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Determining Appropriate Production and Inbound Logistics Practices for a Cassava Supply Chain in Thailand

Jirachai Buddhakulsomsiri[1], Parthana Parthanadee[2,*] and Panchalee Praneetpholkrang[3]

ABSTRACT

This article examines the production and inbound logistics activities, from farms to factories, of cassava products in Thailand. The activities are critical to the total supply-chain cost owing to the large number of farmers and stakeholders involved. The objectives of this study were to estimate the production and inbound logistics costs under different practices and to recommend a set of cost-effective practices. Data were collected from a field study and analyzed. Profits and yields under different practices of cultivation, consisting of stem usage, pest control, and weed control, were evaluated. It was found that proper pest control had significant associations with a higher yield and profit, whereas using existing stems from the previous harvest cycle had a significant association with higher profit. Furthermore, three patterns of labor hiring in harvesting activity were investigated. The results indicated that labor hiring based on a daily wage rate versus a weight-based rate were not statistically different, while a flat rate for the combined activities of harvesting and transportation was found less economical. Finally, the transportation rates of hired trucks and owned trucks were estimated and compared. The results suggested that hiring transportation services was more cost effective than using owned trucks if the truck was primarily used for cassava transportation only. The break-even numbers of trips per year for each truck type were determined as a guideline for farmers to justify owning a truck.

Keywords: cassava, cultivation, harvesting, inbound logistics costs, transportation

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), a versatile tuber crop that is a source of carbohydrate, is extensively grown in diversified environments in tropical zones as it is resistant to drought conditions and can be cultivated without much nurturing (Parthanadee *et al.*, 2009). Cassava is one of the important economic crops of Thailand and has been cultivated widely throughout the country, except in the southern part (Office of Agricultural Economics, 2014). Cassava farmers usually start cultivation at the beginning of rainy seasons and harvest when the roots are aged around 8–12 mth (Parthanadee *et al.*, 2009). In practice, factors that trigger cassava farmers to reap their harvests are weather conditions, market prices and the farmer's financial need (Agricultural Futures Trading Commission, 2007).

[1] School of Manufacturing Systems and Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University, Rangsit Campus, Pathumthani 12121, Thailand.
[2] Department of Agro-Industrial Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
[3] Department of Information and Communication Technology, Logistics Technology Program, Faculty of Science and Liberal Arts, Rajamangala University of Technology Isan, Nakhon Ratchasima 30000, Thailand.
* Corresponding author, e-mail: parthana.p@ku.ac.th

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Food and Agriculture Organization (2013) reported that Thailand produced approximately 22.5 million t of cassava roots with a total harvesting area of 1.25 million ha in 2012. Compared with the world's cassava producers, Thailand was ranked fourth in production volume after Nigeria, Indonesia and Brazil, and was ranked first in terms of export volume and value because of the relatively low domestic consumption. However, in terms of yield, Thailand was ranked thirteenth with a yield of 18 t/ha, far behind the major competitors in ASEAN such as Lao PDR, Cambodia and Indonesia, which produced 24.12 t/ha, 22.59 t/ha and 21.36 t/ha, respectively.

The Thai cassava product supply chain consists of farmers, processing factories, exporters or traders and customers, both domestic and overseas. Upstream in the chain, cassava growers mostly sell their harvests to processing factories immediately after reaping in order to avoid any starch content reduction from delaying. The root supply varies with weather conditions, such as flooding and drought, and on pest outbreaks. Market prices of competitive crops in the country, including maize and sugarcane, clearly affect cassava production. The amounts of cultivated and harvested areas of cassava rely on other crops' prices at a specific time because the farmers usually switch to other crops that offer better prices. The fresh roots of cassava are transported to the nearby factories usually using small or 6-wheeled trucks. There are two buying practices. Typically, the starch manufacturers buy cassava roots with the price based on the starch content, while chip and pellet manufacturers may set a fixed buying price at the factory gate. Once in the factory, the fresh roots will be processed into starch or dried cassava (chips and pellets). These products will be then used as raw materials in other industries, including foods, feeds, ethanol, monosodium glutamate, sweeteners, pharmaceutical products, paper, glues, plywood, textiles and biodegradable plastics.

The Ministry of Commerce (2014) reported on cassava exports with most starch and chips manufacturers in Thailand have an emphasis on export markets rather than domestic consumption. The main market for cassava chips is China, while native starch is mainly sold to China, Taiwan and Indonesia. Japan is the main market for modified starch. Cassava pellets were mainly exported to the European Union, but now the demand has substantially declined. Nowadays, the markets for Thai pellets are somewhat limited. In addition to starch and dried cassava products, ethanol has emerged as one of the major products that uses cassava (generally, fresh and chips) as a raw material. Yet, exporting ethanol is difficult due to competitive market prices and regulations in Thailand.

Thailand and many countries in Asia have recognized cassava as raw material for industry rather than as a staple food for human consumption (United Nations Conference on Trade and Development, 2012). However, cassava production in Thailand continues to thrive because of the massive demand from China. The size of the Chinese population and economy pushes the increasing demand for bio-ethanol and animal feeds. As a result, cassava products are imported to support these industries (Kaplinsky *et al.*, 2010). The Ministry of Commerce (2014) reported that the total export value of Thailand cassava products in 2013 was dominated by payments from China, accounting for 62%, while the second largest market with 12% of the export value was from ASEAN countries, including Indonesia, Malaysia, the Philippines and Singapore. Around 9% and 5% of the total export value come from Japan and Taiwan, respectively, whereas over one hundred other countries account for the remaining 12%.

Domestic demand for cassava and products in Thailand has increased due to the cancellation of the benzene 91 fuel on 1 January 2013, as the Thai government attempted to reduce the use of fossil fuels and to promote greater use of bioethanol for gasohol production (Department of Energy Business, 2013; PTG Energy PCL., 2014). This policy has boosted the use of bioethanol in

Thailand from 1.3 million L/d in 2012 to 2.6 and 2.9 million L/d in 2013 and in the first quarter of 2014, respectively (Department of Alternative Energy Development and Efficiency, 2014). Siamphakdee (2011) suggested that the high capability for cassava production of Thailand can be used to support food industries and the surplus is then available to feed ethanol production. Even though ethanol produced from cassava costs more than that from molasses (Siamphakdee, 2011), it may be more attractive because it can be grown in several soil types and even on land not capable of cultivation (Sriroth *et al.*, 2010).

Silalertruksa and Gheewala (2010) assessed the security of a feasible feedstock supply to support the rapid growth of the ethanol industry in the long run (2008–2022). Demand for cassava was recently boosted by exports and by ethanol production, which would increase substantially once all ethanol factories are in full operation. This might eventually result in the manufacturing sector being confronted with a material shortage. Other fuel crops, such as sugar cane juice and molasses, could be used instead, if the cassava yield cannot be improved (Silalertruksa and Gheewala, 2010).

Production and inbound logistics problems

Thailand has been the world's largest cassava product exporter for decades, despite the lack of appropriate practices for production and inbound logistics that are directly concerned with cassava cultivation, harvesting and transportation from farms to factories. Inbound logistics is considered as the critical part of the supply chain because of the large number of cassava growers in Thailand (almost 0.5 million households), covering more than 50 provinces (Office of Agricultural Economics, 2008). Most farmers cultivate based on their experience, since they do not have access to information and knowledge related to cassava cultivation (Parthanadee *et al.*, 2009). Furthermore, cassava farmers still face problems of low yields as well as the low starch content.

Common cultivation practices include land preparation and fertilizer usage. However, differences in planting activities comprise stem usage, weed control and pest control. Typically, the farmers either use existing stems from the previous harvest cycle, or purchase them from neighboring farmers or stem suppliers because they expect to increase the yield with new cultivars, or because some do not keep their stems from the last cycle due to a lack of planning. Nevertheless, improving yields from using new stems has had varying success due to several factors such as the quality of the available stems in the market and soil compatibility among other factors. Weeds are usually eliminated twice—before starting cultivation and when the cassavas is aged around 3–4 mth. Weed control can be done either using herbicide or by manual removal using with some agricultural tools (such as a hoe). Pest control usually involves the farmers soaking the stems in suitable chemicals before planting or spraying to protect the cassava from pests. Proper organic and inorganic substances for treatment include Thiamethoxam, Imidacloprid and Dinotefuran (Department of Agricultural Extension, 2010), chlorpyrifos-methyl, physic nut oil, ethyl-alcohol 40% (by-product of molasses) and the bacterial suspension KPS 46 (Ngamprasitthi *et al.*, 2012). However, some farmers do not use any substances to avoid side effects to the soil.

About 8–12 mth after planting, the farmers generally harvest the cassava roots using hoes or tractors. Despite the use of tractors, labor is still required for cutting the rootstocks. Parthanadee *et al.* (2009) reported that farmers preferred labor to machinery for harvesting. Therefore, harvesting remains a labor-intensive task. Yet, the agricultural sector in Thailand is now facing a labor shortage. Therefore, new or modified agricultural equipment and machinery is need to resolve the issue (Rojanaritphichet and Witchukit, 2011).

In practice, farmers usually hire labor

at different hiring rates, such as on a daily wage rate (Thai baht per person), a weight-based rate (Thai baht per tonne) or a flat rate for combined harvesting and transportation activities (Thai baht per tonne). The applied rates depend on many factors such as labor availability in areas or during seasons, convenience and local custom and practice among others. Until now, Thai farmers have lacked an appropriate approach to determine the most cost effective rate for labor hiring. As a result, harvesting cost for farmers have not been effectively minimized.

After harvesting, the farmers transport their harvests almost immediately to nearby factories to avoid starch reduction. The transportation distance is classified as short-haul if it is no more than 60 km. The activity is performed by either using their own trucks or using hired trucks from service providers, with mostly 6-wheeled trucks or small trucks. The common transportation rate is weight-based (Thai baht per tonne); however, a rate based on weight, together with distance (Thai baht per tonne-kilometer) seems more rational (Parthanadee *et al.*, 2009). From the study by Parthanadee *et al.* (2009), the transportation rates of 6-wheeled and small trucks averaged 5.08 THB/t-km and 9.49 THB/t-km, respectively. Hence, 6-wheeled trucks tend to be clearly more cost-effective than small trucks. Furthermore, most farmers who own a truck may not keep track of related costs, such as truck depreciation and repairs and maintenance, in addition to the fuel cost. It remains unclear whether hiring or owning a truck is more appropriate for Thai farmers, whose land size and amount of harvest in each cycle are not relatively small.

The objective of this study was to evaluate the efficiency of production and inbound logistics activities, from cultivation and harvesting to transportation. Relevant data were collected from field studies and were primarily subjected to statistical analyses. For cultivation, the research aimed at investigating cassava yields and profits among different practices for cultivation activities—stem usage, weed control and pest control. In the harvesting phase, the most cost effective rate for labor hiring was determined by comparing the three aforementioned rates. Finally, transportation rates for farmers who own trucks and for farmers who hire service providers were estimated and compared. The results led to a break-even analysis to determine an appropriate utilization level of a truck that would warrant a farmer owning a truck rather than hiring one instead. In summary, the results could be used as a guideline for farmers to improve their logistics practices, which would help the whole supply chain to maintain leader status in cassava product trading.

METHODS

Data collection

The relevant data for inbound logistics activities (cultivation, harvesting and transportation) of cassava products were acquired by conducting field surveys during November 2012 to April 2013. A total of 274 farmers scattered over six provinces (Nakhon Ratchasima, Chaiyaphum, Khon Kaen, Kalasin, Kamphaeng Phet and Buri Ram) were randomly contacted and agreed to personal interviews. Some cost and operational data, including insurance premiums, vehicle tax, license fee, registration fee, maintenance and repair costs, truck depreciation and fuel consumption rate were collected from relevant sources of data, such as government agencies, insurance companies and truck manufacturers.

Data analysis for cultivation cost

First, the average costs and their 95% confidence intervals (CIs) of cultivation activities were estimated. Analysis of variance (ANOVA) and Tukey's multiple comparisons were used to compare the differences in the profits and yields of cassava among the different practices. The profits were estimated using an average market price of 2.14 THB/kg during November 2012 to April

2013 (Office of Agricultural Economics, 2014). The cultivation activities with different practices considered stem usage (stems from last cycle versus new stems purchased from suppliers), weed control (with versus without) and pest control (with versus without). Note that the analysis was conducted while taking into account other factors, such as province, area of cultivated land and the buyer among others. These factors only slightly helped in describing the variability in the response, and their *p* values were not significant.

Data analysis for harvesting cost

Even though harvesting equipment has been in use for many years, the harvesting process of cassava in Thailand is still a labor-intensive task. From the field study, the farmers usually hire labor for harvesting using three different hiring rates: 1) a daily wage rate (Thai baht per person per day); 2) a weight-based rate (Thai baht per tonne); and 3) a fixed flat rate (Thai baht per tonne) for the combined activities of harvesting and transportation. The chosen rate depends on the availability of labor, the expected yield on the harvested land, and whether or not the farmer owns a truck. These factors directly affect negotiations regarding the rates which farmers and labor/service providers agree upon.

For cost estimation, the average and the 95% CIs for the weight-based rate and the fixed flat rate could be estimated directly from the data. However, for comparison purposes, the daily wage rate must be transformed to the weight-based rate using the average amount of cassava that a hired labor could harvest in a day. The transformation factor was presented as a harvesting ratio (persons per tonne), which was estimated based on simple random sampling according to Equations 1 – 4 (Scheaffer *et al.*, 2006):

$$H = rW \tag{1}$$

$$r = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} = \frac{\bar{y}}{\bar{x}} \tag{2}$$

$$\hat{V}(r) = \left(\frac{1}{n}\right)\left(\frac{1}{\mu_x^2}\right)s_r^2 \tag{3}$$

$$s_r^2 = \frac{\sum_{i=1}^{n}(y_i - rx_i)^2}{n-1} \tag{4}$$

where

H = Transformed labor rate (Thai baht per tonne)

r = Cassava harvesting ratio (persons per tonne)

W = Average daily wage rate (Thai baht per person)

n = Sample size of farmers (persons)

y_i = Number of labor used in harvesting activity (persons)

x_i = Harvested amount (tonnes)

$\hat{V}(r)$ = Estimated variance of r

s_r^2 = Sample variance of r

After the daily wage rate was transformed, a fixed transportation rate of 150 THB/t, quoted by Public Warehouse Organization (2013), under the government's cassava subsidy scheme (with a distance of no more than 50 km), was added to the daily wage rate and the weight-based rate, so that they could be compared with the fixed flat rate. A single factor ANOVA was then performed to determine whether the labor hiring rates for harvesting activity were statistically different.

Data analysis for transportation cost

Transportation rate estimation

The transportation costs were estimated as two rates: 1) a weight-based rate (Thai baht per tonne), which considers only the amount of cassava loaded on the truck and is usually used between farmers and truck providers; and 2) a weight-distance-based rate (Thai baht per tonne-kilometer), which takes into account transportation distance, in addition to the amount of cassava loaded. The transportation rates in this study were also categorized by truck types (6-wheel, Etak and Etan trucks—see Figure 1) and by truck ownership (own or hired). Note that Etak and Etan are small 4-wheeled trucks locally made for transporting agricultural products in rural Thailand. Both trucks are much cheaper than 6-wheeled trucks, but less efficient in fuel consumption. They are mostly used for short transport distances and small loads. Etan trucks look more roadworthy when compared to Etak trucks; consequently, they are normally used for transporting cassava roots when slightly greater distances are involved.

For hired trucks, the average and 95% CIs for both transportation rates could be calculated directly from the collected data. However, the transportation rates of owned trucks were more complicated to estimate because the costs of owning a truck have many components, including fixed and variable costs. The fixed costs, consisting of vehicle depreciation cost, insurance, vehicle tax, permit fee and license fee, are paid on a yearly basis. The total fixed cost per year was then converted to a per-trip rate using an approximate number of trips made per year. The number of trips was calculated from the total harvesting area (hectares) divided by the harvesting rate (hectares per day), assuming that farmers transport the roots to a factory using only one trip per day. The variable costs, consisting of fuel cost, tire cost, maintenance and repair costs, were estimated from the collected data and related sources of information, such as the insurance agency, the Department of Transportation and truck dealerships and were expressed as a distance-based rate. Finally, the average cost for a trip made by an owned truck and its CI were computed from the sum of the fixed and variable costs.

Break-even analysis

An important aspect of the estimated transportation rates for owned trucks was that the method focused only on the transportation activity associated with cassava roots. In reality, farmers (who owned a truck) use the truck for other purposes as well. This made the comparison between the hiring rate and an owned truck rate unfair because the fixed costs for the owned truck should have been allocated to other transportation activities as well. Therefore, a break-even analysis was performed, to determine the levels of truck utilization that justify farmers owning trucks. The break-even utilization level was expressed as the number of trips per year. The analysis was performed according to Equation 5 that equates the hiring rate to the owned truck rate, and Equation 6 that expresses the number of trips as a function of the costs and transportation requirements.

$$R = \frac{F + VDN}{LN} \quad (5)$$

$$N = \frac{F}{LR - VD} \quad (6)$$

where

R = Hiring rate (Thai baht per tonne)
F = Fixed cost (Thai baht per year)
V = Variable cost (Thai baht per km)
D = Distance (kilometers per trip)
N = Number of trips (trips per year)
L = Full truck load (tonnes per trip)

RESULTS AND DISCUSSION

Sample size

Based on the cassava production in over

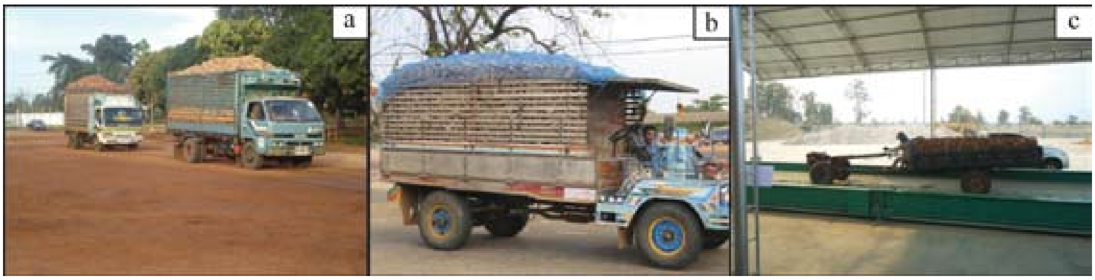

Figure 1 Typical trucks used for agricultural product transport: (A) 6-wheeled truck; (B) Etan truck; (C) Etak 6-wheeled truck.

50 provinces in Thailand in 2013, the provinces were grouped into three strata according to their annual production amounts. Stratum weights, actual samples and proportions are explained in Table 1. The total of 274 farmers dispersed over six provinces were randomly interviewed—91 farmers in Nakhon Ratchasima and Kamphaeng Phet were representatives of the first stratum, 57 farmers in Chaiyaphum were in the second stratum and 126 farmers in Kalasin, Khon Kaen and Buri Ram were in the third stratum.

Demographic data of respondents

Table 2 summarizes the demographic data of the respondents. In the crop year 2012/2013, the amount of land that the farmers used for cassava cultivation ranged between 0.16 ha and 32 ha. Most of the respondents (more than 80%) were smallholder farmers with a planted area of less than 4.8 ha. The factors that farmers considered to select the destination and patterns for selling their harvests included the travelling distance and the quality of the cassava roots in terms of its starch content. That is, if farmers were confident that their fresh roots contained a high starch content, they preferred selling their harvests to starch factories although the transportation distance may be farther in some cases. On the other hand, if the cassava

Table 1 Sample size.

Strata (million t)	Number of provinces	Total production amount (t)*	Stratum weight	Number of provinces sampled	Actual sample	
					Total	Proportion
> 1.5	3	10,189,603	34	2	91	33
1–1.5	6	6,862,051	23	1	57	21
< 1	41	12,796,837	43	3	126	46
Total	50	29,848,491	100	6	274	100

* Source: Cassava production data in 2012 (Office of Agricultural Economics, 2014)

Table 2 Demographic data of the respondents.

Characteristic	Percentage	Characteristic	Percentage
Amount of cultivation land (ha)		Harvesting hiring patterns	
< 1.6	41.04	Daily wage rate	67.1
1.6–4.8	40.64	Weight based rate	23.5
5.0–8.0	8.76	Flat rate for combined activities	9.4
> 8.0	9.56	Truck	
Cassava distribution		10-wheeled	1.7
Chip manufacturer	38.3	Owned	1.7
Starch factory	59.2	6-wheeled	46.1
Intermediary	2.5	Owned	13.1
Cassava sale patterns		Hired	33
Starch and weight based	60.9	Etak	5.1
Weight based	25.0	Owned	3.4
Harvesting area amount	3.2	Hired	1.7
Government's subsidy scheme	10.9	Etan	47.1
Harvesting equipment		Owned	11.9
Tractor	56.7	Hired	35.2
Conveyor	0.8		
Manual	42.4		

tended to have a low starch content or if it had been kept in soil for a long period, the farmers would rather sell their harvests to chip manufacturers where the harvest price relied on weight only. In the current study, approximately 60% of the farmers preferred selling to starch factories, while 38% sold to chip manufacturers and the remainder sold to collectors or intermediaries. It should be noted that the farmers usually do not sell their cassava to an ethanol factory directly because the chip manufacturers or intermediaries often play the role as the vendor who gathers cassava chips or fresh roots for factories. The investigation results indicated that more than a half of the respondents sold their harvests depending on the starch content. Additionally, 25% of the respondents sold their cassava based on weight alone without starch measurement, 11% sold their harvests under the government's subsidy scheme and only 3% sold their harvests to intermediaries based on the harvesting area.

A tractor mounted with a cassava digger is one of the harvesting tools that is used extensively at present by approximately 57% of the respondents used this equipment and 60% of those rented the equipment while the rest owned it with negotiable rates of 300–500 THB/day and 625–2,188 THB/ha. However, 42% still used hoes and only a few used conveyors in a truck loading activity. for the viewpoint of labor hire for cassava harvesting, it was found that a large number of the respondents (67%) would rather hire labor on a daily wage rate (Thai baht per person). Around 24% hired labor based on the amount of harvested roots (Thai baht per tonne), while the remainder hired labor on a flat rate for combined activities, based on the harvested and transported amount (Thai baht per tonne).

The majority of farmers used 6-wheeled (6-w) and Etan trucks to transport their harvests to processing factories, while the respondents who used 10-wheeled (10-w) and Etak trucks for cassava transportation were estimated at 1.7% and 5.1%, respectively. Most of the farmers preferred hiring trucks to using their own trucks. However, the number of farmers who owned trucks was estimated at 30%, disaggregating into 13% owning 6-w trucks, 12% owning Etan trucks and the remaining 5% owning Etak and 10-w trucks. When considering the traveling distance, most of the farmers regularly transported or hired trucks to the nearby factories within short distances. Only 1.7% of the respondents transported their harvests over distances of 100–200 km, using their own 6-w trucks.

Cassava cultivation

The average costs and 95% CIs for various cultivation activities are shown in Table 3. The majority of the cassava cultivation cost is for chemical and organic fertilizers because repeatedly planting cassava over many years gradually diminishes soil nutrients. Thus, adequate fertilizer is required to make up for the nutrient depletion. Consequently, farmers usually spent an average of 5,700 THB/ha on fertilizers.

New stem purchase is the second largest cultivation cost for the farmers who buy new stems from suppliers. In general, a stem costs 1.00–2.50 THB/piece depending on the cassava variety. The number of stems required for cultivation varies according to the density at which the farmers

Table 3 Average costs and 95% confidence intervals (CIs) of cultivation activities.

Activity	Cost (THB/ha)	
	Average	95% CI
Fertilizer	5,700	(5,244 , 6,156)
New stem purchase	3,388	(2,488 , 4,294)
Weed control by herbicide	1,469	(1,206 , 1,738)
Pest control	1,388	(775 , 2,006)

planted cassava per area unit. However, based on the field study data, the average cost of stems was 3,388 THB/ha. In addition, where the sources of the stems were far from the planting area, an additional transportation cost would be incurred.

Weeds were either removed manually (using harrows), or using herbicides. Weed control using herbicides cost farmers approximately 1,469 THB/ha. Some farmers considered they faced pest outbreaks mainly due to drought and the rising temperature. On average, farmers spent around 1,388 THB/ha for pest control activity.

An ANOVA was performed to determine whether the yield and profit were significantly different among the various cultivation practices. Each considered factor—new stem purchase, weed control by herbicide and pest control—has two levels: use or no-use. The results indicated that: 1) the average yields were significantly different with and without pest control ($P < 0.001$); and 2) new stem usage and pest control were significant factors affecting the average profits ($P = 0.005$ and 0.004, respectively). The two-way interactions between factors were not significant.

The results from Tukey's multiple comparisons are shown in Tables 4–5. Without pest control, the average cassava yield was 22.75 t/ha, whereas the farmers could raise the yield with the proper pest control to an average of 28.69 t/ha. The difference in the average yield was 5.94 t/ha, with a 95% CI of (3.13 t/ha, 8.75 t/ha). For new stem usage, there was unexpectedly no statistical difference between the average yields from farms using new stems and those using existing stems from the previous harvest cycle. This may have been because the new stems chosen were not good quality and were not compatible with the soil and weather conditions in the planted areas. Consequently, the yield was not improved as much as the farmer anticipated. Furthermore, the comparisons of profit by pest control in Table 5 show that the average profits were significantly different between practices with and without pest control activity and between using new stem and

Table 4 Multiple comparisons on average yield.

Pesticide	By pest control		
	n	Mean (t/ha)	Grouping
Use	30	28.69	A
No-use	138	22.75	B
New stem	By new stem usage		
	n	Mean (t/ha)	Grouping
Use	81	25.13	A
No-use	87	26.31	A

n = number in sample

Table 5 Multiple comparisons on average profit.

Pesticide	By pest control		
	n	Mean (THB/ha)	Grouping
Use	30	50,800	A
No-use	138	41,394	B
New stem	By new stem usage		
	n	Mean (THB/ha)	Grouping
Use	81	42,281	B
No-use	87	49,913	A

n = number in sample

existing stems. With pest control, the farmers gained an average profit of 50,800 THB/ha; while the average profit was only 41,394 THB/ha without pest control. The approximate increase in profit was 9,406 THB/ha with a 95% CI of (3,013 THB/ha, 15,806 THB/ha). The results implied that despite the cost of pest control, the higher yield from the control could more than adequately compensate for the cost. Therefore, farmers would still be able to raise their profits from this activity. The farmers who used existing stems gained an average profit of approximately 49,913 THB/ha, while using new stems generated an average profit of 42,281 THB/ha. In other words, farmers who used new stems gained 7,631 THB/ha less profit with a 95% CI of (2,313 THB/ha, 12,944 THB/ha) because not only did the farmers have to buy the new stems, but they might also pay more for fertilizer to increase soil nutrients to match the cultivars (Boonseng, 2009), while the average yield did not increase as expected. On the contrary, farmers who used existing stems from the previous harvest cycle were familiar and knowledgeable with the traits of the cultivars, so they could nurture their cassava appropriately. In total, their cost of cultivation tended to be lower.

Cassava harvesting

From the data from the field study, the average harvest hiring rates and their 95% CIs for all three hiring patterns are presented in Table 6. The ANOVA analysis results indicated that the rates were significantly different under the three hiring patterns ($P < 0.001$). Tukey's multiple comparisons revealed that Rate 3 was significantly higher than Rates 1 and 2, while Rates 1 and 2 were not statistically different. With Rate 3, it would cost the farmers, on average, 430 THB/t, which is the least cost effective. Rate 3 was approximately 49 THB/t higher than Rate 1, with a 95% CI of (21 THB/t, 78 THB/t) and approximately 33 THB/t higher than Rate 2, with a 95% CI of (2 THB/t, 65 THB/t). Therefore, where harvesting labor and trucks are available, the farmer should avoid hiring using Rate 3.

Cassava transportation

The average transportation rates and CIs were estimated both per tonne and per tonne-kilometer for the three truck types generally used for cassava root transportation (Table 7). Based on the expected frequency of trips made by the farmers per year, the rates for the owned trucks were significant higher than those for hired trucks. As mentioned earlier, the estimation of transportation rates for owned trucks assumed that the trucks were used solely for cassava transportation activity, which might not necessarily be true. Thus, break-even analysis was performed to determine the levels of truck utilization (in number of trips) that would justify farmers owning the trucks.

The break-even numbers of trips per year for different truck types are shown in Figures 2–4. These were computed as a function of the travel distance and the rate of hired trucks, assuming a full-truck load. The rates of hiring 6-w trucks were in the range 120–300 THB/t with travel distances of 10–120 km. The transportation rates for hiring Etak trucks were 100–150 THB/t with shorter travel distances of 5–25 km. The transportation

Table 6 Average hiring rates and 95% confidence intervals (CIs) for harvesting and transportation activities.

Pattern	*n*	Rate (THB/t)		Grouping
		Average	95% CI	
Rate 1: Daily wage rate for harvesting, plus transportation cost	143	381	(375 , 387)	A
Rate 2: Weight-based rate for harvesting, plus transportation cost	50	397	(377 , 417)	A
Rate 3: Fixed flat rate for harvesting and transportation in combination	20	430	(393 , 467)	B

n = number in sample

Table 7 Average transportation rates and 95% confidence intervals (CIs; in brackets) by truck types and truck ownership.

Truck type	Truck ownership	Weight (t)	Distance (km)	Fixed cost* (THB/trip)	Variable cost (THB/trip)	Total cost (THB/trip)	Transportation rate (THB/t)	Transportation rate (THB/t-km)
6-w	Owned	11.4 (10.0 , 12.9)	37.1 (17.4 , 56.9)	11,773 (7,856 , 15,691)	386 (180 , 591)	12,159 (8,148 , 16,171)	1,054 (749 , 1,359)	48 (35 , 61)
	Hired	9.9 (8.9 , 10.8)	15.9 (13.4 , 18.4)				155 (141 , 169)	13 (11 , 15)
Etan	Owned	4.5 (4.0 , 5.0)	11 (7.5 , 14.6)	16,241 (9,430 , 23,052)	56 (38 , 74)	16,297 (9,474 , 23,120)	3,906 (1,978 , 5,834)	366 (288 , 445)
	Hired	4.5 (4.0 , 4.9)	9.3 (7.6 , 11.0)				132 (124 , 140)	25 (19 , 30)
Etak	Owned	3.4 (2.1 , 4.7)	12.9 (3.1 , 22.8)	19,654 (8,272 , 31,035)	74 (18 , 131)	19,728 (8,297 , 31,159)	7,669 (880 , 14,459)	568 (285 , 850)
	Hired	3.2 (0.6 , 5.8)	4.3 (1.5 , 7.2)				117 (79 , 155)	28 (16 , 40)

6-w = 6-wheeled truck;

* The frequency of trips per year was computed based on total harvesting area (ha) divided by harvesting rate (ha/day)

rates for hiring Etan truck were in range 100–240 THB/t, with slightly greater distances of 5–30 km.

From Figures 2–4, it can be noticed that the break–even number of trips in a year increases as the transportation distance increases because the transportation rates used in practice between farmers and truck providers do not consider travel distance. With a constant load and hiring rate, the average hiring rate becomes cheaper as the truck providers' fixed cost are distributed over a greater distance. This makes it more difficult for an owned truck to break even, resulting into higher numbers of trips required.

For example, hiring a 6-w truck for 150 THB/t with the travel distance 10 km is considered quite expensive. The break-even numbers of trips for an owned truck is only 69 trips per year. However, with a longer distance, such as 120 km, the same hiring rate of 150 THB/t is considered much cheaper because the same amount of cassava is transported farther. The break-even numbers of trips per year for the owned truck becomes logically high at 161 trips per year. In other words, with this transportation rate and distance, the farmer must be able to make at least 161 trips per year to justify owning a truck. This might be somewhat unlikely for a famer to transport only home grown cassava roots within a year. Thus, the farmer may consider buying a truck only where this break-even number of trips can be achieved by including other purposes.

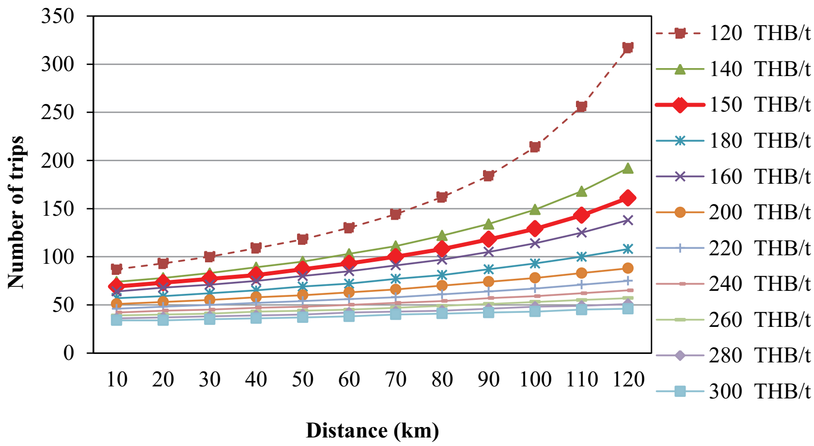

Figure 2 Break-even number of trips per year for a 6-wheeled truck.

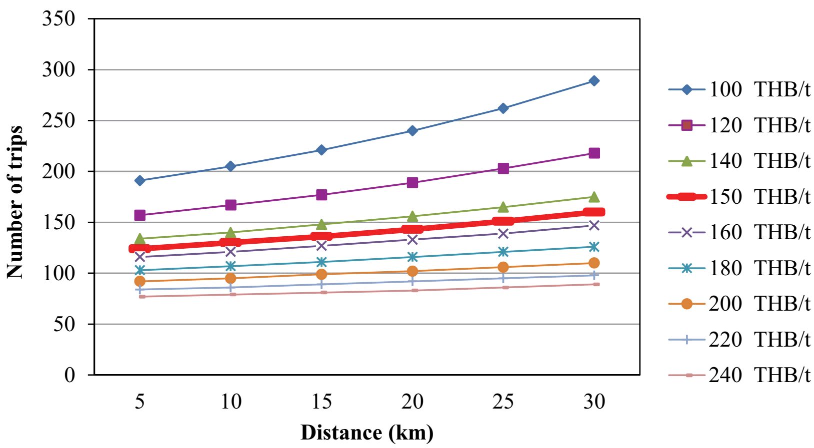

Figure 3 Break-even number of trips per year for an Etan truck.

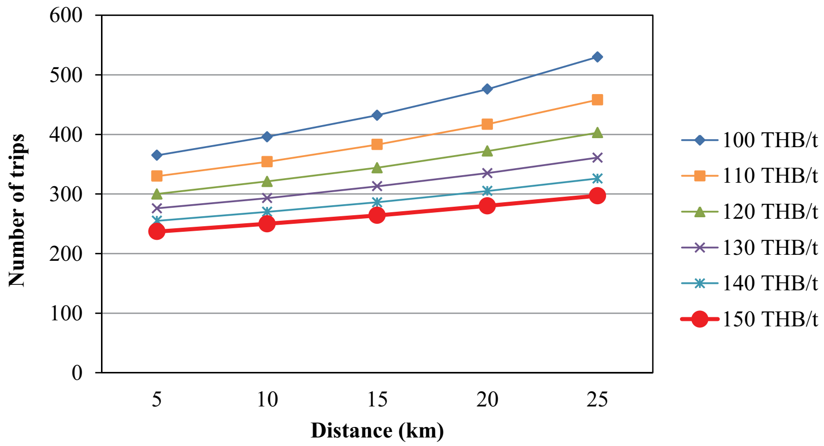

Figure 4 Break-even number of trips per year for an Etak truck.

CONCLUSION

This study evaluated the production and inbound logistics costs of cassava products in Thailand, from farms to factories, which were related to cultivation, harvesting and transportation activities. Appropriate practices for cultivation are to use proper pest control and existing stems from the previous harvest cycle. Regarding labor hiring for harvesting activity, daily wage rate and weight-based rate were more economical. Finally, for transportation, hiring truck service providers was more cost-effective than using an owned truck. To justify owning a truck, appropriate levels of truck utilization, expressed as break-even numbers of trips per year, were suggested.

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