Scale Tractor & Digger		Second-Hand Small-Scale Tractor & Digger	
Fixed Cost:	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai	Baht/Year	Baht/Rai
a.Digger Depreciation Cost	1,260	1.76	1,260	1.76	1,260	1.76
b.Tractor Depreciation Cost	30,870	14.39	30,870	14.39	27,000	12.59
c.Interest Expense & Interest on Investment for Digger	592	0.83	592	0.83	592	0.83
d.Interest Expense & Interest on Investment for Tractor	-	-	15,534	7.24	9,975	4.65
Total Fixed Cost	32,722	16.98	48,256	24.22	38,827	19.83
Variable Cost:	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai	Baht/Hour	Baht/Rai
a.Repair and maintenance cost for digger	0.84	0.59	0.84	0.59	0.84	0.59
b.Repair and maintenance cost for tractor	41.16	28.78	41.16	28.78	18.00	12.59
c.Fuel expense	133.70	93.50	133.70	93.50	133.70	93.50
d.Lubricant expense	13.37	9.35	13.37	9.35	13.37	9.35
e.Driver expense	31.25	21.85	31.25	21.85	31.25	21.85
f.Labor cost	90.00	62.94	90.00	62.94	90.00	62.94
Total Variable Cost	310.32	217.01	310.32	217.01	287.16	200.81
Total Operating Cost		233.99		241.23		220.64
BEP where m/c harvesting cost = manual harvesting cost (Baht/Rai)		44.71		65.73		52.94

Note: Cassava digger lifetime is 5 years or 2,500 hours according to Dr.Sakda Intaravichai. Book value 10%

Digger price: large 20,000 baht, small 7,000 baht

Brand new tractor: large-scale (60-80HP) 900,000 baht, small-scale (<35HP)343,000 baht, Lifetime 10 years

Second-hand tractor: large-scale 400,000 baht, small-scale 150,000 baht, Lifetime 5 years

BAAC loan interest rate 9.75%, Ford Kubota Leasing interest rate 7.5%

BAAC fixed deposit interest (12 months) 3.25%

Mechanization capacity: Large-scale 2.61 rai/hour, small-scale 1.43 rai/hour

Repair & Maintenance cost is averaged at 1.2% of purchased price for every 100 working hours according to Dr.Sakda Intaravichai/ Kasetsart University

Fuel price 35 baht/litre

Fuel consumption rate: large-scale mechanization 7.84 litres/hour, small-scale 3.82 litres/hour

Lubricant expense = 10% of fuel expense

Driver wage 250 baht/day (8 working hours)

Labor rate 120 baht/day (8 working hours), Required 12 mans/day for large-scale mechanization, 6 mans/day for small-scale mechanization

Appendix Table 5: Brand New Price & Leasing of Small Tractor (20-30HP)

Model	Price	Min. Downpayment	Monthly Payment		Pay 3 months once (48 months)		Pay 6 months once (48 months)	
			Interest Rate 6%		Interest Rate 7%		Interest Rate 7.5%	
			60 Months	48 Months	Month 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45, 48	Other Months	Month 6, 12, 18, 24, 30, 26, 42, 48	Other Months
Kubota B2410 4WD (24 hp)	295,000	80,000	4,659	5,555	15,200	1,000	29,938	1,000
Kubota L2808 2WD (28 hp)	310,000	60,000	5,417	6,459	18,000	1,000	35,625	1,000
Kubota L2808 4WD (28 hp)	343,000	60,000	6,132	7,311	20,640	1,000	40,988	1,000
Kubota L3408 4WD (34 hp)	380,000	60,000	6,934	8,267	23,600	1,000	47,000	1,000
Kubota M5000 4WD (50 hp)	609,000	150,000	9,945	11,858	32,147	2,000	63,440	2,000
Kubota M5000 4WD High Lux Tire (50 hp)	625,000	150,000	10,292	12,271	33,407	2,000	66,000	2,000
Kubota M9000 4WD (92 hp)	1,099,000	300,000	17,312	20,641	56,922	3,000	112,840	3,000

Source: Siam Kubota Thailand

Appendix Table 6: Initial Investment on Tractor, Cassava Digger, and Basic Implements

Brand & Model	Brand New	Rear Blade	Cassava Digger	(Baht)
				Total Investment
Ford 6610 (60 hp)	900,000	30,000-35,000	18,000	948,000-953,000
Second Hand Ford 6610	300,000-500,000	30,000-35,000	18,000	348,000-553,000
Euro (55 hp)	390,000	30,000-35,000	18,000	438,000-443,000
Euro (90 hp)	698,000	30,000-35,000	18,000	746,000-751,000
Euro Turbo (90 hp)	720,000	30,000-35,000	18,000	768,000-773,000
Kubota M9000 4WD (92 hp)	1,099,000	25,000-30,000	7,000	1,131,000-1,136,000
Kubota M5000 4WD High Lux Tire (50hp)	625,000	25,000-30,000	7,000	657,000-662,000
Kubota M5000 4WD (50 hp)	609,000	25,000-30,000	7,000	641,000-646,000
Kubota L3408 4WD (34 hp)	380,000	25,000-30,000	7,000	412,000-482,000
Kubota L2808 4WD (28 hp)	343,000	25,000-30,000	7,000	375,000-380,000
Kubota L2808 2WD (28 hp)	310,000	25,000-30,000	7,000	342,000-347,000
Kubota B2410 4WD (24 hp)	295,000	25,000-30,000	7,000	320,000-325,000

Source: AgriSource Interview

Appendix Table 7: Operating and Maintenance Cost of Small Tractor (<30 HP) and Big Tractor (>60HP)

Gasoline Consumption & Maintenance Cost	< 30 hp Tractor	>60 hp Tractor
Gasoline Consumption (Diesel)	300 baht/day (8 hour) ¹	700-1,000 baht/day ²
Digger	7,000	18,000
Digging Plate (small tractor)/ Digging Nail (for big tractor)	500 ³	900 ⁴
Maintenance Cost (Baht/ 100 Working Hours):		
Lubricant & Grease	430	800 baht (7 litres) ⁵
Oil Filter	80	80
Labor	200	200
Tyre (lifetime about 3 years):		
Front Wheel (Baht/ each)	6,500	8,000
Rear Wheel (Baht/ each)	11,000	15,000

Source: Farmers interview

Note: 1. Kubota 28HP consumes diesel gasoline about 13 litres/8 working hours

Diesel price as of 13 Feb 2007: 23.34 Baht/Litre

2. Gasoline consumption about 40 litres/8 working hours/day

3. Change plate for small tractor after harvesting about 120 rai

4. There is three nails for digger of big tractor, each cost about 300 baht. Each set of nails is last long for several years.

5. Lubricant is selling at about 1,400 baht per 18 litres gallon but the big tractor uses only 7 litres.

Appendix Note:

Total Operating Cost for Mechanized Harvesting

Total operating cost for mechanized harvesting can be obtained from the following equation:

$$\text{TCM} = \text{TFC} + \text{TVC}$$

Where:

TCM	=	Total operating cost for mechanized harvesting
TFC	=	Total fixed cost
TVC	=	Total variable cost

Assumption I: Farmer Has Existing Large Tractor And Buys A Digger.

Total Operating Cost for Mechanized Harvesting

Total Fixed Costs

Fixed costs include depreciation cost and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value}) / \text{Lifetime}$$

Lifetime of cassava digger is 5 years or 2,500 hours, according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage value} = (20,000 \times 10) / 100 = 2,000 \text{ Baht}$$

$$\begin{aligned} \text{Digger depreciation cost} &= (20,000 - 2,000) / 5 = 3,600 \text{ baht/year} \\ \text{Or} &= (20,000 - 2,000) / 2,500 = 7.20 \text{ baht/hour} \\ \text{Or} &= 7.20 / 2.61 = 2.76 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{b) Tractor depreciation cost} &= (900,000 - 90,000) / 10\text{yrs} = 81,000 \text{ baht/year} \\ \text{Or} &= 81,000 / 1,500\text{hrs} = 54 \text{ baht/hour} \\ \text{Or} &= 54 / 2.61 = 20.69 \text{ baht/rai} \end{aligned}$$



c) Annual interest expense and interest on investment is shown in the following table:

Table A: Interest Expense & Interest on Investment of Cassava Digger Hitching with Large-Scale Tractor ($\geq 60\text{HP}$)

Investment	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Baht Total
Cassava Digger: Price 20,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	4,000						
Interest on Investment ²		130	130	130	130	130	650
Remaining Principal	16,000	12,800	9,600	6,400	3,200	-	
Principal Payment		3,200	3,200	3,200	3,200	3,200	16,000
Interest Payment (7.5%) ³		1,200	1,200	1,200	1,200	1,200	6,000
Interest Payment (9.75%) ³		1,560	1,560	1,560	1,560	1,560	7,800

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%>

2. BAAC for 12 fixed months deposit interest = 3.25%

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

If loan interest rate is 9.75 percent and interest on investment is 3.25 percent, thus

Interest Expense & Interest on Investment

$$\begin{aligned} &= 1,560 + 130 &&= 1,690 \text{ baht/year} \\ \text{Or} &= 1,690/500\text{hrs} &&= 3.38 \text{ baht/hour} \\ \text{Or} &= 3.38/2.61 &&= 1.29 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{Thus, total fixed cost (TFC)} &= 3,600 + 81,000 + 1,690 = 86,290 \text{ baht/year} \\ \text{Or} &= 2.75 + 20.68 + 1.29 = \mathbf{24.72 \text{ baht/rai}} \end{aligned}$$

Total Variable Cost

a) Digger repairs and maintenance cost is averaged at 1.2 percent of purchase price for every 100 working hours ⁹

$$\begin{aligned} \text{Or} &= (0.012 \times 20,000)/100 \\ \text{Or} &= 2.4 \text{ baht/hour} \\ \text{Or} &= 0.91 \text{ baht/rai if field capacity is 2.61 rai/hour} \end{aligned}$$

b) Tractor repairs and maintenance cost.

According to the Agricultural Engineering Research and Institute, repairs and maintenance costs for agricultural machinery equals to 1.2 percent of price for every 100 working hours.

If a farmer buys a tractor at 900,000 baht, annual repairs and maintenance expenses would equal to 108 baht per hour. With 2.61 rai/hour field capacity, repairs and maintenance expenses would be *41.38 baht/rai*.

⁹ Dr. Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



c) Fuel expense.

According to research and studies by Dr.Sakda Intaravichai and Chuti Muangprasert, large tractors consume diesel at 7.84 liters/hour. The current diesel price is about 23 baht/liter.

Thus, fuel expense equals to $7.84 \times 23 = 180.32$ baht/hour or 69.08 baht/rai.

d) Lubricant expenses for the tractor is about 10 percent of fuel expense which equals to 18.03 baht/hour or 6.91 baht/rai

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or 11.97 baht/rai.

f) Labor expense. Harvesting requires another 12 people for collecting and cutting the cassava roots and loading onto the truck. If daily rate is 120 baht, thus, labor cost is 180 baht/hour ($12 \times 120/8$) or = 68.97 baht/rai

Thus, total variable cost

$$= 2.4 + 108 + 180.32 + 18.03 + 31.25 + 180 = 520 \text{ baht/hour}$$

$$\text{Or} = 0.92 + 44.38 + 69.09 + 6.91 + 11.97 + 68.97 = 199.23 \text{ baht/rai}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 24.74 + 199.23 \text{ baht/rai} \end{aligned}$$

Then, total cost for the machine harvesting operation is 223.98 baht/rai.

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

$$\text{Then: } A_t = (86,290/A) + (1/2.61) + (2.4+108+180.32+18.03+31.25+180)$$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$516.67 = (86,290/A) + (1/2.61) + 520$$

$$\mathbf{A = 64.38 \text{ rai/year}}$$



Assumption II: Farmer Will Buy Both New Large Tractor And Cassava Digger.

Total Operating Cost for Mechanized Harvesting

Fixed Costs

Fixed costs include depreciation costs and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by the straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value})/\text{Lifetime}$$

Lifetime of cassava digger is 5 years, according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage Value} = (20,000 \times 10)/100 = 2,000 \text{ Baht}$$

$$\begin{aligned} \text{Digger depreciation cost} &= (20,000-2,000)/5 = 3,600 \text{ baht/year} \\ \text{Or} &= (20,000-2,000)/2,500 = 7.20 \text{ baht/hour} \\ \text{Or} &= 7.20/2.61 = 2.76 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{b) Tractor depreciation cost} &= (900,000 - 90,000)/10\text{yrs} = 81,000 \text{ baht/year} \\ \text{Or} &= 81,000/1,500\text{hrs} = 54 \text{ baht/hour} \\ \text{Or} &= 54/2.61 = 20.69 \text{ baht/rai} \end{aligned}$$

Note: Using 1,500 tractor working hours/year as average.

c) Annual interest expense and interest on investment for tractor and digger is shown in the following table:

Table B: Interest Expense & Interest on Investment of Ford Large Tractor (60-80HP) and Digger

Investment	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Baht Total
Cassava Digger: Price 20,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	4,000						
Interest on Investment ²		130	130	130	130	130	650
Remaining Principal	16,000	12,800	9,600	6,400	3,200	-	
Principal Payment		3,200	3,200	3,200	3,200	3,200	16,000
Interest Payment (7.5%) ³		1,200	1,200	1,200	1,200	1,200	6,000
Interest Payment (9.75%) ³		1,560	1,560	1,560	1,560	1,560	7,800
Brand New Ford 6610: Price 900,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	180,000						
Interest on Investment ²		5,850	5,850	5,850	5,850	5,850	29,250
Remaining Principal	720,000	576,000	432,000	288,000	144,000	-	
Principal Payment		144,000	144,000	144,000	144,000	144,000	720,000
Interest Payment (7.5%) ³		54,000	54,000	54,000	54,000	54,000	270,000
Interest Payment (9.75%) ³		70,200	70,200	70,200	70,200	70,200	351,000

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%.

2. BAAC for 12 fixed months deposit interest = 3.25%

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

If loan interest rate is 9.75 percent and interest on investment is 3.25 percent, thus

Interest Expense & Interest on Investment for Digger

$$\begin{aligned}
 &= 1,560 + 130 = 1,690 \text{ baht/year} \\
 \text{Or} &= 1,690/500\text{hrs} = 3.38 \text{ baht/hour} \\
 \text{Or} &= 3.38/2.61 = 1.30 \text{ baht/rai}
 \end{aligned}$$

Interest Expense & Interest on Investment for Tractor

$$\begin{aligned}
 &= 70,200 + 5,850 = 76,050 \text{ baht/yr.} \\
 \text{Or} &= 76,050/1,500\text{hrs} = 50.70 \text{ baht/hour} \\
 \text{Or} &= 50.70/2.61 = 19.42 \text{ baht/rai}
 \end{aligned}$$

Thus, total fixed costs (TFC)

$$\begin{aligned}
 &= 3,600 + 81,000 + 1,690 + 76,050 \\
 \text{Or} &= 162,340 \text{ baht/year} \\
 \text{Or} &= 2.75 + 20.69 + 1.30 + 19.42 = 44.16 \text{ baht/rai}
 \end{aligned}$$

Variable Costs

a) Digger repairs and maintenance costs are averaged at 1.2 percent of purchased price for every 100 working hours ¹⁰

$$\begin{aligned}
 &= (0.012 \times 20,000)/100 \\
 &= 2.4 \text{ baht/hour} \\
 \text{Or} &= 0.92 \text{ baht/rai if field capacity is 2.61 rai/hour}
 \end{aligned}$$

b) Tractor repairs and maintenance costs.

¹⁰ Dr. Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



According to Agricultural Engineering Research and Institute, repairs and maintenance costs of agricultural machinery equals 1.2 percent of price for every 100 working hours.

If farmer buys a tractor at 900,000 baht, annual repairs and maintenance expenses would equal to 108 baht per hour. With 2.61 rai/hour field capacity, repair and maintenance expense would be *41.38 baht/rai*.

c) Fuel expense.

According to research and studied by Dr. Sakda Intaravichai and Chuti Muangprasert, large tractors consume diesel at 7.84 liters/hour. Current diesel price is about 23 baht/liter.

Thus, fuel expense equals $7.84 \times 23 = 180.32$ baht/hour or *69.09 baht/rai*.

d) Lubricant expense for the tractor is about 10 percent of fuel expense which equals 18.03 baht/hour or *6.91 baht/rai*

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or *11.97 baht/rai*.

f) Labor expense. The harvesting requires another 12 labors for collecting and cutting the cassava roots loading roots onto a truck. If the daily rate is 120 baht, thus, labor cost is 180 baht/hour ($12 \times 120/8$) or = *68.97 baht/rai*

Thus, total variable cost

$$\begin{aligned} &= 2.4 + 117 + 180.32 + 18.03 + 31.25 + 180 = 520 \text{ baht/hour} \\ \text{Or} &= 0.91 + 44.82 + 69.08 + 6.91 + 11.97 + 68.97 = 199.23 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 44.16 + 199.23 \text{ baht/rai} \end{aligned}$$

Then, total cost for the harvesting machine operation is 243.40 baht/rai.

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting costs are equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

$$\text{Then: } A_t = (162,340/A) + (1/2.61) + (2.4+108+180.32+18.03+31.25+180)$$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$\begin{aligned} 516.67 &= (162,340/A) + (1/2.61) + 520 \\ \mathbf{A} &= \mathbf{120.77 \text{ rai/year}} \end{aligned}$$



Assumption III: Farmer Will Buy Second-Hand Large Tractor (60-80 HP) And Cassava Digger.

Total Operating Cost for Mechanized Harvesting

Fixed Costs

Fixed costs include depreciation cost and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value})/\text{Lifetime}$$

Lifetime of cassava digger is 5 years, according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage value} = (20,000 \times 10)/100 = 2,000 \text{ Baht}$$

$$\begin{aligned} \text{Digger depreciation cost} &= (20,000-2,000)/5 = 3,600 \text{ baht/year} \\ \text{Or} &= (20,000-2,000)/2,500 = 7.20 \text{ baht/hour} \\ \text{Or} &= 7.20/2.61 = 2.76 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{b) Tractor depreciation cost} &= (400,000 - 40,000)/5\text{yrs} = 72,000 \text{ baht/year} \\ \text{Or} &= 72,000/1,500\text{hrs} = 48 \text{ baht/hour} \\ \text{Or} &= 48/2.61 = 18.39 \text{ baht/rai} \end{aligned}$$

Note: Using 1,500 tractor working hours/year as average.

c) Annual interest expense and interest on investment for tractor and digger is shown in the following table:

Table C: Interest Expense & Interest on Investment of Large Ford Tractor (60-80HP) and Digger

Investment	Baht						Total
	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	
Cassava Digger: Price 20,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	4,000						
Interest on Investment ²		130	130	130	130	130	650
Remaining Principal	16,000	12,800	9,600	6,400	3,200	-	
Principal Payment		3,200	3,200	3,200	3,200	3,200	16,000
Interest Payment (7.5%) ³		1,200	1,200	1,200	1,200	1,200	6,000
Interest Payment (9.75%) ³		1,560	1,560	1,560	1,560	1,560	7,800
Second hand tractor (60-80 HP): Price 400,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	80,000						
Interest on Investment ²		2,600	2,600	2,600	2,600	2,600	13,000
Remaining Principal	320,000	256,000	192,000	128,000	64,000	-	
Principal Payment		64,000	64,000	64,000	64,000	64,000	320,000
Interest Payment (7.5%) ³		24,000	24,000	24,000	24,000	24,000	120,000
Interest Payment (9.75%) ³		31,200	31,200	31,200	31,200	31,200	156,000

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%.

2. BAAC for 12 fixed months deposit interest = 3.25%

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

If the loan interest rate is 9.75 percent and interest on investment is 3.25 percent, thus

Interest Expense & Interest on Investment for Digger:

$$\begin{aligned}
 &= 1,560 + 130 &&= 1,690 \text{ baht/year} \\
 \text{Or} &= 1,690/500\text{hrs} &&= 3.38 \text{ baht/hour} \\
 \text{Or} &= 3.38/2.61 &&= 1.30 \text{ baht/rai}
 \end{aligned}$$

Interest Expense & Interest on Investment for Tractor

$$\begin{aligned}
 &= 31,200 + 2,600 &&= 33,800\text{baht/yr.} \\
 \text{Or} &= 33,800/1,500\text{hrs} &&= 22.53 \text{ baht/hour} \\
 \text{Or} &= 22.53/2.61 &&= 8.63 \text{ baht/rai}
 \end{aligned}$$

$$\begin{aligned}
 \text{Thus, total fixed costs (TFC)} &= 3,600 + 72,000 + 1,690 + 33,800 \\
 &= 111,090 \text{ baht/year}
 \end{aligned}$$

$$\text{Or} = 2.76 + 18.39 + 1.30 + 8.63 = 31.08 \text{ baht/rai}$$

Variable Costs

a) Digger repairs and maintenance is averaged at 1.2 percent of purchase price for every 100 working hours ¹¹

$$\begin{aligned}
 &= (0.012 \times 20,000)/100 \\
 \text{Or} &= 2.4 \text{ baht/hour} \\
 \text{Or} &= 0.92 \text{ baht/rai if field capacity is 2.61 rai/hour}
 \end{aligned}$$

¹¹ Dr. Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



b) Tractor repairs and maintenance costs.

According to the Agricultural Engineering Research and Institute, repairs and maintenance costs of agricultural machinery is equal to 1.2 percent of price for every 100 working hours.

If farmers buy a tractor at 400,000 baht, annual repairs and maintenance expenses would equal to 48 baht per hour. With 2.61 rai/hour field capacity, repairs and maintenance expense would be *18.39 baht/rai*.

c) Fuel expense.

According to research and studied by Dr.Sakda Intaravichai and Chuti Muangprasert, large tractors consume diesel at 7.84 liters/hour. Current diesel price is about 23 baht/liter.

Thus, fuel expense equals to $7.84 \times 23 = 180.32$ baht/hour or *69.09 baht/rai*.

d) Lubricant expense for the tractor is about 10 percent of fuel expense which equals 18.03 baht/hour or *6.91 baht/rai*

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or *11.97 baht/rai*.

f) Labor expense. Additional harvesting requires another 12 people for collecting and cutting the cassava roots and loading roots into a truck. If the daily rate is 120 baht, thus, labor cost is 180 baht/hour ($12 \times 120/8$) or = 68.97 baht/rai

Thus, total variable costs

$$= 2.4 + 48 + 180.32 + 18.03 + 31.25 + 180 = 460 \text{ baht/hour}$$

$$\text{Or} = 0.92 + 18.39 + 69.08 + 6.91 + 11.97 + 68.97 = 176.25 \text{ baht/rai}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 31.08 + 176.25 \text{ baht/rai} \end{aligned}$$

Then, total cost for the harvesting machine operation is 207.32 baht/rai.

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

$$\text{Then: } A_t = (111,090 / A) + (1/2.61) + (2.4+48+180.32+18.03+31.25+180)$$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$\begin{aligned} 516.67 &= (111,090 / A) + (1/2.61) + 460 \\ \mathbf{A} &= \mathbf{82.72 \text{ rai/year}} \end{aligned}$$



Assumption IV: Farmer Has Existing Small Tractor And Will Buy A Digger

Total Operating Cost for Harvesting Mechanized

Fixed Costs

Fixed costs include depreciation cost and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by the straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value}) / \text{Lifetime}$$

Lifetime of cassava digger is 5 years or 2,500 hours according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage value} = (7,000 \times 10) / 100 = 700 \text{ Baht}$$

$$\begin{aligned} \text{Digger depreciation cost} &= (7,000 - 700) / 5 = 1,260 \text{ baht/year} \\ \text{Or} &= (7,000 - 700) / 2,500 = 2.52 \text{ baht/hour} \\ \text{Or} &= 2.52 / 1.43 = 1.76 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{b) Tractor depreciation cost} &= (343,000 - 34,300) / 10\text{yrs} = 30,870 \text{ baht/year} \\ \text{Or} &= 30,870 / 1,500\text{hrs} = 20.58 \text{ baht/hour} \\ \text{Or} &= 20.58 / 1.43 = 14.39 \text{ baht/rai} \end{aligned}$$

c) Annual interest expense and interest on investment is shown in the following table:

Table D: Interest Expense & Interest on Investment of Cassava Digger Hitching with Small Tractor (>35HP)

	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	Baht Total
Cassava Digger: Price 7,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	1,400						
Interest on Investment ²		46	46	46	46	46	228
Remaining Principal	5,600	4,480	3,360	2,240	1,120	-	
Principal Payment		1,120	1,120	1,120	1,120	1,120	5,600
Interest Payment (7.5%) ³		420	420	420	420	420	2,100
Interest Payment (9.75%) ³		546	546	546	546	546	2,730

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%.

2. BAAC for 12 fixed months deposit interest = 3.25%

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years



If interest on investment is 3.25 percent and loan interest rate is 9.75 percent, thus

$$\begin{aligned}\text{Interest Expense \& Interest on Investment} &= 546 + 46 = 592 \text{ baht/year} \\ &= 592/500\text{hrs} = 1.18 \text{ baht/hour} \\ \text{Or} &= 1.18/1.43 = 0.82 \text{ baht/rai}\end{aligned}$$

$$\begin{aligned}\text{Thus, total fixed costs (TFC)} &= 1,260 + 30,870 + 592 = 32,722 \text{ baht/year} \\ &= 1.76 + 14.39 + 0.82 = \mathbf{16.98 \text{ baht/rai}}\end{aligned}$$

Variable Costs

a) Digger repair and maintenance costs are averaged at 1.2 percent of purchased price for every 100 working hours¹²

$$\begin{aligned}&= (0.012 \times 7,000)/100 \\ &= 0.84 \text{ baht/hour}\end{aligned}$$

b) Tractor repairs and maintenance costs.

According to the Agricultural Engineering Research and Institute, repairs and maintenance costs of agricultural machinery equals 1.2 percent of price for every 100 working hours.

If a farmer buys a tractor at 343,000 baht, annual repairs and maintenance expenses are 41.16 baht per hour. With 1.43 rai/hour field capacity, repairs and maintenance expense would be *28.78 baht/rai*.

c) Fuel expense.

According to research and studied by Dr.Sakda Intaravichai and Chuti Muangprasert, small tractors consume diesel at 3.92 liters/hour. Current diesel price is about 23 baht/liter.

Thus, fuel expense equals to $3.82 \times 23 = 87.86$ baht/hour or *61.44 baht/rai*.

d) Lubricant expense for the tractors is about 10 percent of fuel expense which equals to 8.79 baht/hour or *6.14 baht/rai*

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or *21.85 baht/rai*.

f) Labor expense. The harvesting requires another 6 people for collecting and cutting the cassava roots and loading roots into a truck. If the daily rate is 120 baht, thus, labor cost is 90 baht/hour ($6 \times 120/8$) or = *62.94 baht/rai*

¹² Dr.Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



Thus, total variable cost

$$= 0.84 + 44.16 + 87.86 + 8.79 + 31.25 + 90 = 259.90 \text{ baht/hour}$$

$$\text{Or} = 0.59 + 28.78 + 61.44 + 6.14 + 21.85 + 62.94 = 181.75 \text{ baht/rai}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 16.98 + 181.75 \text{ baht/rai} \end{aligned}$$

Then, total cost for the harvesting machine operation is 198.73 baht/rai.

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

$$\text{Then: } A_t = (32,722/A) + (1/1.43) + ((0.84+41.16) + 87.86+8.79+31.25+90)$$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$516.67 = (32,722/A) + (1/1.43) + 259.90$$

$$\mathbf{A = 44.64 \text{ rai/year}}$$

Assumption V: Farmer Will Buy A Second-Hand Small Tractor And Cassava Digger

Total Operating Cost for Mechanized Harvesting

Fixed Costs

Fixed cost includes depreciation cost and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by the straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value})/\text{Lifetime}$$

Lifetime of cassava digger is 5 years or 2,500 hours, according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage value} = (7,000 \times 10)/100 = 700 \text{ Baht}$$

$$\text{Digger depreciation cost} = (7,000-700)/5 = 1,260 \text{ baht/year}$$

$$\text{Or} = (7,000-700)/2,500 = 2.52 \text{ baht/hour}$$

$$\text{Or} = 2.52/1.43 = 1.76 \text{ baht/rai}$$



b) Tractor depreciation cost = $(343,000 - 34,300)/10\text{yrs} = 30,870$ baht/year
 Or = $30,870/1,500\text{hrs} = 20.58$ baht/hour
 Or = $20.58/1.43 = 14.39$ baht/rai

c) Annual interest expense & interest on investment is shown in the following table:

Table E: Interest Expense & Interest on Investment of Cassava Digger and Small Tractor (>35HP)

Investment	Baht						Total
	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	
Cassava Digger: Price 7,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	1,400						
Interest on Investment ²		46	46	46	46	46	228
Remaining Principal	5,600	4,480	3,360	2,240	1,120	-	
Principal Payment		1,120	1,120	1,120	1,120	1,120	5,600
Interest Payment (7.5%) ³		420	420	420	420	420	2,100
Interest Payment (9.75%) ³		546	546	546	546	546	2,730
Brand New Kubota Tractor (28HP 4WD), Price 343,000 Baht, Loan from Kubota Leasing							
Down Payment/ Farmer Capital	60,000						
Interest on Investment ²		1,950	1,950	1,950	1,950	1,950	9,750
Remaining Principal	283,000	212,250	141,500	70,750	-	-	
Principal Payment		70,750	70,750	70,750	70,750	-	283,000
Interest Payment (6%) ⁴		16,980	16,980	16,980	16,980	-	67,920
Average interest payment/ year		13,584	13,584	13,584	13,584	13,584	67,920

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%>

2. BAAC fixed deposit interest is 3.25%

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

4. Kubota Leasing interest rate is in the range of 6%, payment period 4 years

BAAC fixed deposit interest at 3.25 percent is used as an interest on investment rate.

BAAC loan is source of funds for digger with interest rate at 9.75 percent. Meanwhile, the source of funds for the tractor is Siam Kubota Leasing Co., Ltd. They require 60,000 down payment and 7,311 baht/month for 4 years. However, the average annual interest payment for 5 years period is used for calculation (see Table 2.14).

Interest Expense & Interest on Investment for Digger
 = $546 + 46 = 592$ baht/year

Or = $592/500\text{hrs} = 1.18$ baht/hour

Or = $1.18/1.43 = 0.83$ baht/rai

Interest Expense & Interest on Investment for Tractor

= $13,584 + 1,950 = 15,534$ baht/yr.

Or = $15,534/1,500\text{hrs} = 10.35$ baht/hour

Or = $10.35/1.43 = 7.24$ baht/rai

Thus, total fixed costs (TFC) = $1,260 + 30,870 + 592 + 15,534 = 48,256$ baht/year

= $1.76 + 14.39 + 0.83 + 7.24 = 24.22$ baht/rai



Variable Costs

a) Digger repairs and maintenance costs are averaged at 1.2 percent of purchased price for every 100 working hours¹³
$$= (0.012 \times 7,000)/100 = 0.84 \text{ baht/hour}$$

b) Tractor repairs and maintenance costs.

According to the Agricultural Engineering Research and Institute, repairs and maintenance costs for agricultural machinery are equal to 1.2 percent of price for every 100 working hours.

If a farmer buys a tractor for 343,000 baht, annual repairs and maintenance expenses are 41.16 baht per hour. With 1.43 rai/hour field capacity, repairs and maintenance expenses would be *28.78 baht/rai*.

c) Fuel expense.

According to research and studied by Dr.Sakda Intaravichai and Chuti Muangprasert, small tractors consume diesel at 3.92 liters/hour. Current diesel price is about 23 baht/liter.

Thus, fuel expense equals to $3.82 \times 23 = 87.86$ baht/hour or *61.44 baht/rai*.

d) Lubricant expense for the tractor is about 10 percent of fuel expense which equals 8.79 baht/hour or *6.14 baht/rai*

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or *21.85 baht/rai*.

f) Labor expense. The harvesting requires another 6 people for collecting and cutting the cassava roots and loading roots into a truck. If the daily rate is 120 baht, labor cost is 90 baht/hour ($6 \times 120/8$) or = *62.94 baht/rai*

Thus, total variable cost

$$\begin{aligned} &= 0.84 + 41.16 + 87.86 + 8.79 + 31.25 + 90 = 259.9 \text{ baht/hour} \\ &= 0.59 + 28.78 + 61.44 + 6.14 + 21.85 + 62.94 = 181.75 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 24.22 + 181.75 \text{ baht/rai} \end{aligned}$$

Then, total cost for the harvesting machine operation is 205.97 baht/rai.

¹³ Dr.Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

$$\text{Then: } A_t = (48,256 / A) + (1/1.43) + ((0.84+41.16) + 87.86+8.79+31.25+90)$$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$\begin{aligned} 516.67 &= (48,256 / A) + (1/1.43) + 259.90 \\ \mathbf{A} &= \mathbf{65.67 \text{ rai/year}} \end{aligned}$$

Assumption VI: Farmer Will Buy A Second-Hand Small Tractor And Cassava Digger

Total Operating Cost for Harvesting Mechanized

Fixed Cost

Fixed cost includes depreciation cost and interest on investment.

a) Digger Depreciation Cost

Depreciation cost is calculated by the straight-line method where:

$$\text{Depreciation cost} = (\text{Purchased Price} - \text{Salvage Value}) / \text{Lifetime}$$

Lifetime of cassava digger is 5 years or 2,500 hours, according to Dr.Sakda Intaravichai of Kasetsart University. Salvage value at the end of lifetime is worth 10 percent of cassava digger buying price.

$$\text{So, Salvage value} = (7,000 \times 10) / 100 = 700 \text{ Baht}$$

$$\begin{aligned} \text{Digger depreciation cost} &= (7,000-700)/5 = 1,260 \text{ baht/year} \\ \text{Or} &= (7,000-700)/2,500 = 2.52 \text{ baht/hour} \\ \text{Or} &= 2.52/1.43 = 1.76 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{b) Tractor depreciation cost} &= (150,000 - 15,000)/5\text{yrs} = 27,000 \text{ baht/year} \\ \text{Or} &= 27,000/1,500\text{hrs} = 18 \text{ baht/hour} \\ \text{Or} &= 18/1.43 = 12.59 \text{ baht/rai} \end{aligned}$$



c) Annual interest expense & interest on investment is shown in the following table:

Table F: Interest Expense & Interest on Investment of Cassava Digger and Second-Hand Small-Scale Tractor (>35HP)

Investment	Baht						Total
	Yr.0	Yr.1	Yr.2	Yr.3	Yr.4	Yr.5	
Cassava Digger: Price 7,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital ¹	1,400						
Interest on Investment ²		46	46	46	46	46	228
Remaining Principal	5,600	4,480	3,360	2,240	1,120	-	
Principal Payment		1,120	1,120	1,120	1,120	1,120	5,600
Interest Payment (7.5%) ³		420	420	420	420	420	2,100
Interest Payment (9.75%) ³		546	546	546	546	546	2,730
Second-Hand Small-Scale Tractor (<35HP) 150,000 Baht, Loan from BAAC							
Down Payment/ Farmer Capital	30,000						
Interest on Investment ²		975	975	975	975	975	4,875
Remaining Principal	120,000	90,000	60,000	30,000	-	-	
Principal Payment		30,000	30,000	30,000	30,000	-	120,000
Interest Payment (9.5%) ³		9,000	9,000	9,000	9,000	-	36,000

Note: 1. Generally, BAAC will loan at 80% of asset price, Farmers need to use their own money 20%>

2. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

3. BAAC interest rate is about 7.5-9.75% per year, payment period 5 years

If the lending interest rate and fixed deposit rate is 9.75 percent and 3.25 percent accordingly,

Interest Expense & Interest on Investment for Digger

$$= 546 + 46 = 592 \text{ baht/year}$$

$$\text{Or} = 592/500\text{hrs} = 1.18 \text{ baht/hour}$$

$$\text{Or} = 1.18/1.43 = 0.83 \text{ baht/rai}$$

Interest Expense for Tractor = 9,000 + 975 = 9,975 baht/yr.

$$\text{Or} = 9,975/1,500\text{hrs} = 6.65 \text{ baht/hour}$$

$$\text{Or} = 6.65/1.43 = 4.65 \text{ baht/rai}$$

Thus, total fixed cost (TFC) = 1,260 + 27,000 + 592 + 9,975 = 38,827 baht/year

$$= 1.76 + 12.59 + 0.83 + 4.65 = 19.83 \text{ baht/rai}$$

Variable Cost

a) Digger repairs and maintenance cost is averaged at 1.2 percent of purchased price for every 100 working hours ¹⁴

$$= (0.012 \times 7,000)/100$$

$$\text{Or} = 0.84 \text{ baht/hour}$$

¹⁴ Dr. Sakda Intaravichai & Chuti Muangprasert, Faculty of Agriculture, Kasetsart University, 2003, Cassava Combine Harvester



b) Tractor repairs and maintenance costs.

According to the Agricultural Engineering Research and Institute, repairs and maintenance costs of agricultural machinery equals 1.2 percent of price for every 100 working hours.

If farmers buy a tractor at 150,000 baht, annual repair and maintenance expense equals 18 baht per hour. With 1.43 rai/hour field capacity, repair and maintenance expense would be *12.59 baht/rai*.

c) Fuel expense.

According to research and studies by Dr. Sakda Intaravichai and Chuti Muangprasert, small tractors consume diesel at 3.92 liters/hour. Current diesel price is about 23 baht/litre.

Thus, fuel expense equals to $3.92 \times 23 = 89.76$ baht/hour or *61.44 baht/rai*.

d) Lubricant expense for the tractor is about 10 percent of fuel expense which equals to 8.79 baht/hour or *6.14 baht/rai*

e) Driver expense. Tractor driver daily rate is about 250 baht/ 8 working hours. So, it's 31.25 baht/hour or *21.85 baht/rai*.

f) Labor expense. Harvesting requires another 6 laborers for collecting the cassava roots out of the tractor track and loading roots into truck. If daily rate is 120 baht, thus, labor cost is 90 baht/hour ($6 \times 120/8$) or = *62.94 baht/rai*

Thus, total variable cost

$$\begin{aligned} &= 0.84 + 18 + 89.76 + 8.79 + 31.25 + 90 = 238.64 \text{ baht/hour} \\ &= 0.59 + 12.59 + 61.44 + 6.14 + 21.85 + 62.94 = 165.55 \text{ baht/rai} \end{aligned}$$

$$\begin{aligned} \text{TCM} &= \text{TFC} + \text{TVC} \\ &= 19.83 + 165.55 \text{ baht/rai} \end{aligned}$$

Then, total cost for the harvesting machine operation is 185.38 baht/rai.

Break-Even-Point

Break-even-point is calculated to find the mechanized harvesting area per year where the mechanized harvesting cost is equal to the traditional manual harvesting cost.

$$A_t = (F_t/A) + (1/C_t) \times (R\&M + F + O + L_0 + L_1)$$

Then: $A_t = (38,827/A) + (1/1.43) + ((0.84+18) + 89.76+8.79+31.25+90)$

Break-Even-Point where A_t is equal to traditional manual harvesting cost at 516.67 baht/rai,

$$\begin{aligned} 516.67 &= (38,827/A) + (1/1.43) + 238.74 \\ \mathbf{A} &= \mathbf{52.87 \text{ rai/year}} \end{aligned}$$

