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Chapter 3
The Development of Agricultural Tools in Thailand: Case Studies of Rice and Maize

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Abstract

This chapter illustrates the field summary of the development of agriculture tools or machines used in upstream supply chain of rice and maize in Thailand in chronological order. It also summarizes Thai government policies which affect to the Thai agricultural industries. It also presents the efficiency and value added once one tools have been replaced by another tools. The paper also presents additional information of available high technology tools in agriculture industries such as drone, remote sensing and weather forecast. In addition, policy implication also suggests in the ending section of this paper.

Keywords: Thailand, Rice, Maize, Agriculture Tools, Efficiency, Value-added

1. Introduction

In Thailand, agriculture has long been the core of the economy since the ancient time. In the past, there have been only human resources applied in the agriculture in Thailand. Since the country has entered in to the early state of aging society and new technology have been employed in our Thai society. Nowadays, several agricultural machine, smart and high technology tools have been adopted in the agriculture sectors in Thailand.

Thailand has adopted new government policy "Thailand 4.0", a new model of Thailand economics' s engine to restructure the economic structure toward "Value-based Economy" by transforming from traditional agriculture to new era of agriculture

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which emphasizes on modern business entities and technology management as agriculture 4.0.

However, it has yet to be examined and consolidated what kinds of machines, applications and tools have been implemented in the agricultural sectors especially, rice and maize upstream supply chain, defined in section three of this paper starting from the past in chronological order and how such these machines, applications and tools contributes to the improvement of rice and maize production. Since the agriculture tools plays critical roles to create efficient production, so they should be evaluated in the context of efficiency and value added creation.

It is also yet to be known which directions the policy should lead the country. The research through field survey tries to identify possible policy actions respective government agencies could take to create enabling environment for more new ideas to be put into practices.

This research project aims to study the step by step development of agriculture tools or machines utilized in the upstream supply chain of rice and maize in Thailand in chronological order. The research also focuses on the impact of tools on contribution of efficiency and value added with the aim to provide policy implications to facilitate the progress.

2. Thai Government Policies

There are two current relevant government policies which have high impact on agricultural industry which are Thailand 4.0 and Thailand Mega Farm. The relevant information can be briefly explained as follows:

2.1 Thailand 4.0 policy

Thailand 4.0 policy was announced by Thai Government in May 2016. This initiative is a sectorial specific industrial initiative. It aims to attract new investment by transforming the economy into new era as an innovation-based manufacturing and services to lift the population into high level of prosperity (The Economist Intelligent Unit 2019). There are four eras of manufacturing and services which are Thailand 1.0, Thailand 2.0, Thailand 3.0 and Thailand 4.0. Thailand 1.0 was agricultural era. Thailand 2.0 is era of light industry with low wage. Thailand 3.0 was heavy industry era with advance machines. The Thailand 4.0 era is creativity, innovation and smart era

of the country. Thailand is now on Thailand 3.0 and heading to Thailand 4.0

Ten target industries under this initiative are next generation automobile, intelligence electronic, advance agriculture and biotechnology, food processing, high wealth medical and tourism, digital, robotics, aviation and logistics, comprehensive healthcare and biofuel & biochemical industries (EEC 2019). Thai government offers tax holiday, import duties reduction, research& investment supports to Thai and foreign investors invested in the ten aforesaid industries with the project located in Eastern Economic Corridor Development plan (EEC) under Thailand 4.0 scheme in Chonburi, Chacheangsao and Rayong provinces of Thailand

According to Thailand 4.0 policy, each ministry has adopted the central policy and developed their sub- policies such as Industry 4.0, Education 4.0 and Agricultural 4.0 (Sirirangsi and Bhandhubanyong 2018). For the Agricultural 4.0, it can be classified into four different agriculture era (Thammasart University 2018) which are:

I. Agriculture 1.0: traditional farming
II. Agriculture 2.0: traditional farming with better marketing and farm management methods
III. Agriculture 3.0: farming with basic technology and mainly produces premium-quality of agricultural products as raw materials of down-stream industries to make into value-added products
IV. Agriculture 4.0: farming that applies advanced technologies such as agriculture drones as fertilizer and pesticide sprayer to reduce production costs and produce innovative products, precision farming to monitor farm health and smart farming to help control farm activities which are watering, harvesting, etc.

2.2 Thailand Mega Farm policy

Thai government by Ministry of Agriculture had promoted and endorsed “Mega farm” or “Large agriculture land plot program” since 2016 by offering soft loan from Bank of Agriculture and Agricultural Cooperative **(**Thammasart University 2018**).** The initiative idea is to pool at least 30 farmers and their farm lands of at least 300 rai as a group to produce a particular type of agricultural product**.** To pool many farmers under this initiative aims to improve the farmers’ economics of scale from farm planning through market distribution of this their agricultural product**.** The integration of knowledge and resource under this initiative shall enhance cost reduction, productivity quality improvement, farmer capability and bargaining power improvement with the market**.**

A qualified plot manager should be assigned to be responsible for farm planning, suitable agricultural technology and tools seeking, business plan development, infrastructure development, quality standard development and market development.

Rice, field crop, rubber, oil palm, fruit tree, vegetable, flower and livestock are the agricultural targets. Total 597 land plots, 1.4 million rais (1 rai = 0.16 Hectare) and 95,169 farmers joined this program in 2016 and 1,934 land plots, 1.97 million rais and 153,789 farmers joined this program in 2017(Department of Agriculture Extension 2019). For rice, there were found that 449 million baht cost reduction and 1,579 million baht value-added during year 2016-2017. For maize, 35.3 million baht cost reduction and 57.58million baht value added during year 2016-2017.

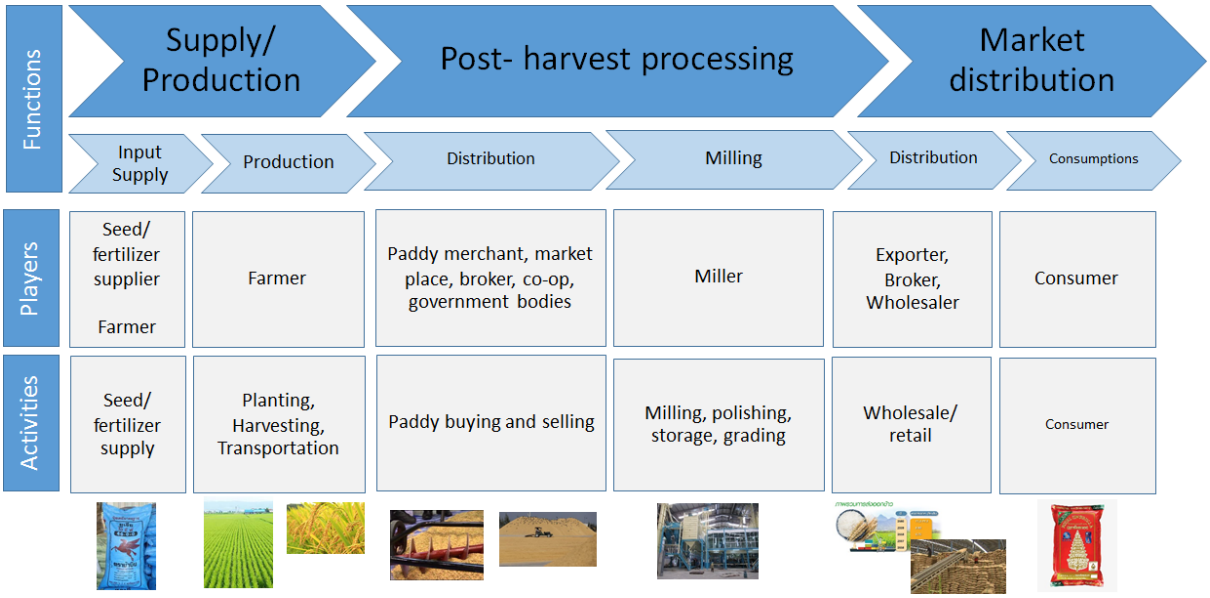
3. Supply Chain of Thai Rice and Maize

Supply chain is the integration between of business activities starting from final customers through distribution, production and production input supplies to provide valued-added products or services to end customers (Suthivatnarueput 2003). The application of supply chain has been used in various indutries such as oil and gas, and petrochemical including agriculture. The supply chain of agriculture can be divided into three categories which are upstream, midstream and downstream (Sirirangsi and Bhandhubanyong 2018). The details of each categories of supply chain are as follows:

I. Upstream supply chain covers activities of input and raw material for planting preparation including seed varities, fertilizer, land, working capital. Stakeholders involving in this activities are seed varieties agents, fertilizer agents, farmers, land owners and banks. In addtion, production is also another activities in this categories.
II. Midstream supply chain includes post-harvest activities which covers milling, storage and transportation of harvested agricultural products in order to transfer the products to downstream supply chain. The relevant stakeholders in this category of supply chain are middlemen, milling, broker, agricultural co-operatives.
III. Downstream supply chain covers marketing and distribution activities of agricultural products to the end users. The stakeholders are middlemen, transportation companies, wholesaler, retailer, logistics provider and customers.

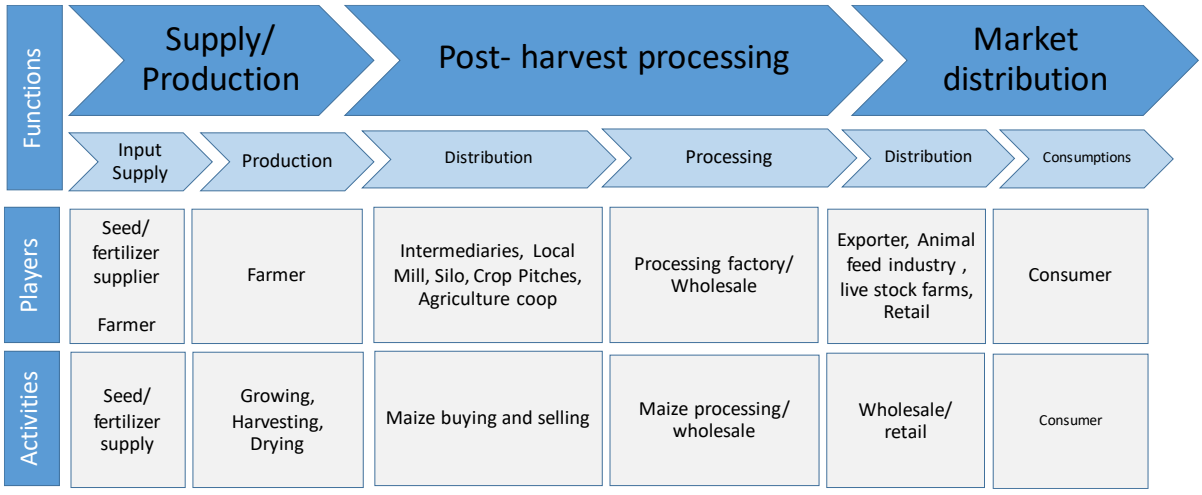
The following figure 1 and figure 2 show the supply chain, relevant activities and relevant stakeholders of rice and maize in Thailand. Since this research focuses on the upstream supply chain of rice and maize, the relevant activities are input supply, production and the relevent stakeholders are seed varieties agent, fertilizer agent and farmers.

Figure 1 Thailand Rice's Supply Chain



Source: Sirirangsi and Bhandhubanyong

Figure 2 Thailand Maize's Supply Chain



Source: Sirirangsi and Bhandhubanyong

4. Research Objectives and Methodology

4.1 Research Objectives

The researchers have collected data on the activities and tools applied in upstream supply chain system using a questionnaire created by the researchers**.** The research will be focused on upstream supply chain of the rice and maize business**.** The objectives of this study are**:**

I. To study the used of agricultural tools in upstream supply chain system of the rice and maize starting from the past in chronological order
II. To study and estimate, if possible, the efficiency once the new tools have been adopted in upstream supply chain system of the rice and maize
III. To study and estimate, if possible, the value added once the new tools have been adopted in upstream supply chain system of the rice and maize

4.2 The Research Methodology

The research had been conducted by interviewed survey of rice and maize from fifty farmers and middlemen in selected provinces of Central and Northeastern regions of Thailand by using direct interview and questionnaire during December 2018 and January 2019. There were twenty-five surveys of rice farmers and middlemen with another twenty-five of maize farmers and middlemen. In Central region of Thailand, the researchers undertook interviews with the farmers and middlemen in two provinces for rice which are Suphanburi and Ayutthaya and five provinces for maize which are Phetchabun, Saraburi, Lopburi, Uthaithani, Nakornsawan. In Northeastern region of Thailand, the researcher undertook interviews with the farmers and middlemen in two provinces which are Buriram and Srisaket for rice and three provinces which are Loei, Nakorn Rachasima and Nong Khai for maize.

The questionnaire of rice and maize for the farmers in this research comprises three sections which are general information of farmers, planting information and used agricultural tools with their efficiency and value added. For the first section, general information covers name, age, address, educational background, years of experience and family information of the farmer. The second part includes the information of cultivation area, crop, planting method, water sources, fertilizer & insecticide, soil

preparation, seed acquisition, weed control, harvesting and transportation. The third section covers information of used tools, their efficiency and value added in each process which are soil preparation, planting, fertilizing, watering, pesticide application, harvesting storage and transportation to the market.

For middlemen, the questionnaire composed of two parts which are general information and used tools with efficiency and value added. The first part covers company information, interviewee personal information, historical rice information and company's customers' information. The second part includes used tools, their efficiency and value added in each process which are weighting, moisture management, quality inspection, dehumidification, storage and transportation.

To collect data from the field, researchers had made a visit to each farmer by explaining the overall research objective and expectation at the beginning of interviewed survey. The farmers answered the first and second sections using the questionnaire by themselves. Since the educational background of farmers is not sufficient to answer the third section of farmer's questionnaire, the researchers asked several questions to help estimate the efficiency. The asking questions began with the agricultural tools the farmer had used since the past to present. According to survey's result, the researcher tried to sequence used tools in chronological order. Once a tools had been changed such as labor to tractor, the researchers tried to estimate the efficiency according to survey data in term of time saving, labor saving and productivity improvement by asking time consumed, labor cost and productivity before and after using the particular tools. For value added matter, only qualitative data could be collected since there are no rice and maize price database which relates to the changing of tools.

For middleman, researchers have made a visit to each middleman by explaining the research objective and expectation at the beginning. The middlemen could answer the first and second sections using the questionnaire by themselves. According to survey's result, the researcher tried to sequence used tools in chronological order. Once a tool had been changed such as labor to tractor, the researchers tried to estimate the efficiency according to survey data in term of time saving, labor saving and productivity improvement by asking time consumed, labor cost and productivity before and after using the particular tools. For value added matter, only qualitative data could be collected since there are no rice and maize price database which relates to the changing of tools.

5. General information and activities of rice cultivation

In this section, the surveyed result is illustrated for rice cultivation. There are two main sub sections which are general information and field activities of rice farmers and general information and activities of rice middlemen. The details are explained in following sub sections.

5.1 General information and field activities of rice farmers

5.1.1 Farm sizes and income

In term of farmers' characteristics in the study, most of them has primary education while a few people of them has high school education. The average farm family size of the respondent households are four members. The average of experience of rice farming was approximately twenty-eight years. However, they only have three years of experience in organic rice farming.

The main income source of the farmers in the study is rice cultivation but some farmers also earn other sources of income such as wage employment and bakery for the surveyed farmers in the central region and wage employment, animal husbandry and vegetable plantations for the surveyed farmers in Northeastern region.

The average rice field size of is approximately 35 *rai* (5.6 hectares) for overall survey, while the average of the rice field size of surveyed farmers for central region is 50 *rai* (8 hectares) and for the northeastern region is 22 *rai* (3.5 hectares). All farmers in the studied area have applied chemical fertilizers for their rice production.

5.1.2 Land preparation methods

All farmers perform their soil tillage by using tractors. They till roughly for the first time and then till the soil in regular furrows in the second round. In some areas, the field are required of further plowing and stirring plow with a steep moldboard for stubble land respectively.

Almost 67 percent of studied farmers in the study applied chemical fertilizer before their planting. Especially in Central areas, 90 percent of surveyed farmer used fertilizer before planting. All Northeastern farmers had cropped either Sunn Hemp or soybean as green manure or rotated crops. On the contrary, Central farmers had not planted other rotated crop before their rice planting.

5.1.3 Choice of seed varieties

All surveyed farmers were found to acquire seeds from neighborhood shops which would be sub agent of seed companies. The amount of seeds used were approximately 20-25 kilograms per rai.

5.1.4 Planting

All studied farmers in north eastern region plants their rice for one crop per year and they start planting during the month of May. While 100 percent of surveyed farmers of central plant rice for two crops per year. They begin planting in May for the first crop. Then second crop is begun in November. All farmers in the studied area applied chemical fertilizers for rice production.

Rice production systems are divided into two main agro-ecosystems: irrigated and rain-fed. Irrigation planting system can be found in Central region. Meanwhile, main water source in Northeastern areas mainly relies on rain.

Transplanting seedlings and wet direct seeding method are very popular planting method in the Central region. In Northeastern region, they use transplanting seedlings and rice drops method.

5.1.5 Weed control

All farmers in the study use herbicides. When weed occur, additional sprayings would be performed either in total field areas or in specific areas.

5.1.6 Harvesting

All surveyed farmers in the Central regions harvest the first crop production in August and second crop production in May in the following year. For studied farmers in Northeastern region harvesting is done in August. Harvesting have normally been done by harvester and threshing machine. Information and practices used for rice cultivation can be concluded in Table 1 as follows:

Table 1 Information and practices used in this study

Area	Central	Northeastern
Land preparation		
Land clearance	Plough roughly for the first time Plough in regular furrows for the second time	Plough roughly for the first time Plough in regular furrows for the second time

	Plowing Field Stubble plowing	Plowing Field Stubble plowing
Fertilize the soil (%)		
None	10%	55%
Fertilize use	90%	45%
Rotated crops		
None	100%	-
Rotated crop	-	100% (Sunn Hemp or soybean)
Planting Method		
Wet direct seeding	60%	-
Transplanting seedlings	40%	55%
Rice drops	-	45%
Weeding control		
None	-	-
Herbicide	100%	100%
Harvesting Method		
Harvester	100%	100%
Threshing machine	100%	100%

Source: Farmers' interview

5.1.7 Paddy storage

All farmers in the study pack the paddy rice in hemp sack and sell them immediately as shown in table 2.

5.1.8 Transportation of paddy rice to sell

Transportation of paddy rice has done by trucks or carts fixed to small tractors. Farmers transport the rice grain to local merchants. This is the normal practices in most surveyed sites.

Table 2 Sale time and sale method

Area	Central	Northeast
Sale Time		

Immediately	100%	100%
Storing in the barn	-	-
Sale method (%)		
Transport to merchant	100%	82%
Merchants coming to field	-	18%
Transportation (%)		
Use truck	40%	56%
Use a cart with small tractor	60%	33%
Use pick-up	-	11%

Source: Farmers' interview

5.2 General information an activities of Rice middlemen

Currently, most of surveyed farmers in Central and Northeastern regions sell their paddy rice to either to the local middlemen who gather, produce and deliver to the rice mill or sell directly to rice mills. To sell paddy rice to the middlemen, it is normally taken place at market place, the place which farmers and middlemen can meet and provides auxiliary facilities such as weighting station, drying place and etc. with service fees. The rice middlemen are indispensable in facilitating trade between farmers and rice mills. The product price depends on the rice varieties and the humidity content of the paddy rice. Rice containing over 14 percent the humidity content shall be sold at lower price.

6. General information and activities of maize cultivation

In this section, the surveyed result is illustrated for maize cultivation. There are two main sub sections which are general information and field activities of maize farmers and general information and activities of maize middlemen. The details are explained in following sub sections

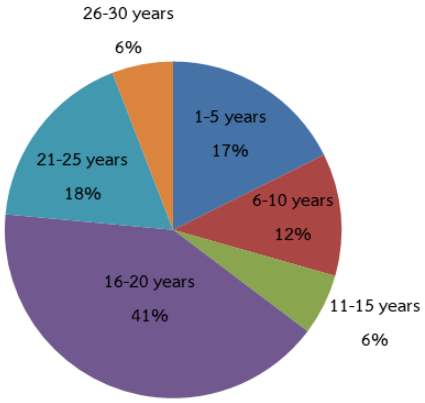
6.1 General information and field activities of Maize Farmer

6.1.1 Farm sizes and income

For the maize farmer's characteristics in this study, the majority pursued only primary

education while a few farmers hold the high vocational certificate. The farming experience varies from at the beginning level to thirty years of experience (Figure 3).

Figure 3: Maize Farming Experience (Year)



Source: Farmers' interview

The main income source of the farmers in the study is maize cultivation but some farmers also earn other sources of income such as wage employment and fruit tree cultivation for the surveyed farmers in the Central region and petty trade and paddy rice plantations for the surveyed farmer in Northeastern region.

In this study farmers were divided into three different groups of field size (small, medium and large size). For small size, field area is less than 20 *rai* (3.2 hectares). For medium size, field area is about 20-50 *rai* (3.2-8 hectares) while for large size, field size can be larger than 50 *rai* (over 8 hectares). The majority of field sizes are either medium or large farm sizes with around twenty-three percent were small farm size. Moreover, each group further divided into three ownership categories which are owned, owned & tenant, and tenant. The details are shown in Table 3.

Table 3 Farm size and occupational group

Area	Small size < 20 *rai* (<3.2 ha)			Medium size 20-50 *rai* (3.2-8 ha)			Large size > 50 *rai* (over 8 ha)		
	Owned	Owned & Tenant	Tenant	Owned	Owner & Tenant	Tenant	Owned	Owned & Tenant	Tenant
Overall	17.60%	0	5.90%	17.60%	5.90%	17.60%	11.90%	17.60%	5.90%

Source: Farmers' interview

6.1.2 Land preparation methods

In all surveyed area, small and large tractors had been used for land preparation. All studied farmers had performed soil tillage twice by using tractors. They tilled roughly for the first time and then tilled the soil in regular furrows in the second round. Almost 53 percent of farmers, they had not fertilized the soil before planting while 47 percent applied fertilizer or cropped Sunn Hemp before their planting. Common fertilizer formula were 16-20-0, 15-15-15, 20-15-15 respectively.

6.1.3 Choice of maize varieties

All surveyed farmers were found to acquire seeds from neighborhood shops which would be sub agent of seed companies. Only a few sites in Northeastern region that the farmers used the seeds from seed companies and from the Bank of Agriculture and Agricultural Cooperatives (BAAC). P4311 and NKs7328 were popular in Northeastern region. CP-301 was also popular in some sites in Central areas. The studied percentage of maize varieties are illustrated in Table 4.

Table 4: Common maize varieties planted by farmers

Area	Common maize varieties	Use (%)
Central	CP-301	42.8
	CP-801	14.3
	Pacific 777	14.3
	D-Karp	14.3
	CP-301 + CP369	14.3
		100
Northeast	P4311	40
	NKs7328	30
	NKs6253	10
	CP-303	10
	CP-504 + CP-640	10
		100

Source: Farmers' interview

6.1.4 Planting

Most of surveyed farmers who planted one crop maize per year would start planting

during the month of May until July. For those who planted two crop maize per year they would do the planting in May for the first crop. Then the second crop would be performed in August or September.

In all studied areas, planting was done using a tractor with maize seed planter. All of main water source rely on rainfall. In some area of Phetchabun (Central region) and Loei (Northeastern region) provinces had the ability to access water from deep well. They could sometimes grow maize in the dry season.

6.1.5 Weed control

In Central region, around 86 percent of farmers used herbicides. When weed occurred, additional sprayings were performed either in total field areas or in specific areas. On the other hand, only 40 percent of surveyed farmers in the Northeastern region used herbicide.

6.1.6 Harvesting

Studied farmers in the central region would harvest in rainy season. For those who wanted to plant another crop after the first crop would do the harvesting in August. For farmers who would plant only one crop per year, they would harvest in September. Meanwhile Northeastern farmers who planted maize in the late rainy season would harvest their maize in December. Harvesting was done by manual labor. Maize output, sale time and sale method of this study can be concluded in Table 5.

Table 5: Maize output, sale time and sale method

Area	Central	Northeastern
Yield (kg/rai)		
Average	1650	1040
Maximum	2000	1750
Minimum	1200	500
Sale Time		
Immediately	71%	100%
Storing in the barn	29%	-
Sale method (%)		
Transport to merchant	86%	100%
Merchants coming	14%	-

to field		
Transportation (%)		
Use truck	83%	90%
Use a cart with small tractor	17%	10%

Source: Farmers' interview

Information and practices used for maize cultivation can be concluded in Table 6 as follows:

Table 6: Information and practices used in maize in this study

Area	Central	Northeastern
Land preparation		
Land clearance	Plough roughly for the first time Plough in regular furrows for the second time	Plough roughly for the first time Plough in regular furrows for the second time
No. of tillage	2	2
Fertilize the soil (%)		
None	29%	70%
Cropped the plant	14% (cropped Sunn Hemp before planting)	10% (cropped Sunn Hemp before planting)
Fertilize use	57%	20%
Fertilizer type	16-20-0 15-15-15 27-12-6	16-20-0 20-15-15
Rate of fertilizer use (kg/rai)	25-50	25-30
Planting Method	seeding with tractor	seeding with tractor
Weeding control (%)		
None	14%	60%
Herbicide	86%	40%
Harvesting Method (%)		

Labor	71.4%	80%
Tractor	14.3%	20%
Labor & Tractor	14.3%	-

Source: Farmers' interview

6.1.7 Maize storage

In this study, harvested maize of the majority of surveyed farmers was sold to merchants. They did not keep any maize grain for their home use or seeds for next crop. They would have to sell it immediately even at low price. In some areas of central region, they would keep the grain for another period of time in the storage barns where it can be stored for more than 10 tons.

6.1.8 Transportation of maize to sell

Transportation of maize grain was done by trucks. Farmers would transport the maize to the merchants. This was the normal practices in almost surveyed sites. In some cases of Saraburi province, there were merchants from other districts coming in and trading in the farmers' villages. In Phetchabun (Central region) and Loei (Northeastern region) provinces, the farmers used carts fixed to small tractors (E Tan) as transportation means. The percentage of transportation mode can be concluded in Table 5.

6.2 Maize middlemen

Majority of farmers quickly sell their maize directly or indirectly to local merchants or middlemen. Some large middlemen keep the maize in the warehouse or silo. In the northeastern region, they would not buy maize that its humidity content would be higher than thirty-five percent. The local merchant and middlemen would pay maize price on the spot price basis depending on humidity level.

7. Efficiency and Value Added of Used Agricultural Tools

Tables 7, 8 and 9 illustrate used agricultural tool, their efficiency and value added collected data from surveyed rice farmers in central & northeastern region, central region and northern region respectively. They show the development of used tools in each activities of supply chain starting from soil preparation to transportation in

chronological order. It should be noted that time in each table indicates only the earliest year which farmers within this survey changed one tools to another tools. It may not indicate the first time of a particular tools used in the particular region.

For the efficiency point of view, the researcher tried to estimate the efficiency themselves since there have been no database of relevant information. The illustrated number only indicates whether the efficiency had been improved once new tools would apply. For value added point of view, since there is no relevant database especially historical price, the value added shows only qualitative term only when value added would be improved.

Comparing with Tables 8 and 9, used agricultural tools from surveyed information between central region and north eastern region is not different. The surveyed farmers in both regions had used the same tools and at almost the same time.

Table 7: Used Agricultural Tools and Their Efficiency and Value Added: Surveyed Rice Farmers of Central region and North Eastern Region

Process	**The development of agrictural tools for rice production in chronological order**				**Value added**
1. Soil preparation	**1961**			**1992**	Better quality of rice since rice plant grows well
	Hoe	Water buffalo	Walking tractor	Tractor	
				89% Labor saving 56 % time saving 13% higher productivity	
2. Planting		**1999**	**2002**	**2004**	Better quality of rice because there are enough spacing to grow, it grows well.
	Human Labor	Rice drop machine	Direct seeding machine	Embroidery transplanting machine	
		90% time saving 80 % Labor saving	50% time saving 70 % Labor saving	80% time saving 70 % Labor saving	
3. Fertilizing		**1992**			
	Human Labor	Spreader Machine			
		21% time saving			
4. Watering		**1957**			
	Rain-fed	Water pump			
		58% drought improvement			
		54% time saving			
5. Applying pesticide				**1996**	
	None	Human Labor	Back Sprayer (Man)	Back Sprayer (Machine)	
				33% Labor saving 21 % Time saving	
6. Harvesting		**1982**	**1982**		
	Human Labor	Harvester	Combine Harvester		
		68% time saving 66 % Labor saving	72% time saving 90 % Labor saving		
7. Storage		**1957**			Better rice preservation
	None	Barn			
8. Transporation		**1968**	**1968**		
	Pick Up Truck	Cart fixed to small tractor (E Tan)	Truck		
		54% time saving 74 % Labor saving	78% time saving 93 % Labor saving		

Source: Developed by Authors from Farmers' interview

Table 8: Used Agricultural Tools and Their Efficiency and Value Added:
Surveyed Rice Farmers of Central Region

Process	The development of agrictural tools for rice production in chronological order				Value added
1. Soil preparation	**1961**			**1992**	Better quality of rice since rice plant grows well
	Hoe	Water buffalo	Walking tractor	Tractor	
				90% Labor saving 60 % time saving 15% higher productivity	
2. Planting		**1999**	**2002**	**2004**	Better quality of rice because there are enough spacing to grow, it grows well.
	Human Labor	Rice drop machine	Direct seeding machine	Embroidery transplanting machine	
			70% time saving 50 % Labor saving	70% time saving 80 % Labor saving 20% higher productivity	
3. Fertilizing		**1996**			
	Human Labor	Spreader (Machine)			
		20% time saving			
4. Watering		**1957**			
	Rain-fed	Water pump			
		60% drought improvement 55% time saving			
5. Applying pesticide			**1993**		
	None	Back Sprayer (Man)	Back Sprayer (Machine)		
			35% Labor saving 20 % Time saving		
6. Harvesting			**1982**		
	Human Labor	Harvester	Combine Harvester		
			70% time saving 90 % Labor saving		
7. Storage		**1957**			
	None	Barn			
8. Transporation		**1971**			
	Pick Up Truck	Cart fixed to small tractor (E Tan)			
		75% time saving 55 % Labor saving			

Source: Developed by Authors from Farmers' interview

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Table 9: Used Agricultural Tools and Their Efficiency and Value Added Surveyed Rice Farmers of North Eastern Region

Process	The development of agricultural tools for rice production in chronological order				Value added
1. Soil preparation	**1961**			**1979**	Better quality of rice since rice plant grows well
	Hoe	Water buffalo	Walking tractor	Tractor	
				86% Labor saving 53 % time saving 11% higher productivity	
2. Planting		**1999**	**2002**		Better quality of rice because there are enough spacing to grow, it grows well.
	Human Labor	Rice drop machine	Embroidery transplanting machine		
		90% time saving 80 % Labor saving 15% higher productivity	80% time saving 70 % Labor saving 20% higher productivity		
3. Fertilizing		**1992**			
	Human Labor	Spreader (Machine)			
		24% time saving			
4. Watering		**1957**			
	Rain-fed	Water pump			
		52% drought improvement			
		52% time saving			
5. Applying pesticide				**1996**	
	None	Human Labor	Back Sprayer (Man)	Back Sprayer (Machine)	
				28% Labor saving 24 % Time saving	
6. Harvesting		**1982**	**1987**		
	Human Labor	Harvester	Combine Harvester		
		80% time saving 90 % Labor saving	68% time saving 66 % Labor saving		
7. Storage		**1957**			Better rice preservation
	None	Barn			
8. Transporation		**1968**	**1968**		
	Pick Up Truck	Cart fixed to small tractor (E Tan)	Truck		
		50% time saving 70 % Labor saving	78% time saving 93 % Labor saving		

Source: Developed by Authors from Farmers' interview

Tables 10, 11 and 12 illustrate used agricultural tool, their efficiency and value-added collected data from surveyed maize farmers in central & northeastern region, central region and northern region respectively. They show the development of used tools in each activities of supply chain starting from soil preparation to transportation in chronological order. It should be noted that time in each table indicates only the earliest year which farmers within this survey changed one tools to another tools. It may not indicate the first time of a particular tools used in the particular region.

For the efficiency point of view, the researcher tried to estimate the efficiency themselves since there have been no database of relevant information. The illustrated number only indicates whether the efficiency had been improved once new tools would apply. For value added point of view, since there is no relevant database especially historical price, the value-added shows only qualitative term when the value added

would be improved.

Comparing with Tables 11 and 12, the surveyed farmers in both regions had used almost the same tools and at almost the same time. The surveyed farmers of northeastern region used human labor for fertilizer and harvesting activities while the surveyed farmers of central region used tractor and harvester in fertilizer and harvesting activities.

Table 10 Used Agricultural Tools and Their Efficiency and Value Added: Surveyed of Maize Farmers of Central + North Eastern Region

Process	**The development of agrictural tools for rice production in chronological order**				**Value added**
1. Soil preparation	**1961**			**1992**	Better quality of maize since they have a ability to find sufficient nutrition
	Hoe	Water buffalo	Walking tractor	Tractor	
			50% time saving 15% higher productivity	69% labor saving 64 % time saving 66% higher productivity	
2. Planting		**1998**			Better quality of maize output due to the quality of planting
	Human Labor	Maize seed planter			
		81% labor saving 81 % time saving 86% higher productivity			
3. Fertilizing		**2015**			Better quality of maize dute to the sufficient level of fertilizer
	Human Labor	Human Labor+tractor 100% labor saving 100 % time saving 100% higher productivity			
4. Watering		**2016**			Better quality of maize dute to the sufficient level of water
	Rain-fed	Water pump 45% labor saving 45% time saving 65% higher productivity			
5. Applying pesticide		**2000**		**2010**	Better quality of maize due to no weeds to compete with nutrition
	None	Hand Sprayer	Electricity Sprayer	Planter + Sprayer	
		60% labor saving 30 % time saving 62% higher productivity	55% labor saving 18 % time saving 63% higher productivity	100% labor saving 50 % time saving 50% higher productivity	
6. Harvesting		**2015**			
	Human Labor	Harvester			
		85% labor saving 85 % time saving 13% higher productivity			
7. Storage		**1979**			
	None	Barn			
8. Transporation	**1983**	**1994**			
	Cart fixed to small tractor (E Tan)	Truck			
	67% time saving 62 % labor saving	71% time saving 74 % labor saving			

Source: Developed by Authors from Farmers' interview

Table 11 Used Agricultural Tools and Their Efficiency and Value Added:
Surveyed Maize Farmers of Central Region

Process	The development of agricultural tools for rice production in chronological order				Value added
1. Soil preparation	**1961**			**1992**	Better quality of maize since they have a ability to find sufficient nutrition
	Hoe	Water buffalo	Walking tractor	Tractor	
			50% time saving 15% higher productivity	60% labor saving 53 % time saving 59% higher productivity	
2. Planting		**2000**			Better quality of maize output due to the quality of planting
	Human Labor	Maize seed planter			
		71% labor saving 76 % time saving 82% higher productivity			
3. Fertilizing	Human Labor				
4. Watering		**2016**			Better quality of maize dute to the sufficient level of water
	Rain-fed	Water pump 50% labor saving 50% time saving 80% higher productivity			
5. Applying pesticide		**1999**	**2000**		Better quality of maize due to no weeds to compete with nutrition
	None	Hand Sprayer	Electrical Sprayer		
		72% labor saving 28 % time saving 63% higher productivity	55% labor saving 18 % time saving 63% higher productivity		
6. Harvesting	Human Labor				
7. Storage		**1979**			
	None	Barn			
8. Transporation	**1983**	**1997**			
	Cart fixed to small tractor (E Tan)	Truck			
	60% time saving 50 % labor saving	64% time saving 63 % labor saving			

Source: Developed by Authors from Farmers' interview

Table 12 Used Agricultural Tools and Their Efficiency and Value Added:
Surveyed Maize Farmers of North Eastern Region

Process	The development of agrictural tools for rice production in chronological order				Value added
1. Soil preparation	**1961**			**1992**	Better quality of maize since they have a ability to find sufficient nutrition
	Hoe	Water buffalo	Walking tractor	Tractor	
			50% time saving 15% higher productivity	72% labor saving 76 % time saving 69% higher productivity	
2. Planting		**1998**			Better quality of maize output due to the quality of planting
	Human Labor	Maize seed planter			
		89% labor saving 84 % time saving 89% higher productivity			
3. Fertilizing		**2015**			Better quality of maize dute to the sufficient level of fertilizer
	Human Labor	Human Labor+tractor 100% labor saving 100 % time saving 100% higher productivity			
4. Watering		**2016**			Better quality of maize dute to the sufficient level of water
	Rain-fed	Water pump 40% labor saving 40% time saving 50% higher productivity			
5. Applying pesticide		**2008**	**2010**		Better quality of maize due to no weeds to compete with nutrition
	None	Hand Sprayer	Planter + Sprayer		
		63% labor saving 38 % time saving 45% higher productivity	100% labor saving 50 % time saving 50% higher productivity		
6. Harvesting		**2015**			
	Human Labor	Harvester			
		85% labor saving 85 % time saving 13% higher productivity			
7. Storage					
	None				
8. Transporation	**1983**	**1994**			
	Cart fixed to small tractor (E Tan)	Truck			
	80% time saving 85 % labor saving	74% time saving 78 % labor saving 10% higher productivity			

Source: Developed by Authors from Farmers' interview

Tables 13 and 14 below show the study of used tools and their efficiency and value added of rice and maize middlemen respectively in Central and North Eastern region. The details are below:

Table 13 Used Tools and Their Efficiency and Value Added of Rice Middlemen: Central + North Eastern Region

Process	The development of tools of rice middlemen in chronological order				Value added
1. Weighting		**1987**			
	Mechanical weight scale	Digital weight scale			
		75% labor saving 84 % time saving 78% higher accurcy			
2. Moisture measurement		**1999**			
	Hand touch	Moisture meter			
		74 % time saving 76% higher accuracy			
3. Rice quality inspection		**1999**			
	Visual inspection	Mini brown rice miling machine 53% time saving 65% higher accuracy			
4. Dehumidification		**1999**			High quality of rice due to sufficient level of humidity
	Rain-fed	Dehumidifier			
		53% labor saving 48% time saving			
5. Storage		**1992**	**2013**		
	Warehouse	Silo	Cooling silo		
		30% loss saving	30% loss saving		
6. Transportaion				**1977**	
	Tractor	Cart fixed to small tractor (E Tan)	Truck	Trailer	
				83% labor saving 49 % time saving	

Source: Developed by Authors from Farmers' interview

Table 14 Used Agricultural Tools and Their Efficiency and Value Added of Maize Middlemen: Central + North Eastern Region

Process	The development of tools of rice middlemen in chronological order				Value added
1. Weighting		**1998**			
	Mechanical weight scale	Digital weight scale			
		82% labor saving 84 % time saving 75% higher accurcy			
2. Moisture measurement			**1988**		
	Hand touch	Moisture meter	Digital moisture meter		
			80 % time saving 77% higher accuracy		
3. Rice quality inspection					
	Visual inspection				
4. Dehumidification		**1999**			High quality of rice due to sufficient level of humidity
	Rain-fed	Dehumidifier			
		50% labor saving 30% time saving			
5. Storage					
	Warehouse				
6. Transportaion				**1977**	
	Tractor	Cart fixed to small tractor (E Tan)	Truck	Trailer	
				83% labor saving 52 % time saving	

Source: Developed by Authors from Farmers' interview

8. Additional Information of Agricultural Tools in the Market

The following are high technology agricultural tools which are available in the market. These are agricultural drone, remote sensing and weather forecasting. The details are shown below:

8.1 Agricultural Drone

According to the interview meeting with one of drone service providers in agricultural sector, Mr. Prokchon Promkungwahn on January 2019, he informed the researchers about the current situation of agriculture drone in Thailand. Agricultural drone has been used in Thai agricultural industry since 2016. Its capacities are able to fly automatically according to the assigned routes, and carry water or other liquids up to thirty-six kilograms in order to spray fertilizers and hormones. The most popular brand of agricultural drone in Thailand is DJI which is the Chinese agricultural drone brand. The benefits of agricultural drone are time saving, money saving and high quality of fertilizer spray. For time saving, it takes five minute to complete fertilizer or hormone spray comparing with at least thirty minutes of human labor. The direct labor cost of human labor for fertilizer spray with other benefits including lunch and water is approximately 100-120 baht per rai while the cost of drone services is approximately 80-100 baht per rai depending on travelling distant of drone service provider. The wind power causing by drone propeller can flip the paddy and maize leaf over. Consequently, the fertilizer and hormone can be sprayed thoroughly. Comparing with the human labor, drone has less chance to damage rice and maize plant. The limitation of agricultural drone service industry in Thailand is currently lacking of drone pilot and pilot assistant.

There are approximately six hundred to eight hundred drones in Thailand. Some farmers bought and operated drones themselves. There are service companies providing agriculture drone services which are fertilizer and hormone spray, plant health monitoring and other surveys to the agricultural markets including paddy and maize. According to the field survey with paddy and maize farmers, the surveyed farmers have yet used the drone services but they have heard about the services. In addition, there is strongly interested to use the drone services if the services are available in their area and the cost must be competitive comparing with employing human labor.

8.2 Remote Sensing

Geo-Informatics and Space Technology Development Agency (GISTDA) is an independent organization in Thailand (GISTDA 2019). They aim to develop geo-informatics and space technologies and applications including remote sensing and geographic information system (GIS). GISTDA has applied remote sensing and GIS techniques to monitor the cultivated area of rice maize, sugar cane and cassava plantation. The objective of project is to estimate suitable harvest date of each agricultural product and total production of each product. They provide relevant studied information on their website. The information will be updated every two weeks. The surveyed farmers had never applied this tools since it is very complicated tools which require a lot of techniques while the education level of farmers is primary school to vocational school.

8.3 Weather forecasting

In Thailand, there are government office, academic institutions and private sectors that provide weather forecast information through social media and application**.** Thai Meteorological department provides up to date information of weather forecasting, hydrological, agro Meteorological, geographic information system **(**GIS**)**, climatology datum, weather warning, storm tracking and earthquake report in Thai and English **(**Thai Meteorological department, 2019**).** The department reports their forecast and studies on their website and Facebook **(**Thai Meteorological department 2019**).**

For academic institution, King Mongkut Institute of Technology Ladkrabang **(**KMITL**)**, one of leading university in Thailand, had developed and studied several weather indicators such as surface precipitation rates, temperature, humidity, wind speeds with direction and water paths of hydrometer in details for each country in Asia and Pacific by using several mathematical models with their artificial intelligent **(**KMITL 2019**).** They provide the aforesaid information via their own application named “WMAPP” In addition, the institution provides the weather forecast to Thai Royal Making and Agriculture aviation, Ministry of Agriculture**.**

For private company, DTAC, one of Thai mobile telecommunication providers, and their affiliated start-up companies have launched “Farmer info” App which provides weather forecast information for specified agricultural area, agricultural health monitoring and crop planning with remote sensing and machine learning algorithm

since October 2018**.** The service fees begin from 30 baht per month up to 800 baht per month based on the amount of planting area **(**DTAC 2019**).**

According to this research field survey with the farmers in several provinces, they know the availability of services but most of them have used free information from Thai Meteorological department and they also share the weather forecast among their other farmer members within their network via line application, one of the most famous social network applications in Thailand**.**

9. Policy Implications

Based on the Thailand 4.0 and Mega-Farm components in the Thai government policy and the survey results from the upstream production of rice and maize in Central and Northeastern regions, measures are proposed as policy implications. The ultimate objectives of these measures are strengthening the production bases of these two most important crops in Thailand.

I. Human resources development: The education background of Thai farmers is mostly primary, secondary, or vocational school graduated. Operation of simple tools or machineries would not cause any problem for them. However, to apply drone, sensors for precision farming, weather forecast application, etc., some technical know-how would be crucial. The two prongs approaches are proposed by firstly, organizing the short courses of "how-to" to train the present farmers of necessary application techniques for advance tools. Secondly, attractive formal education on advance technology for agriculture such as the Innovative Agricultural Management (IAM) curriculum in Panyapiwat Institute of Management (PIM), Thailand should be promoted to high school students. This would ensure qualified, well-trained, up-to-date thinking agricultural workforces in Thailand in the years to come.
II. Farmer Co-operative Promotion: The outcome from the field survey is that the farming operation in Thailand mostly operates by individual family with small plots of rented or owned lands. Farmer co-operative or co-op like those practices in Japan or other developed countries should facilitate the Mega-Farm policy of the government. The co-op will raise the bargaining power of the farmers in dealing with the other parties be it government organization or private ones like

mill plant owners, seed varieties sellers, middlemen, equipment rental services, etc. The co-op could also operate as the organizer for training and education for all members too.

III. Shared Tools and Equipment System: The investment cost for advanced tools and equipment tend to be very high. Shared Tools and Equipment System either operated by government support unit or co-op should be promoted. Recently, there are several overseas subsidiary companies that provide rental services for tools and equipment. So, the investment cost will be affordable and access to up-to-date tools and equipment would be possible. Besides, necessary maintenance or upgrading of tools and equipment will be easier with the shared system.

10. Conclusion

This research paper explains the result of the study of development of agriculture tools used in upstream supply chain of rice and maize in Thailand in chronological order. Data collection collected from selective farmers and middlemen in various provinces in Central and North Eastern regions of Thailand. The paper also studied the efficiency and value added of used tools and also summarizes relevant policies which affect to the agricultural industry. In additional, the paper also explains the hi-tech tools which are available in the market and can apply in the agricultural industry.

The tools, especially smart or hi-tech tools which are currently used in midstream and downstream of the agricultural industries are suggested for further study. Also, the comparative study of the smart and hi-tech tools which are currently used in upstream supply chain of agricultural sector in different countries is recommended for further study. There are three suggested policy implications in this study to strengthen the production bases of these two most important crops in Thailand which are Human resources development, farmer Co-operative promotion and shared tools and equipment system.

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