OPTIMIZATION AND APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN SUPPLY CHAIN AND INBOUND TRANSPORT FOR CASSAVA STARCH INDUSTRY

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Rattanasit Tangkitjaroenmongkol

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ABSTRACT

This research was focused on the business processing of the supply chain process in the cassava starch industry, using the Integrate DEFinition for function modeling (IDEF0) and value stream mapping to identify the problems in business process activity and the supply chain process for the cassava starch industry.

The improvement of the business process was studied as well as the potential suitability of cassava service centers (CSC) to collect and transport the cassava roots from multiple farms to a cassava starch mill in the western region of Thailand.

The objective of the research was to minimize total costs, which include the investment costs for the CSCs and the transportation costs from the farms to the CSCs. The purpose of the CSCs as collection hubs is to improve the efficiency in the collection process, and reduce the stockpile at the mill, with smooth operation and management of logistics inbound.

There were two mathematical models employed for design and analysis: ordinary k-mean clustering with Weka program, and modified k-mean clustering by multiplying the parameter by the volume of cassava roots in the farms with MATLAB coding. These were used to find the best solution that reduces distances and total costs, with the number of locations set at 5, 10, 15, 20, 25 and 30 locations, and then to find with Dijkstra's algorithm and the Geographic Information System (GIS), the closest CSCs.

From these results, the new design model for cassava service centers (CSCs), showed the best results used 20 locations with an area of 5 rai each, and the total costs were 43,753,989.98 baht per year, using the modified k-mean clustering. Preprocessing and transport to factory had better results than the current transportation model. In the business process model with IDEF0 and value stream mapping, there have to be improvements in the information system and network, and the Kanban system that has been so important in getting the business process time and lead time of inbound transportation reduced from 6 hours to 1 hours and getting greater efficiency in the supply chain process.

KEY WORDS: CASSAVA STARCH INDUSTRY / BUSINESS PROCESS / VALUE STREAM MAPPING / K-MEAN CLUSTERING / GEOGRAPHIC INFORMATION SYSTEM

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การหาค่าที่เหมาะสมที่สุด และการประยุกต์ใช้ระบบภูมิศาสตร์สารสนเทศในห่วงโซ่อุปทาน และการขนส่งขาเข้าโรงงานของอุตสาหกรรมแป้งมันสำปะหลัง

OPTIMIZATION AND APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN SUPPLY CHAIN AND INBOUND TRANSPORTATION FOR CASSAVA STARCH INDUSTRY

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บทคัดย่อ

งานวิจัยนี้ทำการศึกษาและวิเคราะห์ปรับปรุงการขนส่งโดยการตั้งศูนย์รวบรวมและจัดเตรียมผลผลิตมันสำปะหลังสดที่เหมาะสม และจัดระบบการขนส่งจากไร่มันสำปะหลังผ่านศูนย์ดังกล่าวไปยังโรงงานแป้งมันสำปะหลัง โดยทำการศึกษาในเขตพื้นที่ภาคตะวันตกของประเทศไทย โดยเน้นการจำแนกและอธิบายถึงองค์ประกอบของกิจกรรมในอุตสาหกรรม แก้ปัญหาระบบกระบวนการทางธุรกิจและการจัดการการขนส่งด้านโลจิสติกส์ขาเข้าในอุตสาหกรรมแป้งมันสำปะหลัง โดยใช้ IDEF0 และ Value Stream Mapping (VSM) ในการวิเคราะห์และออกแบบระบบทางธุรกิจทั้งห่วงโซ่อุปทาน

โดยในส่วนของการวิเคราะห์ระบบการขนส่งด้วยแบบจำลองทางคณิตศาสตร์ ได้ใช้วิธีการจำแนกกลุ่มข้อมูลด้วยค่าเฉลี่ยเค (K-mean clustering) เปรียบเทียบ 2 กรณี: วิธีการจำแนกกลุ่มข้อมูลด้วยค่าเฉลี่ยเคแบบปกติโดยใช้โปรแกรม Weka กับวิธีการจำแนกกลุ่มข้อมูลด้วยค่าเฉลี่ยเคแบบทำการคูณถ่วงน้ำหนักด้วยปริมาณผลผลิตมันสำปะหลังสดในแต่ละไร่โดยใช้โปรแกรม MATLAB เพื่อหาผลลัพธ์การจัดตั้งศูนย์รวบรวมและระบบการขนส่งที่ดีที่สุด โดยจำแนกกรณีจำนวนการตั้งศูนย์ออกเป็นขนาด 5, 10, 15, 20, 25 และ 30 จุด และทำการประเมินและแสดงผลด้วยวิธีการ Dijkstra's และแอพพลิเคชั่น closest facility ของโปรแกรม ARCGIS

จากผลลัพธ์ที่ได้แสดงให้เห็นถึงการออกแบบระบบการขนส่งรูปแบบใหม่ที่ดีที่สุด ได้จากการใช้วิธีการจำแนกกลุ่มข้อมูลด้วยค่าเฉลี่ยเคแบบทำการคูณถ่วงน้ำหนักด้วยปริมาณผลผลิตมันสำปะหลังสดในแต่ละไร่โดยใช้โปรแกรม MATLAB โดยจัดตั้งศูนย์จำนวน 20 แห่งบนพื้นที่ขนาด 5 ไร่ โดยใช้ค่าใช้จ่ายทั้งหมดต่ำสุดที่ 43,753,989.98 บาทต่อปี และผลลัพธ์ดังกล่าวเมื่อนำมาปรับปรุงและประยุต์ใช้ระบบในกระบวนการทางธุรกิจดังกล่าว สามารถช่วยลดเวลานำในการขนส่งจากปกติใช้เวลา 6 วันเหลือเพียง 1 วัน และยังช่วยเพิ่มประสิทธิภาพในห่วงโซ่อุปทานให้ดีขึ้นอีกด้วย

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CHAPTER I
INTRODUCTION

1.1 Background Justification

The global agricultural market is important for developing countries. Thailand is one among those. The cassava or tapioca is one of the products of Thai agricultural economy for long time. The country with majority of rural population has been practicing agricultural production for quite some time. The significant growth of agricultural products can generate cash income for developing countries that is why many researchers and logistics research groups in Thailand consider the supply chain and logistics system in agricultural economics as important.

Agricultural production focuses on 7 major crops—namely rice, tapioca, rubber, maize, sugar cane, mung beans, and tobacco leaves—which are grown mostly for export purposes. Crop production is expected to increase as a result of genetic research on plants improves yields and as cultivated areas are expanded. However, falling global market prices and adversed weather conditions are likely to reduce farm incomes (Encyclopedia of the Nations, 2010). The supply chain and logistics research is a management tools to improve product and reduce cost.

In 2001, Thailand's agricultural trade ranked 10th in the world, and that accounted for 11.7% of agricultural exports (Pornpimol, 2006), Thus, the Thai government policy was to promote exporting agricultural products, which the international trade data of Thailand in 2008 reflected this in the report to the ministry of commerce of Thailand (Table 1.1 and Figure 1.1). The cassava products was top five of agricultural commodities exported from Thailand (Ministry of Commerce of Thailand, 2009) and the values of cassava products exported were top five of agricultural exports Table 1.2 (and Figure 1.2) (Ministry of Commerce of Thailand, 2009; Parthanadee et al., 2009).

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Table 1.1 Agricultural products exporting value of Thailand in 2007- 2008

Product	2007		2008	
	million Baht	million US$	Million Baht	Million US$
Rubber	194,333.73	5,639.98	223,628.25	6,791.73
Rice	119,215.43	3,467.43	203,218.72	6,204.07
Cassava Products	48,552.24	1,404.46	47,765.08	1,455.63
Fresh Fruit, Freeze and Dry	13,200.08	383.91	13,589.29	415.70
Corn	3,537.69	103.07	7,197.94	216.77
Vegetable Fresh, Freeze and dry	6,867.14	198.41	6,898.92	210.07
Other	16,784.56	485.92	16,566.40	504.05
Total	402,495.87	11,683.18	518,864.66	15,798.02

Source: Ministry of Commerce of Thailand, 2009; Parthanadee et al., 2009.

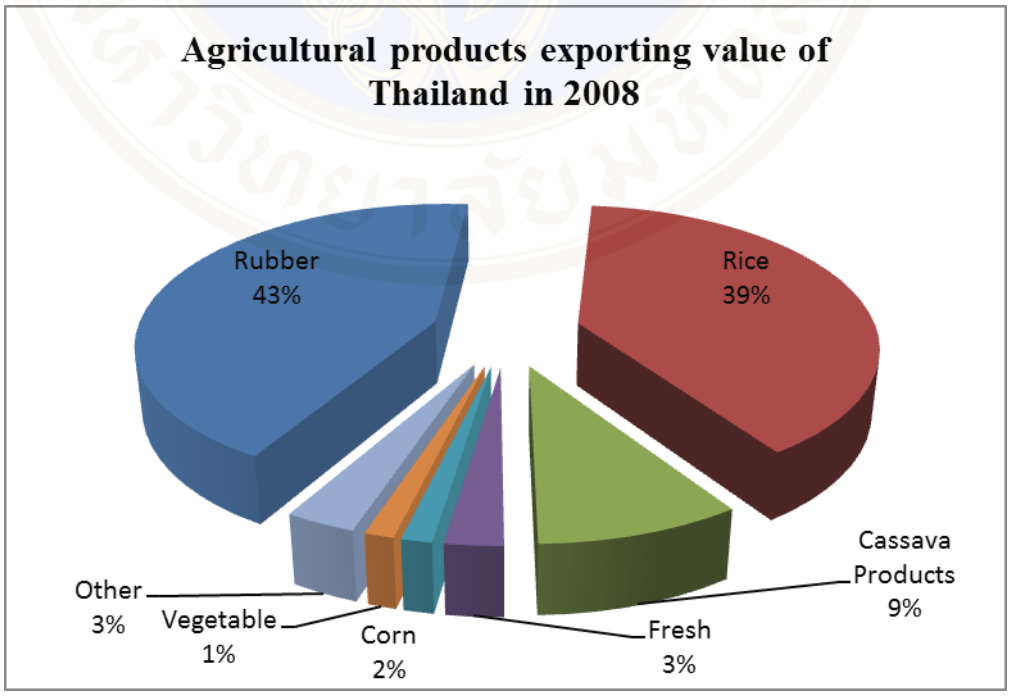

Figure 1.1 Percentage of Agricultural products exporting value of Thailand in 2008 (Ministry of Commerce of Thailand, 2009; Parthanadee et al., 2009)

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Table 1.2 Agricultural products exporting volume of Thailand in 2007 – 2008

Unit: tons

Product	2007	2008
Rubber	9,192,517.55	10,216,042.58
Rice	7,241,458.94	5,228,408.16
Cassava Products	2,965,877.67	2,832,071.10
Fresh Fruit, Freeze and Dry	703,322.31	725,754.29
Corn	375,749.00	672,897.32
Vegetable Fresh, Freeze and dry	202,111.35	216,730.68
Other	513,732.50	462,845.53
Total	21,194,769.31	20,354,749.65

Source: Ministry of Commerce of Thailand, 2009; Parthanadee et al., 2009.

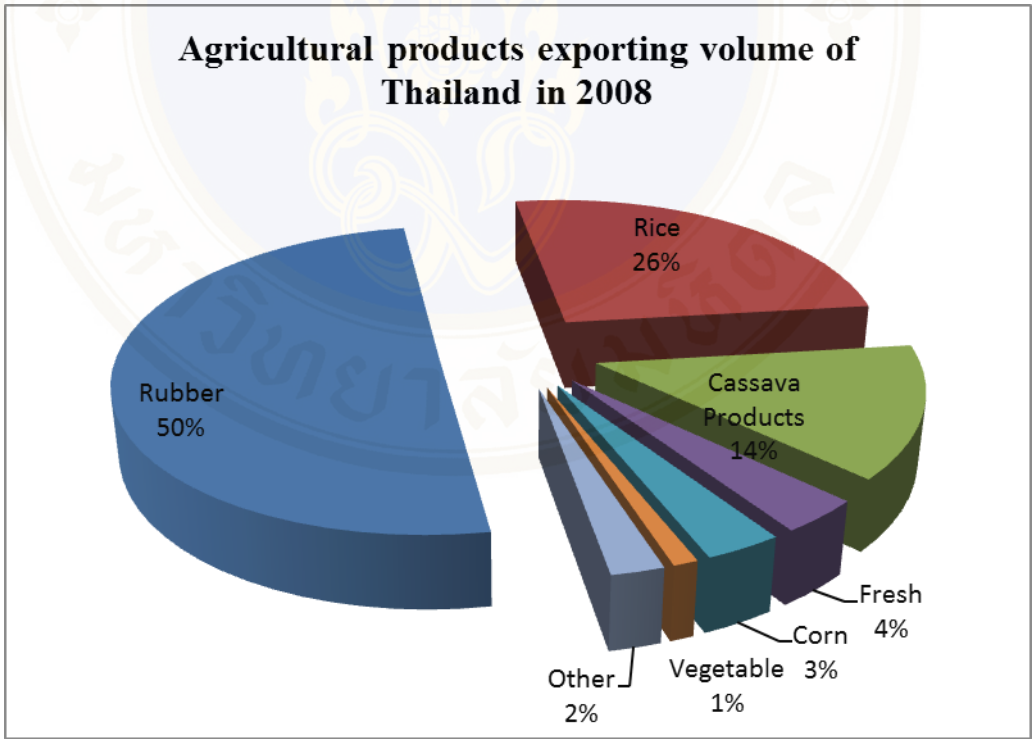

Figure 1.2 Percentage of Agricultural products exporting volume of Thailand in 2008 (Ministry of Commerce of Thailand, 2009; Parthanadee et al., 2009)

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With higher EU tariffs and Sanitary & Phytosanitary (SPS) regulations imposed by the developed world, have caused a continuous decline of the processed food exports from developing countries. Phytosanitary standard agreement and the associated WTO's regulation are subject to changes; however, it is difficult to meet an advancement in scientific knowledge relating to health hazards and improvement in food processing technology. Various processes and product methods, testing, certification & approval procedures including the materials requirement during transport are directly related to food safety. Therefore, regulations are likely to cause serious disadvantage impacts to farmers and rural communities including agricultural exporters whose intention is to export agricultural products to international markets (Panutampon and Lianchamroon, 1998).

Cassava or tapioca is an important agricultural commodity in Thailand. Also majority of Thai farmers own their farm land spread over rural areas. The reason is that nature of cassava can be harvested all over the year and can be grown in most suitable lands in Thailand. Due to the high price of cereals and higher cost of fodder production in European Union, it gives the opportunity for Thailand to offer the lower price of cassava products to EU as substitute materials for their feed industries. Therefore, the farmers and the cassava industry have a greater potential to export and gain more benefits to the economic of Thailand.

However, the output of cassava is traditionally important to Thailand which provides about 95% of the world's cassava exports, totaled 16.5 million tons per year (Janssen and Wheatley, 1985), and can generate income more than 40,000 million baht per year. Most of the cassava use for internal consumption is estimated at 33%, processed into tapioca flour 19%, chips and pellets 8%, and transformed to ethanol 6%, remainder exported to the world market for fodder and fuel oil (Figure 1.3).The cost of product mostly comes from the cost of material (cassava root) calculated to be 60% of the total cost of production (Sriroth et al., 2000; Parthanadee et al, 2009).

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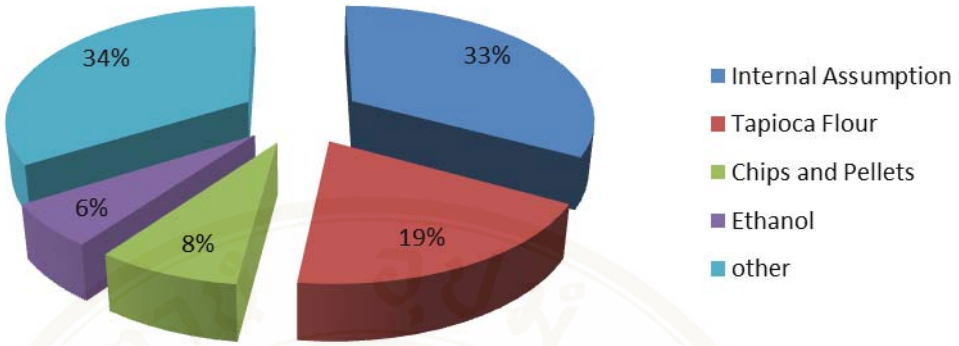

Figure 1.3 Percentage volume utilization of cassava

The advantages in cassava production is it can be easily planted, resistance to drought, and can be cultivated on different quality of soils. Thai people cultivate cassava in many areas such as north-eastern parts and midland area of Thailand. Major disadvantages of cassava production in Thailand is low product quality, which negatively affects to the efficiency of cassava production is low, moreover, the distance of transportation from farm to cassava transformation industries is far and causing long chain of logistic. Furthermore, the cassava production is influenced by the cassava price sale to factories. Not only the cassava is planted in unsuitable area that tends to low efficiency of production, but also the growing areas are dispersed. This reason makes it difficult to resources' management and technology transfer. Moreover, the roots of cassava from farmers has short post-harvest storage life or short life after it has been harvested which usually takes a long time for transportation to transformation industries, so it affects the quality of fresh root of cassava and decreases the efficiency of production. Also various transactions from transportation of fresh roots to processing plants and industries usually cause damages before reaching the production process. In order to meet the standard of SPS regulation that stressed on the ability to improve and develop more food safety standards and quality of cassava logistics system and farming, farmers can produce high quality of cassava root to cassava industry. And agricultural export community needs help to improve the exporting process to meet the standard requirement of the world export market.

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Cassava starch industries utilize cassava roots as raw material inside the country. The cassava, or tapioca, is a main raw material for starch manufacture. The benefit of value added from cassava starch or tapioca flour is more than the root products itself. Additionally, the tapioca can also be the base material for various industries such as human food and animal feed industry, bio-fuel industry, and ethno-medicine. (Wikipedia, 2008)

Previously, many sources of data presented the cassava products as important agricultural economics of Thailand, since the export volume was second, next to rice, with export value was third under the rubber and rice. Thailand has cultivated cassava in area ranking third of the world, under Brazil and Nigeria (Office of agricultural economics, 2551a) and export cassava products at the top of the world (FAOSTAT, 2009). In year 2007/08, it was reported that cassava production volume in Thailand was 25.57 million tons (Office of agricultural economics, 2551a). The cassava production volume has increased even more because the demand volume for national consumption and export has increased continuously. Presently only one research by Parthanadee et al (2552) conducted the study of the supply chain and logistics research of cassava in Thailand. But that research has not been used in applied mathematical model and Geographic Information System (GIS) for the cassava supply chain and logistics.

This research study presents a case of cassava starch and tapioca flour supply chain in Thailand, using applied mathematical model and Geographic Information System (GIS) to analyze problems and find appropriate solution to improve the supply chain and logistics system of cassava starch and tapioca flour. The mathematical model has used the Linear Programming to analyze transportation problem. However, Information management necessitates using instrument for collecting, storing, retrieving and making analysis of the complex data. Geographic Information system (GIS) has been used to collect, retrieve, and analyze spatial and non-spatial data, answer the question and support decision. Global positioning system (GPS) has been used for measurement of location and position of the cassava planting area including industry site. Geo-informatics can give higher accuracy, up to date, and valuable information to support decision making. The information can be used for management and to present the solution of efficient product management.

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1.2 Research Objectives

1.2.1 To study and analyze the relationship of cassava roots, cassava starch process and tapioca flour industry in the supply chain and logistics system.

1.2.2 To study and develop the transportation process of cassava starch supply chain industry. This is to locate and position planted areas, plants, method and mode of cassava roots, tapioca flour transportation, expenses, and ways to improve the efficiency of transportation process of cassava starch industry.

1.3 Scope of Study

Due to a large number of cassava farmers and wide spread of cassava starch factories in 45 provinces in Thailand (Office of agricultural economics, 2551; 2552), this research will limit its scope of study to a certain area where cassava factories and cassava growers are represented for all of cassava starch industry because from constrain of time and budget. This research has decided to select the one factory in Ratchaburi province, and cassava farmers groups in Western Thailand include 4 provinces, namely Kanchanaburi, Ratchaburi, Suphan Buri, and Nakhonpathom provinces. However, the outcome of this research can be used to apply to other native and modified starch industry in other areas as well, if the factory has available budget and time for the study, this research can be conducted in any area. The details of study scope in this research are as follows:

1.3.1 Location of study in Western Thailand

An area under study includes 4 provinces namely Kanchanaburi, Ratchaburi, Suphan Buri, and Nakhonpathom provinces. And there cassava productions were transported to a cassava starch factory in Ratchaburi province.

1.3.2 To study and analyze the cultivation and transportation system

To make analysis of Geographic Information of plantation, characteristics of potential and suitable area at district, and provincial level, transportation technology, pattern of management, and manufacturing system and cassava transportation approach.

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1.3.3 Application of Geographic Information system and Global positioning system

The study will include Geographic Information Systems and Global Positioning System. Geographic Information Systems is intended to be used for analyzing spatial and attributing data.

1.3.4 To study the role of supply chain and logistics in cassava starch agricultural economics

The study includes planning, management and operating control of transport, stock, distribution and value added of cassava for Optimized System, and Cost Reduction in order to consume in local market and for export.

1.3.5 To study the operating and management of Transportation Logistics for cassava starch agricultural economics

Beginning with finding raw material to finishing production, planning operation, managing production lines and controlling of activities to move and unmove of facility in cassava flow process. The detailed activities appear in figure 1.4 and include the followings:

1.3.5.1 To study the integration of supply and demand chain of cassava starch with IDEF0 (Integration DEFinition for function modeling) (Ross and Schoman, 1977; Ross, 1977; Sarkis and Lin, 1994) and Value Stream Mapping (Singh, Garg and Sharma, 2010; Rauniyar, 2007).

1.3.5.2 To manage and operate transportation of cassava starch system for optimized transportation logistics system by mathematical model with K-mean clustering (Winston, 1994; Hiller and Lieberman, 2005) and Application of GIS: Network Analyst (Chou, 1997)

- Finding and purchasing system of cassava root
- Studying operating transportation systems
- Value-added and reduced transportation cost activities of cassava starch
- Logistics activities coordination of cassava starch logistics

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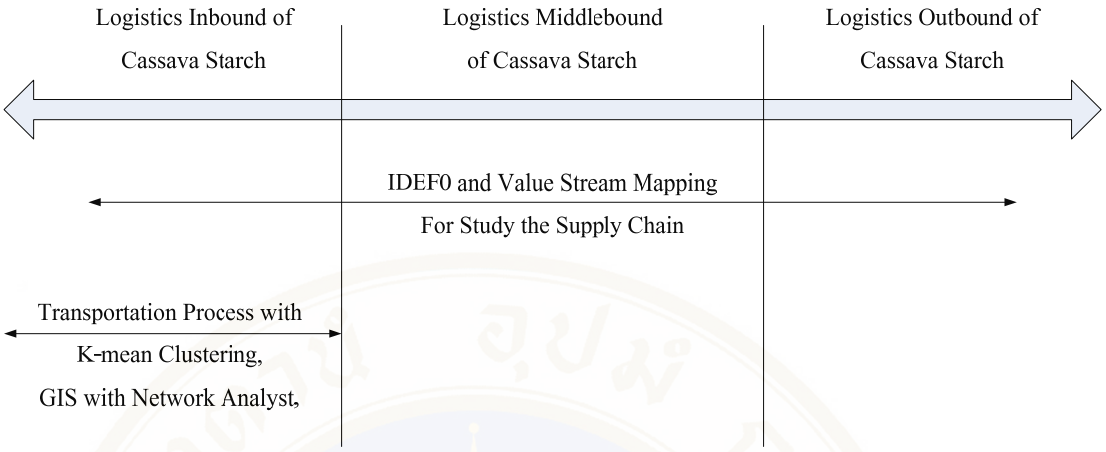

Figure 1.4 The scope of work and activity mapping in this research

1.3.6 To study factors affecting cassava starch logistics system

The factors which affect cassava starch logistics system are as follows:

1.3.6.1 Physical and Social Data: is collected from Department of Land Development, Department of Environmental Quality Promotion, Department of Rural Highways, and Department of Provincial Administration. They are:

- Administrative boundary
- Cassava industry location
- Existing cassava planted area
- Road and pavement

1.3.6.2 Economic Data: is collected from National Statistical Office, Department of Agricultural, and Office of Agricultural Economics. They are:

- Production
- Yield per rai
- Transportation cost
- Cost of cassava production
- Production capacities

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1.4 Definition

1.4.1 Cassava planted area means cassava or tapioca planted area of farmer in existence.

1.4.2 The potential suitable areas of cassava plantation means areas afford to cultivate cassava, ability to promote farmers to use that area for cultivation and choose the right seed suitable to that area, to improve cassava production.

1.4.3 Cassava root means the cassava product right after being harvested before transportation to the transformation process in cassava industry.

1.5 Expected Results

This research can produce benefits in many fields as follows:

1.5.1 To know the material and information flow of the present situation of cassava starch supply chain and logistics for the agriculture sector and industry sector and find ways to develop and improve efficiency of supply chain and logistics management.

1.5.2 To be beneficial to commercial cassava farmers, Cultivation, plant management ,improve efficiency of cassava, create value added of cassava production by cluster plantation, and improve the negotiation authority of cassava farmers

1.5.3 To be benefited Banpong's Cassava Industry which is one of the establishments that involve in this research study. The company has the ability to follow the research study to develop their processes including transportation for reducing cost of production. To avoid damages of the raw material fresh root of cassava and a transportation process affected the quality of composition of cassava itself and sufficiently reduce production capacity of industry.

1.5.4 Policy benefits, the government sector can utilize the result of research study of cassava starch logistics to be used to decide the annual capital cost for purchasing cassava at appropriate price. And determination of optimized system by application of Mathematical modeling and Geographic Information System as guideline in order to set up the committee of cassava policy to control the price and act

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like a hub for logistics and supply chain management between farmers and industry sector which is similar to the committee on sugar and sugar cane industry in Thailand.

1.5.5 Public and society benefits, according to the current Thai cassava industry mentioned above the major costs of production are labor and material , so most of the benefit falls on domestic commercial uses. When the cassava logistics system has been improved that will make the value-added to people who have been involved with this industry namely farmers, cassava starch industry or manufacturers and related industry such as equipment and machine industry, and other industry that use much if cassava as major raw material. The study can be used as a model for analysis and management of cassava starch logistics in other area.

1.5.6 By decreasing the cost of production procedure effectively, high production capacity, suitable equipment, processing time, and increasing the competitive advantage of the cassava's market the result from this research study can be used for analysis of the storage area that are suitable for cassava plantation or cassava distribution centers. In the future, this research study can be advantageous to the preparation of the study of cassava industry that can efficiently produce the high quality of cassava production that requires collaboration of all parties especially the farmers. To improve and develop the cassava farming system through the farmers for higher efficiency can produce high quality of cassava for starch industry as normally call "Contact Farming" in a more complex process.

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CHAPTER II
LITERATURE REVIEW

2.1 Background Information of Cassava

In a recent year, global agricultural market is important for developing countries. For countries with a small urban population, increasing agricultural exports can growth than expanding domestic market demand. The significantly growth of agricultural products can generate cash income for developing countries. The fact that why developing countries export more agricultural product compared to developed countries.

With some 20.4 million hectares of farm land (Ekasingh et al., 2007), Thailand is play the important role on agricultural, although the country has increased their export products for instant Jasmine Rice, Rubber, Cassava (Tapioca), Corn, and Sugarcane. In 2001, Thailand's agricultural trade was rank 10^{th} in the world accounted for 11.7% of agricultural exports (Pornpimol, 2006). Thus, Thai government is to promote exporting agricultural products, which has increased significantly in recent decades.

Cassava or tapioca is a tropical root crop which has played an important role for the Thai economy as long as 30 years ago (Sukprasert, 2007). Thai cassava products mainly have depended on export market. The large scale exports to EU was a driving force behind the growth of the cassava chip and pellet industry and also have encouraged farmers to grow cassava rather than other cash crops. The high export demand has increased domestic prices and prevented the use of cassava products in the country. The changes of EU policy in 1993 led to decrease of cassava pellet demand as well as its price which affected the entire cassava production industry.

It contributed about 7,000 million baht in Gross Domestic Product and ranks sixth following rice, rubber, vegetables and fruits, sugarcane and maize (FAO, 2003; Ekasingh et al., 2007). Cassava originated in Brazil and Paraguay and was introduced into the southern part of Thailand from Indonesia since 1786 (Danai,

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1994). Its commercial production started in the East of Thailand and it was gradually distributed throughout the country, especially in the Northeast region since 1974 (Jrungsit and Autchara, 2004), due to increasing demand from aboard and need of less attention of cassava production. Thailand is the Asia's largest producers of cassava, shared 37 percent of the total cassava products in Asia and the world's third largest producer, after Nigeria and Brazil (FAO, 2000b; Ekasingh et al., 2007).

Table 2.1 Statistic data of Thailand crops production and cultivated of cassava during 2007-2009

Data	2007	2008	2009
Household Quantity (ครัวเรือน)	474,823	480,484	512,601
Harvested Area (rai)	7,338,809	7,397,098	8,292,146
Production (Ton)	26,915,541	25,155,797	30,088,024
Yield per rai (Kgs.)	3,668	3,401	3,628
Production cost (Baht/Ton)	824	1,079	1,229
Price of farmer sold (Baht/Ton)			
Fresh root cassava	1,180	1,930	1,190
Net profit return (Baht/Ton)	356	851	-39

Source: Office of Agricultural Economics (2009)

Cassava or tapioca industry is an important agricultural industry in Thailand. Also many Thai farmers are owns their farm land spread over rural areas (Detail in Table 2.1). Cassava is the major crop of Thailand which trade to the 5th rank of all agricultural export. The reason is that nature of cassava can be harvested all over the year and can be growth in suitable landscape in Thailand. According to the high price of cereal and feed production in European Union, create the opportunity for Thailand to offer the lower price of cassava products that can be a choice for EU to seek for substitute material for their feed industries. Therefore, the farmers and the cassava industry increased the potential to export which indicates the important benefit to the economic in Thailand.

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A shift of cassava processing from pellet to starch due to the free trade environment contributed to the development of native starch industry which results in the development of the basic material for further processing into high value-added products and modified starch. The domestic use of cassava products as animal feed needs to be encouraged. Especially by the government, to reduce export dependency and to free up the use of maize for other domestic or export purposes.

2.2 Cassava Production

Cassava (*Manihot esculenta*), also called manioc (France), tapioca or yucca (Spanish) , is one of the most important food crops in the humid tropics, being particularly suited to conditions of low nutrient availability and able to survive drought (Burrell, 2003; Nyerhovwo, 2004). However, the Tapioca usually calls in production from cassava. The scientific name is Manihot esculenta. Cassava is woody shrub of the Euphorbiaceae (spurge family) native to South America that is extensively cultivated as an annual crop in the tropical and subtropical regions where its edible starchy is major source of carbohydrates.

Cassava is the third largest source of the carbohydrates for human food in the world, with Africa as the largest canter of production (Fauquet and Fargette, 1990; Tienwong, 2008). It originated in western and southern Mexico, part of Guatemala and the northeast of Brazil. It is evidence that it was grown 5,000 years ago in Columbia, 4,000 years ago in Peru, and 2,000 years ago in Mexico. It was brought to Africa by the Portuguese and was encouraged as a famine food and reserved during locust attacks. Caasava is the most important root crop of the lowland tropics (Tienwong, 2008).

Cassava was introduced into the southern part of Thailand from Malaysia during 1786 – 1840 (Cenpukdee et al, 1992; Sriroth et al., 2000) and was gradually distributed throughout the country within a few years. The plant grows to a height of 1 to 3 m and several roots may be found on each plant, the crop normally contains 5 to 10 tuberous roots which are induced by short photoperiod. Its leaves are palmate and it is cross pollinated (Tienwong, 2008). Although cassava leaves are sometimes

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consumed, the major harvested organ is the tuber, which is actually a swollen root. The plant is propagated mostly from stem cuttings. A major limitation of cassava production is the rapid post-harvest deterioration of its roots which usually prevents their storage in the fresh state for more than a few days (Okezie and Kosikowski, 1982; Nyerhovwo, 2004).

Cassava ranks very high among crops that convert the greatest amount of solar energy into soluble carbohydrates per unit of area. Among the starchy staples, cassava gives a carbohydrate production which is about 40% higher than rice and 25% more than maize, with the result that cassava is the cheapest source of calories for both human nutrition and animal feeding. A typical composition of the cassava root is moisture (70%), starch (24%), fiber (2%), protein (1%) and other substances including minerals (3%) (Nyerhovwo, 2004).

Compared to other crops, cassava excels under suboptimal conditions, offering the possibility of using marginal land to increase total agricultural production (Cock, 1982). Plant breeders, agronomists and recently molecular biologists have made substantial improvements in cassava yields during the last two decades. While, genetic characterization and mapping has revealed some insights into the molecular nature of cassava (Tonukari et al. 1997; Fregene et al. 2003; Nyerhovwo, 2004).

2.2.1 Plantation area and cultivation

The cassava planted area for the whole country was 0.17 million ha in 1968. Over the two decades of development, it rose at the average rate of 13.2 percent per year and reached its peak at about 1.6 million ha in 1989. The environmental suitable area is the tropical area between latitude 30 degree north and latitude 30 degree south, and higher 2,000 meter from the sea level (Parthanadee et al., 2009). Due to its drought tolerance property, low investment needed and the ability to grow in almost all types of soil, but loamy sand soil type is better because it is easy to harvest (Ekasingh et al, 2007). The temperature suitable is average upper than 25° C. Thailand environmental and temperature area is one of the most suitable for cassava plantation (See Figure 2.1) (Biopact, 2007; FAO, 2000). The planted area expanded rapidly in response to the growing demand for animal feed in Europe as the main market of Thai cassava pellets. But in 1993, the EU has Change the Common

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Agricultural Policy (CAP), cassava became less competitive with locally produced barley, and exports of cassava pellets decreased rapidly and caused the reduction in planted area from 1993 to 2005 at the average annual rate from 2.52 percent. The Northeast of Thailand were found the most concentrated areas of cassava plants followed by the Central and North regions, respectively (see Figure 2.2) (Ekasingh et al, 2007; Office of Agricultural Economics, 2009). The most popular plantation area is in the Northeast region over 4,242,124 rai or 54.73 percent of the cassava plantation area of Thailand and Nakhon Ratchasima province is the biggest planting cassava with the proportion of 25.53 percent of total planted area in 2009 (see Figure 2.2).

Cassava is ampliate and breeding by stem. They are harvest by classify the suitable stem, fresh, and new age between 8 – 12 month. It is not have disease or some pest. Separate breeding to 20 centimeter and have knot not least than 5 knots to harvest in suitable grab between them (Department of Agriculture, 2002). However, from their breeding by stems that effect to ampliate speed when compare with other agricultural breeding by seed. The development of cassava species to be good quality is more important.

Until the early 1990s, the most popular cassava variety was the local variety. A Selected local variety was name Rayong 1, and was the first variety used as a source of industrial raw material (Sriroth et al, 2000). The cassava breeding program has continued progressively at:

- Rayong Field Crops Research Center (RAY-FCR), Department of Agricultural (DOA), Ministry of Agriculture.
- Sriracha Research Center of Kasetsart University (KU), Ministry of University Affairs, and
- Research and Training Center of the Thai Tapioca Development Institute (TTDI) Foundation.

The goal of cassava breeding in Thailand is to increase yields and root starch content, as well as the crop’s adaptability to a wide range of growing conditions. Starch yield is a function of starch content and root dry matter yield (Sriroth et al, 2000) there has been no systematic institutional breeding of cassava for improved cooking in Thailand. Of the many varieties developed and released only a few are now widely adopted as followed table 2.2.

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Table 2.2 Recommended cassava varieties in Thailand.

Cultivar	Year released	Parent	Main feature
Rayong 1	1975	From local cultivars	High yield Good adaptability
Rayong 3	1983	MMex 55 x MVen 307	High root DM Low cyanide
Sriracha 1	1983	MKU 2-162 x Rayong 1	High yield Good adaptability
Rayong 60	1987	MCol 1648 x Rayong 1	Early harvest High yield
Rayong 90	1991	CMC 76 x V43	High root DM High yield
Kasetsart 50	1992	Rayong 1 x Rayong 90	High root DM High yield Good adaptability
Rayong 5	1994	CMR 27-77-10 x Rayong 3	High yield High root DM Good adaptability
Rayong 72	1999	Rayong 1 x Rayong 5	High yield Relatively high DM Adapted to Northeast Thailand
Huaybong 60	2003	Rayong 5 x Kasetsart 50	High yield High root DM High starch viscosity
Rayong 7	2005	CMR 30-71-25 x OMR 29-20-118	High yield Good adaptability
Rayong 9	2005	CMR 31-19-23 x OMR 29-20-118	High yield of ethanol
Kyoprodnee	2007	Rayong 5 x CMR 29-20-118	High yield High root DM
Huaybong 80	2009	Rayong 5 x Kasetsart 50	High yield Short range plants

Source: Limsila et al, 1996; Sarakarn et al, 2001; Parthanadee et al., 2009

From the table 2.3 illusions with the comparison the production volume and percentage starch in cassava in each variety report by Thai Tapioca Development

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Institute (2008a) and Department of Agriculture (2008) and other research has studies and compare in cassava variety.

Table 2.3 The comparisons of cassava variety development.

Cultivar	Year Developed	Year released	Production (Ton/rai)	Starch Volume (%)
Rayong 1	-	1975	3.22	Rainy: 18.3% Dry: 24.0%
Rayong 3	1975	1983	2.73	Rainy: 23% Dry: 28%
Rayong 60	1980	1987	3.52 4.2*	18.5% Rainy: 20%* Dry: 24%*
Sriracha 1	1983	1990	N/A	21.9%
Rayong 90	1978	1991	3.65 3.81*	23.7% Rainy: 24%* Dry: 25-27%*
Kasetsart 50	1984	1992	5.4 4.4*	25% Rainy: 23%* Dry: 28%*
Rayong 5	1982	1994	4.02 4.4*	22.3% Rainy: 22.7%* Dry: 27-29%*
Rayong 72	1990	1999	5.09	20.0% Rainy: 20-22%* Dry: 24.0%*
Huaybong 60	1991	2003	5.8	25.5%
Rayong 7*	1992	2005	6.08*	27.7%* Rainy: 23%* Dry: 27-29%*
Rayong 9*	1992	2005	4.9*	Rainy: 24%* Dry: 28-31%*
Kyoprodnee*	1992	N/A	4.77*	Rainy: 25.8%* Dry: 29-32%*
Huaybong 80	1992	2009	5.5	27.3%

Source: Edit from Thai Tapioca Development Institute (2008a); Department of Agriculture (2008); Parthanadee et al. (2009)

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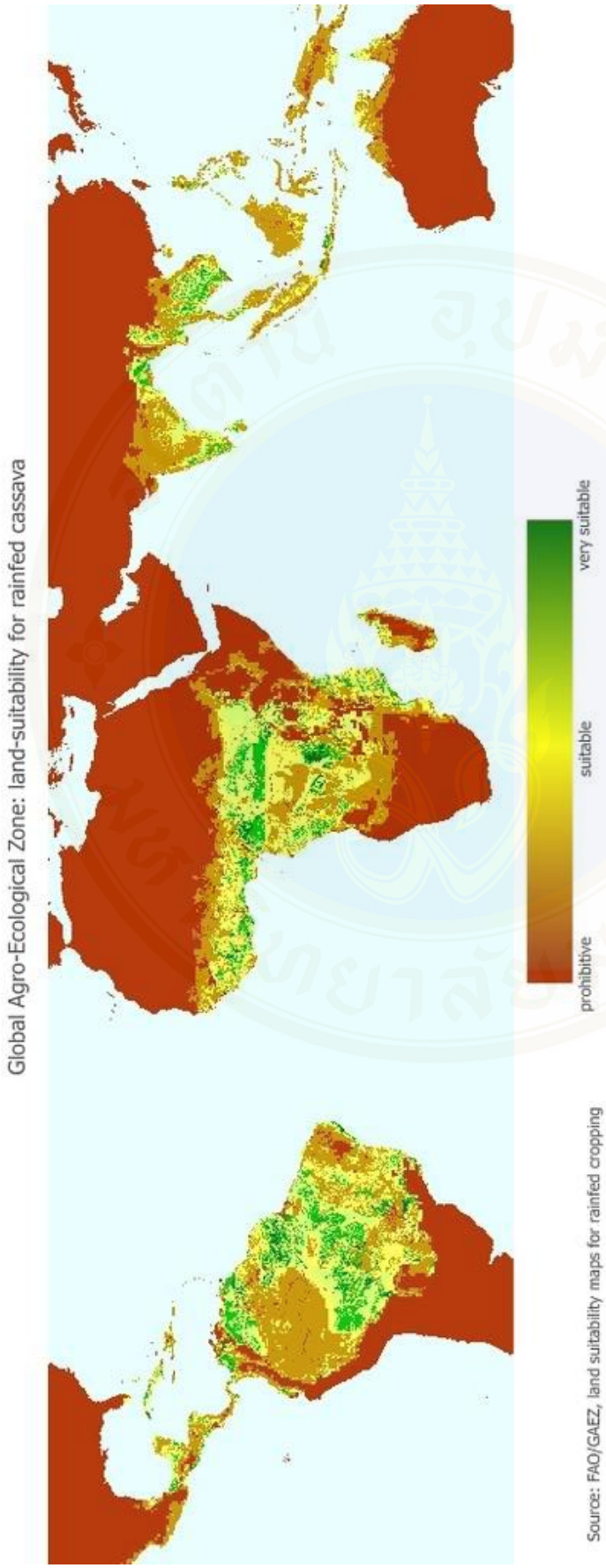

Figure 2.1 Land-suitability for rainfed cassava in the world agricultural area

Source: FAO/GAEZ (2000); Biopact (2007); Parthanadee et al, (2009)

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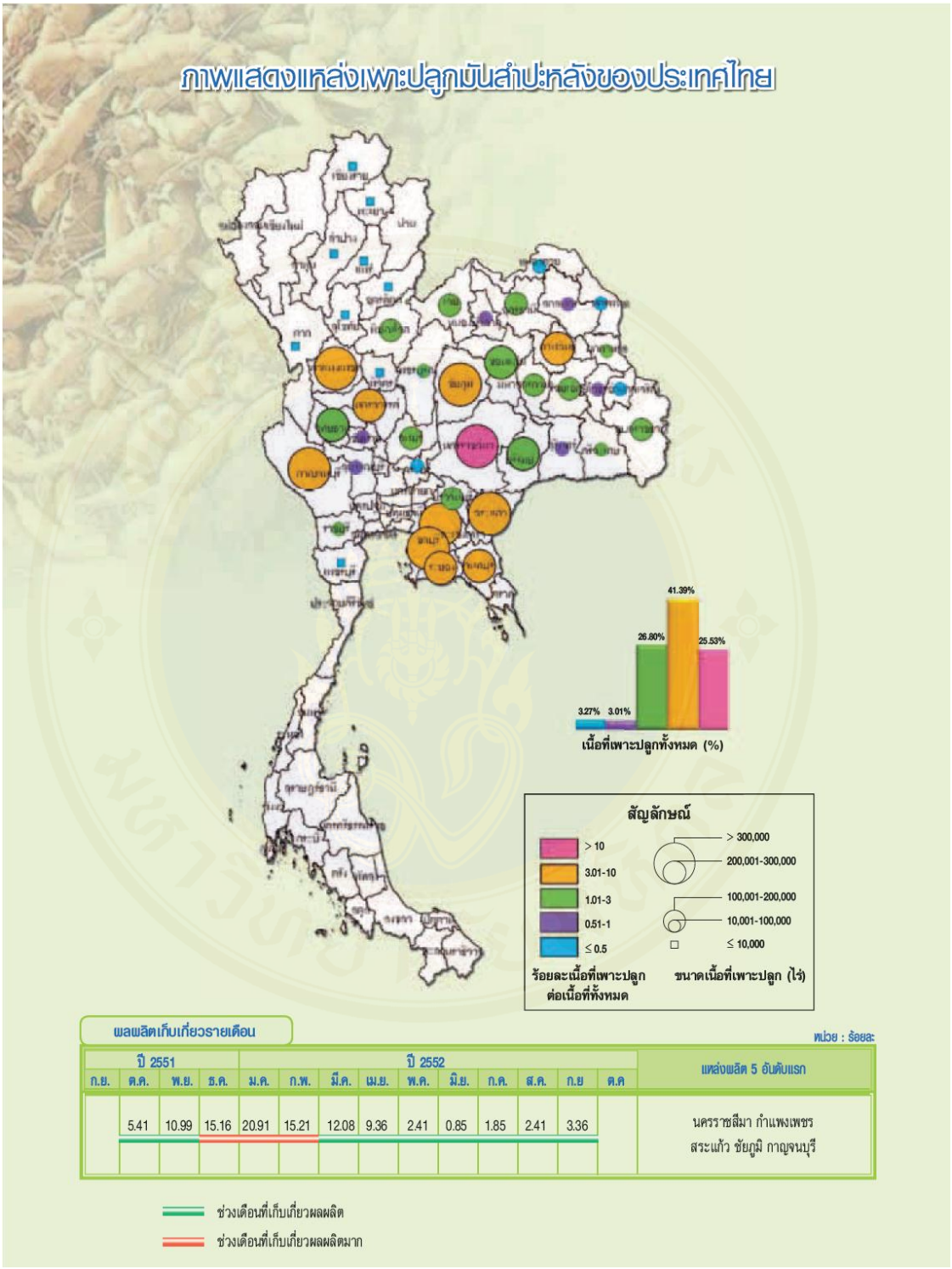

Figure 2.2 Cassava plantation areas in Thailand

Source: Office of Agricultural Economics, (2009)

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2.2.2 Production and yield

From the Land Development Department (LDD) had separate zones of cassava production with agricultural ecology in 7 production zones of Thailand, as follows;

Zone 1, East region of Thailand had the cultivation area about 248 thousand hectares as province including: Prachin Buri, Chachoengsao, Sa Kaeo, Chanthaburi, Rayong, Chon Buri, and Trat province.

Zone 2, the drought zone, Southern of Northeast region of Thailand had the cultivation area about 321.6 thousand hectares as province including: Buri Ram, Chaiyaphum, and Nakorn Ratchasima province.

Zone 3, Southern of Northeast region and boundary of Mekong River of Thailand had the cultivation area about 56 thousand hectares as province including: Nakhon Phanom, Mukdahan, Yasothon, Amnat Charoen, Ubon Ratchathani, Si Sa Ket, and Surin province.

Zone 4, Middle of Northeast region of Thailand had the cultivation area about 68.8 thousand hectares as province including: Maha Sarakham, Roi Et, Kalasin, and Khon Kaen province.

Zone 5, Northern of Northeast region of Thailand had the cultivation area about 112 thousand hectares as province including: Loei, Nongbua Lamphu, Udon Thani, Nong Khai, and Sakon Nakhon province.

Zone 6, Northern region of Thailand had the cultivation area about 91.2 thousand hectares as province including: Chiang Rai, Uttaradit, Phitsanulok, Nakhon Sawan, Uthai Thani, Kamphaeng Phet, Phetchabun, Tak, Sukhothai, Phare, Nan, Lampang, Phayao, and Phichit province..

Zone 7, Middle region of Thailand had the cultivation area about 118.4 thousand hectares as province including: Saraburi, Lop Buri, Chai Nat, Suphan Buri, Kanchanaburi, Ratchaburi, and Phetburi province.

From the detail of every cassava production area, the cassava production zone at 5, 6, 7 and the cassava production area in 1 and 3 zone near boundary of Cambodia were have the land of effectively for cassava production. However, the cassava production system in this area was fall behind, and the cassava mills for starch and chip in this area not more competitive like other area.

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According to the statistical data from the Office of Agricultural Economics (OAE, 1980- 2005), total production of cassava increased from 2.6 million ton in 1968 to its peak at 24 million ton in 1989 before falling to 17 m. ton in 2005 due to the decrease of planted area. Contribution of the cassava production from the Northeast has been decreasing from about 63 percent in 1979 to 51 percent in 2005 (Ekasingh et al, 2007). Cassava yields vary with cultivars, season of planting, soil type and fertility. In 1965, cassava yield was at 14.5 ton per ha and the average yield over the following two decades (1966-1985) had not been changed from 14.5 ton per ha. During 1986-1995, the average yield had been decreased to 13.9 ton per ha and for the last decade (1996-2005), it has been increased to 16.7 ton per ha with the lowest record at 14.2 ton per ha in 1996. For the Northeast region, the average yield at the same period was a little bit lower (16.1 ton per ha) than that of the whole country. The highest yield was in the Central region (17.8 ton per ha) also see in figure 2.3 to 2.4.

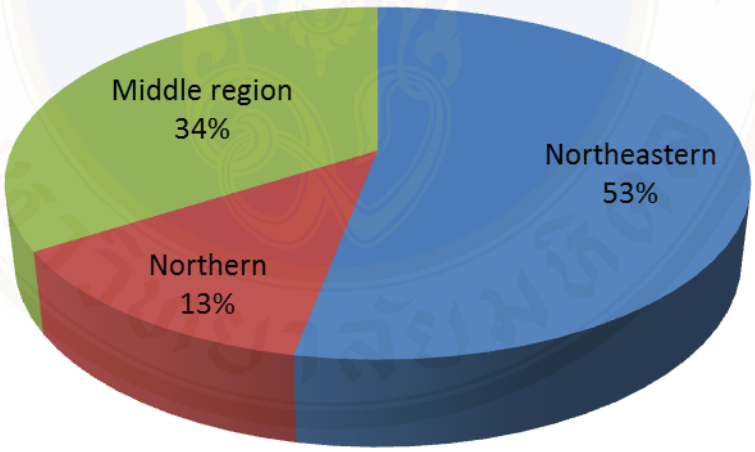

Figure 2.3 Sources of cassava production of each region in 2004

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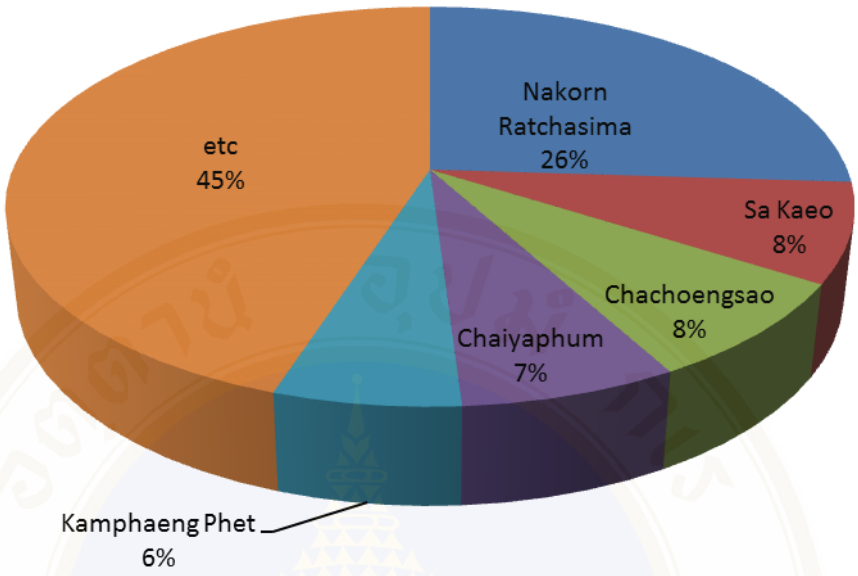

Figure 2.4 Sources of cassava production in top 5 provinces and either in 2004

Productivity (root yield and root starch content) in fresh roots is variable and influenced by many factors as table 2.4 to 2.7 (Sriroth et al, 2000). Varietal characteristics, in part, can govern starch productivity. Hence, the main purpose of cassava varietal improvement in Thailand is to increase starch yield. Other selection criteria for varietal improvement include early harvest time, stake quality, root shape with white flesh and tolerance to pests and diseases. Initially, little varietal improvement was practiced as cassava was grown only a limited area. As the planting area and importance of cassava increased, varietal improvement became important. Parent stock was derived mainly from local collection and clonal selection.

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Table 2.4 Genotype factor influencing starch productivity and quality

Author	Genotype factor				
	root yield	root starch content	root cyanide content	amylase content	swelling power
Rodjanaridpiched et al (1993)	√	√			
Santisopasri et al (2000)	√	√	√		
Bokanga et al (1994)			√		
Moorthy and Ramanujam (1986)				√	√

Table 2.5 Farm management factor influencing starch productivity and quality

Author	Farm management factor					
	Irrigation		Fertilizer application		Intercropping system	Weed control
	root yield	cyanide	root yield	cyanide	root yield	root yield
Howerler (1985)				√		
Bokanga et al (1994)		√				
CIAT (1990)				√		
Sittibusaya et al (1993)	√		√		√	√
Nayar et al (1993)			√			
Tongglum (1996)			√			
Phien and Vinh (1996)					√	√

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Table 2.6 Environmental factor influencing starch productivity and quality

Author	Environmental factor											
	Rainfall								Soil characteristic		Soil temperature	
	root yield	root starch	root cyanide	granule size distribution	swelling power	paste viscosity	pasting temperature	gelatinization temperature	root yield	root cyanide	root yield	gelatinization temperature
Rodjanaridpiched et al (1996)				√	√							
Pardales and Esquibel (1996)	√											
Sriroth et al (1998a)		√		√	√		√					
Sriroth et al (1998b)		√	√	√	√		√					
Sriroth et al (1999)						√	√					
Santisopasri et al (2000)	√	√	√			√	√					
Asaoka et al (1991)				√							√	
Bokanga et al (1994)			√							√		
CIAT (1980)	√											

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Table 2.7 Environmental factor influencing starch productivity and quality (continued)

Author	Environmental factor											
	Rainfall								Soil characteristic		Soil temperature	
	root yield	root starch	root cyanide	granule size distribution	swelling power	paste viscosity	pasting temperature	gelatinization temperature	root yield	root cyanide	root yield	gelatinization temperature
Defloor et al (1998)	√	√				√		√				√
CIAT (1990)			√									
Kurotjanavong, K. (1998)						√	√					
Oates et al (1997)						√						
Petchalanuwat, C. (1999)						√	√					
Petchalanuwat et al (1996)						√	√					
Asaoka et al (1992)								√				
Weite et al (1996)									√			

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2.2.2.1 Cassava starch Quality

Thai cassava starch is traded based on quality which was classify to various levels and specified by customer's need. The standard of cassava starch quality for each grade was established in 1978 by the Ministry of Industry as followed table 2.8 (Thai Industrial Standard Institute, 1978; Sriroth, 2000). As each of the quality grades has its own market, the standard has not included viscosity and microbial analysis. The most important quality standard is that cassava starch contains no color, no odor nor any of a few other impurities. Starch paste provides high viscosity with transparent appearance (Sriroth, 2000).

Quality of cassava starch is variable, being affected by many factors like table 2.4 to 2.7. Both starch quantity and quality are sensitive to the conditions at and immediately after planting. Drought during the early establishment period results in roots with low dry weight and starch content (Pardaies and Esquibel, 1996). The starch quality was important in the conditions immediately prior to harvest. Onset of rain after an extended dry period results in starch with different Characteristics (Sriroth et al, 2000; Santisopasri et al, 2000).

Variability in root quality and the physic-chemical properties of extracted starch ultimately influence the quality of starch-made products, to understanding and knowing the history of the raw material must be important. Therefore collecting planting data and monitoring the management of the crop was suggested as a means to upgrade cassava starch quality (Sriroth, 2000).

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Table 2.8 Quality standard of Thai cassava starch established by Ministry of Industry.

Qualification	Grade		
	1	**2**	**3**
Moisture content (% maximum)	13	14	14
Starch (% minimum by polarimetric method)	97.5	96	94
Ash (% maximum)	0.15	0.3	0.5
Acid insoluble ash (% maximum)	0.05	0.10	0.15
Protein (% maximum)	0.3	0.3	0.3
Fiber (cm^3 in 50g starch before drying)	0.2	0.5	1.0
pH	4.5 to 7	3.5 to 7	3.0 to 7
Residue on 150 μm sieve (% maximum)	1	3	5

Source: Sriroth et al, (2000); Ministry of Industry, (1978).

2.2.3 Production system and technology

The first wave of cassava processing technology, from Malaysia and Singapore, was for small-scale production of meal and flour. The meal was prepared by dry milling sundried cassava chip followed by sieving. Otherwise, Cassava starch (also known as cassava flour or tapioca flour) involved wet milling with a saw-tooth rasper, sedimenting the slurry on a starch table, or in starch ponds, and sun drying.

Cassava is the major root crop of consumption for people in many countries and also as a feed. It has several qualities which enable to yield well in the marginal

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environments characteristic of many tropical regions especially in areas of poor soils and/or low rainfall**.** The root has no period of maturity and can be harvested over a time span to several months if necessary. The nature of cassava growth makes it especial suitable for integration into the associate cropping system important in tropical agriculture. Among the tropical root cassava is unique in having the restricted harvested life. The deterioration in quality can be very fast sometime root become unacceptable for human consumption within 24 hour of harvested (Janssen and Wheatley, 1985).

In commercialized production, cassava is grown as sole cropping system in upland under rain-fed condition. Intercropping of cassava is practiced to a very limited extent even in experimental systems it has been successfully intercropped with peanut and mungbean (Chanual, Narongsak and Preecha, 2001; Ekasingh et al, 2007). To grow cassava, stems from 10 to 12 month old plants destined for planting are usually cut into long lengths, tied in bundles and stored in shady conditions. Just before planting, they are cut to the normal planting lengths of 15-20 cm. Land is usually prepared by using an owned hand tractor or a hired four-wheel tractor. Farmers usually plow 15-20 cm deep once or twice to bury residues of the previous crop. Cassava is high flexibility with respect to the timing of planting and harvesting. Chanual, Narongsak and Preecha (2000) reported that in Thailand, about 23-31 per cent of cassava was planted in May, followed by 10-20 per cent in April and 11-17 per cent in June and another 10-20 per cent in October or November, at the end of the rainy season. In the Northeast, typically most of the farmers plant it in the beginning of the rainy season (May to June) which provide the best yield but it also depend on the soil types. To decide which season to plant both quantity of rain and type of soil are important factors.

Consumers nowadays are faced with food or food ingredients that may derive from distant countries or continents, and with a less transparent food supply. Safety concerns must cover the range of different food chains relevant to a certain food product or product group, including all relevant producers, manufacturing sites and food service establishments within a country as well as those importing into the country (Aruoma, 2005; Ekasingh et al, 2007)**.**

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The consumer market is usually quite far from farm or plantation because of the distance of transportation is far and takes such a long transaction. The production of the root has to be handled within the short time of processing. Necessitate a close integration of producer, intermediately, wholesaler, retailer, and consumer, so that the demand can transfer the product to be easier and less damage of product. The transportation in affective way is important to deliver the root crop of cassava to any transaction to reduce all the risk, time required, cost, and waste.

2.3 Farm Size, Farm Price and Value

Cassava is grown by a large number of small scale farmers (3 million households) (Klanarong et al, 2000; Ekasingh et al, 2007). Most cassava farmers (68 per cent) plant cassava in areas ranging from 1.0 to 5.75 ha (Chanual, Naronsak and Preecha, 2000). No organized large-scale plantations have been established in Thailand, this is prohibited by the accumulation of land act (Klanarong et al., 2000). The farm prices are commonly fluctuating depending on total production and the starch content in the roots. A low price is usually received in February and March when bulk quantities of the roots are marketed, also in July and August of the rainy season when the starch content becomes low. However, farmers who are able to produce cassava with high starch content could sell roots for native starch processing, while those producing roots of low starch content could sell roots for chips and pellets for animal feed (FAO, 2004a). The export capability also contributes to the price instability (FAO, 2003). According to statistical data from OAE, since 1990 the average farm price of the whole country had fluctuated within the range of 0.58- 0.98 baht per kg, except in 1995, 1998, 2002 and 2005 that the farm price was higher than 1 baht per kg due to higher export demand. In 2005, the farm gate price in the Northeast is about 6 percent higher than that of the whole country. The farm price increased to the highest record a 1.41 baht per kg (1.33, for the whole country) due to decrease of production as the result of drought in Northeast as well as the higher export demand for chip and starch. The farm value has been increased from 12,834 million baht in 1990 to 22,528 million baht in 2005 with the average annual rate of 7.3 percent (Table 2.3.2).

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2.4 Cassava Costs and Profit

Production costs were mainly depend on time of planting and environmental conditions during growth which need different weed control regimes and inputs and it is reflected in the variable cost (Klanarong et al., 2000) following from table 2.9 and 2.10. Variable costs account for about 80% of the total costs. Major components of production costs in descending order were labor, land rent, and material (Sriroth, 2000). Net income per rai veried from -20.61 to 911.09 baht during 1995-1997. In 1997 there was an oversupply of fresh roots, which depressed the root price to 700 baht per ton (TTTA, 1998; Sriroth, 2000). The Ministry of Commerce, in an attempt to protect the farmers, intervened in the purchasing cycle by providing soft loans to starch factories to encourage them to purchase root at 1,000 baht/ton. This situation was short-term, as a few months later, the environmental conditions, mainly drought due to EI Nio, led to a sharp reduction in cassava root yields. Indonesia was particularly affected and the country had to import cassava products from Thailand to supplement this shortfall. The root price in Thailand increased to 2.22 baht per kg resulting in an average root price for 1998 of 1,766 baht per ton (TTTA, 1999).

In early 1997, the low root price also led to a reduction in the area planted to cassava that year, which in turn resulted in a high price of roots in 1998 (up to 2,500 baht). Aggravating the situation of cassava was the new exchange rate in July 1997 (from 25 to 42 baht/dollar). The crop harvested in late 1999, was not affected by a high price as in the previous year. The cassava root price in Dec 1999 was about 920 baht per ton (Sriroth, 2000).

In 2000, the world economic crisis was reflected by a reduction in meat consumption and surplus of cereals, especially of maize, driven by reduced demand from the feed sector. This had depressed the current maize and maize starch prices, and as cassava products (pellets, starch) have to compete directly with maize, this had substantially reduced the price of these cassava products that subsequently reflected the lower root price, i.e. 630 baht per ton (Office of Agricultural Economics, 2005).

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Table 2.9 Variable and fixed costs of cassava planting in Thailand during 2003-2004.

	2003	**2004**
Variable costs (baht/rai)	**1,952.88**	**2,014.31**
Labor costs	1,149.78	1,206.98
Land preparation	289.88	293.08
Planting	133.79	136.58
Weed control	340.17	346.59
Harvesting	385.94	430.73
Transportation	-	-
Material costs	617.53	624.21
Planting material	182.91	204.69
Fertilizers	286.43	272.21
Herbicides	135.15	134.27
Fuel	6.71	6.71
Accessories	4.66	4.66
Miscellaneous costs	185.57	184.79
Reparation	-	1.67
Interest	185.57	183.12
Fixed costs (baht/rai)	**335.11**	**335.11**
Land rent	324.34	324.34
Depreciation	9.63	9.63
Interest	1.14	1.14
Production costs (baht/rai)	**2,287.99**	**2,349.42**
Production cost (baht/kg)	0.74	0.72
Yield (kg/rai)	3,087.00	3,224.00
Price (baht/kg)	0.93	0.80
Net income (baht/rai)	582.92	245.78
Net income (baht/rai)	0.19	0.08

1 rai = 0.16 hectare (ha)

1 US$ = 41 baht until December 2005.

Source: Office of Agricultural Economics, 2005

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According to information from the Centre of Agricultural Information, total production cost of cassava in the Northeast in 2005 was about 2,526 baht per rai (15,790 baht per ha). About 87 percent of total cost is variable cost which includes labor (50 percent), material costs (28 per cent) and interest (8 percent) and the rest is fixed cost (13 percent). Most of cassava farmers use family labor with temporary hired labor. Yangmood (1994) reported that the average labor requirement for cassava production was about 96 man-days per hectare, of which family labor accounted for 50 man-days and the rest was hired labor. Labor demand peaks occur during planting, weeding and harvesting periods. There was no significant difference of production cost between the whole kingdom and the Northeast. But the profit per hectare of the Northeast farmers was 1,070 baht (16 percent) higher than that of the whole kingdom farmers since the farm gate price in the Northeast was higher following from Table 2.8.

The majority of the production costs in the cassava starch industry was the expenditure on purchasing unprocessed cassava root, which makes up to 83% of costs. The rest were the costs of electricity (9%), fuel (5%), water supply (1%), and labor (2%). In figure 2.5 (Chavaloarit and Ongwandee, 2009) shows the average proportion of relative production costs according to the eight selected plants, and a wide variation in the costs of production among the studied plants depending on their production efficiency.

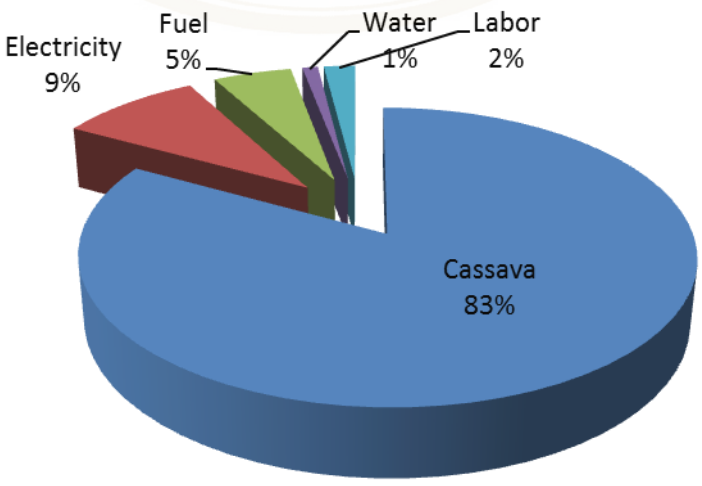

Figure 2.5 Average production costs of the studied tapioca starch plants

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Table 2.10 Variable and fixed cost of cassava production in 2005

	Whole Kingdom		Northeastern Region	
Variable costs (baht/rai)	**Baht**	**%**	**Baht**	**%**
Labor costs	2,248.4	87.03	2,194.3	86.8
Land preparation	1,324.9	51.28	1,275.1	50.4
Planting	325.1	12.58	304.3	12.0
Weed control	162.2	6.28	156.5	6.2
Harvesting	403.7	15.63	404.8	16.0
Transportation	433.8	16.79	409.4	16.2
Material costs	717.4	27.77	716.6	28.5
Planting material	224.8	8.70	220.3	8.7
Fertilizers	321.7	12.45	338.6	13.4
Herbicides	159.5	6.18	143.9	5.7
Fuel	6.7	0.26	10.9	0.4
Accessories	4.6	0.18	2.7	0.1
Miscellaneous costs	206.1	7.98	202.5	8.0
Reparation	1.6	0.06	3.0	0.12
Interest	204.4	7.91	199.5	7.9
Fixed costs (baht/rai)	335.1	12.97	332.1	13.1
Land rent	324.3	12.55	319.5	12.6
Depreciation	9.6	0.37	11.2	0.4
Interest	1.14	0.04	1.36	0.05
Production costs (baht/rai)	2,583.5	100	2,526.5	100
Production cost (baht/kg)	0.94		0.94	
Yield (kg/rai)	2,749		2,674	
Price (baht/kg)	1.33		1.41	
Income (baht/rai)	3,656.1		3,770.3	
Profit (baht/rai)	1,072.6		1,243.8	

1 rai = 0.16 ha

Source: Center for Agricultural Information, OAE (2006)

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2.5 Sources of Raw Material

Cassava was suit to the agronomic conditions of the production areas in Thailand. Particularly, the excellent drought tolerance of this plant allows and almost all soil types found in Thailand. From the studied of Sriroth et al (2000) has found the rapid expansion of the cassava planting area from only 0.4 x 10^6 hectares in 1973 to 1.5 x 10^6 hectares in 1990 (with a shift of total fresh root production from 6.3 to 20 x 10^6 tons (Cenpukdee et al, 1992)). At 2000, 17 x 10^6 tons of cassava root (10% of the global total), as followed table 2.11.

Table 2.11 Global planting area and productivity of cassava in 1999.

Countries	Planting acreage (hectares)	Total production (tons)	Yield per hectare (tons/hectare)
World	16,601,523	165,986,471	10.00
Asia	3,366,398	45,767,700	13.60
China	230,065	3,650,903	15.87
India	250,000	6,000,000	24.00
Indonesia	1,205,330	14,728,292	12.22
Philippines	210,000	1,786,710	8.51
Thailand	1,150,000	16,930,200	14.72
Vietnam	231,700	1,783,400	7.70
Africa	10,851,947	91,285,877	8.41
Congo	2,260,000	17,891,000	7.91
Ghana	629,680	7,171,450	11.39
Mozambique	1,015,000	5,639,000	5.56
Nigeria	3,050,000	33,060,000	10.84
Tanzania	693,190	6,128,000	8.84

Source: Sriroth et al, 2000

In Thailand, the cultivation time of cassava is planted in November to January (They call “late rain crop”) or February to April (They call “early rain crop”). Weeds are controlled for the first 2 to 3 months, and fertilizer (N-P-K = 15-7-18, it can be flexible depend on soil condition of planting) is applied at the rate of 625

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kg/hectare (Sriroth et al, 2000). There is virtually no commercial trade in cassava planting material in Thailand. It is usually obtained from the farmers' own fields at the previous harvest. Farmers who purchase cassava stakes are those who are new cassava farmers or wish to change varieties or increase the planting area. Hired labors are usually from the local or neighbor areas. Other inputs such as chemical fertilizers, herbicide, pesticide, fuel and tractor are imported.

Harvest was either during the early or late rain period when roots were about 10 to 12 months old, the harvest time of cassava most were gets in January and February. However, in practice, harvesting was early advanced because farmers wanted to take the money early, a decision based on the prevailing root price. Fluctuation in cassava price is a common occurrence governed by root supply and the world price for maize. Roots, after harvesting were transport to the factory in early 4 day before roots be rotten, 55% for chip/pellet and the other 45% for starch production (Department of agriculture, 2009) as figure 2.6.

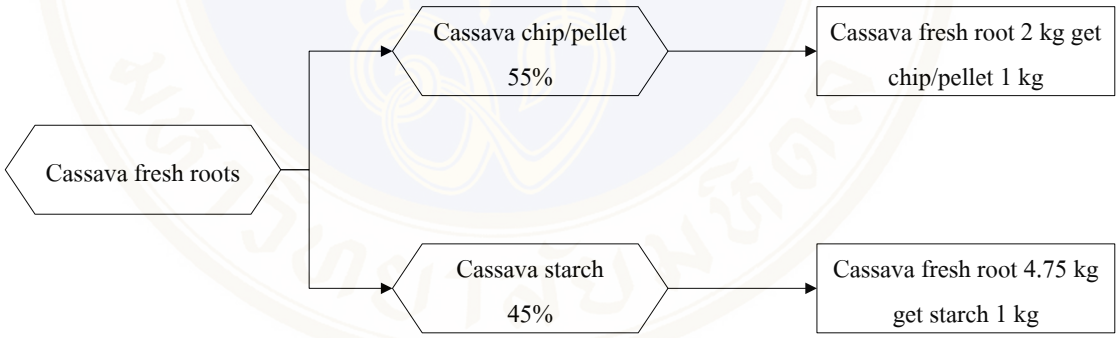

Figure 2.6 Cassava production and alternative way of product in Thailand
Source: Department of agriculture, 2009

Transportation was usually undertaken by middleman, farmers do not have the resource to transport roots. Delivery was within one day. As root prices were fluctuating daily, the farmer's decision to harvest is based on prevailing root price, transportation cost and their need to repay loans. As a rule, roots delivered to starch factories are in areas where transportation distance (and cost) are low, but sometime

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depend on root price in each factory and make profit for farmer than nearly factory, but this ensures raw material freshness.

Productivity (root yield and root starch content) in fresh roots is variable and influenced by many factors. Varietal characteristics, in part, can govern starch productivity. Hence, the main purpose of cassava varietal improvement in Thailand is to increase starch yield. Other selection criteria for varietal improvement include early harvest time, stake quality, root shape with white flesh and tolerance to pests and diseases. Initially, little varietal improvement was practiced as cassava was grown only in a limited area. As the planting area and importance of cassava increased, varietal improvement became important. Parent stock was derived mainly from local collections and clonal selection. In 1975, the cassava variety Rayong 1 was officially released (Rodjanaridpiched et al, 1993; Sriroth et al, 2000).

The second phase of cassava varietal improvement was mostly with local hybridization. This work was carried out in collaboration between Rayong Field Crops Research Center in the Department of Agriculture, Kasetsart University and the Thai Tapioca Development Institute. Between 1975 and 1994, seven improved varieties with desired characteristics were released for industrial use, these included Rayong 1, Rayong 3, Rayong 5, Rayong 60, Rayong 90, Sriracha 1 and Kasetsart 50 (Sriroth et al, 2000). Thailand has an efficient extension service, which ensures the new varieties are disseminated to farmers to replace the traditional local variety. Rayong 5 and Kasetsart 50 are the varieties recommended to farmers for industrial purposes. There has been no genetic manipulation of cassava in Thailand.

2.6 Cassava Starch Processing in Native and Modified starch

Cassava in Thailand has been mainly produced for export in the form of chips and pellets for animal feeds and starch. In 1982, 88 percent of the total cassava roots production was utilized for chips and pellets. This share declined to 70 percent by 1992, while the share of root utilization for starch increased from 12 to 18 percent. By 1996, root utilization was about equally divided between starch and pellet production (FAO, 2000 a). Currently, about 55 percent of 18 million ton of the cassava

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root production in each year is converted to starch and another 45 percent is for chip and pellet (Ekasingh et al, 2007).

The cassava pellet industry began in 1967, a few years after the start of cassava exports to the EU. According to Klanarong et al (2000), development of this product was stimulated by a need to improve the uniformity in shape and size of cassava chips required by compound feed producers/users. In addition, during transportation, loading and unloading of chips, the dust generated caused serious air pollution, placing pressure on European importers to improve the nature of cassava products handled by the ports. Production of pellets involves pressing chips, in an extruder, through a large die. The heat and moisture in chips helps in the formation of a pellet-shaped product, known as a soft pellet. Later processes involved steam grinding extrusion to create strong pellets on cooling – these were known as hard pellets. The production process for cassava pellets is shown in Figure 2.7**.** Exports of hard pellets began in 1981; by 1987 hard pellets dominated pellet production in Thailand, and by 1989 were virtually the only pellet product exported to Europe. Raw materials for pellet manufacture (cassava chips) are purchased from chip factories - pellet factories do not produce chips. Purchase price is directly dependent on the export price of pellets in Bangkok. The quality of the chips is also an important consideration. Moisture content should not exceed 16 percent. Exceeding of moisture content will attract a price penalty, but no reward is given if the moisture is less than 16 per cent. The sand content should not exceed 4 per cent. There are approximately 200 pelleting factories in Thailand, with a total capacity of about 10 million ton per year. However, the EU quota is only 5 million ton, and this is the sole market for this product. Factories are therefore working at only 50 per cent of their capacity (3-4 months in year).

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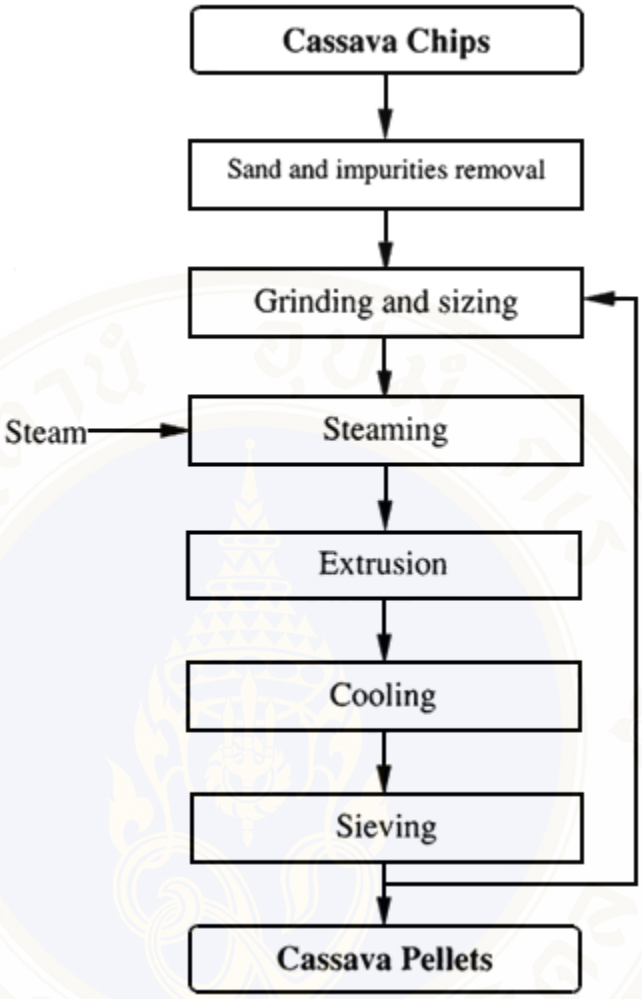

Figure 2.7 Process for production of cassava pellets

Source: Sriroth, 1999; Ratanawaraha et al, 2000.

For the cassava chip processing, Klanarong et al (2000) reported that cassava chip factories are small-scale enterprises and most of them have no formal company registration. The factories typically located close to plantations, with simple equipment, mainly a chopper. Roots are transferred to the chopper by tractor. After chopping into small pieces, the chips are sun-dried on a cement floor for 2 to 3 days. As a rule of thumb, 2-2.5 kg of fresh root (with 25 percent starch content) is required to produce 1 kg of chip. The standard of cassava chip, when sun-dried, must have a moisture content of less than 14 percent and sand content not more than 3 percent. Cassava chip production can be found mainly in the Northeast. Nakhon Ratchasima has the highest chip and pellet production in both the Northeast and Thailand. Cassava

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chip can be used as raw material for animal feed, alcohol, and ethanol. As for ethanol, it has received much attention lately from both the public and private sector due to rising fuel prices.

Cassava starch industry had been developed from a cottage scale. Demand for cassava starch increased dramatically, and led to development of the starch manufacturing process in 1970. According to FAO (2004 a), the recorded numbers of cassava starch factories increased from 50 in 1970 to 146 factories in 1978. But in 1989, only 47 factories, with annual production capacity of 1.3 million ton, were registered as members of the Thai Tapioca Flour Industries Trade Association (TTFITA). By 1995, the registered number of factories increased to 54 factories before decreasing to 49 factories in 1998 but the production capacity was increased to 1.8 million ton per year. During this time span, the location of starch factories had shifted from the Central region to the Northeast. Morakot (2004) reported that in 2004, there were 62 starch factories with the production about 2 million ton per year, or 5 percent of the global total (35 million ton) for all starches.

2.6.1 Manufacturing Process of Native Cassava Starch

The production of native starch from cassava root involves seven major stages. These include root washing, chopping and grinding, fibrous residue separation, dewatering and protein separation, dehydration, drying, and packaging (Chavalparit and Ongwandee, 2009; Sriroth et al, 2000) and the details of the process of cassava starch as below.

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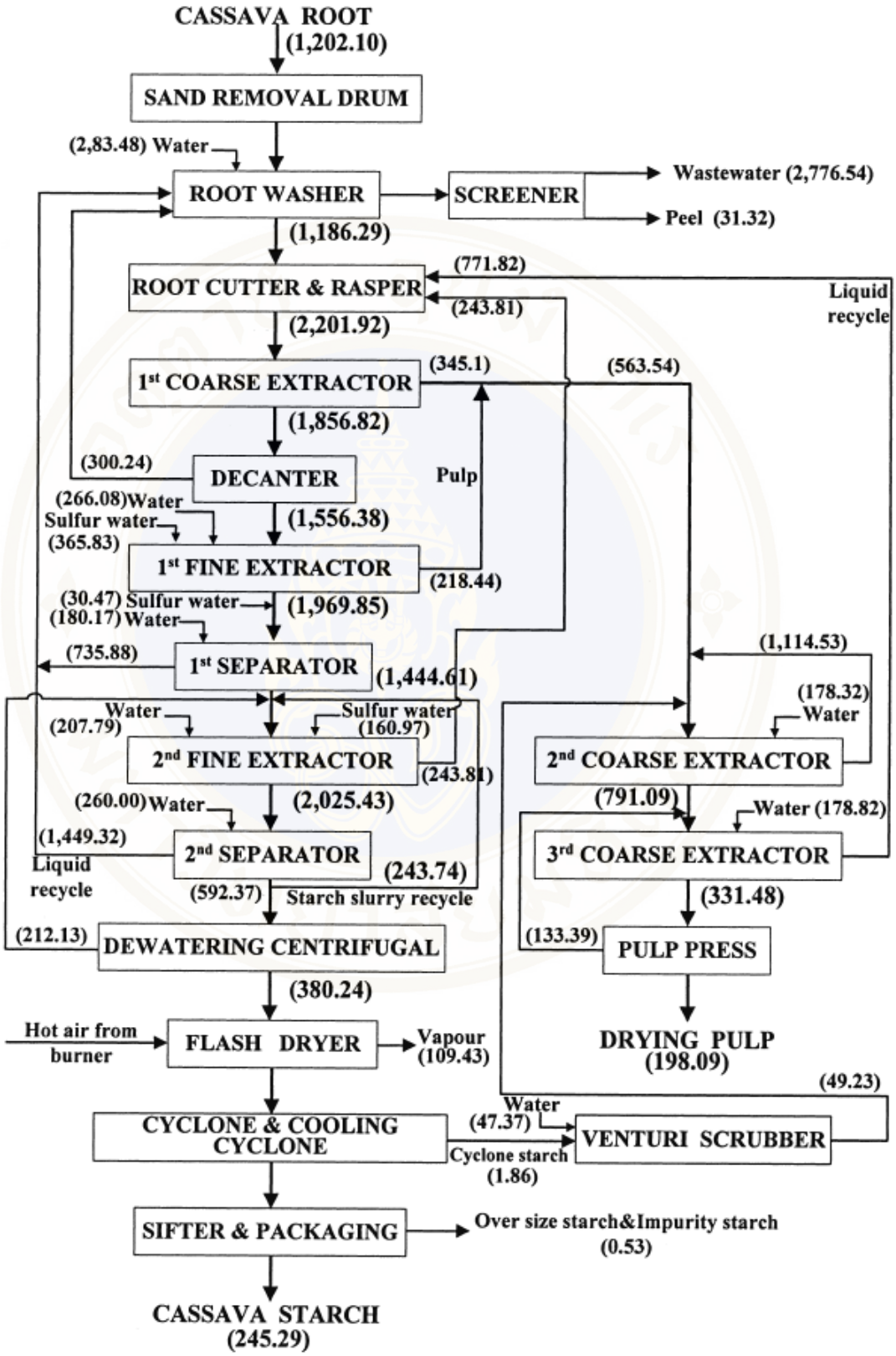

Figure 2.8 Mass balance of cassava starch manufacturing process in a starch factory [unit: tons/day] (Sriroth et al, 2000)

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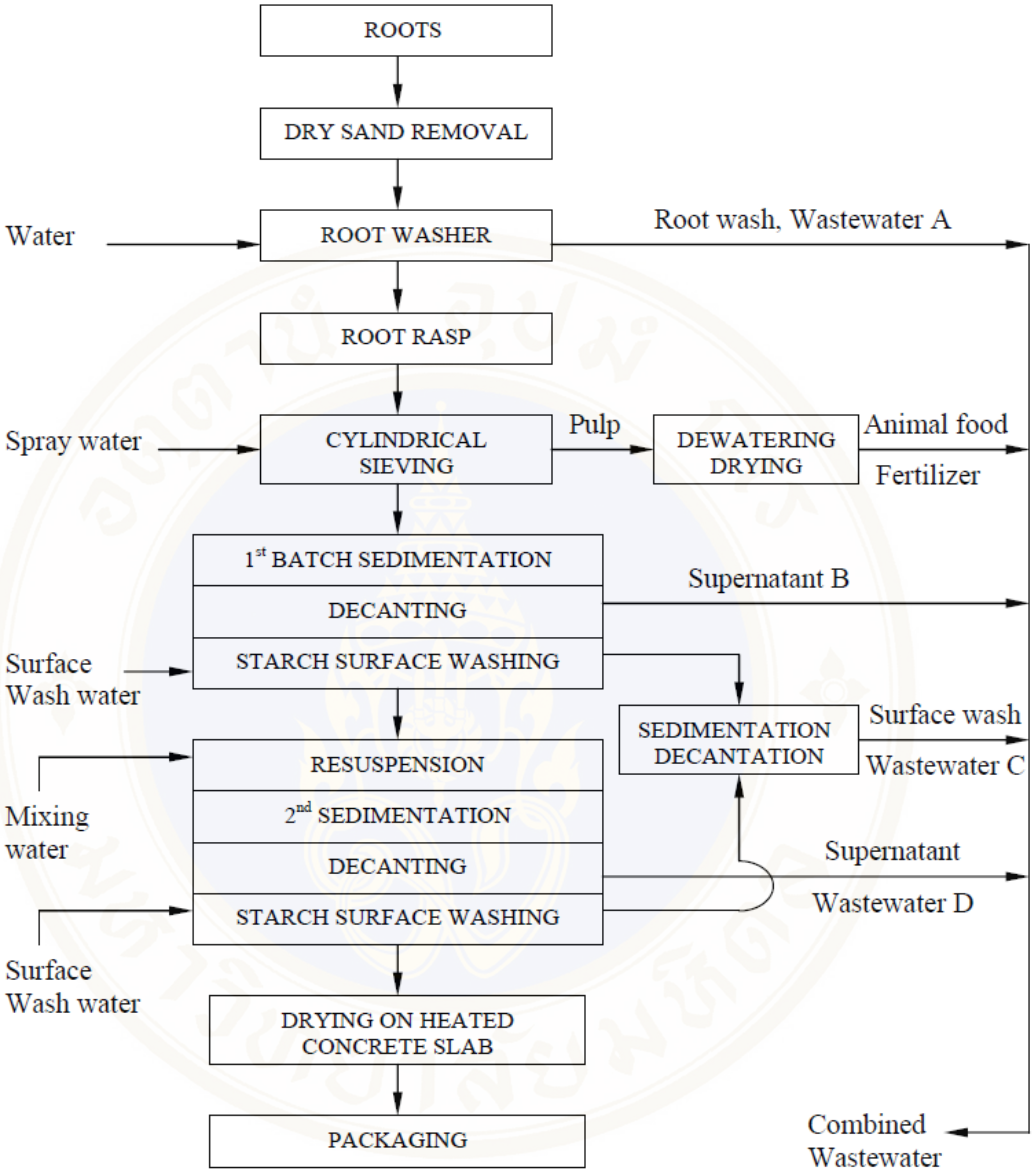

Figure 2.9 Native cassava starch processing (Thailand)

Source: Thanh, 1984; Seejuhn, 2002

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2.6.1.1 Root preparation

Despite the introduction of mechanization, roots are mainly manually harvested – a legacy of the small farm sizes. Roots are transported to factories by small trucks or trolleys. At the factory gate 5 kg-samples are weighed in water using a Rieman balance, a method adopted from the potato industry for estimating root starch content A Rieman balance, in fact, measures root apparent density from root weight in air and in water. The relationship between apparent density and starch content in cassava root is highly correlated, this has been verified using roots produced under different growth conditions; Colombia and Thailand.

For trading purpose, root price is based on root starch content. Root purchasing using this system is well accepted, as the farmers are rewarded for high root starch content. Starch content above 25% is rewarded; each 1% increase leads to a 5% higher payment. Unfortunately, for the farmer, for each 1% drops in starch content a 5% price reduction is imposed. In general, root starch content varies in the range of 20 to 30%, as estimated by the balance. On arrival at the factory, roots are deposited onto a cement floor for short-term storage. Generally, factories will only purchase sufficient roots to fulfill a daily crushing capacity of 600 to 800 t.

Roots are presented for processing by transferring to a root hopper ($5m^3$). The roots are moved onto chain conveyors and transported with a velocity of 20 to 40 m/min. Each conveyor set has a carrying capacity of about 15 to 20 t of roots per hour. Soil and sand are removed as the roots (15 to 20 t/h) pass through a cylindrical root sieve, dimensions (W × L × H) of 1.20 × 1.50 × 40 m, rotating at 10 to 15 rpm. Soil, sand, pieces of broken peels and impurities pass through the sieve. Roots after sieving are transported into a water chamber where they are washed and moved by a paddle blade rotating at 10 rpm. Water used for washing is re-circulated from later processing stages. Capacity of washing is 15 to 20 t of roots per hour. Consequently, for a standard sized factory with a starch capacity of 200 t per day (requiring 700 to 800 t of roots), two sets of root hopper, root sieve and washers must be installed.

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2.6.1.2 Rasping

Washed roots are chopped with a cutting blade running at 250 rpm, driven by a 10HP electric motor. The small root pieces are gravimetrically fed to the raspers. Popular are simple local made saw-tooth raspers, which consist of a drum (diameter 77.5 cm) with 144 blades on its surface; 210 teeth are distributed along the 30 cm length of the blade. Attempts have been made to optimize the drum speed, but usually 1,000 rpm is adopted by most factories in Thailand. The domestically produced rasper operates at a capacity of 5 to 6 t of chopped roots per hour. About 6 to 8 raspers are installed to support each chopper. Neither oxidation nor discoloration takes place during rasping. Liquid recycle from the process is fed along with chopped root into the rasper. As factories prepare to move up the quality ladder, some are planning to install higher speed and capacity raspers such as HOVEX (HOVEX Engineering, Veendam, Netherlands). Some are trying with the local modified higher speed raspers.

2.6.1.3 Extraction

Early in the modernization phase, cassava starch processors commonly incorporated a single stage decanter for fruit water separation; this was adopted from the potato starch processing industry. However, many processors (about 50%) believe that the levels of protein and other impurities are too low to warrant the use of a decanter. The decanters commonly installed in factories are Alfa Laval NX-418 (Alfa Laval Co., Ltd., Sweden) and Kokusan Seiko SD-16DSE (Kokusan Seiko Co., Ltd., Japan). The fruit water is used for root washing or is directly discharged as wastewater. The material balance and flow diagrams of a starch factory working with are presented in Figs. 4.3. Fresh rasped root slurry from the rasper (if no decanter) is pumped through a series of extractors, from coarse to fine. The extractors are continuous centrifugal perforated baskets, dimensions (W × L × H) of 1.14 × 1.36 × 2.10 m, operating at 800 rpm. The capacity of this stage is 0.75 to 1.50 t dry solid per hour. Pulp from the coarse extractor is repeatedly re-extracted using the same screen aperture (35 to 40 mesh or 355 to 425 μm) as in the first pass, until minimal starch content of the pulp is achieved. Moisture content of the pulp is then reduced by a screw press and the pulp finally discharged out of the process. The moisture content of pressed pulp is about 60 to 70% and starch content about 45 to 55% (dry basis). High

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starch content of the pulp reflects both low efficiency of the rasping stage and composition of the cell membrane and cell walls. Composition of polysaccharides, pectic substances and non-starch polysaccharides are in turn influenced by variety and environmental factors.

Starch slurry exiting the coarse extractor contains a large amount of fine fiber which must be removed in the fine extractor. The extractors are equipped with a filter cloth and screen with an aperture of 100 (150 μm) to 120 (125 μm) mesh. Fine extraction is repeated with a finer screen aperture (140 to 200 mesh). The extraction is normally completed by a series of coarse and fine extractors.

Extraction is a continuous process; fresh pulp slurry is fed into the top of the first extractor together with water and SO2 water (for fine extractors). In some factories, extra screening equipment, such as a vibrating screener (150 to 250 mesh screen or 63 to 106 μm screen) from SWECO Co., Ltd. (USA) or local manufacturers (Bangna Steel Work Ltd. and S.W. Multitech Starch Co., Ltd.), are installed to remove fine fiber from the slurry. During transport to each extraction stage starch slurry is passed through a hydrocyclone to ensure complete removal of sand. Extra filtration equipment, such as rotary brush strainer, is installed to protect from the passage of a starch clump. Strainers from Westfalia Separator Industry GmbH, Germany (SBB100 and BSB200) and S.W. Multitech Starch (Thailand) are commonly used in Thai factories.

2.6.1.4 Starch separation and dewatering

Starch slurry received from fine extraction (with or without vibrating screener) has a concentration of 10 to 17 °Bé. Water is then separated from the starch slurry, increasing the concentration to 18 to 20 °Bé, using a separator.

The common separators are of the two-phase nozzle type such as TX 310 or TX 612 from Alfa Laval (Sweden) or DA30 or SDA 70 from Westfalia Separator Industry GmbH (Germany). Separators from Chinese and Japanese manufacturers are also installed in some factories. To increase the concentration from 10 to 17 °Bé up to 18 to 20 °Bé, either two stages of separation or re-circulation are required. The installation of the first separation stage between the fine extractors is also normally practiced in Thai factories.

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Three-phase separators such as SDA 60 and SDA 130 of Westfalia Separator Industry GmbH (Germany) have been introduced into some factories. Three-phase separators help to reduce the number of processing stages and water consumption. Only two factories in Thailand are using a hydrocyclone series for starch separation.

2.6.1.5 Dewatering

Normally dewatering is done by a horizontal centrifuge, with baskets of 1.20 m diameter and 0.65 m length, operated at 900 rpm. The capacity of a typical centrifuge is 1.5 t dry solid per hour. The filter cloth has a specific weight of 2,440 g/m^2 and total filter area of about 2.45 m^2. One cycle (about 10 min.) of dewatering discharges about 240 kg cake. Moisture content in the starch cake is about 35 to 40%. A typical factory with capacity of 200 t starch per day needs about 8 to 10 dewatering centrifuges. In a conventional system, the dry solid content in the filtrate is high. Thus, by using the filtrate as circulating liquid, the probability of acid formation due to microbial activity is increased. An alternative process of dewatering, namely high-pressure filtration has been studied. The results are promising. The high-pressure filtration (Larox Oy, Finland) is now applied in some modified starch factories.

2.6.1.6 Drying

A pneumatic conveying dryer, known as flash dryer, is commonly used in Thai starch factories. There are two groups of operation depending on the source of thermal energy, namely simple hot air or thermo-oil. Using the hot air as a heat exchanger is causing problems in terms of temperature fluctuation, therefore many factories are switching to use thermo-oil as a heat exchanger. The installed thermo-oil boilers are from Scherrer (Germany), Konus Keisel (Germany), Fr. K. Bay GmbH (Germany) and S.W. Multitech Starch Co., Ltd. (Thailand). Normally, about 100 t/h of hot air (170 to 200 °C) is blown into the drying tube of the flash dryer. Starch cake with a moisture content of about 38% is blown with hot air and dried to 12% moisture within 6 s. The throughput of one normal dryer is 8 to 10 t dried starch per hour. Temperature fluctuation remains a problem, often due to variation in the moisture content and feeding rate of cake entering the dryer. At this range of moisture and temperature, heat moisture treatment can be a problem. Starch quality ultimately is affected. Loss through the two cyclones is also problematic. Venturi scrubbers to trap

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this loss have been installed in some factories, 37.5% of the starch loss, or 2.7% of total starch produced, can be recovered.

2.6.1.7 Storage

Starch discharged out of the dryer is of low moisture content, about 9 to 12%. It is also dusty. Cassava starch is packed into 30 or 50 kg double layer polyethylene bags or linen cloth jumbo size (600 kg). The 50-kg starch bags are laid on each other in the storehouse. A pile of bags up to 4 to 5m (20 to 30 bags) causes no problem for storage in short time.

Effects of storage of cassava starch for three weeks under different conditions of temperature (20 and 30 °C) and relative humidity (22, 52 and 93%) has been studied. Relative humidity seems to negatively influence the flow properties of the starch. Total water uptake and crystallinity are apparently not affected. Storage of cassava starch for four weeks at 22, 50, 52, 80 and 92% relative humidity and 30 ± 2 °C has been investigated. Paste viscosity values of all samples were the same. However, prolonged storage (0 up to 7 months) under ambient condition (30 °C and 53% relative humidity) of cassava starch that contains sulfur dioxide (0, 153 and 190 mg sulfur dioxide/kg starch) led to a decrease in peak viscosity, which varied depending on sulfur dioxide content in starch. Changes in peak viscosity as a function of storage time for starches are different, influence of sulfur dioxide content is well described by a non-linear regression model ($R^2 \geq 0.95$). Starch with extremely high level of sulfur dioxide (190 mg/kg), after seven month of storage, presented a peak viscosity reduction from 417 to 360 RVU (3 g starch at 14% moisture content in 25mL water).

2.6.2 Manufacturing Process of Modified Cassava Starch

There are three methods to make modified starch in Thailand (Ratanawaraha et al, 2000), i.e.:

2.6.2.1 Degradation *or conversion:*

Starch is rendered less sticky in three ways:

- Acid conversion: Hydrochloric and sulfuric acids react with starch liquid to decrease the degree of stickiness, and to reduce the temperature of gelatinization. This starch is called “acid modified starch”.

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- Oxidization: Starch reacts with chloride in alkaline starch liquid. The starch thus derived will become less sticky with the degree of chloride used and the reaction time. This starch is called “oxidized starch” or “hypochlorite modified starch”. The process of modified cassava starch with oxidization has following in figure 2.10.

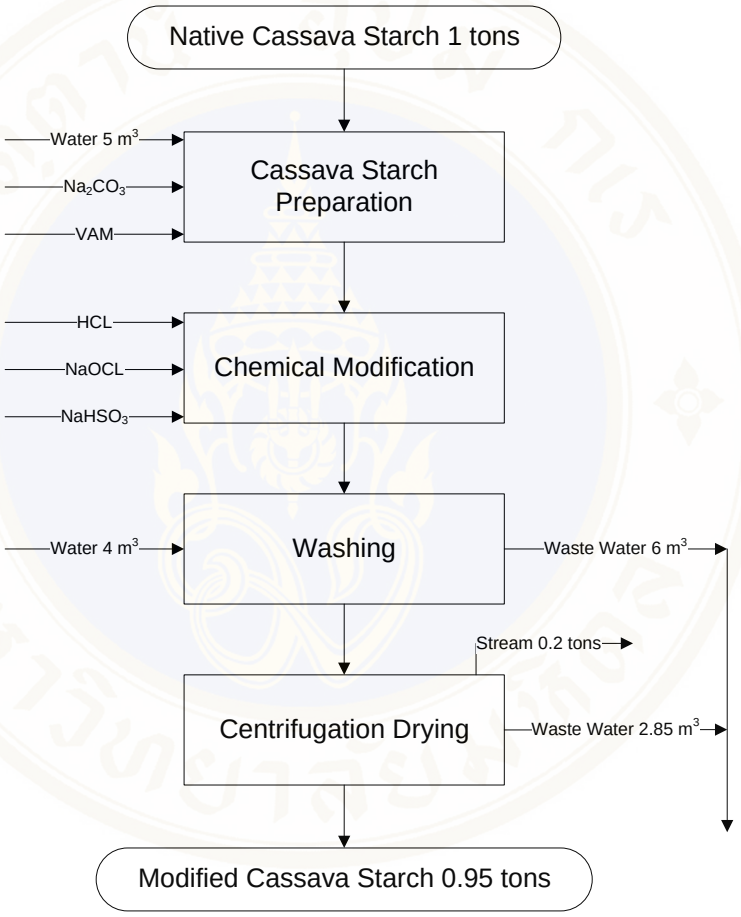

Figure 2.10 Modified starch manufacturing process with oxidization

- Dextrinization or pyroconversion: Starch is roasted in a drum under high temperature, while certain acids are sprayed to react with it. This process will make the starch less sticky. The product is called “dextrin”, which consists of three types: white dextrin, popular yellow dextrin, and British gums. The converted starch is suitable for the glue industry.

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2.6.2.2 Pregelatinization

Liquid starch in 40–50% concentration is drum-dried. Starch is cooked and dried to form a thin crispy layer. It is ground and sifted to obtain a fine powder, which immediately becomes glue when cold water is added to it. The starch at this stage is called “cold water soluble starch” or “alpha starch”.

2.6.2.3 Derivatives

These are processed starches whose molecular structures have been altered through chemical reactions. Examples in this group include esters (acetated starch and phosphoric acid ester), starch ether (carboxymethyl etherand hydroxy-ethyl starch), and cross-linked starch. (Thai Tapioca Flour Trade Association, 1994).

2.7 Modified Cassava Industry

More than two-thirds of the total production of cassava is used as food for humans, with lesser amounts being used for animal feed (Nwokoro et al. 2002; Nyerhovwo, 2004) and industrial purposes. The future demand for fresh cassava may depend on improved storage methods, but the markets for cassava as a substitute for cereal flours in bakery products and as energy source in animal feed rations are likely to expand.

Starch is one of the most important plant products to man. It is an essential component of food providing a large proportion of the daily calorific intake. In West Africa (Nyerhovwo, 2004), cassava flour and gari (a processed cassava product) are consumed in large quantities. Cassava starch is recommended for use in extruded snacks for improved expansion. It is also used as a thickener in foods that are not subject to rigorous processing conditions. Cassava starch, which is very bland in flavor, is used in processed baby foods as a filler material and bonding agent in confectionary and biscuit industries.

The starch was known that produced from grain or root crops, also mainly used as food. However, Starch was readily converted chemically, physically, and biologically into many useful products to date, and used to produce such diverse product as food, paper, textiles, adhesives, beverages, confectionery, pharmaceuticals,

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and building materials (Parthanadee et al, 2009). The cassava starch had many remarkable characteristics, including high paste viscosity, high paste clarity, and high freeze-thaw stability, which were many advantageous to many industries.

2.7.1 The advantages of cassava starch (IITA, 2011)

The cassava starch just is easy to extract using a simple process (when their compared to other starch process) and transport in small-scale with limited capital. Adhesive production can often preferred with cassava starch that more viscous, work more smoothly, and provide stable glues of neutral pH.

- The advantages of cassava starch production have following:

  - High level of purity.
  - Excellent thickening characteristics.
  - A neutral (bland) taste.
  - Desirable textural characteristics.
  - A relatively cheap source of raw material containing a high concentration of starch (dry-matter basis) that can equal or surpass the properties offered by other starches (maize, wheat, sweet potato, and rice).

Cassava starch is produced for native starch in primarily process with the wet milling of fresh cassava roots. Therefore, in some countries such as Thailand was produce with dry process for native starch products. The main cassava constituent was starch. About 100 kg of cassava roots may be obtained with mature in 25% starch, from dry cassava chips in 60% starch, and about 10% starch from dry pulp.

Private industry (mainly starch factories) plays an important role in promotion and distribution of new technology. Mechanized land preparation, fertilizer application, and mechanical or chemical weed control are becoming more common (FAO, 2000a). Besides, biotechnology progress has been achieved in the control of pests and diseases and in improving the characteristics of the final cassava products (FAO, 2000b).

The process of starch from cassava roots, after cassava farmers are harvested or selected for starch extraction, age and root quality are critical factors.

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Cassava roots need to be processed almost immediately after harvest, as the roots were highly perishable and enzymatic processes accelerate deterioration within 1-2 days (Chavaloarit and Ongwandee, 2009). The quality starch in first-rate could be obtained from cassava using only water, and which make particularly suitable processing of cassava starch and flour for developing countries and rural industries (International Institute of Tropical Agriculture (IITA), 2011).

2.8 Cassava Marketing

2.8.1 Marketing channels

As a perishable crop, fresh cassava roots must be processed within a few days. Therefore, after rooting up, most of the fresh roots are quickly sold and processed to be cassava products. The main traders buying the fresh roots comprise of the local vendors and traders who forward the produce for chip and pellet (45 per cent) and processing to starch (55 percent). However, some farmers directly sell the fresh roots to the local factories around the production area. Cassava chips from small-scale enterprises are sold to pellet industries that either directly export the chips or pellets or sell to traders (Klanarong et al, 2000). In most cases, the small chip factories sell their products to large factories that in turn sell a consolidated consignment to pellet companies (Klanarong et al, 2000). Time from purchases of chips to their sale is rapid, factories in Thailand do not have silo facilities for storage, and all transactions are direct, middlemen or brokers are not involved. For cassava starch production, about 60 percent of cassava starch produced is exported and the rest is domestically used as the native and modified starch.

2.8.2 Domestic markets

Domestic consumption of cassava products has been considered as very low compared to its production. Most of cassava chips and pellets are exported and about 40 percent of cassava starch is used in the country. In Thailand, cassava starch is used as a prime raw material in making monosodium glutamate and lysine. Klanarong et al. (2000) reported that the highest local consumption of starch (24 percent of starch

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in 1998) was by these two industries. Beside household consumption, cassava starch is also used as raw material in various industries in Thailand such as sweetener (glucose, fructose and sorbitiol), textiles, paper, plywood, medicine and food (instant noodle, tapioca pearl and seasoning sauce) as well as bio-degradable products (packing material). For Thailand's domestic cassava chips, the quantity of chips used locally for animal feed, in 1996, was around 100,000 ton (2.5 percent of the export chips). But with the promotion of the government, domestic use of cassava chips as animal feed has been increasing. Klanarong, et al 2000 reported that local consumption of chips for animal feed was estimated at 800,000 ton in 1998.

2.8.3 Export markets

Thailand has been very successful in the development of cassava product export industry. Cassava was developed into an important export item of Thailand in the 1950s (LePoer, 1987) and now Thailand is the world's largest exporter of cassava products accounting for about 90 percent of world trade in 2004 (The Agricultural Futures Exchange of Thailand, 2006). From near zero in 1960 (FAO, 2000a), Thailand's exports of chips and pellets grew to the average of seven million ton annually in 1984–93. Cassava pellets had been the main cassava export products of Thailand with the highest record of export value at 23.7 billion baht (86 percent of total cassava products export value) with the quantity of 8.1 million ton in 1992, according to statistical data from the Department of Customs. The EU had been the main export market for this product followed by South Korea and Japan. But the CAP reform of the EU in 1993 caused the falling quotations of cassava pellets in the EU resulting in the dramatic decrease of the cassava pellets export quantity from 6.6 million ton in 1993 to 1.53 million ton in 2002. This put a pressure on Thai exporters to seek additional markets, especially in Asia (FAO, 2000a). China has become an important export market of Thai cassava products, replacing the EU market, after the implementation of a free trade area between Thailand and China in 2003 which resulted in the abolition of a 6 percent tariff on Thai cassava products (FAO, 2004b). China is interested in Thai cassava chips for alcohol and animal feed industries, not the pellets. Hence, the export market has been shifted from pellets to chips since 2003. The export quantity and value for cassava chips has dramatically increased from 0.03

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million ton with the value of 94 million baht in 2000 to 2.77 million ton with the value of 12 billion baht in 2005 (Table 2.9). China is the sole export market for Thai cassava chips in 2005, according to statistical data from the Department of Foreign Trade. Akarapong (no date) reported that about 40 – 50 percent of China's imports of cassava products are from Thailand. A further increase of cassava chips export to China is expected as the Chinese government promotes the use of cassava and corn instead of molasses in alcohol producing industry together with the expected use of gasohol in 2008. China is also promoting the use of cassava pellets in animal feed industry to Chinese producers (Akarapong, no date). This would be a market opportunity for cassava pellets export.

Whereas cassava pellets export market decreased, exports of cassava starch increased during 1993 to 2005. Its export quantity and value increased from 0.46 million ton with the value of 2.34 billion baht in 1993 to 1.01 million ton with the value of 9.36 billion baht in 2005, according to statistical data from the Department of Customs. The average export price of cassava starch decreased from 357 US$ per ton in 1995 to 172 US$ per ton in 2003 before increased again to be 251 US$ per ton in 2005 (The Thai Tapioca Trade Association, 2006). Taiwan is Thailand's largest importer of starch, among a group of 10 major importing countries (Table 2.10). The export market to Taiwan increased from 0.18 million ton (39 per cent of the total exports) in 1993 to 0.63 million ton (46 per cent) in 2005. Second largest market is China with the share of 11 percent of the total export quantity, followed by Indonesia (10 percent), Malaysia (7 per cent) and Japan (6 per cent) in 2005. China's demand for starch is expected to rise to 1 million ton in 2013 (Akarapong, no date).

2.9 Supply Chain and Logistics Management

In today's the global economy has rapidly changed, many companies are able to change with the times to adapt and thrive in the increasing uncertainty in the word of the early 21st century. They can be recognized by their ability to anticipate and understand changes in the market, to looking new opportunities, to deliver new customer services, and to adapt their businesses rapidly to meet and exceed their

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customers' requirements. All these companies have recognized the importance of one key element, agility (or Flexibility) to change fast. Agile businesses view themselves as the center, or hub of networks of material and information flows. These flows extend from the customer interface at marketing and sales through production and procurement to the building of relationship with suppliers. These businesses achieve agility through a constant review and realignment of these closely linked networks. Over the past decade, a new term, supply chain management (SCM), has been coined to a management approach to deliver this required agility to change while maintaining cost efficiency (Huang et al, 2005).

Many once-central operational corporate activities-product design and development, services and facilities management, logistics, and manufacturing have been taken over by suppliers. Consequently, there has been an ever increasing focus on managing the external relations of production and the control of resource flows from source to consumer. The term "supply chain management" has been coined to represent these activities. Although supply chain management has experienced enormous growth as both a business imperative and a legitimate field of academic study, it is far from being a coherent body of thought, still less a universally adopted practice. The myriad manifestations and implications of externalization have generated a hugely complex subject matter.

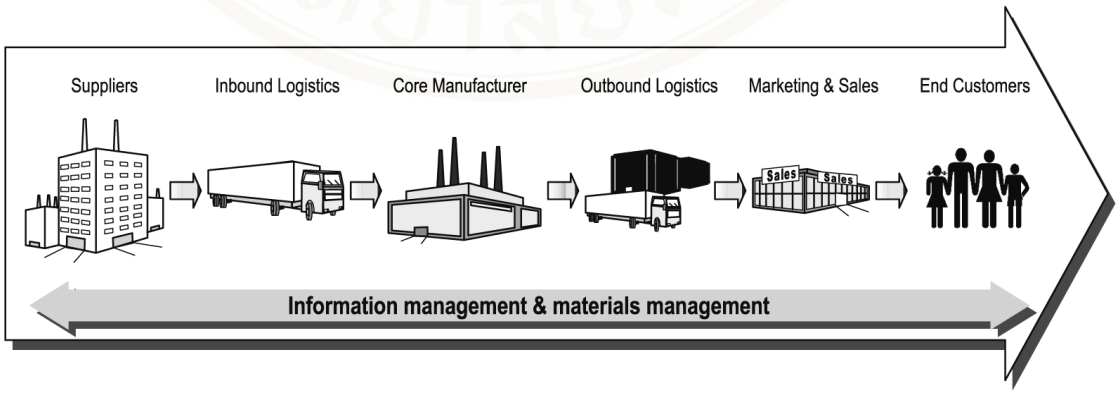

Figure 2.11 General flow chart of supply chain

Source: Chan et al, 2003

Supply chain management is a set of procedures to efficiently integrate market participants so that merchandise is produced and distributed at the right

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quantities, to the right locations, and at the right time in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi, Kaminsky, and Simchi-Levi, 2000). Van der Vorst defines an agricultural supply chain as the planning and control of the flow of materials and information from agricultural producers to end-users (Lentz and Akridge, 1997). For any supply chain, the general processes and structure can be depicted as shown in figure 2.11, in which six core processes are linked. These core processes categorize the typical function areas in supply chain (Chan et al, 2003). The supply chain encompasses many logistical components that include transportation, customer service levels, inventory management, information flow, and order processing (Ballou, 1999). Goals of supply chain management are to eliminate uncertainty associated with the movement of goods, to reduce inventories, and to decrease overall system costs. Information technology systems that foster communication provide an important foundation for effective supply chain management and at reducing uncertainties in the pipeline (Schlecht et al, 2004).

SCM is having profound impact on business results. It encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flow' (Handfield & Nichols, 1999). Clearly, the idea of SCM is to view the chain as a total system and to fine-tune the decisions about how to operate the various components (companies, functions, and activities) in ways, which will produce the most desirable overall system performance in the long run (Huang et al, 2005). Doing so is extremely difficult due to the number and complexity of the decisions to be made, as well as the inter- and intra-organization issues that must be addressed. Never has so much technology and brainpower been applied to improving supply chain performance. Examples include point-of-sale scanners that allow companies to capture the customer's voice. Electronic data interchange lets all stages of the supply chain hear that voice and react to it by using flexible manufacturing, automated warehousing, and rapid logistics. Concepts such as quick and accurate response, efficient consumer response, mass customization, lean manufacturing, and agile manufacturing offer models for applying new technologies to improve performance.

One can argue that a proliferation of interpretations of what SCM means has led to some confusion among researchers and practitioners. There should be some

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characteristics unique to supply chain management that differentiates it from past research that fell under the aegis of integrated logistics. Houlihan (1985) made it clear that the differentiating factor is the strategic decision making aspect in managing the supply chain. SCM reaches out beyond the boundaries of cost containment and links operating decisions to strategic considerations within and beyond the company. To assist organizations in achieving better strategic decision making, a number of researchers and practitioners have devoted their efforts to developing models to describe the elements and activities of a supply chain. Beamon (1998) provided a literature review on multi stage-supply chain modeling, which consists of four categories, namely, deterministic model (Voudouris, 1996), stochastic model (Tzafestas & Kapsiotis, 1994), economic model (Christy & Grout, 1994), and simulation model (Towill, 1991). The author proposed a research agenda for supply chain design and analysis: (1) the evaluation and development of supply chain performance measures, (2) the development of models and procedures to relate decision variables to the performance measures, (3) consideration of issues affecting supply chain modeling, and (4) the classification of supply chain systems to allow for the development of rules-of-thumb or general techniques to aid in the design and analysis of manufacturing supply chains (Huang et al, 2005).

2.10 The Business process methods and System Analysis

The high competitiveness of modern economics leads companies to a continuous refinement of their business and manufacturing processes. Time and motion studies and continuous quality improvement programs are very useful tools in the study of manufacturing systems. However, the high numbers of strategies, techniques and methods which can be improvement make analysis of these systems difficult (Hernandez-Matias et al, 2006). The reasons are the complexity of the manufacturing system and the high number of implied factors. In many cases, the results obtained from conventional analysis are lacking in a detailed description of the system's current state. The effort that implies the use of process analysis charts, data summary panels, modeling tools, check lists or the use of quality tools is wasted due to a lack of integration of this information in subsequent phases.

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Many manufacturing enterprises are undertaking a critical analysis and redesign of their business processes to achieve breakthrough improvements in performance. Business process reengineering (BPR) is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in measures of performance such as cost, time, quality, speed, and services (Ross, 1977). The general idea of business process reengineering (BPR) is to provide means for optimizing and enhancing business processes both in the product area and in administration. BPR utilizes components of several other tools and concepts such as Systems Engineering, IDEF (Integration DEFinition), activity-based costing (ABC), brainstorming workshops (BW), functional economic analysis (FEA), process benchmarking (PB), customer satisfaction measurement and cross functional team building in addition to total quality management (TQM) of the quality movement. BPR seeks performance breakthroughs through radical redesign of strategic, value-added business processes and the systems, including the resources, and organizational structures that support them.

Manufacturing analysis for continuous improvement is a technical area with high significance due to the increase of quality and flexibility requirements for end customers. There are many applications cases where manufacturing analysis through modeling methods is performed in order to take decisions (Hernandez-Matias et al, 2006; Vernadat, 2004):

- Diagnosis of a disorder (material, information or control flow).
- Restructuring a manufacturing process to improve its performance.
- Business Process Reengineering (BPR).
- Implementation of Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES) and Product Data Management (PDM).
- Tuning the organization structure to face business change.
- Large-scale systems integration.
- Alignment or conformity to norms (ISO 9000, ISO 14000).
- Management decision (activity externalization/ internationalization).
- Implementation of Activity Based Costing (ABC) with cost accounting method.

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- Implementation of Just In Time (JIT), Total Quality Management (TQM), and Total Productive Maintenance (TPM) strategies.
- Diagnosis of wastes (capacity, resources or cost).

From the study of Rother and Shook (1998) affirms that the main properties of this technique are nearly completely in accordance with many of the utilities required for a manufacturing redesigning tool (Lasa et al, 2008):

- The analysis of the initial situation is based on the acquisition and treatment of numerical data and it uses a graphical interface where is easy to see the relationship between material and information flows.
- The systemic vision provided for each product family flow reflects manufacturing system inefficiencies.
- The provision of a common language for the term and the unification of lean concepts and techniques in a unique body.
- The possibility to be the starting point of the strategic plan for improvement.

Lasa et al (2008) are also concluded about the existing tools in the area of business and manufacturing process for continuous improvement do not cover the same framework as value stream mapping, neither the same objectives nor the same level degree of completion of manufacturing design.

The process mapping (Paper et al, 2002) based on the flow diagram chart this is a well-known tool to model any business system or subsystem (Hines and Rich, 1997). The business process reengineering movement supported this technique for the following two reasons: first it is based on the measurement and analysis of quantitative data (Hammer, 1990); and lastly, various possible standardized languages make tool practical and useful (Baudin, 2002). However it is too generic and difficult adapted to manufacturing systems modeling (Oyarbide, 2003; Lasa et al, 2008).

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2.10.1 Integration Definition for Function Modeling (IDEF0)

IDEF methodology (NIST, 1993; Hernandez-Matias et al, 2008) is the main technique of Business Process Modeling (BPM) for reengineering processes to obtain sustained improvements in the output of manufacturing system (Arne and Leo, 1994; Ki-Young, 2000; Bruce, 1997). It is a descriptive methods based on geographical and text description of functions, information and data. The flexibility of the method resides in its capacity for allowing the analysis of complex systems, where there is a need to study multiple levels of detail in a way the analyst can understand the system. Analyzing the different IDEF approaches may the IDEF0 be the most widely used version in manufacturing analysis (Hernandez-Matias et al, 2008). It consists of a hierarchy of diagrams, text and glossary. The diagrams represent a set of system functions such as boxes (Activities), objects interface (arrows) and information. The attachment point between arrows and boxes indicates the interface type (input, control, output and mechanism). The generation of many levels of detail through the model diagram structure is one of the most important features of IDEF0 as a modeling technique.

The Integration DEFinition Zero (IDEF0) method is a variant of process mapping. It has been developed and oriented towards modeling manufacturing systems. This tool makes a functional structured analysis to describe the activities of the manufacturing system in a hierarchical way (Hernandez-Matias et al, 2008). IDEF0 was derived from a well-established graphical language known as the structured analysis and design technique (SADT) (Ross and Schoman, 1977; Ross, 1977). The Air Force commissioned SADT developers to develop a function modelling method for analyzing and communicating the functional perspective of an entire system. The IDEF0 (function modeling method) is designed to model the decisions, actions, and activities of a manufacturing organization or system in a structured graphical form. It provides users with a powerful means of analysis and development for the manufacturing enterprise. Furthermore, the IDEF0 modeling method establishes the scope of analysis either for a particular functional analysis or for future analyses from another system's perspective. As an analytical tool, IDEF0 assists the modeler in identifying the functions performed and then what is needed to perform them.

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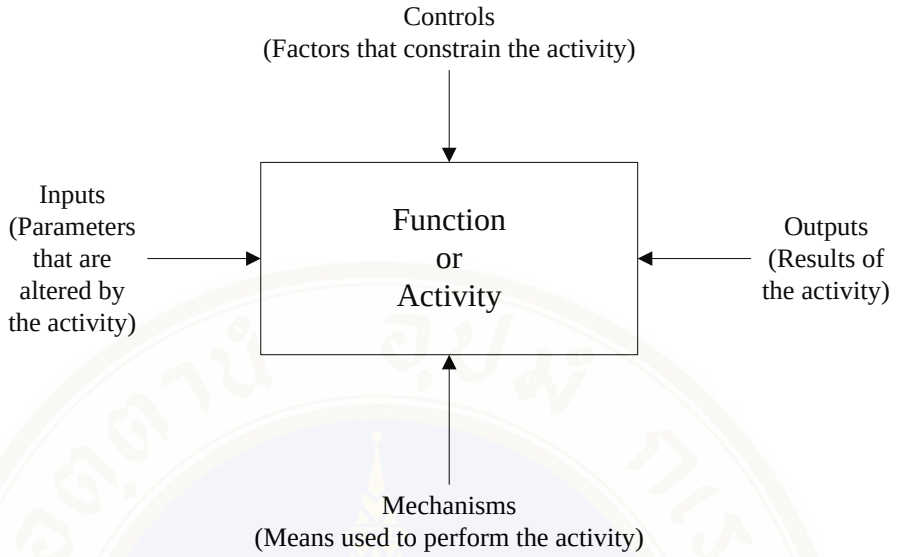

Figure 2.12 Basic IDEF0 Syntax (Kim and Jang, 2002)

The IDEF0 model diagram displayed in Figure 2.12 is based on a simple syntax. Inputs are shown as arrows entering the left side of the activity box, while the outputs are shown as exiting arrows on the right side of the box. Controls are displayed as arrows entering the top of the box, and mechanisms are displayed as arrows entering from the bottom of the box. Inputs, controls, outputs and mechanisms (ICOMs) are all referred to as concepts (Kim and Jang, 2002). The following definitions are assigned to the building block (Rensburg and Zwemstra, 1995):

- Activity or Function: An activity is a named process, function, or task that occurs over time and has recognizable results.
- Input: The information/ material needed to produce the output of the activity.
- Control: The information and material that constrain an activity.
- Output: Information or materials produced by the activity.
- Mechanism: People, machines, or existing systems that perform or provide the energy to the activity.

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A box in an IDEF0 model, after all, represents the boundaries drawn around some activity. Inside the box is the breakdown of that activity into smaller activity, which together comprises the box at a higher level. This hierarchical structure helps the practitioner to keep the scope of the model within the boundaries represented by the decomposition of the activity. This organizational strategy is also useful for hiding the unnecessary complexity from view until a more in depth understanding is required as shown in figure 2.13 (Kim and Jang, 2002).

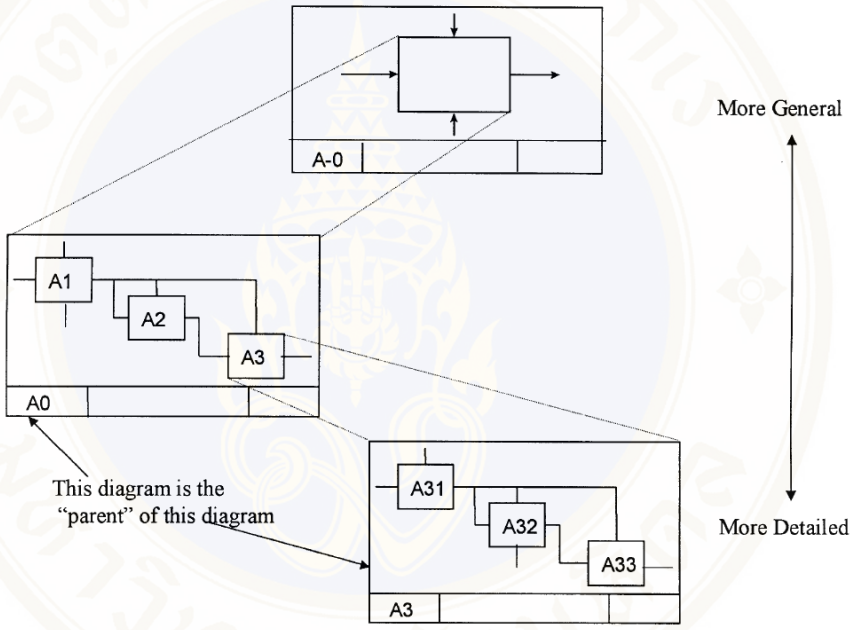

Figure 2.13 Decomposition construction of an IDEF0 model
(Sarkis and Liles, 1995; Kim and Jang, 2002)

However, IDEF is a descriptive method based on the graphical and text description of functions, information and data that is often only of use as an aid to documenting and validating processes. It is static and qualitative, which is a drawback to the analysis of processes (Shen et al, 2004). And there have a number of disadvantages in terms of its time-based function, including cumbersomeness, ambiguity in activity specification, and perhaps most significantly, its static nature (Wu, 1989; Colquhoun et al, 1996). Such a hierarchy of activity models does not explicitly represent the conditions or sequence of processing. In analyzing an IDEF0 model, it may be possible to find activities, which are unnecessary, including

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duplicates, bottlenecks, or candidates which are put in parallel. The major constrains of IDEF0 include the following (Busby and Williams, 1993; Kim et al, 1993; Zhang et al, 1999):

- It is a static representation of the system, indicating functional relationships, but not necessarily specifying any dynamic aspects within it. It is a limit of functional precedence.
- It is plainly not a quantitative model, and this makes it harder for someone to use an IDEF0 model as a compelling case for change. It is difficult to evaluate the model mathematically.
- It is the subjective aspect of a process model. Although perhaps inevitable, it sets limits to the value of the modeling exercise. It is difficult to understand information flow between diagrams.
- It does not explicitly represent the real-time status and sequences of activities. The activities may be placed in a left to right sequence within decomposition, and then connected with the flows. We also do not know the information source of input, output or control data.
- It is inadequate for the analysis and design of manufacturing information systems, because these methodologies were basically developed for traditional business applications.

2.10.2 Value Stream Mapping and Application

As the complexity of manufacturing and business is growing newer value stream tools are emerging. Recently, there exists a plethora of different tools and techniques developed for different purposes and waste reduction or elimination (Seth and Gupta, 2005). A value stream includes all activities required to transform a product from raw material into the finished goods. Value stream mapping scrutinizes business processes from beginning to end and a visual representation map is drawn of every process involved in the material and information flows. The value stream mapping helps to identify the current flow of material and information in processes for a family of products, highlighting the opportunities for improvement that will most significantly impact the overall production system. Then a future state map is drawn to show how things should work for best competitive advantage (Rauniyer, 2007).

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In essence, Value Stream mapping (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System) (Ramest et al, 2008). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process. Waste being any activity that does not add value to the final product, often used to demonstrate and decrease the amount of 'waste' in a manufacturing system. VSM can thus serve as a starting point to help management, engineering, production associates, schedulers, suppliers, and customers recognize waste and identify its causes.

The combination of supply chain and sustainability thinking demonstrates the value of an objective integrated appraisal of supply chain, various wastes and even emission aligned to a systems approach. VSM (Rother and Shook, 1999) has been widely used to evaluate intra- and inter-company waste. The mapping reviews the flows of information and physical goods, aiming at eliminating waste and thereby improving quality, cost and delivery. Value added time percentage is the key metric of the mapping – comparing value adding (VA) with non-value adding (NVA) activity (Monden, 1993; Irani et al., 2000). Hines and Rich (1996) have identified seven VSM tools to identify the wastes present in any system in form of inventory, overproduction, over capacity, wrong processing methods, NVA activities, etc.

A value stream is all the actions (both value and non-value added) the required to bring a product, or group of products that use many of the same resources in much the same way, through the main flow essential to every product from raw material to the arms of the customer (Browning, 1998). VSM is a pencil and paper visualization tool that shows flow of material and information as a product makes its way through the value stream (Rother and Shook, 1999). VSM serves as a starting point to help management, engineers, suppliers, and customers recognize waste and its sources.

2.11 Geographic Information System (GIS)

Geographic Information Systems (GIS) is an integrated assembly of computer hardware, software, geographic data and personal designed to efficiently

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acquire, store, manipulate retrieve, analyze, display and report all forms of geographically referenced information geared towards a particular set of purposes (Burrough, 1986; Kapetsky and Travaglia, 1995; Nath et al, 2000). There are essentially two types of GIS: vector and raster systems. These systems differ in the manner by which spatial data are represented and stored. Burrough (1986) and Meaden and Kapetsky (1991) provide useful comparisons of vector and raster systems. In both systems, a geographic coordinate system is used to represent space. Many coordinate systems have been defined, ranging from simple Cartesian X-Y grids to spatial representations that correspond to the real world such as latitude/longitude pairings, State Plane coordinates or the Universal Transverse Mercator system coordinate system (Burrough, 1986; Thomson, 1998; Nath et al, 2000).

An integrated model based on geographic information systems (GIS) and mathematical programming is developed to evaluate the economic potential and the infrastructure requirements of agricultural production from agricultural residues (Parker et al, 2010). GIS is one of analysis tools that work with both spatial and non-spatial using in analyzing as well as displaying in different formats. GIS may be considered as a support tool for planners using to make decision in site and facility selections at strategic or planning stage in a supply chain (Pitaksringkarn and Taylor, 2005). The unique capabilities of GIS make it outstandingly useful as an analysis and visualizing tool because it allows capture both spatial element and geographic location of facilities (Raicu et al, 2002). GIS is used as a decision tool to support logistics and marketing managers to evaluate locating options for facilities based on costs and customer demand (Valchopoulou et al, 2001)

In geographic information system environment, the process of logistics collection and distribution center was divided into two stages: 1) selection candidate regions qualitatively, and 2) extract an optimal region from candidate regions quantitatively (Lv et al, 2008). Geographic information systems (GIS) are recognized as one of the new technologies which can be usefully introduced to decision support system (DSS) for vehicle routing (Keenan, 1998). Many examples of vehicle route and GIS integration were use of the GIS for storing data and displaying routes, without significant use of the spatial processing abilities of the GIS. A resent paper by Marzolf et al (2006) notes that GIS is largely used on operation research/management science

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(ORlMS) to feed mathematical models, with the modeling capabilities of the GIS being less often used.

Table 2.12 example of an agricultural routing SDSS

Objective	Active Required	SDSS technique
Identify Collection Point	Identify convenient locations on roads for collections	Associate polygon Volumes with arcs on road network
Build Routing Problem	Identify quantities to be transported	Calculate polygon areas in database and device volumes from these
Build Road Network	Generate distance/travel time data for use by mathematical procedures	Standard GIS operation called within macro
Establish Routing Parameters	Enter speed, capacity, etc.	User intervention using from interface
Routing Vehicle	Apply routing algorithm	Customized routing model calling SDSS routines
Refine Solution	Interactive user modification of routes	Display routes in GIS interface, user alternations lead to dynamic recalculation of volumes

Source: Marzolf et al, 2006

A real-world problem, where the parameters are independent, is the combined location-routing problem (Keenan, 1998). Location problem are complex in them and are an existing area of integration of modeling techniques and GIS (Keenan, 1998; Church, 2002). In such a problem, the total demand or supply in the problem needs to be allocated to a limited number of locations. Vehicle routes are then generated to visit those locations. In the agriculture term, the GIS and routing had effective synthesis of routing algorithms, and a decision support system based on geographic information system techniques in table 2.10

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2.12 Mathematical Model with Facility Location and Transportation Process of Inbound Logistics Management

In the situation of complexity in the real world, that too hard to handle because they are many constrain and multi-objective. To help us understand in this world, a particular phenomenon mathematical by means of a function or an equation could help us. Which mathematical model was idealization of the real-world phenomenon but never a completely accurate representation. Although that any model has limitations, the results and conclusions provided from a good variable (Giordano et al, 2003).

With a variety of conditions can causes researcher to abandon hope of achieving any success when regarding the question of constructing a mathematical model. The complexity can occur when attempting to use a model given by a system of partial differential equations or a system of nonlinear algebraic equation. Sometime the problem may be so large that effect to capture all the necessary information in a single mathematical model. For instance, suppose the goal is to draw conclusions about an observed phenomenon in the real world. One procedure would be to conduct some real-world behavior trials or experiments and observe their effect on the real-world behavior.

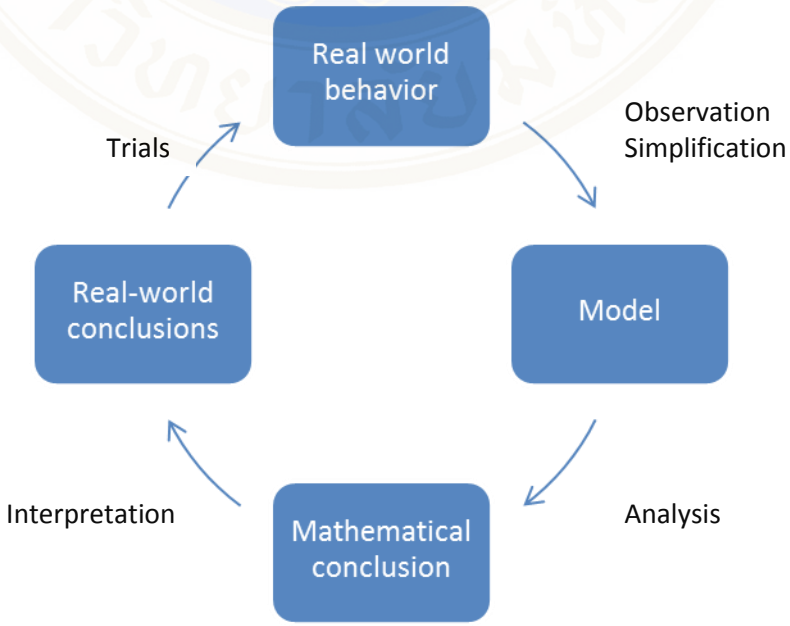

Figure 2.14 Reaching conclusions about the behavior of real-world systems (Giordano et al, 2003).

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An examination of figure 333 suggests an alternative way of reaching conclusions about the real world. The behavior with specific observations being studied and identify the factors that seem to be involved. And conjecture tentative relationships among the factors their have selected, thereby creating a rough model of the behavior. Having constructed a model, we then apply appropriate mathematical analysis leading to conclusions about the model. And the last was interpreting mathematical conclusions in term of the real-world problem.

For the definition of mathematical model as a mathematical construct designed to study a particular real-world system or phenomenon that includes graphical, symbolic, simulation, and experimental constructs. In figure 2222 depicts this differentiation between models.

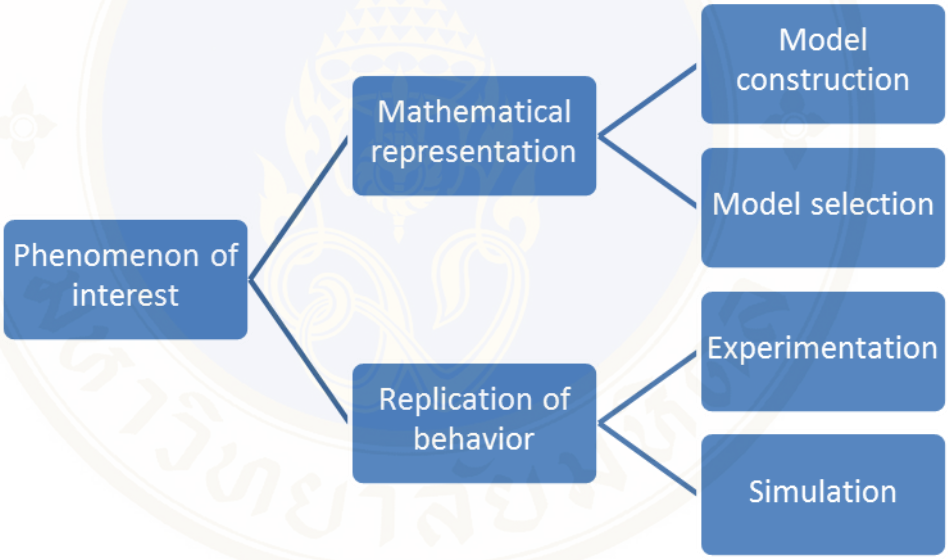

Figure 2.15 The nature of the model (Giordano et al, 2003).

The distinction between the various model types as depicted in figure 2222 is made solely for ease of discussion. For instance, the distinction experiments and simulations is based on whether the observations are obtained directly (experiments) or indirectly (simulation). In the end, the model properties consider as following:

Fidelity: The preciseness of a models' representation of reality.

Costs: The total cost of the modeling process.

Flexibility: The ability of change and control conditions affecting the model as required data are gathered.

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2.12.1 K-means algorithm for clustering analysis

The clustering formulations that are based on minimizing a formal objective function, the K-means clustering technique is simple, and we begin with a description of the first choose K initial centroids, where K is a user specified parameter, namely, the number of clusters desired. Each point is then assigned to the closest centroid and each collection of points assigned to a centroid is a cluster. The centroid of each cluster is then updated based on the points assigned to the cluster. After that, to repeat the assignment and update steps until no point changes clusters, or equivalently, until the centroids remain the same (Tan et al, 2006).

Then the algorithm iterates between two steps till convergence (Wu et al, 2008):

- Step 1: Data Assignment. Each data point is assigned to its closest centroid, with ties broken arbitrarily. This results in a partitioning of the data.
- Step 2: Relocation of "means". Each cluster representative is relocated to the center (mean) of all data points assigned to it. If the data points come with a probability measure (weights), then the relocation is to the expectations (weighted mean) of the data partitions.

One issue to resolve is how to quantify "closest" in the assignment step. The default measure of closeness is the Euclidean distance, in which case one can readily show that the non-negative cost function,

$$\sum_{i=1}^{N}\left(\underset{j}{argmin}\left\|x_i - c_j\right\|_2^2\right) \quad (1)$$

Normally, the cost function will decrease whenever there is a change in the assignment or the relocation steps, and hence convergence is guaranteed in a finite number of iterations. The greedy-descent nature of k-means on a non-convex cost also implies that the convergence is only to a local optimum, and indeed the algorithm is typically quite sensitive to the initial centroid locations, about K-means is formally descripted by algorithm and steps to find solution in table 2.13 and 2.14, respectively.

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Table 2.13 Basic K-means algorithm

1: Select K points as initial centroids.
2: **repeat**
3: Form K clusters by assigning each point to its closest centroid.
4: Recompute the centroid of each cluster.
5: **until** Centroids do not change,

Source: Tan et al, 2006.

Table 2.14 Input and steps to find solution

Input: - K (number of clusters) - Training set $\{x^{(1)}, x^{(2)},\ldots, x^{(m)}\}$, $x^{(i)} \in R^n$ (drop $x_0 = 1$ convention)

Randomly initialize K cluster centroids $\mu_1, \mu_2,\ldots, \mu_k \in R^n$
Repeat{
for i = 1 to m
$c^{(i)}$:= index (from 1 to K) of cluster centroid closest to $x^{(i)}$
for k = 1 to K
μ_k := average (mean) of points assigned to cluster k
}

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2.13 Related Research

The logistics transportation process of many agricultural in Thailand did not have planning before go to factories or mills. Their management is not centralized and there is a lack of coordination for vehicle arrival to the mill. The mill's storage deposit is common the lorries queues at the high production season, but at the lower production season it can be un supply of agricultural at the mill, which means it must stop the processing (Fontanilla et al, 2010). Sahraeian and Kaveh (2010) applied capacitated P-median problem (CPMP) by hybrid k-means clustering and fixed neighborhood search algorithm to fine the discrete location problem, CPMP locates P-facilities between the candidate points, in order to satisfy the customer demand. In proposed method, K-means clustering algorithm has fined a proper solution for Fixed Neighborhood Search algorithm (FNS). The computational results of this research had shown the efficiency proposed algorithm in regard of the quality of solution.

From the study of Parker et al (2010) were focuses on evaluating the economics potential and infrastructure requirements of hydrogen production from agricultural residues, a representative green energy pathway by using geographic information and a mix-integer nonlinear programming model are constructed for finding the most efficient and economical configuration of the whole pathway.

Fontanilla et al (2010) using mixed integer programming to analysis the oil palm fresh fruit bunches (FFB) to optimized the logistics transportation process with internal and external collection points (ICP and ECP) and minimized the transportation costs. From their result can reduced up to 40% of transportation cost thereafter using of the model. Another study of mixed integer linear programming, which was solve the problem sending a set of products from single origin to a common destination proposed by Zanoni and Zavanella (2007). Similarly, recommend modification of known heuristics to solve it. The results of computational present how the modified heuristics are effective and efficient. lannoni and Morabito (2009) applied discrete simulation techniques to study the process of unloading in a sugar cane mill. With the using those techniques the performance of process was analysed, with the aim to avoid delays for lorries and reduce the queuing at the sugar cane mill.

Another study of sugar cane production had study by Kaewtrakulpong (2008) presented the results of a research conducted to improve efficiency and to

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reduce the cost of harvesting and transport an area of 618 hectares in northeast Thailand. The methodologies of this study had using in two stages: 1) Data collection (surveys, interviews, time and motion studies to harvesting and transport) and 2) Carrying out two models, a crop simulation to find the best way to introduce mechanical harvesting, using as input the size of the lots, the length of the lines, the amount of cane, and distance to the factory, and a model of multi-objective optimization (Minimize the number of days of operation; Minimize the total travel distance of trucks and minimize the time deterioration of the cane harvested) for the transport of cane plants. Accounting of this work with the mechanization of the harvesting there are significant reductions in terms of cost per hectare, particularly when harvesting green cane. The multi-objective model using of the allocation of resources, the reductions in the total cost are from 4% to 9%.

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CHAPTER III
RESEARCH METHODOLOGY

This chapter reviews the research study area selection and data sources and collection. The conceptual framework of methodology is described.

3.1 Research Study of Area Selection

As reviewed in the section above, the research objective is to study the cassava starch supply chain and logistics system to reduce transportation cost, and plan the potential suitable area for the cassava plantation in Western Thailand by using the mathematical model and Geographic Information System (GIS). The structure of research study area is illustrated in Figure 3.1.

Initial steps, this research focused on an overview of cassava production activity from raw material to finishing product with tapioca flour send to customers in the Western of Thailand. Review the research papers, journals and books for finding the spatial and non-spatial data have been carried out. The transportation problem is the state-of-art in the logistics management and it is easy to see the matching between demand and supply. The logistics cost from transportation is considerably higher than other activities as it depends on uncertainty of energy cost.

The second step, to survey and observation of characteristics and activities of cassava farmers' groups, traders, starch factory, exporters and customers of starch industry in Western parts of Thailand. This research operation enable us to know the role of cassava starch industry and the best practices for starch supply chain and logistics management, with the IDEF0 (Ross and Schoman, 1977; Ross, 1977; Sarkis and Lin, 1994) and Value Stream Mapping (Singh, Garg and Sharma, 2010; Rauniyar, 2007) and understand the relationship, transaction between sectors, and analysis to explanation the problem in supply chain.

The final step is to study and find the solution of transportation problem in the logistics inbound and outbound, and to find the best practices of transportation

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sector of cassava starch supply chain and logistics management. The research tool used involve mathematical model with K-mean clustering and Dijkstra's algorithm to analyst and conclude with the application of Geographic Information System (GIS) with Network Analyst.

The result, this research aims at constructing the case study of cassava starch supply chain and logistics management in terms of transportation sector to be the best practices of agricultural management so as to help the cassava farmers, traders and relevant starch factory to reduce the waste activity and improve the role of competitive trading in domestic and export markets.

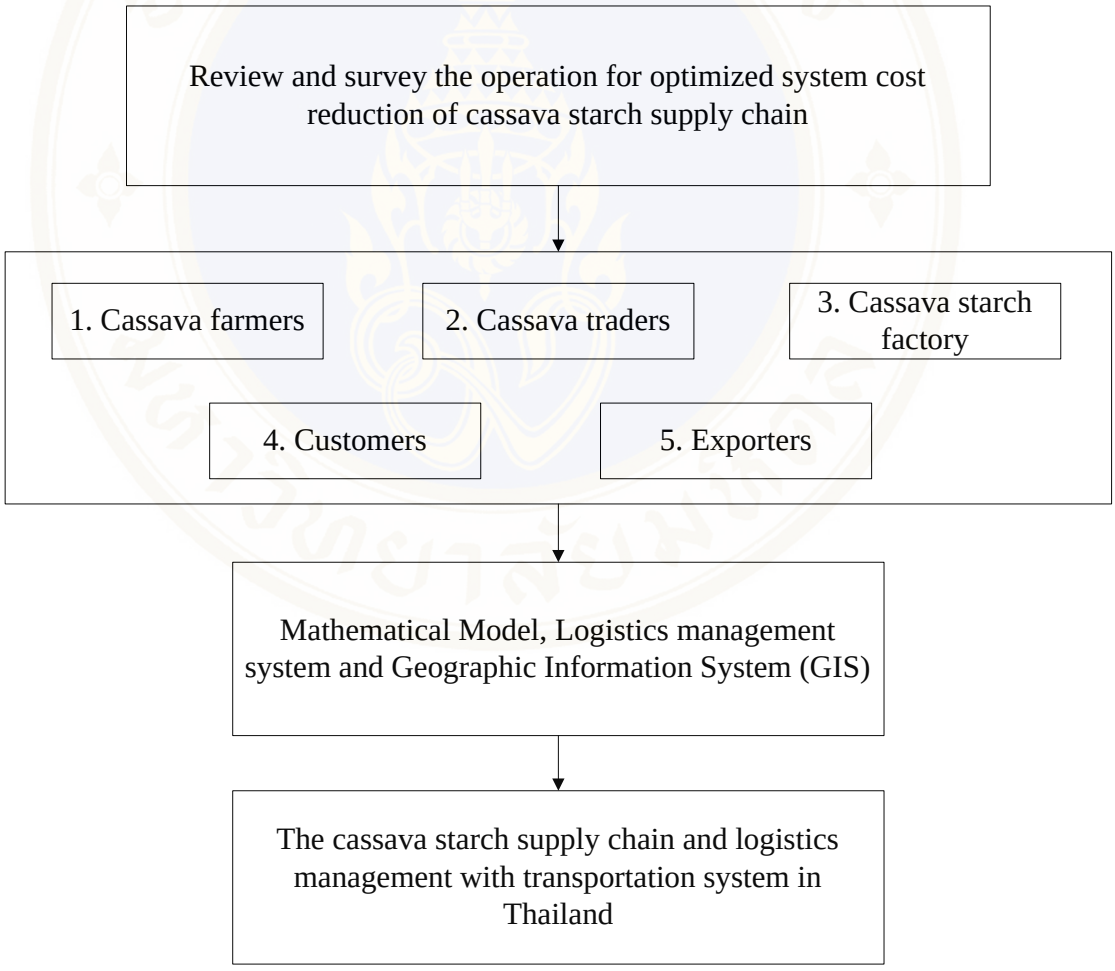

Figure 3.1 The Structure of Research Study of Cassava Starch Supply Chain and Logistics Industry

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3.2 Data Sources and Collection

This Study collected data and information from sources as follows:

3.2.1 Primary Data: Collecting the primary data has been carried out from field survey, observation, and interview to verify the collected data. Conduct interview with cassava farmer, employee of factory, stakeholder and exporters, as follows;

- To collect the Global Positioning System (GPS) of cassava plantation and cassava yard, the observation focuses on activity of cassava cultivation up to harvest, stock, and transportation from farms to cassava yard or factory.
- To collect the Global Positioning System (GPS) of factory, by observation of activity of cassava and cassava starch to stock, manufacturing and transportation from factory to customer or exporters.
- To collect the Global Positioning System (GPS) of customer or exporters for position of destination of supply chain of cassava and tapioca flour.

3.2.2 Secondary Data: Collect the secondary data from the relevant organization including statistic data, spatial data and non-spatial data such as thesis, research reports, journals, books, articles, and annual report, which are:

- Cassava planted area map, Department of Agriculture, at the scale of 1:50,000.
- GIS Database is digital file format at the scale of 1:50,000. compose:
    - Department of Provincial Administration:
        - Administrative boundary: Provincial boundary, district boundary and sub district boundary in 2006.
    - Department of Agriculture:
        - Cassava planted area in 2008
        - Cassava Starch Industry Location in 2008
    - Department of Rural Highways:

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- Transportation

- Data on Cassava planted area, production, yield per rai, cassava price, cost of cassava production; transportation cost from farm to industry, this data will be collected from Department of Agriculture and Office of Agricultural Economics.
- Production capacities, manufacturing process and information have been collected from cassava starch factory.
- The capacity to transportation and cost, the type of product for each customer and spatial data collected from cassava starch factory.

3.3 Conceptual Framework of the Research Methodology

From the introduction and literature review, the conceptual framework of this research methodology has been illustrated as follows:

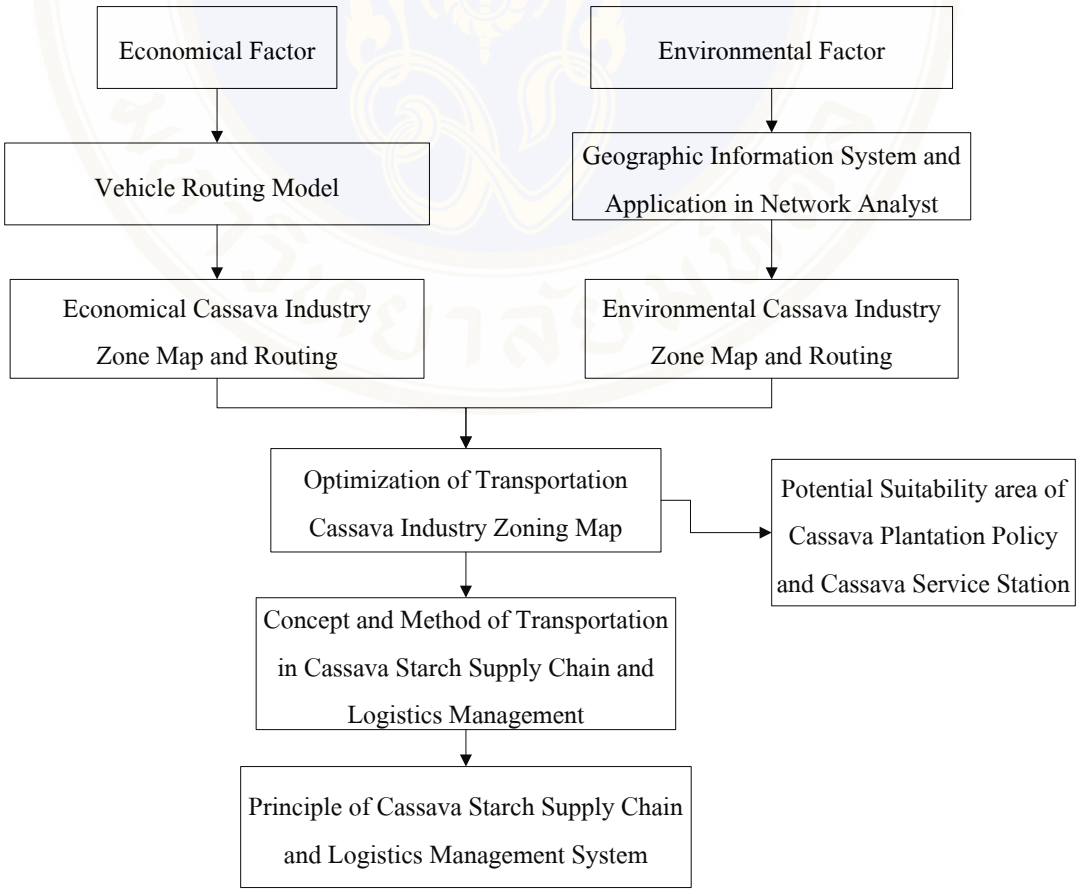

Figure 3.2 The Conceptual Framework of Research Methodology

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From the figure 3.2, at first step there are two parts to make analysis i.e. factors in economics and in environment. The economic factors focus on making analysis of the non-negative travel costs: C_{ij} and some constraint to use in equation of K-mean clustering and the dijkstra's algorithm. In the environmental factors focus on the geographic position, spatial and non-spatial data of cassava farmers and starch factory using Geographic Information Systems (GIS) and application of this program: Network Analyst.

The second step focuses on making analysis of the factors in each part, the economics factors by Vehicle Routing Problem with Capacity to know the transportation suitability and the environmental factors focus on application of Geographic Information Systems to understand the suitable areas and routing zone map.

The solution of each part was combined to find the Optimization in economics and environmental factors. Afterward, this step will provide information on the potential suitable area of cassava plantation, distance from starch factory, and the transportation routing.

The final step from the optimal solution the formation of the concept and method of transportation in cassava starch supply chain and logistics management will realize. This research intends to create the methodology to be used as the principle of transportation in cassava starch supply chain and logistics management systems.

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3.4 Methodology

In this section, research methodology will be presented. The proposed system consists of main steps as follows:

3.4.1 Literature Review and review of the related Information

3.4.1.1 Review of the Related Information about Cassava and Cassava Starch Supply Chain, the information of cassava supply chain has been obtained from literature review and research approach. It is intended to create the information flow and material flow of cassava supply chain system with IDEF0 and Value Stream Mapping ((Sutherland and Canwell, 2004; Ross and Schoman, 1977; Ross, 1977; Sarkis and Lin, 1994; Singh, Garg and Sharma, 2010; Rauniyar, 2007) with this purpose to understand the integrating operation and network management of cassava supply chain and logistics system.

3.4.1.2 Review of the Related Information about Geographic Information System (GIS), the information on Geographic Information System (GIS) will be gathered from agricultural research applied with GIS approach in literature review.

3.4.1.3 Review of the Related Information about Vehicle Routing Problem and Network Analyst, the information on Vehicle Routing Problem with Dijkstra's algorithm and Application of GIS: Network analysis will be applied in agricultural management and research literature review.

3.4.2 Survey, observation and collection of data from the farmer's plantation, location of factory, and customers of cassava starch industry.

This data collection from primary and secondary data sources it was decided to use Global Positioning System (GPS) and Geographic Information System (GIS). The details of data collection are as follows:

- Location, capacity of product, and data approach of each farmer and cassava yard.
- Location, capacity of manufacturing and data approach of cassava factory in the case study area.

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- Location, capacity of finished products and data approach of customers.

3.4.3 Study and analysis of current business and system process of cassava starch industry

This step wants to study the role and present work of business process to defined the process problem from cassava starch industry in Thailand, and show the activity flow that is happening and is the analysis of working process by using Integration Definition for Function Modeling (IDEF0) and showing the value stream mapping starting from cassava farms until the step of goods production transport to customers.

3.4.4 Create the digital mapping

The digital map presents the factory positioning, boundary of cassava plantation area, network of transportation, service level of pavements, ways to transport cassava to factory, and the transport management to customers.

3.4.5 Analyze the criteria statistical data and approach except GIS map

The criterion for statistical data is numerical such as capacity, time to move, fixed and variable cost. The data will be calculated and the criteria created and made a secondary data.

3.4.6 Formulate and develop the mathematical model

The criteria for statistics data has been used to formulate and develop the mathematical model with K-mean clustering, Dijkstra's algorithm and Network Analysis to find the optimal of transportation, potential suitability area, and mode of transport in cassava starch supply chain system.

3.4.7 Analyze and evaluate the results from each scenario model

From the mathematical model formulation and the digital map have been used to calculate and run the model in digital mapping to analyze in each scenario of

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each mode of transport and capacity condition. This research uses the mathematical model of cost and digital map to specify the boundary of potential suitable area of cassava plantation, if the plantation area of farmers is foreign, it can be used as the Hub for purchasing area to reduce transportation cost.

The methodology of this research was represent the method of transportation of cassava roots from farms to cassava starch mills with the collecting location likely hub and sending the production directly to factory, the total distance there have analysis from the distance direct from farms to SCS and SCS to factory, and multiply by the number of trips, calculate by capacity of farms divide by 21 tons that mean the truck can carry weight of cassava root per trip in 21 tons. To the transportation cost are calculated from the fuel consumption of 10 wheel of trucks is 10 kilometer/lite and the diesel price in situation of this research study is 30 baht/lite, the step to analysis with K-mean clustering, Dijkstra's algorithm, and GIS as following:

3.4.6.1 Traditional Transportation methods in current state (AS-IS Process) have used location from the real data location of cassava root plants as following:

a) Analysis the spatial data with Geographic Information System (GIS).
b) Analysis the traditional routing from farms to cassava starch factory and from farms to each collecting location and continues to cassava starch mill with dijkstra's algorithm of Closest Facility application in GIS.
c) Calculate the traditional transportation cost and investment costs to evaluate the traditional case.

3.4.6.2 New Transportation methods in the future state (TO-BE Process) has used to find location of new cassava root plants with k-means clustering for the number location in 5, 10, 15, 20, 25, and 30 locations to find the suitable solution of investment as following:

a) Analysis the spatial data with Geographic Information System (GIS).

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b) Analysis to finding suitable area for collecting location from without weight of volume of production in each farm location by k-mean clustering with Weka 3.6.3, as in

$$Min\ Z = \sum_{i=1}^{n} \sum_{j=1}^{k} \left\| X_i^{(j)} - \mu_j \right\|^2 \quad (1)$$

And the steps of analysis by Weka are find solution following the table 3.1

Table 3.1 Input and steps to find solution with Weka

Input: - K (number of clusters) - Training set $\{x^{(1)}, x^{(2)},\ldots, x^{(m)}\}$, $x^{(i)} \in R^n$ (drop $x_0 = 1$ convention)

Randomly initialize K cluster centroids $\mu_1, \mu_2,\ldots, \mu_k \in R^n$
Repeat{
for i = 1 to m
$c^{(i)}$:= index (from 1 to K) of cluster centroid closest to $x^{(i)}$
for k = 1 to K
μ_k := average (mean) of points assigned to cluster k
}

c) Analysis to finding suitable area for collecting location from k-mean clustering does include the weight of volume of production in each farm location with MATLAB, as in

$$Min\ Z = \sum_{i=1}^{n} \sum_{j=1}^{k} W_i \left\| X_i^{(j)} - \mu_j \right\|^2 \quad (2)$$

And the steps of analysis by MATLAB are find solution following the table 3.2

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Table 3.2 Input and steps to find solution with MATLAB

Input: - K (number of clusters) - W (capacity of each data location) - Training set $\{x^{(1)}, x^{(2)},\ldots, x^{(m)}\}$, $x^{(i)} \in R^n$ (drop $x_0 = 1$ convention)

Randomly initialize K cluster centroids $\mu_1, \mu_2,\ldots, \mu_k \in R^n$
Repeat{
for i = 1 to m
$c^{(i)}$:= index (from 1 to K) of cluster centroid closest to $x^{(i)}$
for k = 1 to K
μ_k := average (mean) of points assigned to cluster k and $x^{(i)}$ are already multiply by $W^{(i)}$
}

At above function, $X_i^{(j)}$ shows the location of customers i which is allocated by center μ_j to the cluster j, and W_i is the number of capacity production in each farm location. All above function minimizes the sum of squared distance between each farm and the centroid of the cluster that farms belong to it, as the same in condition of distance between centroid of cluster and cassava mill.

d) Analysis the new model routing from farms to each collecting location and continues to cassava starch factory with dijkstra's algorithm of Closest Facility application in GIS.

e) Calculate the new model transportation cost are calculated from the fuel consumption of 10 wheel of trucks is 10 kilometer/lite and the diesel prices in situation of this research study is 30 baht/lite and investment costs to evaluate the new model case.

3.4.8 Compare and measure the results of information

The results obtained of various scenarios have to be compared and measured. Find the best results that can be used with the optimal solution between the traditional and new model to improvement the business process of this research.

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3.4.9 Implementing design and evaluated TO-BE process for business process improvement

This step there is design of conceptual improvement model and evaluated the business process based on the research results. From the comparison result will be used to design the model and apply to improve the business process in cassava starch industry in Thailand.

3.5 Equipments or Facilities

The following facilities are used in this study:

3.5.1 Facilities (hardware)

- PC computer under Windows 7 operation system
- GPS
- Digitizer
- Inkjet Printer

3.5.2 Softwares

- IDEF0 Model, Value Stream Mapping	: Microsoft Visio, BPWIN
- Geographic Information System analysis	: ArcGIS 9.3
- Clustering Data Analysis	: Weka 3.6.3, MATLAB
- Vehicle Routing Analysis	: Dijkstra's Algorithm, Network Analyst by ArcGIS 9.3

3.5.3 Map

- Cassava planted area map, Office of Agriculture, at the scale of 1:50,000.
- GIS Database is digital file format; Department of Agriculture, Department of Provincial Administration and Department of Highways and Rural Highways, at the scale of 1:50,000.

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CHAPTER IV
A CASE STUDY OF CASSAVA STARCH INDUSTRY IN THAILAND

Apart from the rice and sugarcane industries, the cassava starch processing industry has played an important role in the Thailand's agricultural economy. Only 45% of the cassava root harvested in Thailand is delivered to starch-processing plants, while the rest is used in the production of pellets and chips (Department of agriculture, 2009; Ekasingh et al, 2007). Currently, Thailand has a total production capacity of native and modified starch at about 16,910 and 4,350 ton/day, respectively (Chavalparit and Ongwandee, 2009). Normally, these cassava plants operate 24 hours a day for 8-9 months, from September to May.

This chapter represent to the role of cassava starch in supply chain management, the situation of cassava starch production in supply chain (Figure 4.1) had got sourcing from the cassava farmers amount 2,140 people in 4 provinces, the total production of cassava roots in western region of Thailand was 1,611,699.74 tons per year. And transportation was usually undertaken by middleman or Owner of cassava yards, the alternative way of cassava root production has 4 choices:

- Cassava yard: to collect and produce to be cassava chips product.
- Cassava starch factory: to produce to be cassava starch product.
- Cassava pellets factory: to produce to be cassava pellets product.
- Ethanol and Ethyl Alcohol Factory: to produce to be Ethanol product.

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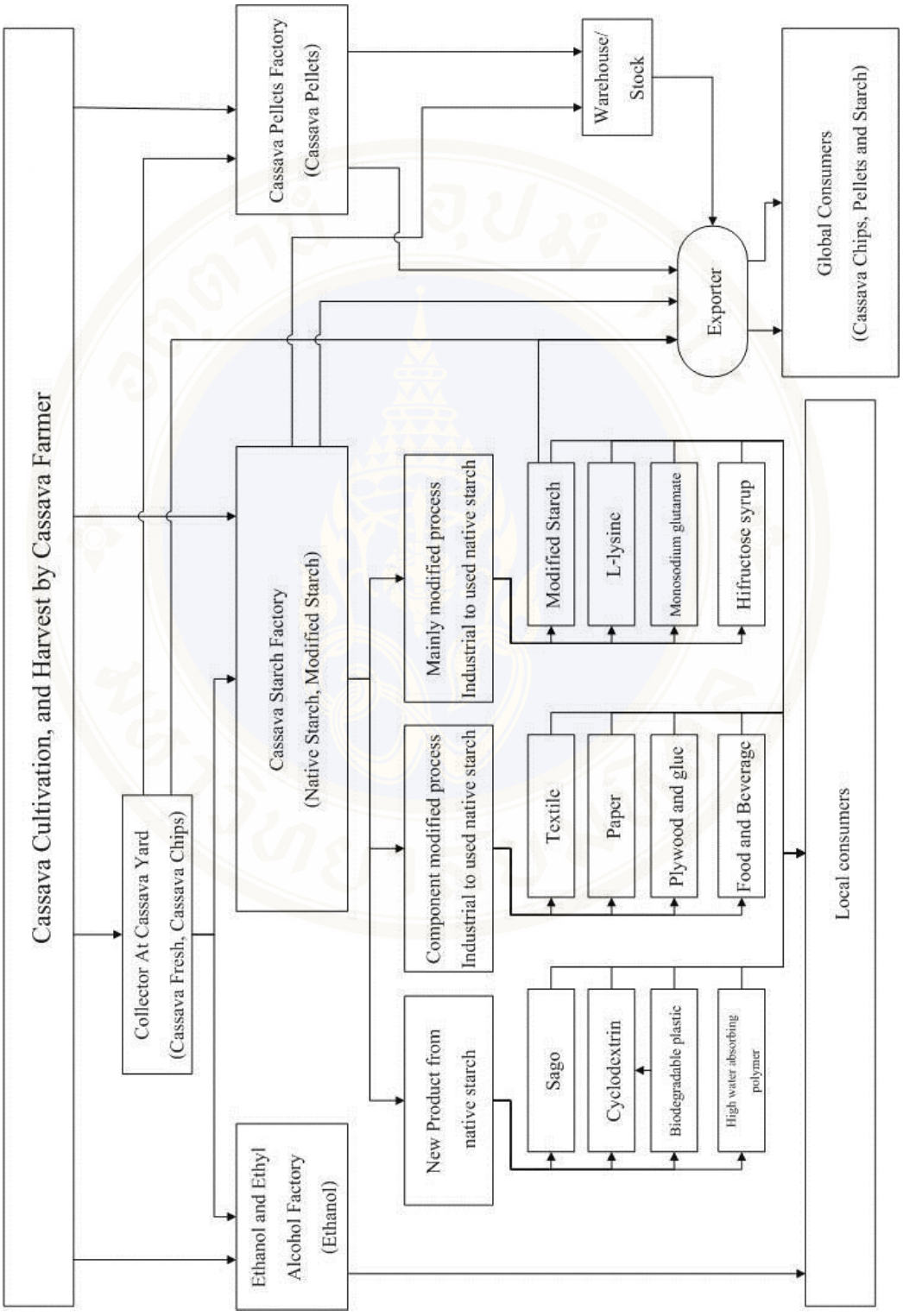

Figure 4.1 The role of supply chain mapping of cassava starch industry in Thailand

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After produce the native cassava starch, which product can produce to be many products such as:

- New product from native starch: Sago, Cyclodextrin, Biodegradable plastics, High water absorbing polymer.
- Component modified process industrial to used native starch: Textile, Paper, Plywood and glue, Food and Beverage.
- Mainly modified process industrial to used native starch: Modified starch, L-lysine, Monosodium glutamate, Hifructose syrup.

4.1 A Case Study of Cassava Starch

This research has using the case study of cassava starch industry to define and analysis the supply chain and logistics problem in the western region of Thailand, to studies about the business process and relational activities in supply chain, logistics and transportation system. We has decided to select a cassava starch factory and cassava farms groups in western of Thailand include 4 provinces, namely Kanchanaburi, Ratchaburi, Suphan Buri, and Nakhonpathom provinces. The case study area has illustration in figure 4.2.

From the study area, this research has separated to studies in 2 topics:

- to study in business processes of cassava starch industry by using IDEF0 and value stream mapping to define and discussion about the supply chain, logistics and transportation in current state and design the new business process to improvement with the future state of business process.
- To study and analysis the inbound of transportation in logistics system of cassava starch industry that we was define the problem from analysis of current business processes, in order to reducing the transportation cost from cassava farms to cassava starch factory by using the hub to collecting cassava roots. The methods in this step use ordinary K-mean algorithm clustering by Weka, modify K-mean algorithm include the capacity of cassava roots in each farm clustering by MATLAB. Finally, the total distance of transportation process in each algorithm has analysis, evaluate and visualizing by network analyst application of GIS.

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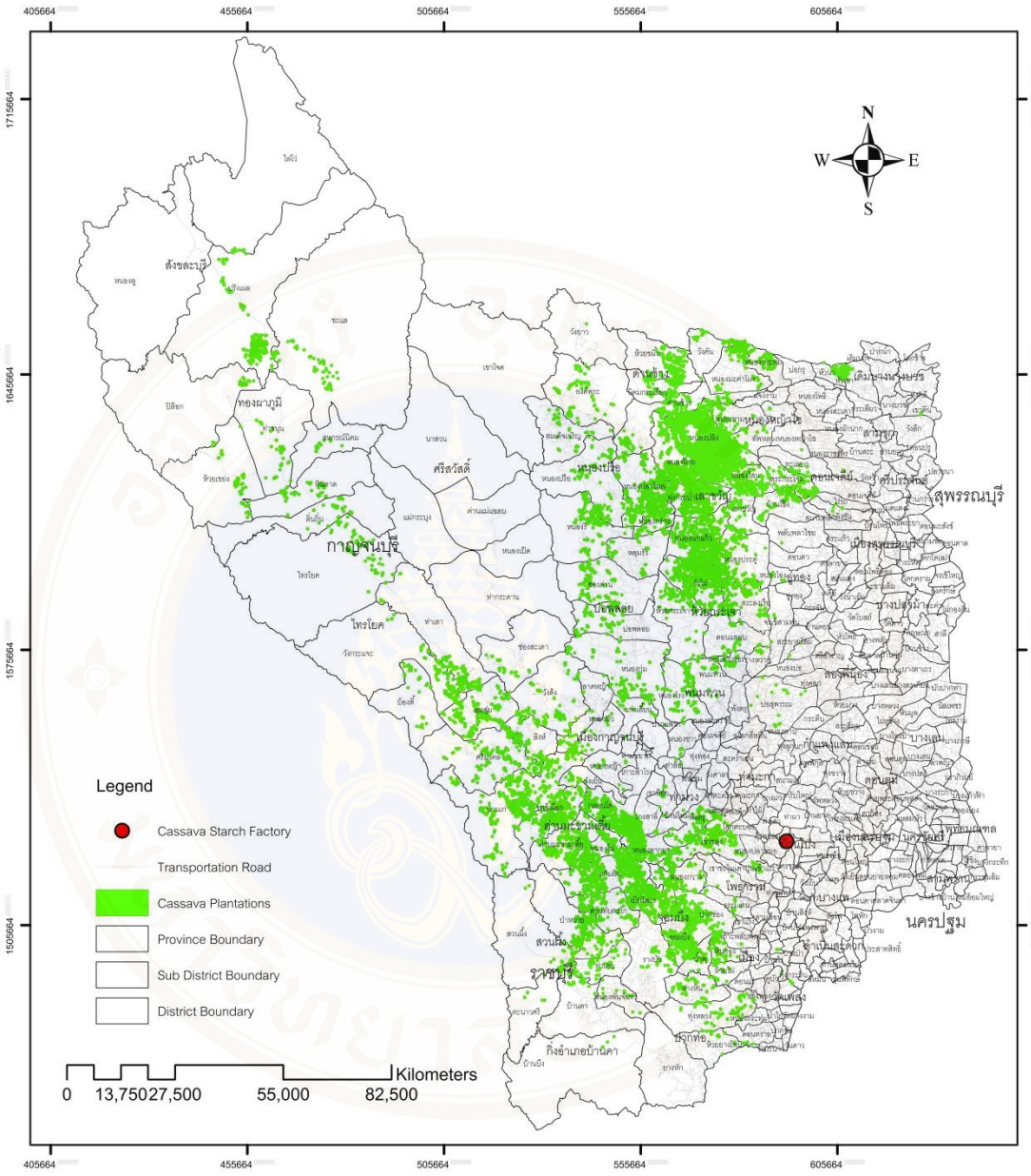

Figure 4.2 The study area of inbound logistics of cassava starch management

4.1.1 The current state of inbound transportation process and management

The transportation and business processes of cassava starch industry in Thailand are in the same level all around the country. The production of cassava roots has collecting and decides to the cassava yard or cassava starch factory are depended on the value of prices to sell the cassava roots and wanted from each industry as in figure 4.1. After sending to cassava yard, the cassava roots are getting to collected and

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modify or sending to cassava starch factory to produce to be native starch and modified starch also.

In this case study, after study and collected data from the business processes and logistics activities. The cassava yards has character to be the middle man and collected the cassava roots from farm directing to the cassava starch factory. However, the traffic road in the front of cassava starch factory was so jam and incur many accident from the trucks were transport cassava roots to factory, and the number of cassava yards are so many and difficult to manage because there have the accumulate location center or Cassava Service Center (CSC) in 33 locations and in each location has the investment cost is so high that afford to the researcher to find optimal solution in the number of Cassava Service Center (CSC) and suitable location by using spatial data.

This research was collected and study from many cassava yards that collect the cassava roots from farms had investment cost in each plant that construction has included to construct in the weight station cost, operation cost and labor cost. There was the summarize the investment cost had following in table 4.1

Table 4.1 The investment cost to constructed the cassava yard and capacity of yard

The area of cassava yard (rai)	**The capacity of cassava yard (tons/day)**	**The capacity of cassava yard (tons/year)**	**The investment cost of cassava yard (baht/year)**	**Investment cost/ capacity of yard (baht/tons)**	**Total cost (baht/ tons/ year)**
3	150	54750	750,000	5,000.00	13.70
5	250	91250	1,000,000	4,000.00	10.96
7	350	127750	1,500,000	4,285.71	11.74
10	450	164250	2,000,000	4,444.44	12.18
20	900	328500	4,200,000	4,666.67	12.79

1 hectare = 6.25 rai

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From the data of accumulate location area in the current state, there has 33 accumulate location to collected the cassava roots from farms to cassava starch factory. The 33 locations have shown in figure 4.3.

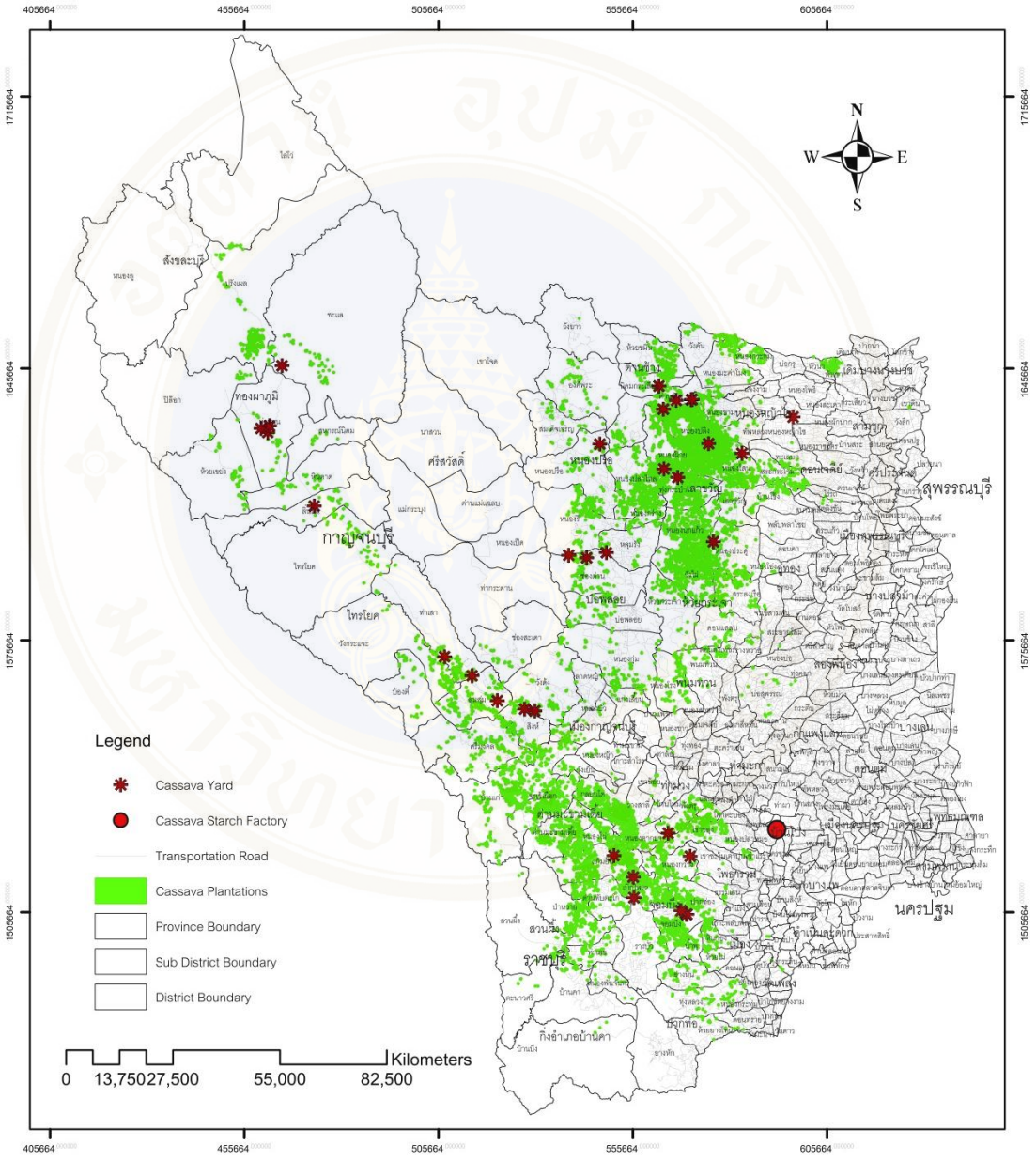

Figure 4.3 The 33 location of accumulate center to collected cassava roots from farms to cassava starch factory in current state

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The step of analysis the distance of transportation process in this research have using Dijkstra's algorithm and GIS with closest facility application to evaluate and establish the transportation routing in 2 steps: from cassava farms accumulate to 33 location centers and from 33 accumulate location centers to cassava starch factory of the case study, there are shown in figure 4.4 and 4.5, respectively.

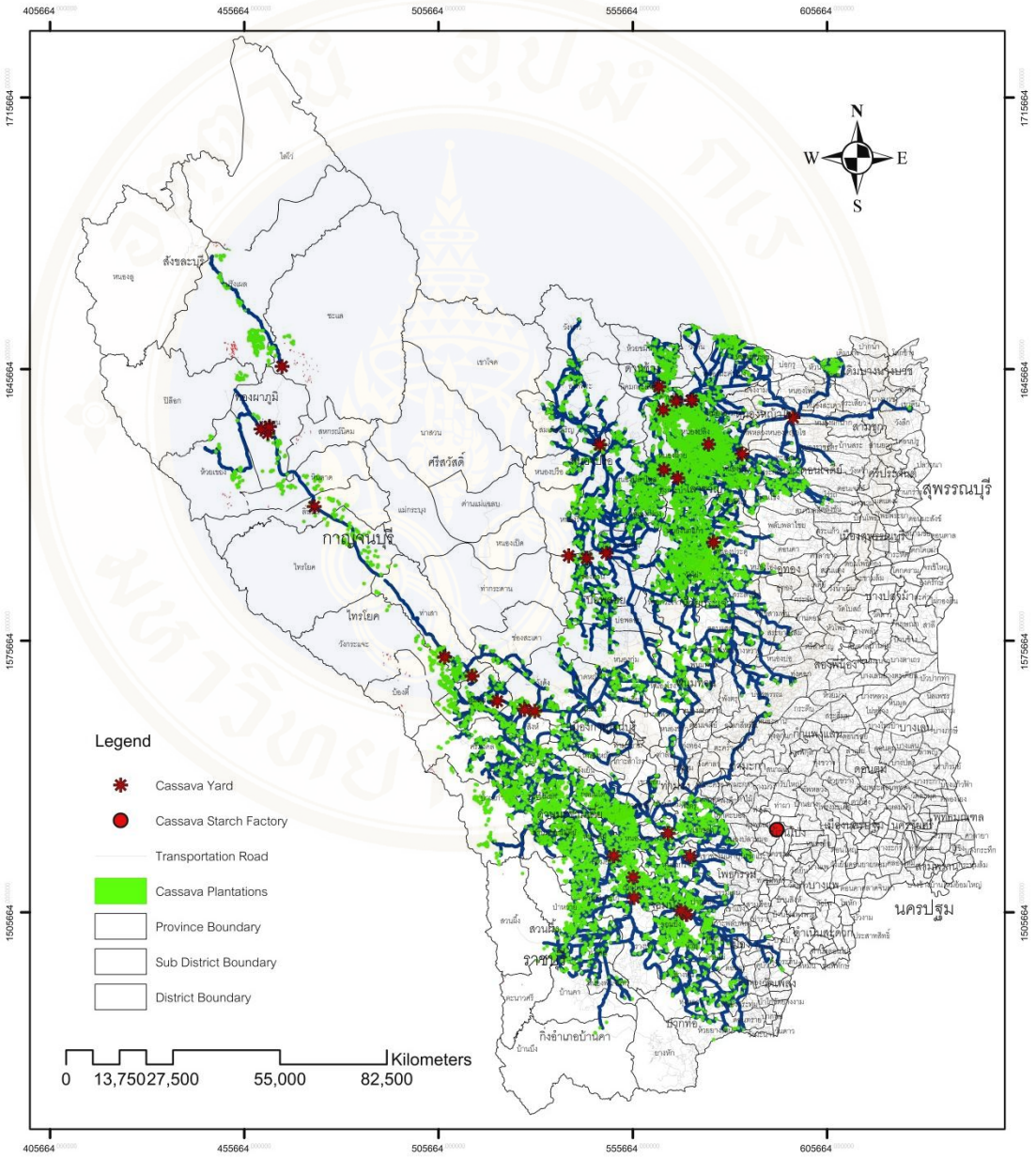

Figure 4.4 The results of routing to carry cassava roots from farms to 33 accumulate location centers in current state

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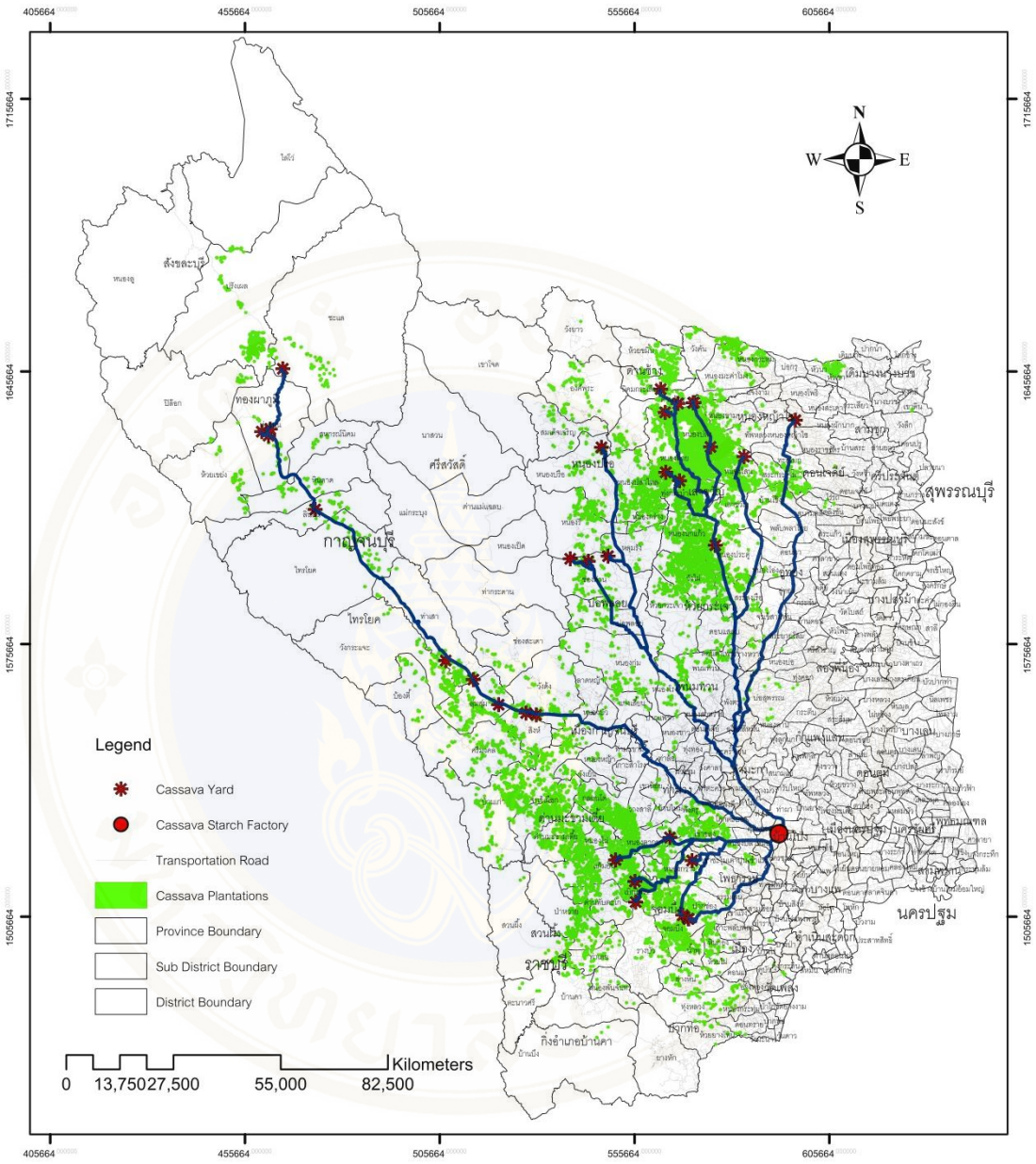

Figure 4.5 The results of routing to carry cassava roots from 33 accumulate location centers to cassava starch factory in current state

After to analysis and evaluate the transportation distance and total investment cost has shown in table 4.2 and 4.3. In the table 4.2, there have represented the total distance from farms to Cassava Service Center (CSC) in 33 locations is 1,014,426 kilometers/year and total distance from Cassava Service Center (CSC) to cassava starch factory is 6,547,466 kilometers/year, finally in total distance to

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transport cassava roots from cassava farms to cassava starch factory is 7,561,893 kilometers/year (the total distance there have analysis from the distance direct from farms to SCS and SCS to factory, and multiply by the number of trips, calculate by capacity of farms divide by 21 tons that mean the truck can carry weight of cassava root per trip in 21 tons), that it affecting to transportation costs to 22,685,679.70 baht/year has shown in table 4.3 (the transportation costs was calculated from the fuel consumption of 10 wheel of trucks is 10 kilometer/lite and the diesel prices in situation of this research study is 30 baht/lite). The investment costs of Cassava Service Center (CSC) location has separated to 5 types: 3 rai, 5 rai, 7 rai, 10 rai, and 20 rai to find out about the area suitability for operating accumulate service to collect the cassava roots to factory.

Table 4.2 The results from the transportation process of cassava roots from farms to cassava starch factory in current state

Unit: kilometer (km)/year.

Number of CSC location	Total Distance from Farms to CSC	Total Distance from CSC to Factory	Total Distance from Farms to Factory
33	1,014,426	6,547,466	7,561,893

Table 4.3 The results of the transportation and investment costs from Cassava Service Center location in current state

Unit: Baht/year

Number of CSC location	33
Transportation costs	22,685,679.70
Investment costs of area location in 3 rai	25,414,014.70
Investment costs of area location in 5 rai	33,531,211.76
Investment costs of area location in 7 rai	50,069,155.46
Investment costs of area location in 10 rai	66,590,235.29
Investment costs of area location in 20 rai	139,219,747.06

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From the results of table 4.3, the investment costs of Cassava Service Center (CSC) have difference costs depended on the area location. from the average capacity of Cassava Service Center are collected to 48,473.07 tons/year, it is lower than the maximum capacity of 3 rai area location that mean there can constructed the area location in each CSC from 3 rai to 20 rai, the area location in 3 rai of 33 locations has investment costs in 25,414,014.70 baht, the area location in 5 rai of 33 location has investment costs in 33,531,211.76 baht, and area location in 7 rai, 10 rai, and 20 rai has investment costs in 50,069,155.46 baht, 66,590,235.29 baht, and 139,219,747.06 baht, respectively.

Table 4.4 The results of the total cost from transportation and investment costs of Cassava Service Center location in current state

Unit: Baht/year

Number of CSC location	33
Total costs of area location in 3 rai	48,099,694.40
Total costs of area location in 5 rai	56,216,891.46
Total costs of area location in 7 rai	72,754,835.16
Total costs of area location in 10 rai	89,275,914.99
Total costs of area location in 20 rai	161,905,426.76

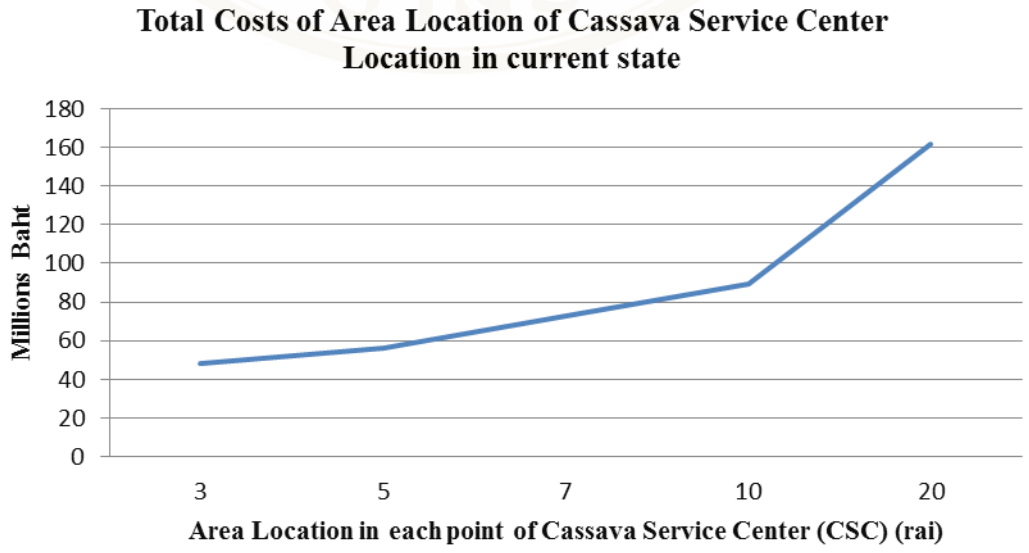

Figure 4.6 The results of total costs of Cassava Service Center (CSC) in current state

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From the table 4.4, there can conclude about the total cost from the current state that there solution come from the transportation costs and investment costs per years in each type of area location. The total costs of area location in 3 rai is 48,099,694.40 baht/year, total costs of area location in 5 rai is 56,216,891.46 baht/year, and total costs from 7 rai, 10 rai, and 20 rai is 72,754,835.16 baht/year, 89,275,914.99 baht/year, and 161,905,426.76 baht/year, respectively (see in figure 4.6)

4.2 Towards a Business Process Model of Supply Chain in Cassava Starch Industry in Current State (AS-IS Process)

4.2.1 Business process model with Integration DEFinition for function modeling (IDEF0) in current state

These researches have use IDEF0 model and programming with All Fusion Process Modeler Version 4.1.4 (BPWin) to create the relationship of activity and process control. From the data and information of business and manufacturing process of supply chain in cassava starch industry in the previous chapter, we can defined and create the role of framework of supply chain system of cassava starch industry (AS-IS Process) has shown from below in figure 4.7 - 4.14. The full decomposition of the activities within a cassava starch industry of supply chain system in current state is summarized in table 4.5.

From the table 4.5 has shown about the decomposition of activities within a cassava starch industry of supply chain system in current state. There have 5 figure diagrams to telling about the relationship of overall and details in activities of cassava starch supply chain. In level of A0 diagram are told about the overall of supply chain in cassava starch industry. Level of A1 diagram is told us about the relational of farming and details in activities of farming in level of A1.1 to A1.4 diagram. A2 level diagram is told about the manufacturing of native starch and there have the sub activities of organization in level A2.1 to A2.6, and manufacturing processes in A2.3.1 to A2.3.8 diagrams. In the manufacturing of modified starch are also the same steps like native starch, and finally in the A4 level diagram to focus in activity of transport and contract to customers.

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Table 4.5 A full decomposition of activities within a cassava starch industry of supply chain system in current state

Diagram Level	Details
A0	Supply Chain Process in Cassava Starch Industry
A1	Farming
A1.1	Plantation
A1.2	Middle Man
A1.3	Cassava Yard
A.14	Transportation to factory
A2	Manufacturing for Native Starch
A2.1	Forecasting & Production Planning
A2.2	Purchasing of Native Starch
A2.3	Process Manufacturing for Native Starch
A2.3.1	Rotary Screener
A2.3.2	Washing Basin
A2.3.3	Remove the Stump & Chopper
A2.3.4	High Speed Rasper
A2.3.5	Fine Pulp Extractor
A2.3.6	Separator & Dewatering Centrifugal
A2.3.7	Flash Dryer & Packaging
A2.3.8	Take to Stock
A2.4	Quality & Maintenance
A2.5	Sale & Marketing
A2.6	Warehouse of Native Starch
A3	Manufacturing for Modified Starch
A3.1	Forecasting & Production Planning of Modified Starch
A3.2	Purchasing of Modified Starch
A3.3	Process Manufacturing of Modified Starch
A3.3.1	Slurry
A3.3.2	Chemical Modification
A3.3.3	Sieving
A3.3.4	Washing
A3.3.5	De-watering
A3.3.6	Drying & Packaging
A3.3.7	Take to Stock
A3.4	Quality & Maintenance
A3.5	Sale & Marketing
A3.6	Warehouse of Modified Starch
A4	Customers
A4.1	Transport from Factory
A4.2	Local Customers
A4.3	Oversea Customers
A4.4	Transport by Truck or Train to Customer
A4.5	Transport by vessel to Customers

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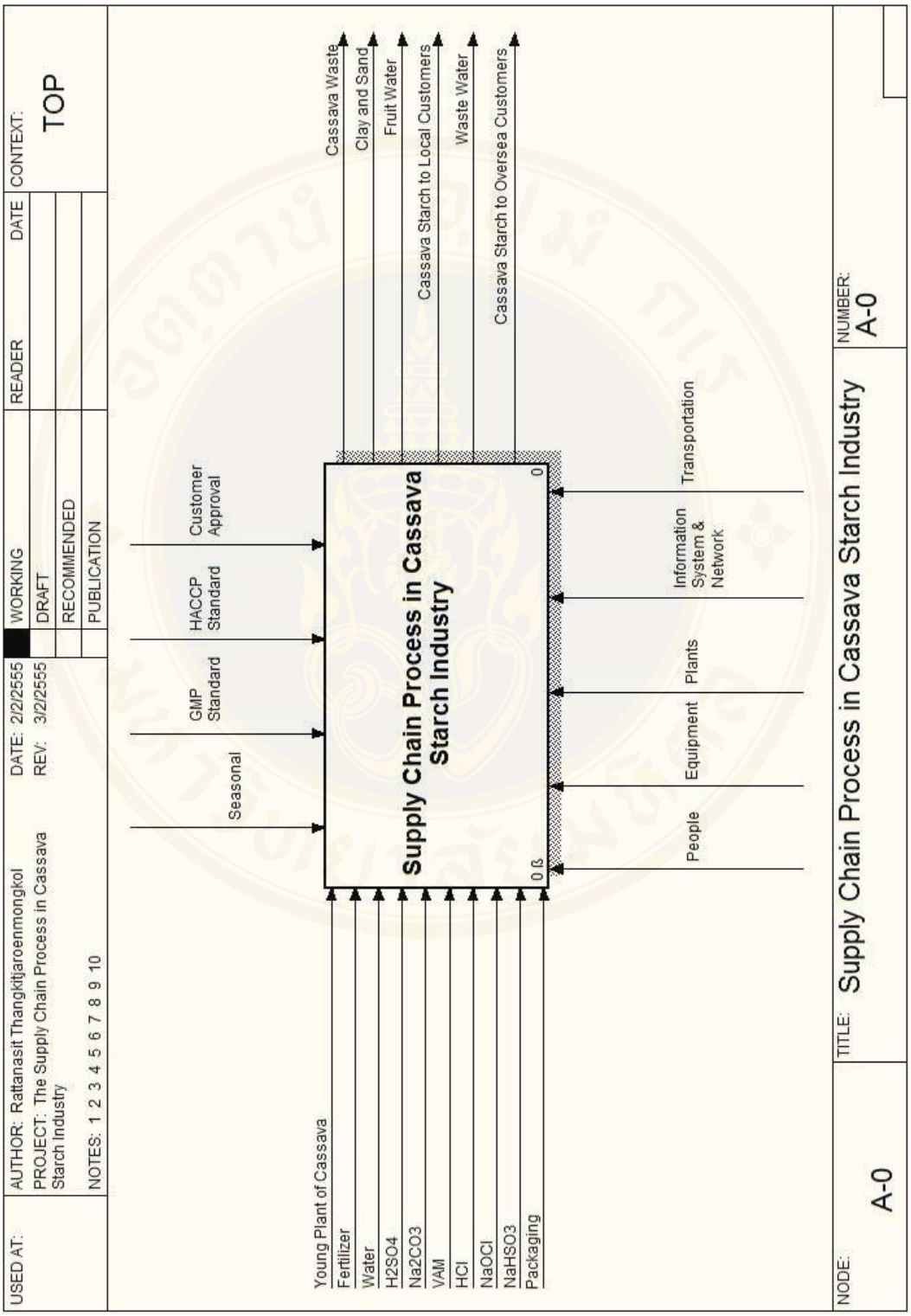

Figure 4.7 The Context Level of Supply Chain Process in Cassava Starch Industry of Thailand

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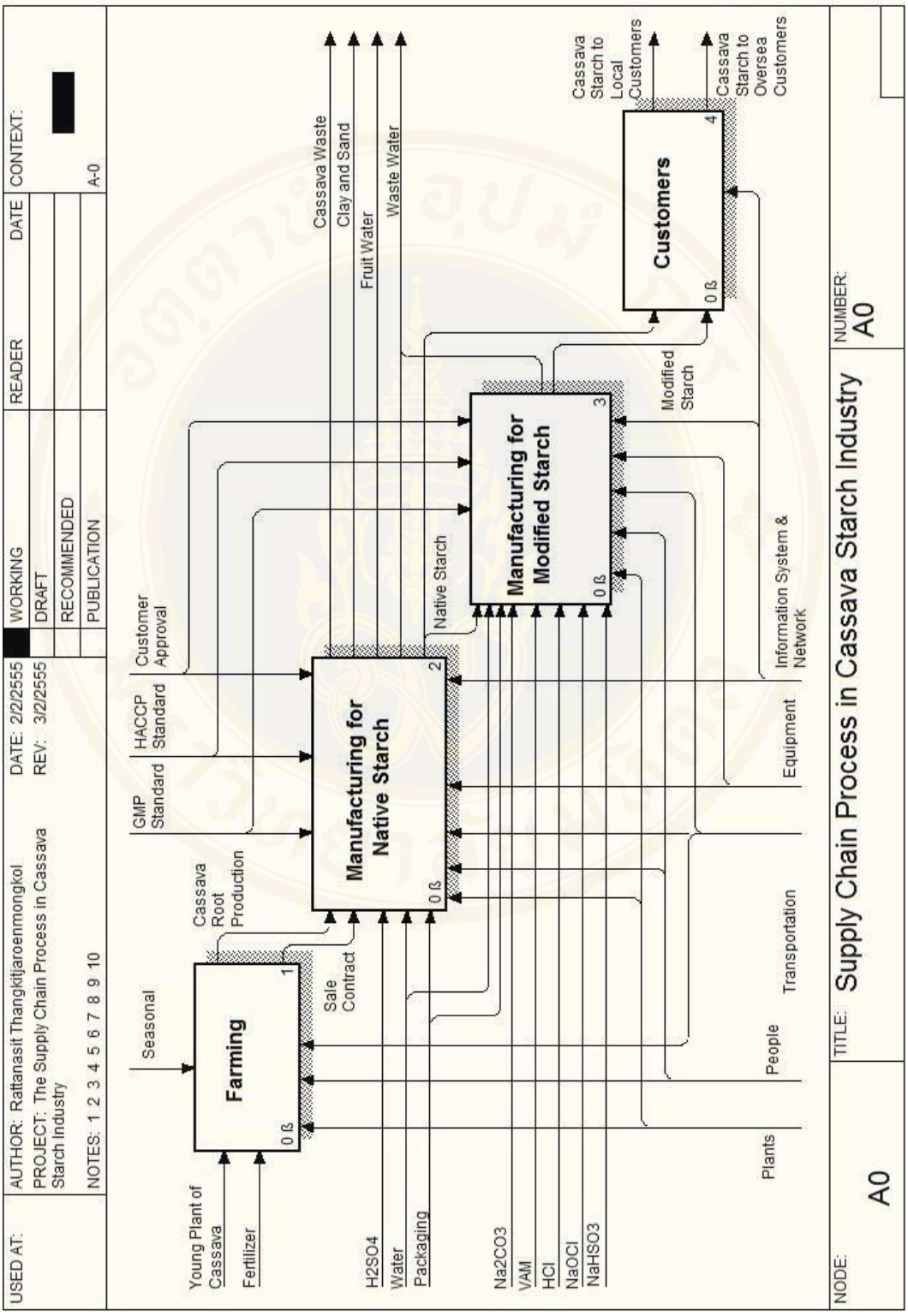

Figure 4.8 The A0 Level to explain relation activity of Supply Chain Process in Cassava Starch Industry of Thailand

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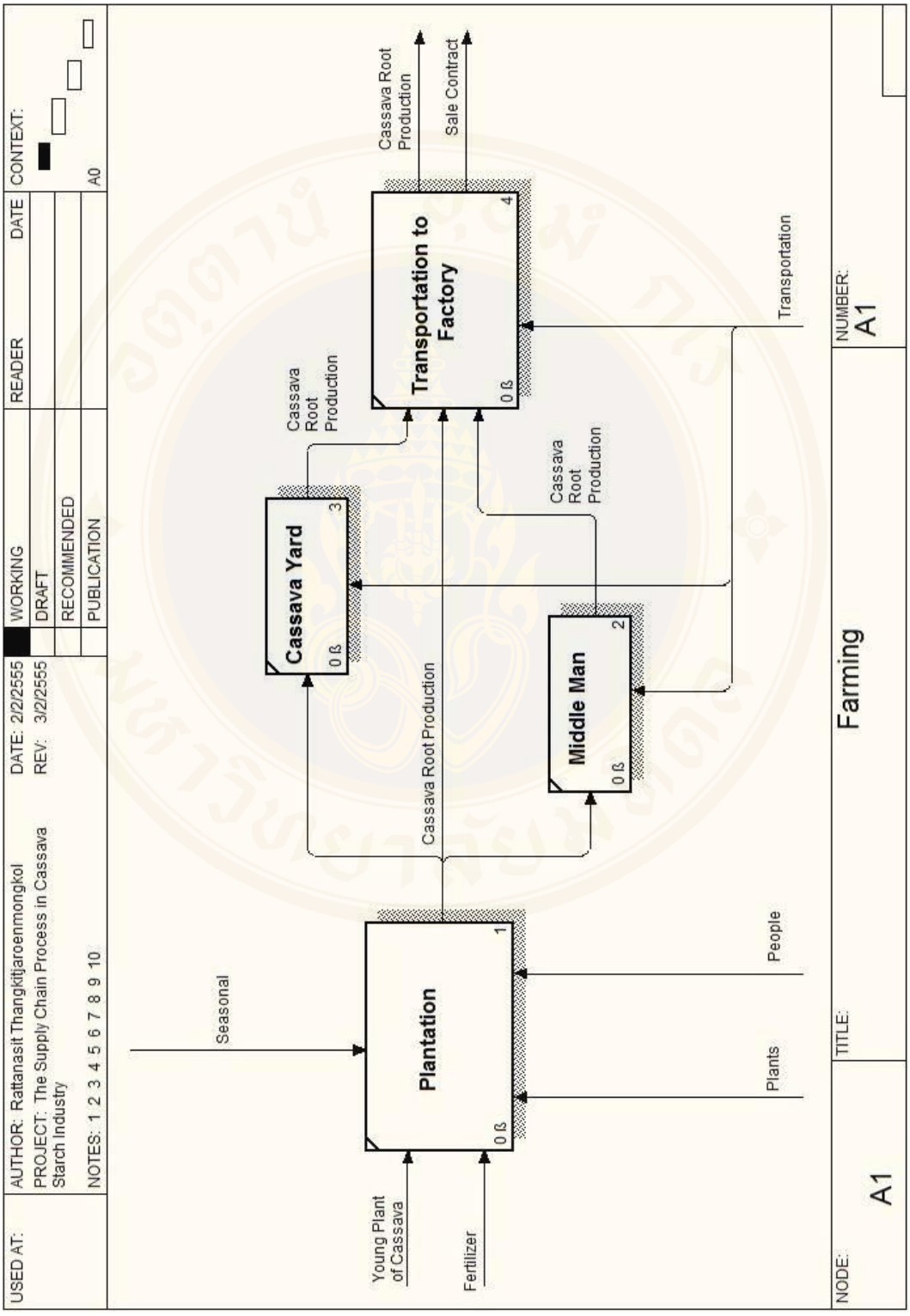

Figure 4.9 The A1 Level to explain the activity in inbound of Supply Chain Process in Cassava Starch Industry of Thailand

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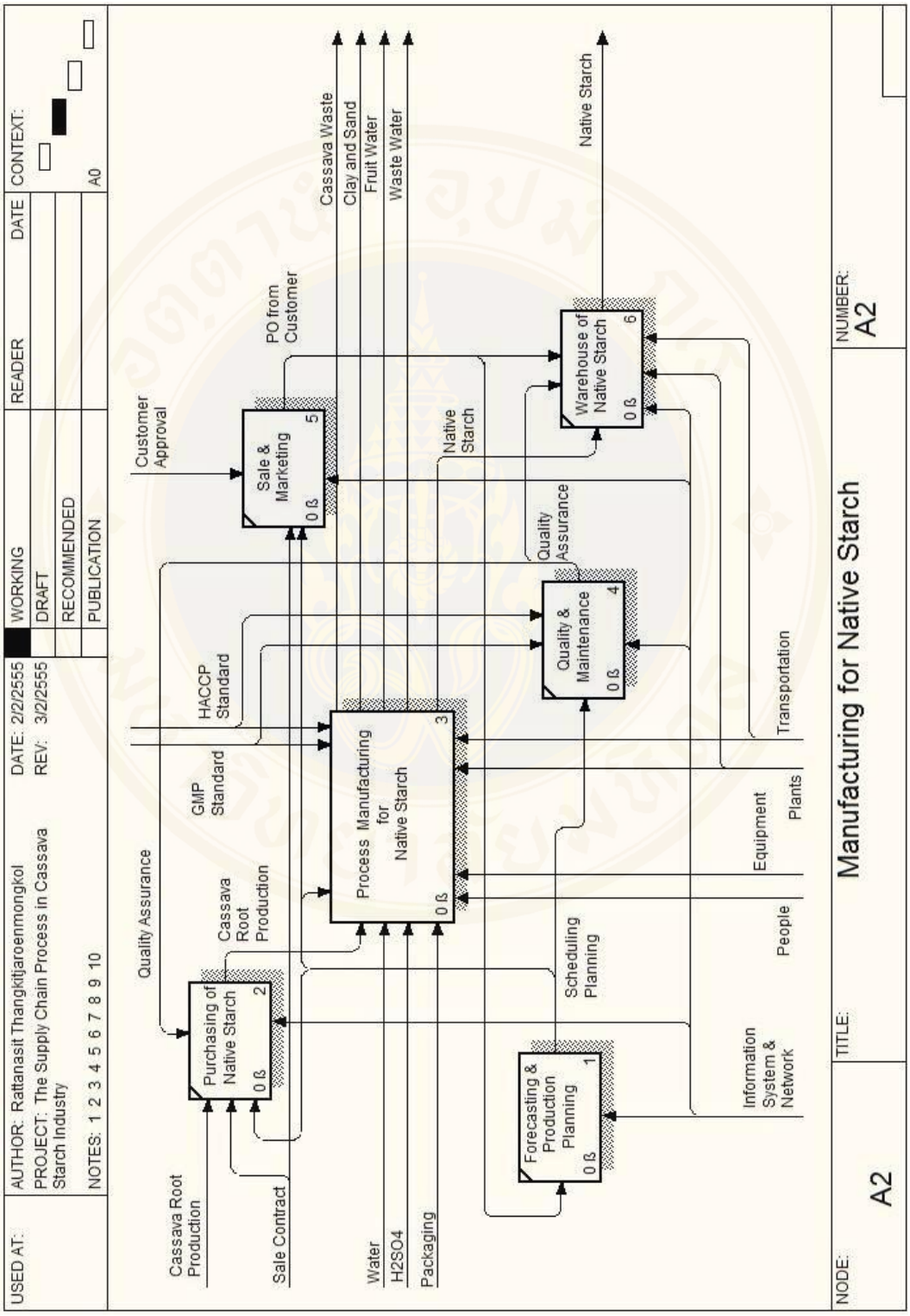

Figure 4.10 The A2 Level to explain the activity in native starch factory of Supply Chain Process in Cassava Starch Industry of Thailand

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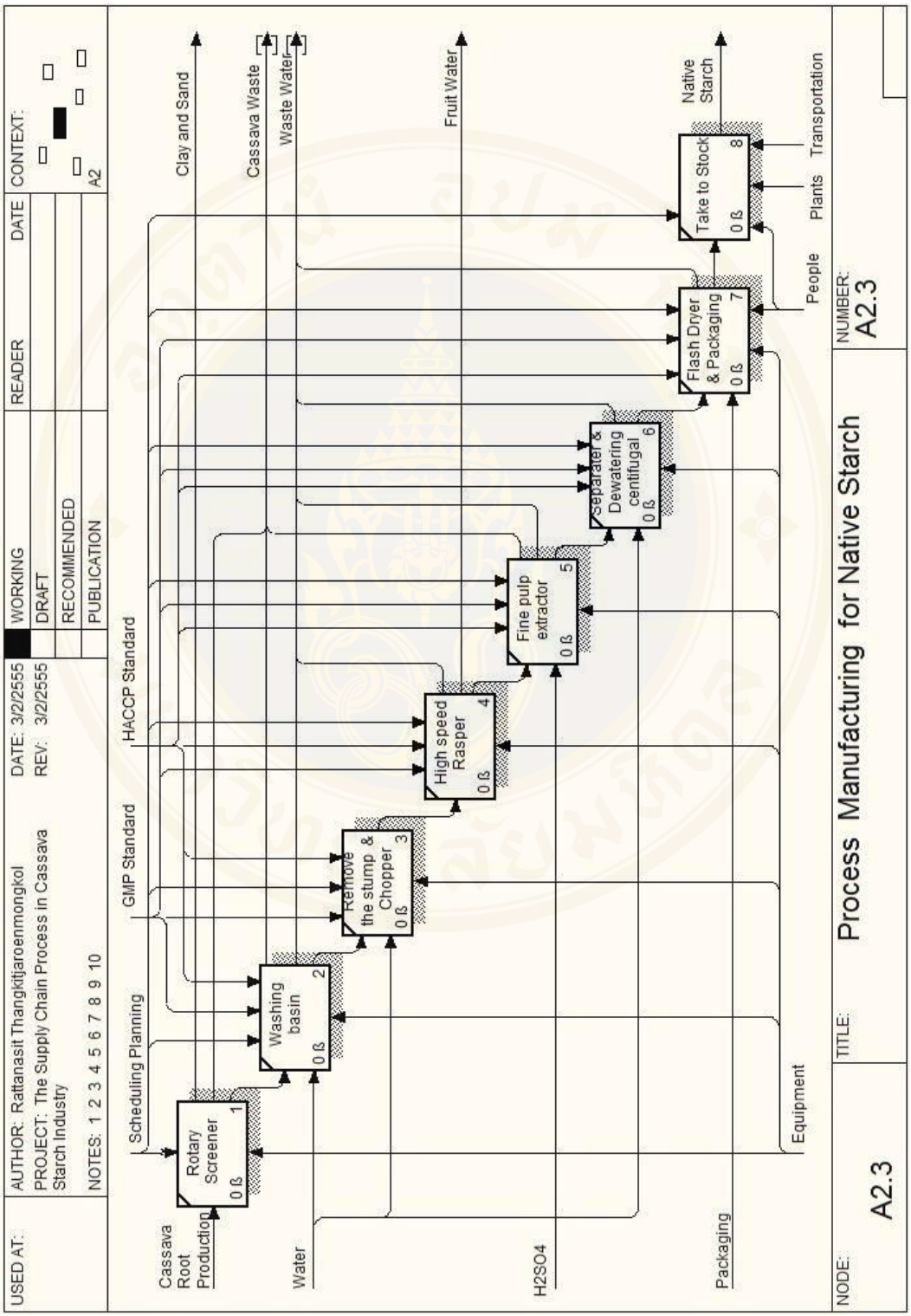

Figure 4.11 The A2.3 Level to explain the native starch process of Supply Chain Process in Cassava Starch Industry of Thailand

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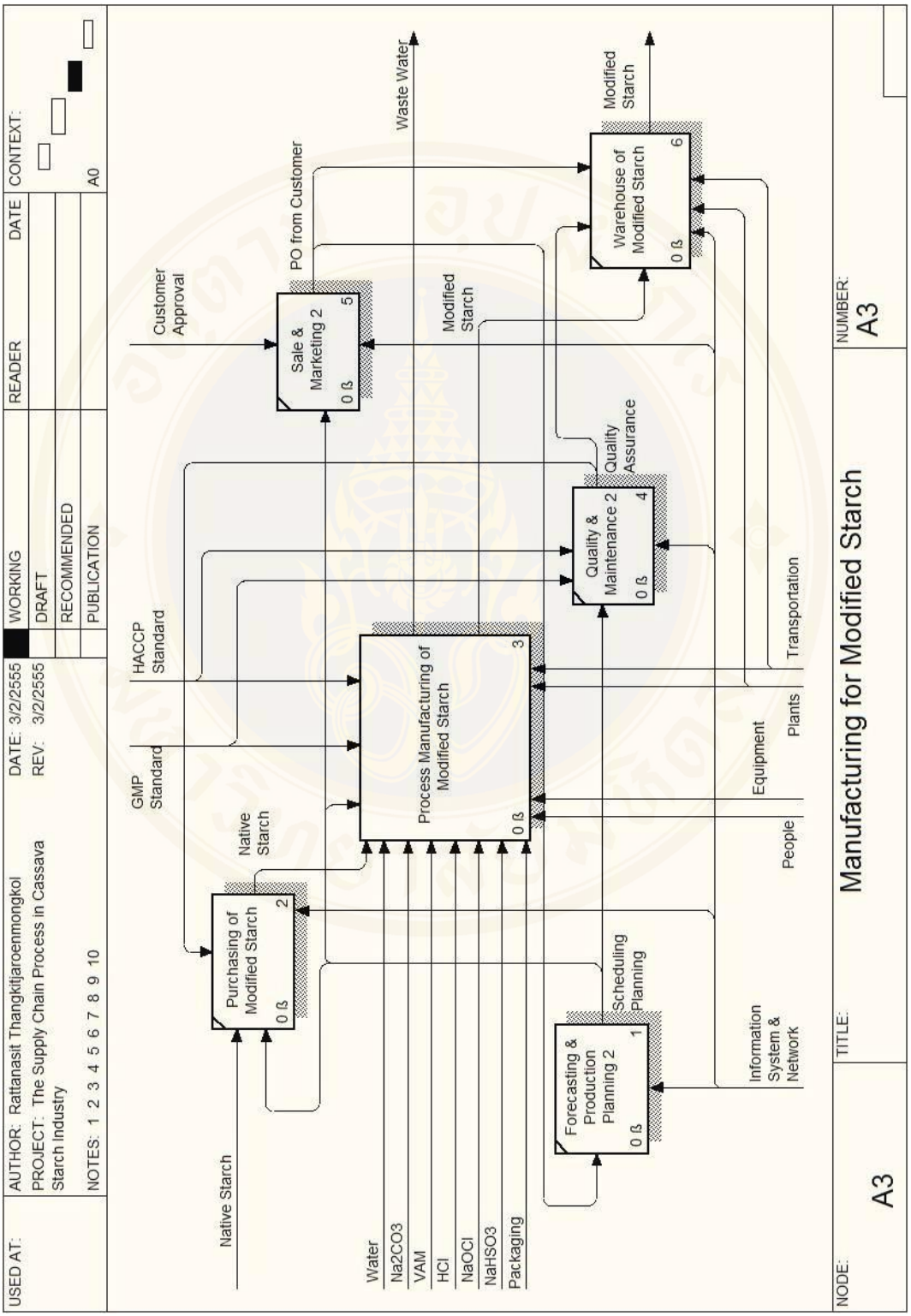

Figure 4.12 The A3 Level to explain the activity in modified starch factory of Supply Chain Process in Cassava Starch Industry

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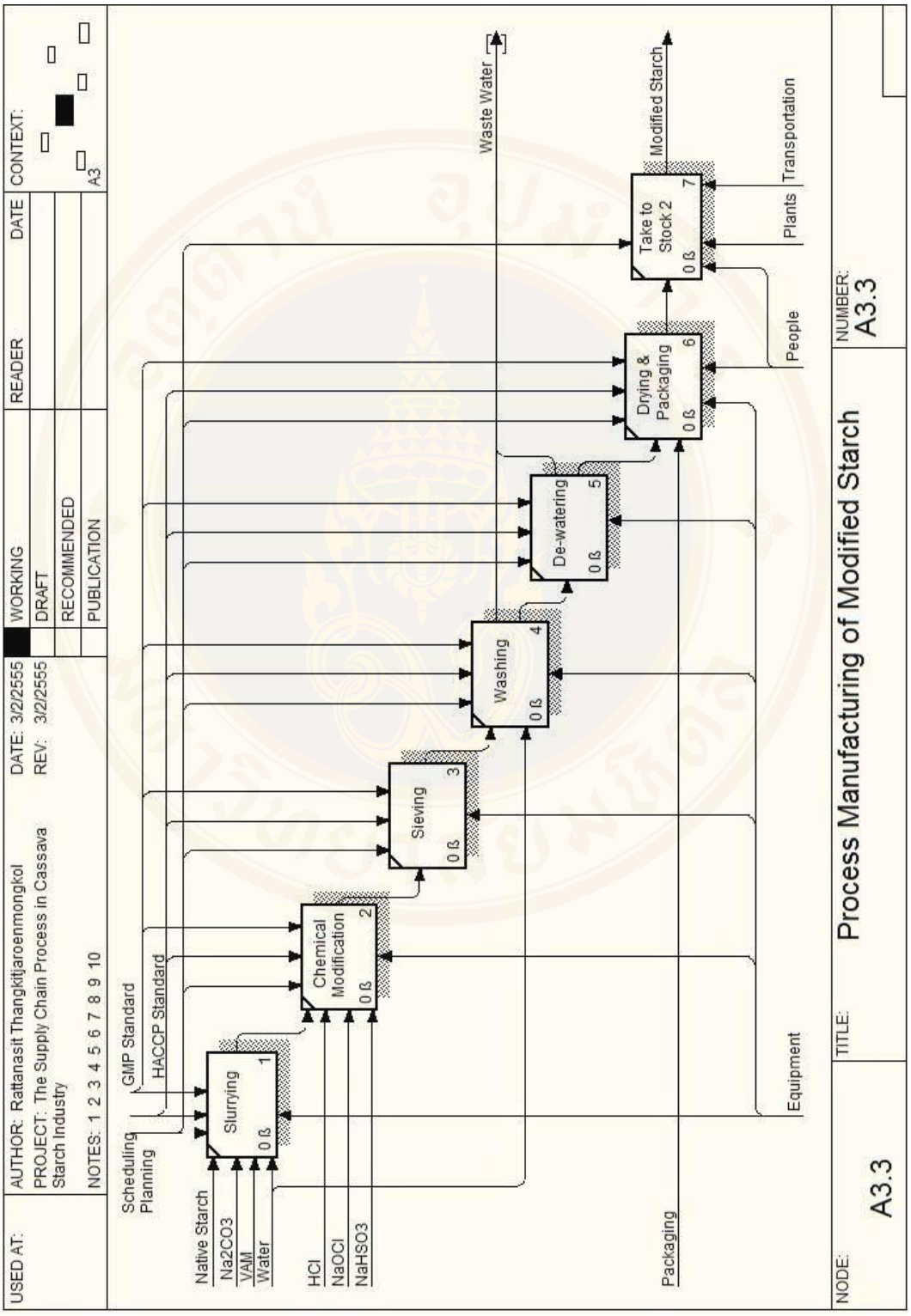

Figure 4.13 The A3.3 Level to explain the modified starch process of Supply Chain Process in Cassava Starch Industry

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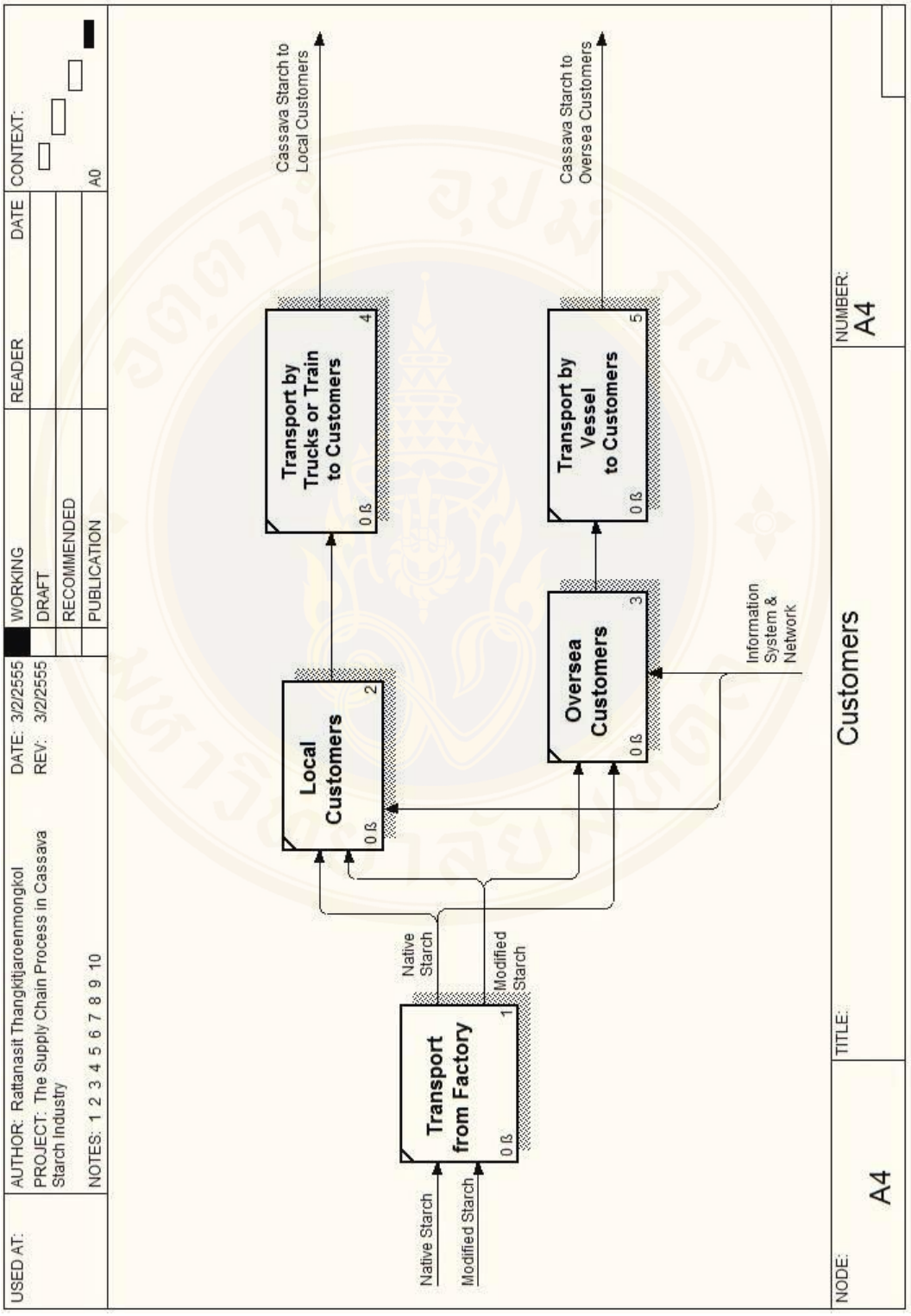

Figure 4.14 The A4 Level to explain the activity in outbound of Supply Chain Process in Cassava Starch Industry of Thailand

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From the figure 4.7 – 4.14 has shown the model of business process of cassava starch supply chain system, in the figure 4.7 was shown the context level on the top of Supply Chain Process in cassava starch industry. There have input from the left side with the young plant of cassava, fertilizer, water, packaging, and chemical compound such as: H_2SO_4, Na_2CO_3, HCl and so on, all of thing is the factors to produce the cassava starch in native and modified. From the control factors in module has from the top with seasonal, Good Manufacturing Practice (GMP) Standard, Hazard Analysis and Critical Control Point (HACCP), and customer approval, which factors help to known the process control in system must depend on. The mechanism factors of this module have from the bottom with people, equipment, plants area, information system & network, and transportation, which factors want to represent about the equipment or utility what there need to produce cassava starch. And the final output from the right to go out the supply chain process, while there want to show the finishing good and waste product from the supply chain system with cassava starch to local customers, cassava starch to oversea customers, cassava waste, clay and sand, fruit water, and waste water. In this context level, we want to understand the overview of the factors that impact to supply chain system. After their known the factors that relate in model next step we were going to analyst and defined in deep of the function in supply chain system of cassava starch industry with the diagram of A0 to known the sub function and activity of supply chain to be inbound logistics system, native starch of cassava manufacturing processing, modified starch of cassava manufacturing processing, and finally in the outbound logistics system to consumers.

In A0 diagram is shown the relationship between the activity of supply chain with farming, manufacturing for native starch, for modified starch and finally to customers as following in figure 4.8. From this diagram have sequences from farming activity when there get young plant to cultivation and using fertilizer to improve the soil of plantation is the input factors, the seasonal to control cultivation process, the mechanism has using the transportation, plant area and people to do, output of the farming activity is cassava roots production and including the information flow about sale contract to the cassava native starch factory. After cassava native starch factory have got the cassava root production, H_2SO_4, water and packaging to be input of diagram. The control of this activity is Good Manufacturing Practice (GMP) and

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Hazard Analysis and Critical Control Points (HACCP) standard to control quality in production process and customer approval about the details of product that there want. Surely to the mechanism of manufacturing of native starch factory and modified starch factory are the same factors with equipment, plant area, people, information system & network, and transportation. The modified starch are also using water and packaging, but there got more about native starch, Na_2CO_3, VAM, HCL, NaOCI $NaHSO_3$ to be input of activity. And output there got the native and modified starch depends on process and finally sending to customers.

From A1 diagram was shown in figure 4.9 has represented the relation of activity of supply chain with farming, just like inbound logistics system also, which one had the young plant of cassava and fertilizer to be the input factors for cultivation and harvest the cassava root production to be output in the right side, the sale contract is the output because the sale contract document had sending to factory after there have the product to be commitment and make sure that cassava farmers did not took the cassava root product to other factory, and there had the control factors from the seasonal to control the suitability of time and weather for plantation. In the mechanism factors of farming module, there used the plants area and people to cultivation and transportation to transport product to factory.

From activities of A2 level of manufacturing in native starch in figure 4.10 are similarly to the activities of A3 level but have different in the factors of input and output of the diagram in figure 4.12. The activities in figure 4.11 are represented the process of cassava starch manufacturing in native starch and similarly like the figure 4.13 to shown about the manufacturing process of modified starch. And finally in figure 4.14 has represented to explain about the logistics outbound of cassava starch industry to sale to local customers or oversea customers.

4.2.2 Business process model with value stream mapping (VSM) in current state

Case study demonstrates the application of value stream mapping in cassava starch manufacturing industry located in the western region of Thailand. With the help of value stream mapping technique current state map of cassava starch manufacturing is prepared and various the bottleneck and lead time these process have

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been identified. To address these gap areas and to bridge the gap between current state and proposed state of manufacturing, a few modifications are made in the current state. With consideration of proposed modification, a future state map is prepared and improvements achieved are noticed.

Current state map of value stream mapping for the cassava starch manufacturing process has shown from below (Figure 4.15). That figure has shown the relationship between manufacturing processes, material and information flow, and these shown the time between process to help us to defined the lead time and queue model. The process of value stream mapping was start from the cassava starch factory had forecast the production of cassava in 60 day before harvest and send the sale contract to took the time meeting when the cassava farmers had send the cassava product to factory. And their factory had sending the fertilizer supply to the farmers to use in their plantation.

After the harvest product of cassava roots, their farmers was used the middle man to transport cassava roots from farms went to cassava starch factory. However, in the front of cassava starch factory have the many trucks which transport the cassava roots from the many farms around the factory to sale cassava product to factory, and the constrain of manufacturing capacity of factory that affecting to made the queuing time take longer and longer again. In the figure 4.15 in the first inventory symbol there have the lead time to waiting before send the cassava roots to the process line has 6 day that is too long to made the productivity of cassava roots to be decline and impact to the machine in the process line to take the cost of maintenance increasingly.

In the process of manufacturing of cassava starch in native starch in figure below that process using the push process to produce the cassava product and they got the value added time to 317 min per unit or 5 hours and the non-value added time to 12,079 min per unit or to be 8 and a half day that occur, and the total time for producing cassava product in a unit is 12,396 min or 8 day and 18 hour to produce from farms transport to factory and modified to be goods are too long. Thereafter, there saw to inventory of the cassava roots has to 4,500 tons, but the capacity of cassava factory is 1,200 tons per day. This is the problem in this research much be concern it.

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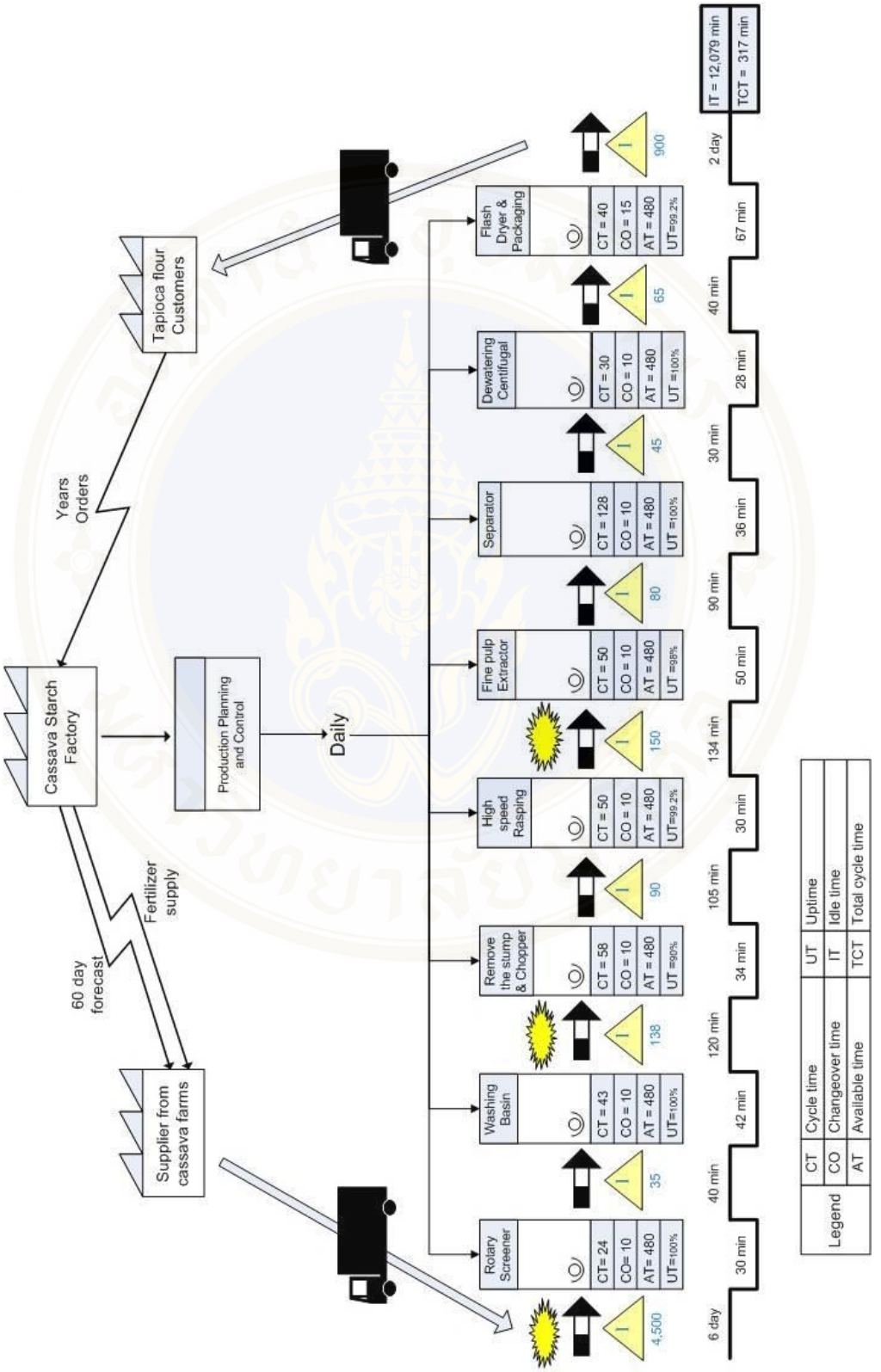

Figure 4.15 The value stream mapping of the current state in supply chain of cassava starch industry in Thailand

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CHAPTER V
RESULTS AND DISCUSSION

The determination of this chapter followed during to design the new business process model of supply chain in cassava starch industry in future state and analysis was focused on inbound transportation and logistics strategies for location-allocation of accumulate center of cassava farmers' cooperation, or cassava service station (CSC), and to decline the distance and time to transport the cassava roots in freshen condition with ordinary K-mean clustering by Weka and modify K-mean clustering with constrain of capacity of cassava product in each cassava location farm by MATLAB, Dijkstra's algorithm, and application of geographic Information system with network analyst, after that, there has to evaluated the new business and manufacturing processes with value stream mapping.

5.1 The design in the new conceptual model of improved business process of cassava starch industry in future state (TO-BE Process)

The discussion of this section was focused on the added information, technique to developed process and particular points to improved business process of cassava starch supply chain management with the mathematical model by K-mean algorithm and geographic information system (GIS) with closest facilities application to improve the transportation process from inbound transportation and logistics system. After there are using the IDEF0 to defined the problem and used technique about the knowledge in manufacturing system improvement in the previous chapters, we can defined and create the future state of the framework of supply chain system of cassava starch industry (TO-BE Process) has shown from below in figure 5.1 – 5.9. The full decomposition of the activity within a cassava starch industry of supply chain system in future state, after to developed and improvement processing, is summarized in table 5.1.

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Table 5.1 A full decomposition of activities within a cassava starch industry of supply chain system in future state

Diagram Level	Details
A0	Supply Chain Process in Cassava Starch Industry
A1	Farming
A1.1	Plantation
A1.2	Middle Man
A1.3	Cassava Yard
A1.4	Accumulate Center of Cassava Farmers Cooperation
A1.4.1	Accumulate from Farms
A1.4.2	Check Inspection
A1.4.3	Rotary Screener Clay & Sand
A1.4.4	Washing Cassava Roots
A1.4.5	Packing to Trucks
A.15	Transportation to factory
A2	Manufacturing for Native Starch
A2.1	Forecasting & Production Planning
A2.2	Purchasing of Native Starch
A2.3	Process Manufacturing for Native Starch
A2.3.1	Rotary Screener
A2.3.2	Washing Basin
A2.3.3	Remove the Stump & Chopper
A2.3.4	High Speed Rasper
A2.3.5	Fine Pulp Extractor
A2.3.6	Separator & Dewatering Centrifugal
A2.3.7	Flash Dryer & Packaging
A2.3.8	Take to Stock
A2.4	Quality & Maintenance
A2.5	Sale & Marketing
A2.6	Warehouse of Native Starch
A3	Manufacturing for Modified Starch
A3.1	Forecasting & Production Planning of Modified Starch
A3.2	Purchasing of Modified Starch
A3.3	Process Manufacturing of Modified Starch
A3.3.1	Slurry
A3.3.2	Chemical Modification
A3.3.3	Sieving
A3.3.4	Washing
A3.3.5	De-watering
A3.3.6	Drying & Packaging
A3.3.7	Take to Stock
A3.4	Quality & Maintenance
A3.5	Sale & Marketing
A3.6	Warehouse of Modified Starch
A4	Customers
A4.1	Transport from Factory
A4.2	Local Customers
A4.3	Oversea Customers
A4.4	Transport by Truck or Train to Customer
A4.5	Transport by vessel to Customers

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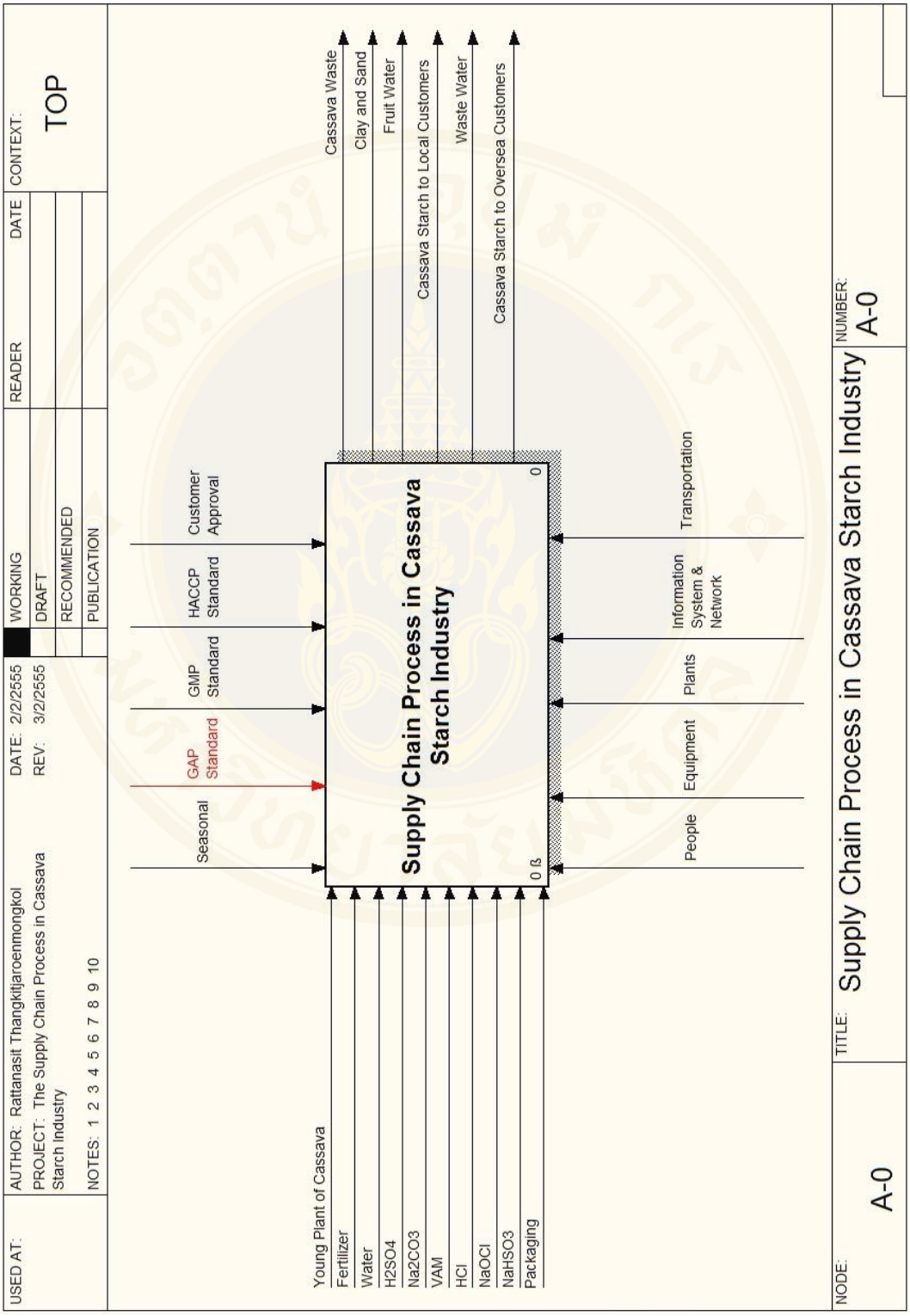

Figure 5.1 The Context Level of Supply Chain Process in Cassava Starch Industry of Thailand in Future State

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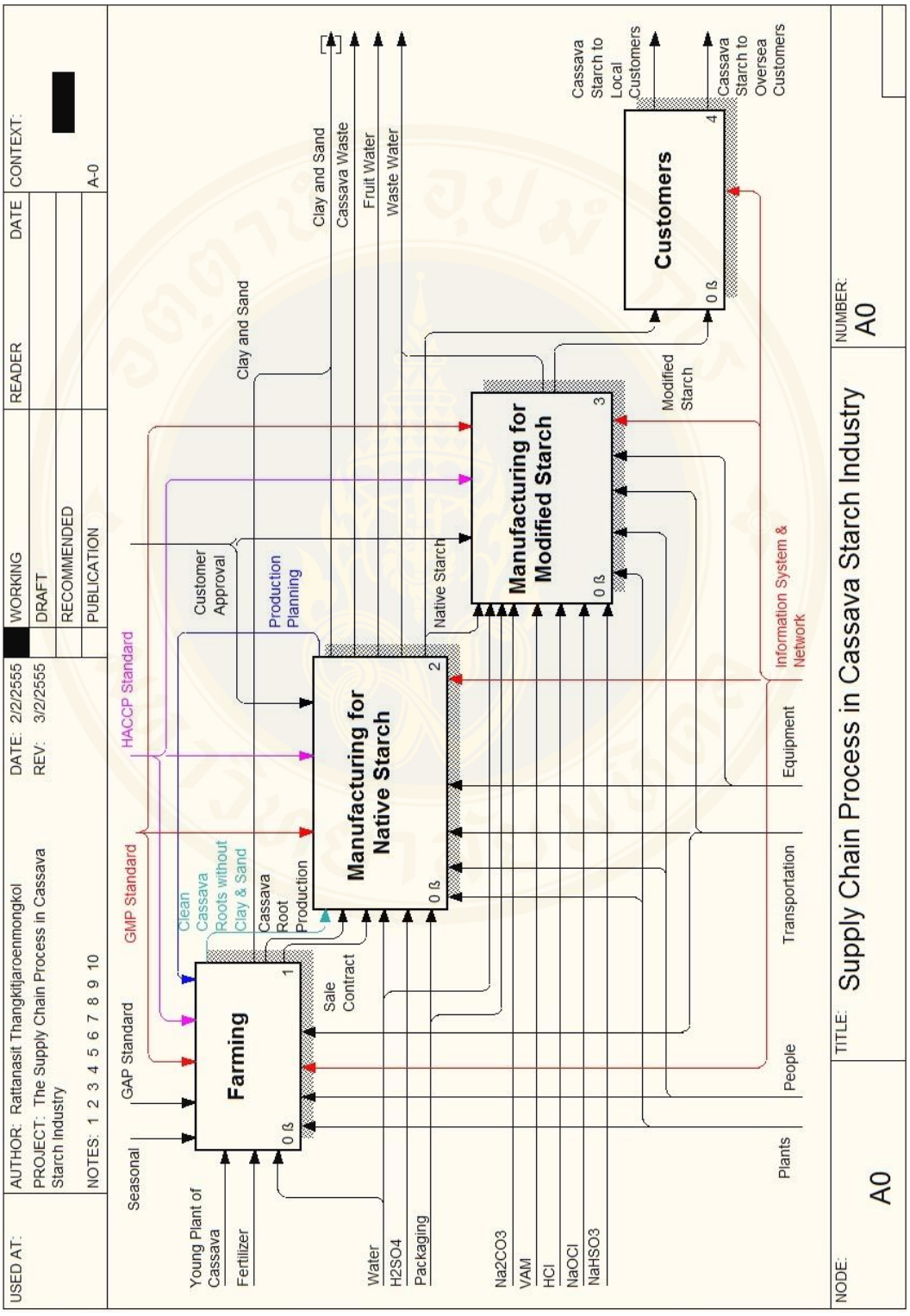

Figure 5.2 The A0 Level to explain relation activity of Supply Chain Process in Cassava Starch Industry of Thailand in Future State

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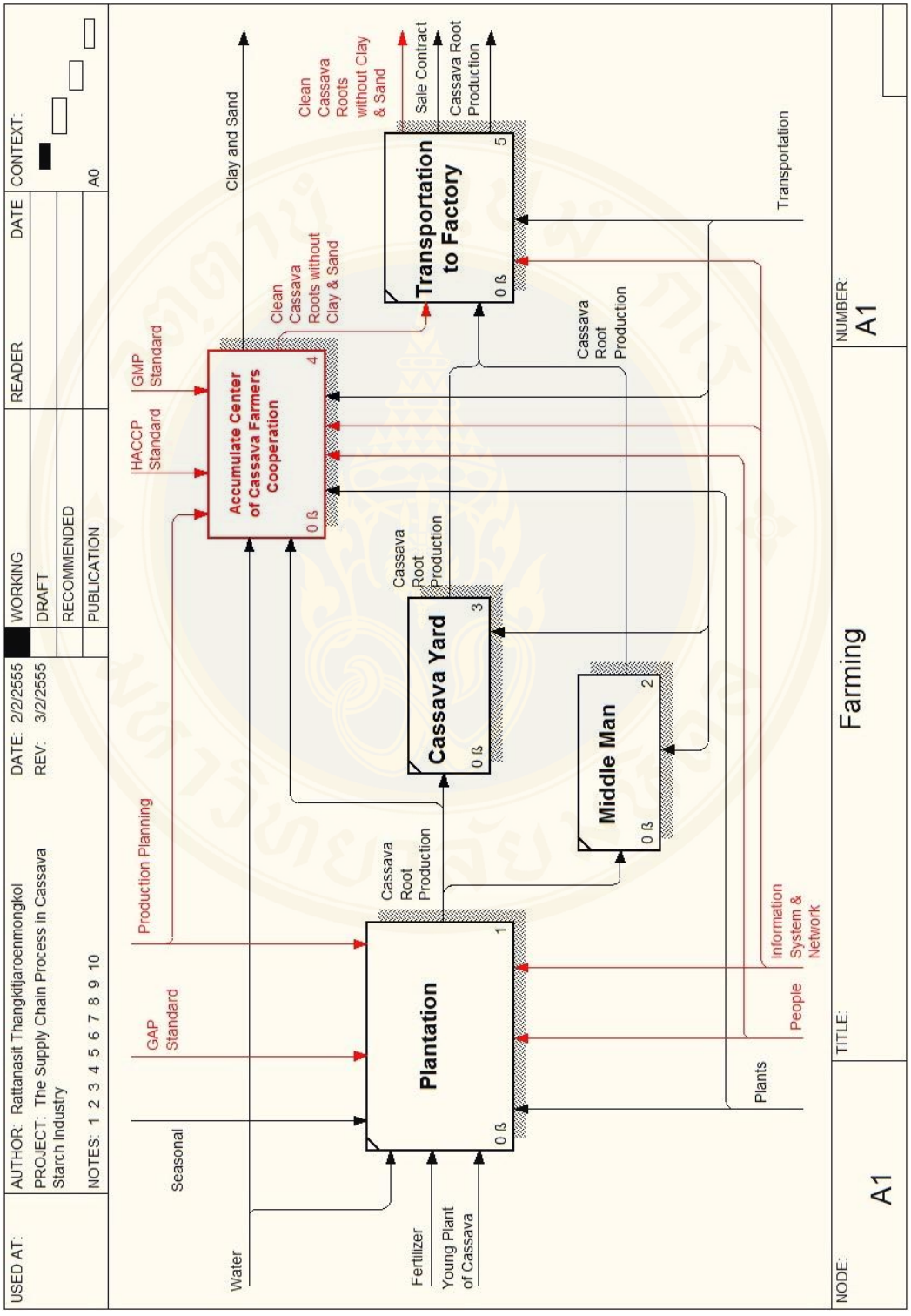

Figure 5.3 The A1 level to explain the activity in inbound of Supply Chain Process in Cassava Starch Industry of Thailand in Future State

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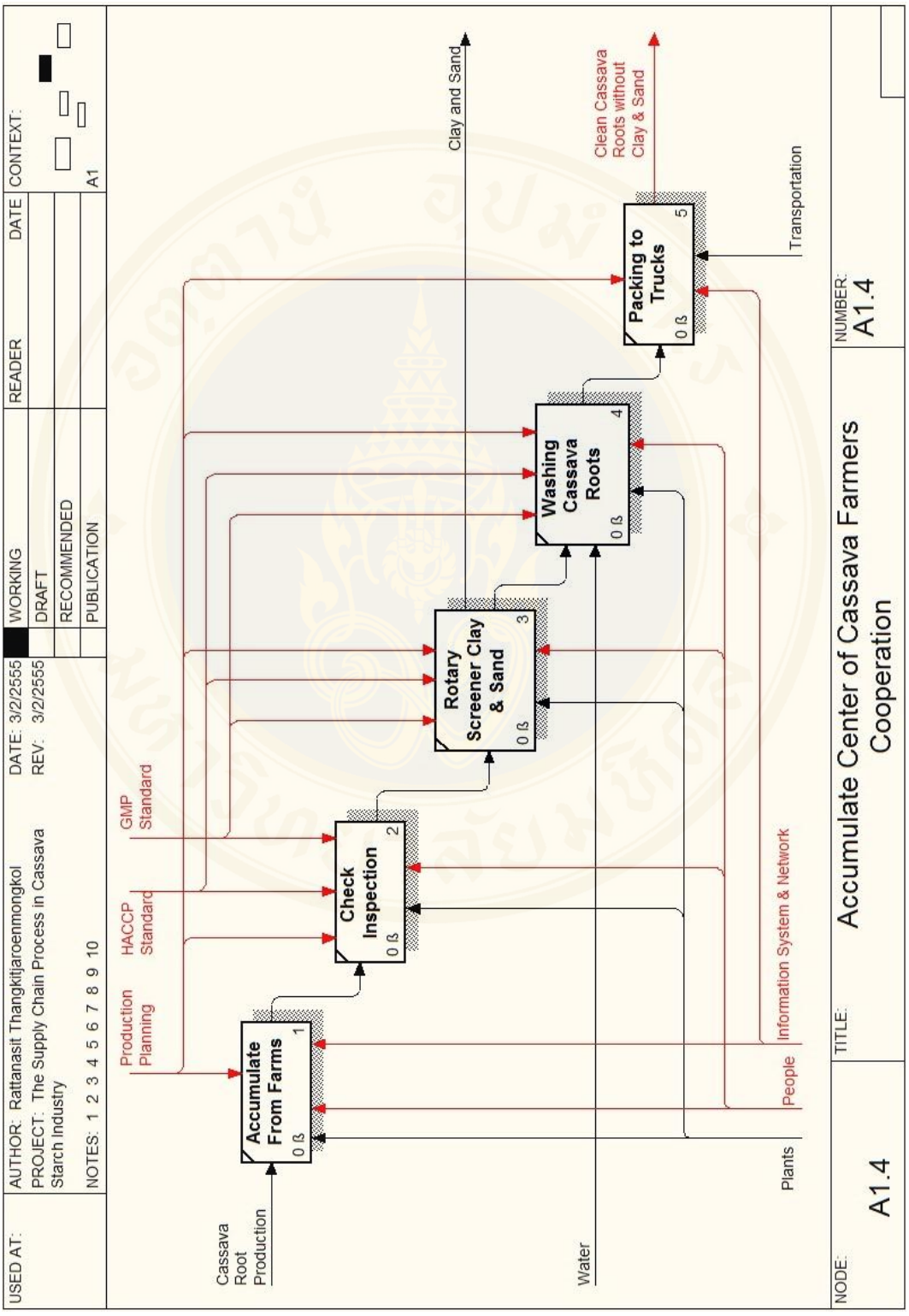

Figure 5.4 The A1.4 level to explain the Activity in Accumulate Center of Supply Chain Process in Future State

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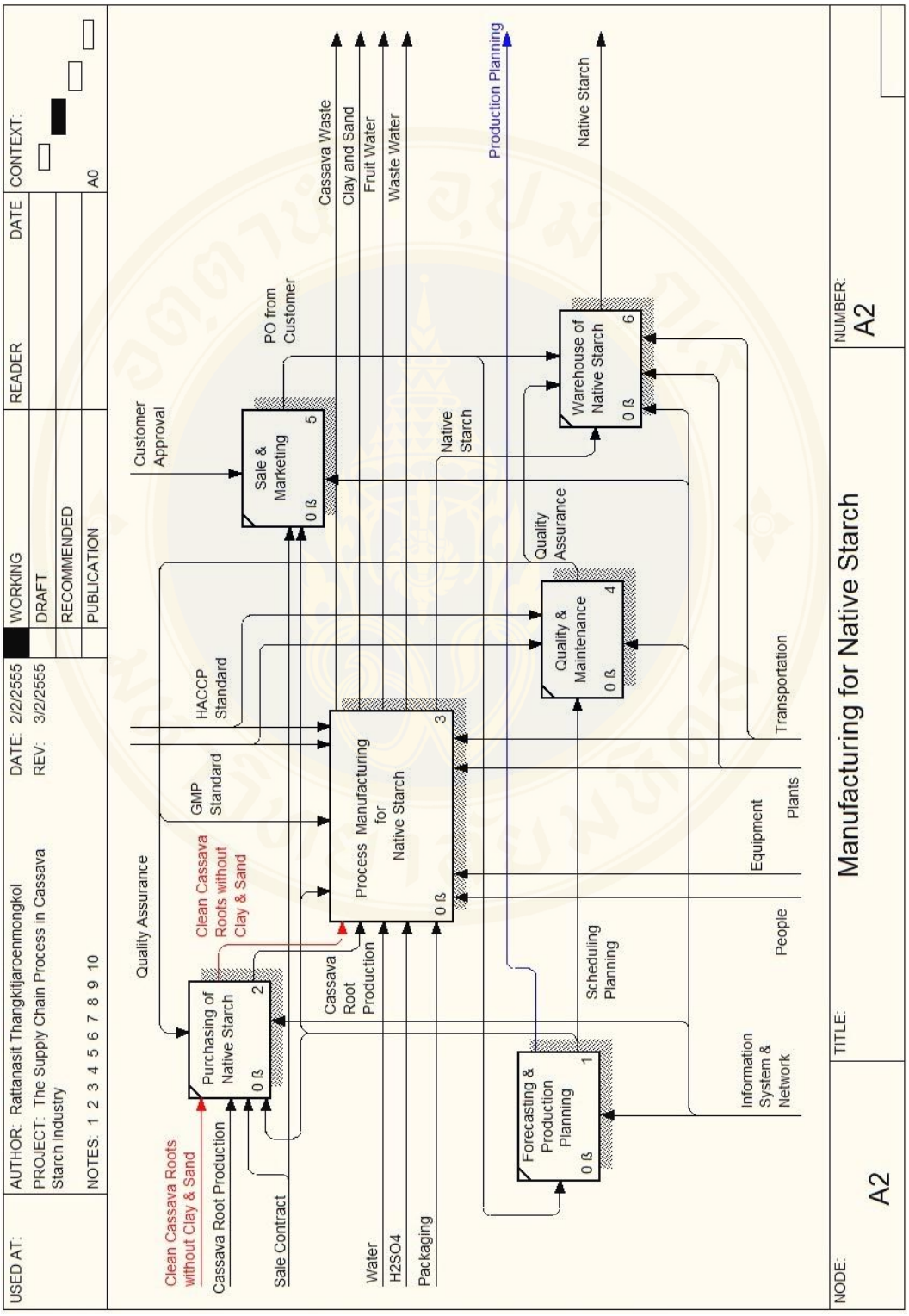

Figure 5.5 The A2 level to explain the activity in native starch of Supply Chain Process in Future State

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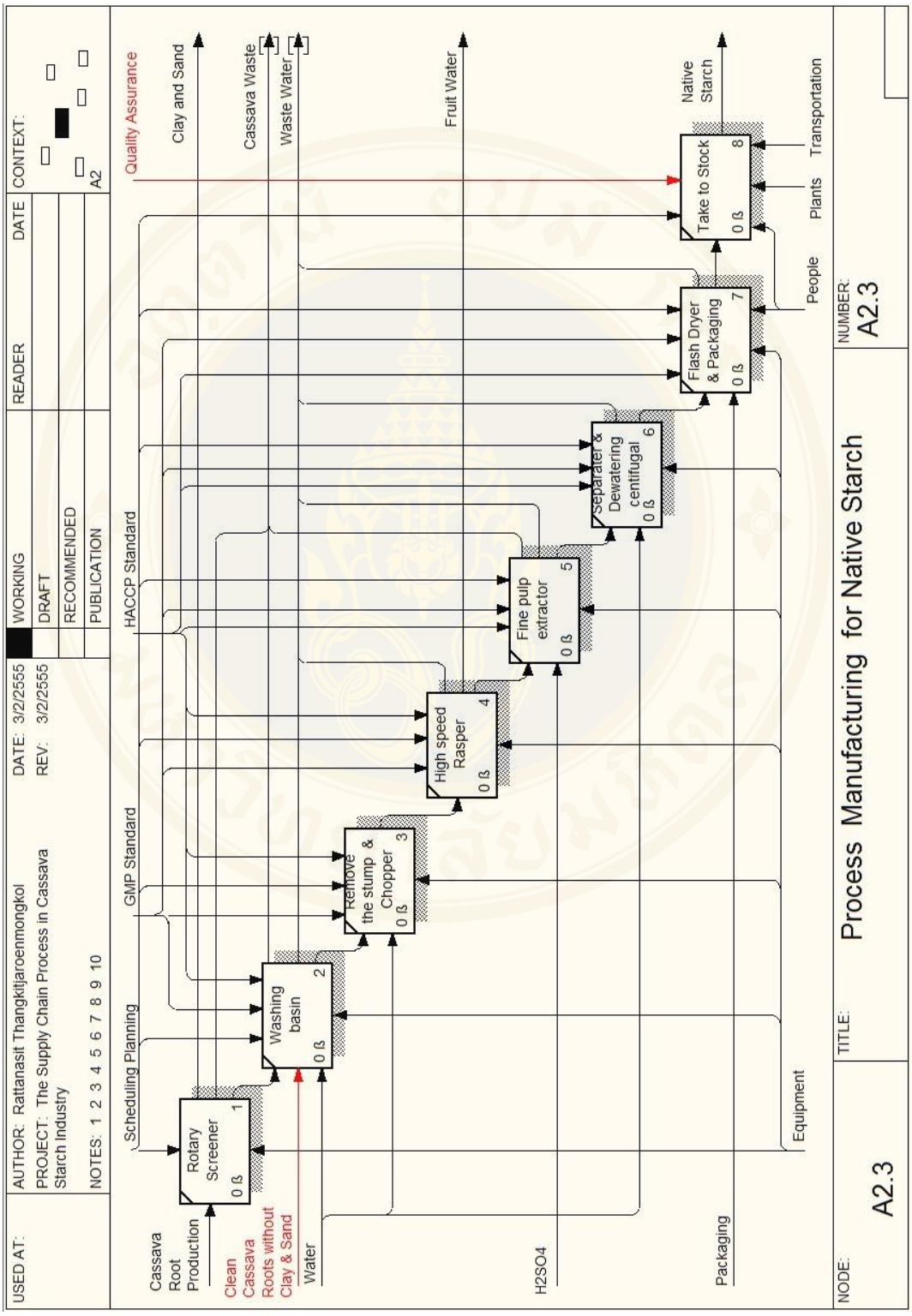

Figure 5.6 The A2.3 level to explain the native starch process of Supply Chain Process in Future State

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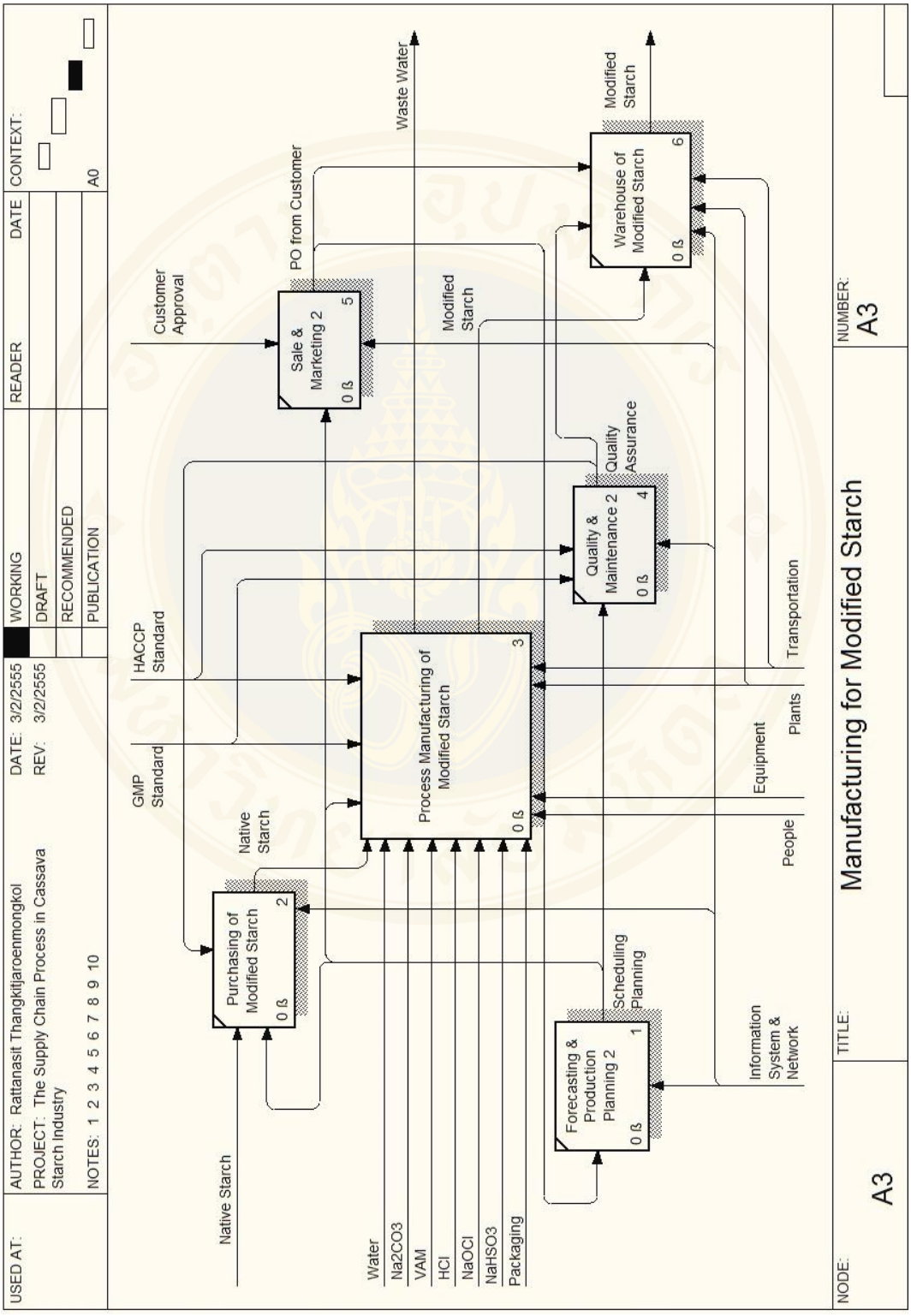

Figure 5.7 The A3 Level to explain the activity in modified starch factory of Supply Chain Process in Future State

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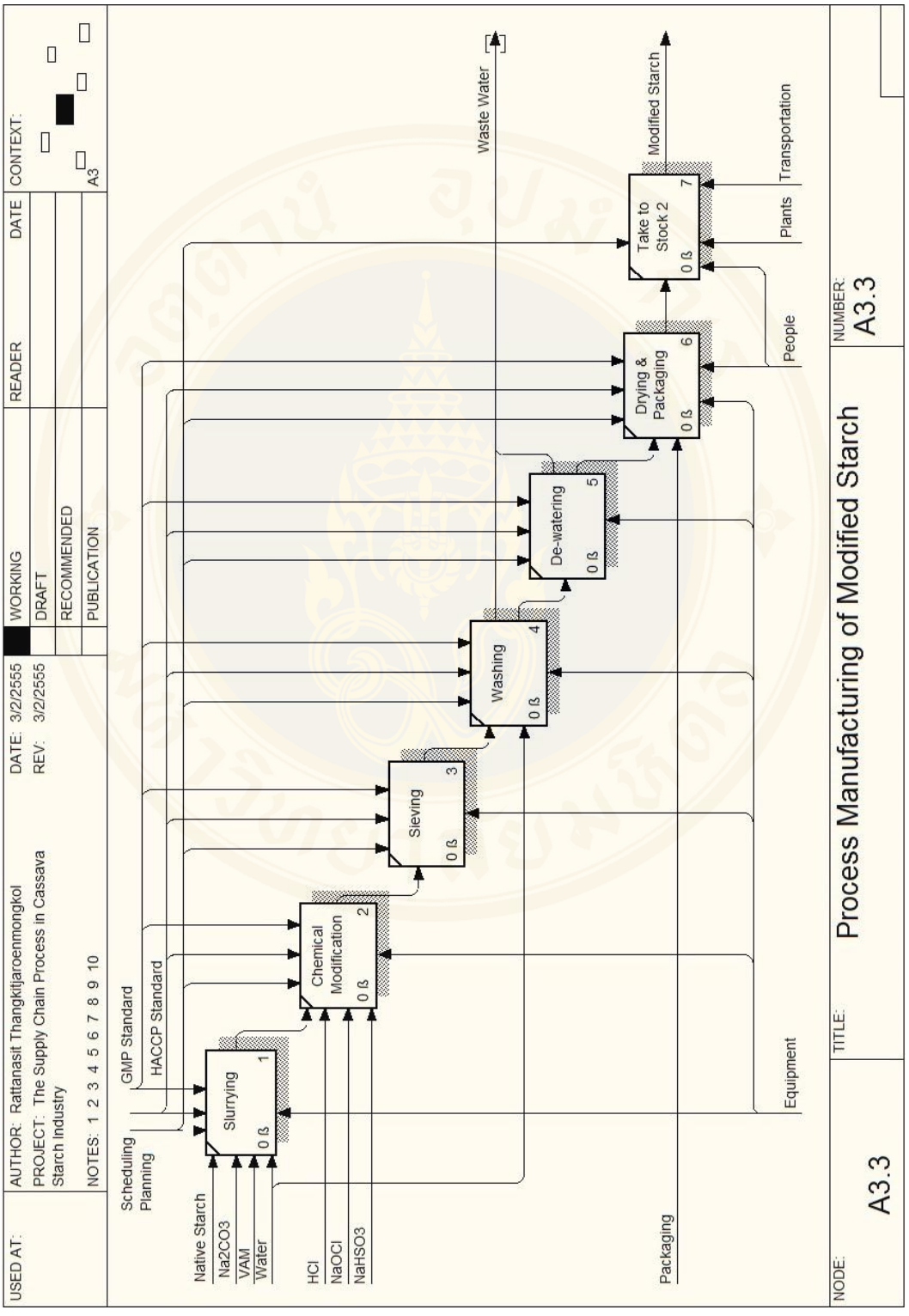

Figure 5.8 The A3.3 Level to explain the modified starch process of Supply Chain Process in Future State

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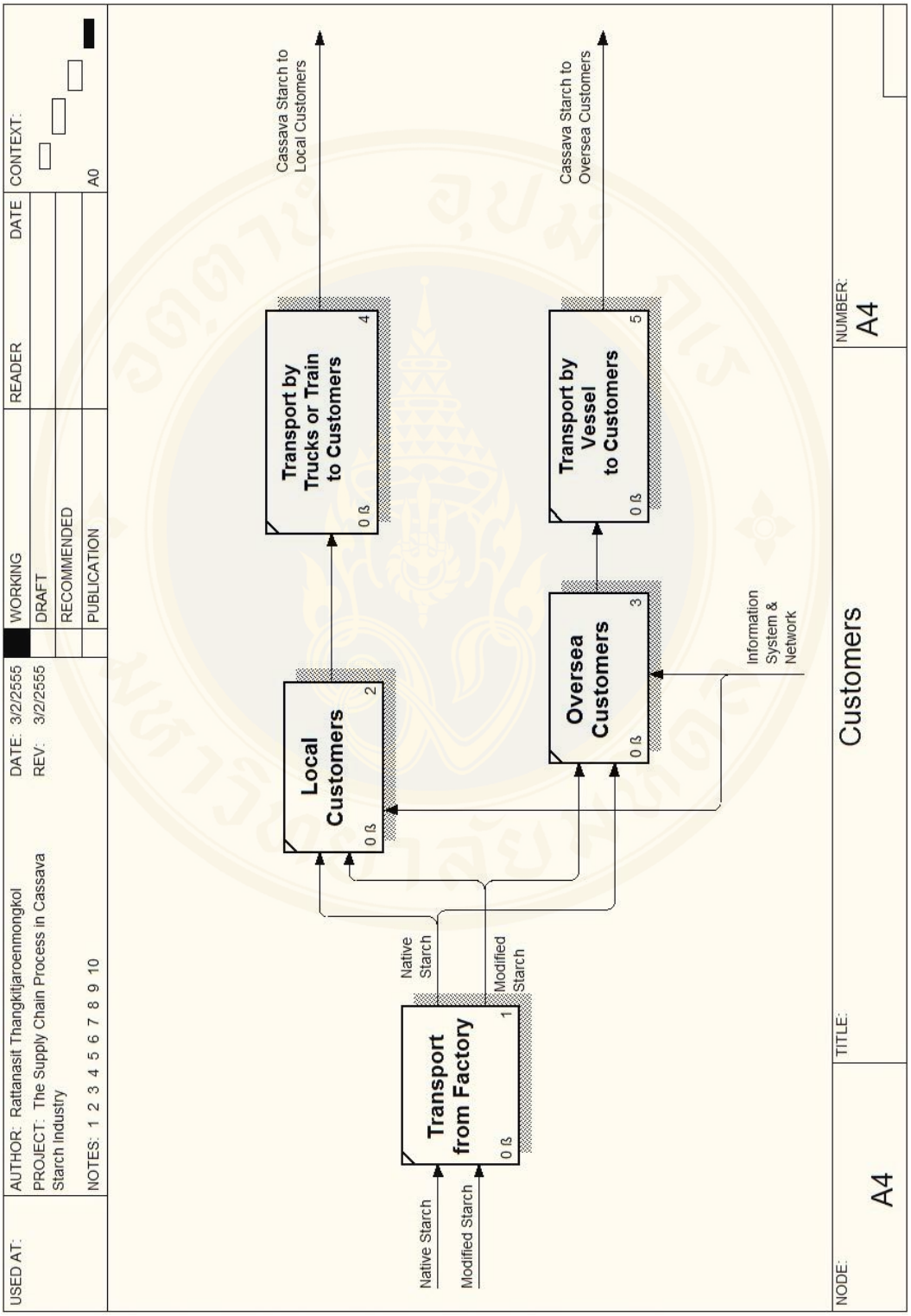

Figure 5.9 The A4 Level to explain the activity in outbound of Supply Chain Process in Future State

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From the figure 5.1 – 5.9 has shown the business process model of cassava starch supply chain system, while there has already improve the process of supply chain system, in the figure 5.1 was shown the context level on the top of supply chain process in cassava starch industry. That figure has shown the input factors, mechanism factors, and output factors were the same like the context level of supply chain process in cassava starch system in the current state. However, only to the control factors has added another one factor with Good Agricultural Practice (GAP) standard to improve the process of farming and plantation of cassava cultivation in order to improve the cassava root productivity.

From the context level, we have to view in deep to the detail of supply chain processing of the function with the diagram of A0 (in figure 5.2) to known the sub function, activity, and relational of supply chain of inbound logistics system, native starch of cassava manufacturing processing, modified starch of cassava manufacturing processing, and finally in the outbound logistics system to consumers.

In the A0 diagram from figure 5.2 has shown the functional of cassava supply chain in the same with the AS-IS process. First, there had the farming function to represent the activity from cassava farms got through the factory like inbound logistics system. However, there has changed the factors from the processing to improve the production in which processing. There have improve with there get the GAP standard in the control factor to improve the process of cultivation in the cassava plantation, and has improved to add-on the GMP and HACCP standard to help in the accumulate center, or Cassava Service Center (CSC), and to decreasing lead time to prepared cassava production and have the production planning document of the factory to the accumulate center in order to balance the queuing from accumulate center get going to customer with scheduling planning which one can help to reduce the queuing in the front of cassava starch factory, and save the freshen of cassava roots before transport to cassava starch factory (in figure 5.3). And the last factors to added in the future state is information system and network to improving the data communication and tractability the cassava root to help the team of production planning can make plan and scheduling to reduce lead time and process time which one must effecting to the capacity of factory will be improvement.

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From the output of the farming module in figure 5.2 is the cassava roots product has cleaning without clay and sand for carry to the manufacturing of starch process module of activity in supply chain, we have design to change about the output of module, there have to communicate about the production planning data has sending to farms owner and Cassava Service Center (CSC) to planning for harvesting and transporting to factory on time scheduling made by department of production planning, native starch factory, and about the information system & network are also design to communicate in two way communication from farms along to customers.

From the A1 diagram in the figure 5.3 has represented to the new design of inbound cassava logistics processes, there have design to plantation control from Good Agricultural Practice (GAP) to make quality in cassava root products. And there got to scheduling from the department of production planning in order to harvesting in schedule for transport to cassava starch factory in time to be process that there can help to decline the waiting time and traffic in front of cassava starch factory. This diagram has added the module of accumulate center of cassava farmers cooperation, in order to manage the cassava roots from farms collect to factory and for help to cassava farmers has value-added to local area to improve income of cassava farmers by cooperation in local area.

In this module of accumulate center of cassava farmers cooperation in figure 5.4 has explanation from figure 5.3 about the activities for preprocesses in the cassava root products to make it clean and fresh. There have got to process control by scheduling from the production planning department of cassava starch factory HACCP and GMP standard, and there got the people to operate in this Cassava Starch Center is the cassava farmers in local area who have free time from harvesting cassava roots product. Therefore, the clean cassava roots have getting transport to cassava starch factory.

In the figure 5.5 has shown the A2 diagram, in this diagram has represented the manufacturing of native starch in cassava starch factory are similarly like the current state in figure 4.10 but there have different in the factors of scheduling from the production planning department has sending to cassava farm owners and CSC locations to make production in time of scheduling plan. And the activities process in native starch manufacturing in diagram A2.3 from figure 5.6 has reduce

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preprocess and there get only to milling the cassava starch production. And there added the quality assurance to control the cassava starch product for make standard check in final before take them to stock.

From activities of A3 in manufacturing of modified starch diagram, A 3.3 in milling process of modified starch diagram and A4 for the customers diagram are nothing change and be the same as the business processes of cassava starch manufacturing in current state.

5.2 The results from new design transportation of inbound logistics management on cassava starch industry in the future state

The new design model of inbound logistics and transportation method has used the ordinary k-mean clustering and modified k-mean algorithm in order to find the best location of cassava yards. Which location had using to be service of collecting, weighting and scheduling planning before transport to cassava starch mill. The k location of cassava yards had random and determined to the best location that was minimize Euclidean distance from many farms in each cassava location yard, and minimize the total distances and investment values from k location of cassava yards.

From the methodology to analysis the location of Cassava Service Center (CSC), there have to analysis in 2 types as below:

- The ordinary k-mean algorithm has been used the Weka program application to design the position and number CSC location in 5, 10, 15, 20, 25, and 30 suitable locations without considering to the volume of cassava roots in cassava farms.
- The modified k-mean algorithm by using MATLAB with including to consider in the volume of cassava root in cassava farms to be weighting parameter design of k-mean clustering of CSC location in 5, 10, 15, 20, 25, and 30 suitable locations.

After there are find out about the suitable location in many types, there have to analyze continuous with dijkstra’s algorithm of closet facility application in GIS to evaluate and establish the routing solution and number of distance are occur in

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each type of number location of CSC. About the investment cost has finding from the fixed and variable cost to investment the CSC location and increasing when there have got more location number of CSC. After all, there have summaries and compare solution in each type to find the minimum total cost solution from transportation cost plus to the investment cost. About the investment cost, there have to analyst to the same cost from table 4.1 and determine to the suitable location area in each Cassava Service Center location.

The summary of total investment cost in the CSC locations has shown in table 5.2 that results of investment cost from that table have used in the method of ordinary k-mean with Weka and modified k-mean with MATLAB in the same types.

Table 5.2 The total investment costs of Cassava Service Center (CSC) location types

Unit: Baht/year

Number of CSC locations	**the service area of CSC location (rai)**				
	3	**5**	**7**	**10**	**20**
30	23,230,416.17	30,584,332.94	45,626,071.00	60,649,258.82	126,681,721.76
25	-	25,701,199.53	38,251,285.21	50,779,110.58	105,818,066.11
20	-	20,876,499.41	30,939,106.51	40,973,888.23	85,022,582.64
15	-	-	23,752,142.01	31,298,517.64	64,363,443.52
10	-	-	-	21,947,776.46	44,045,165.28
5	-	-	-	-	25,090,330.56

From the table 5.2, the investment cost has been different from the number of CSC locations and the service area of CSC location. In some part there do not have costs because in some type there cannot receive cassava root from the capacity of service area. From the serviceable of CSC location have shown in table 5.3 with mean there can or cannot to serviceable from each type of CSC location and service areas. The level of serviceable in each type is depend on the capacity of service area of CSC location can receive and operate to factory. In example, the 30 location of Cassava Service Center (CSC) in service area of 3 rai can receive the cassava root volume not more than 54,750 tons, the average cassava root from farm to 30 CSC location is 53,320 tons. Thus, the service area of 3 rai in 30 CSC locations can be used. But there

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cannot use to the 25 CSC locations because the average volume of s5 CSC location is 63,984.46 tons that volume is much more than 54,750 tons. The 25 CSC locations of service area in 3 rai are not being appeared.

Table 5.3 The serviceable of Cassava Service Center (CSC) in each type.

Number of CSC locations	Average volume of cassava roots in CSC (tons)	the service area of CSC location (rai)				
		3	5	7	10	20
		54,750	91,250	127,750	164,250	328,500
30	53,320.38	Can	Can	Can	Can	Can
25	63,984.46	Can not	Can	Can	Can	Can
20	79,980.57	Can not	Can	Can	Can	Can
15	106,640.76	Can not	Can not	Can	Can	Can
10	159,961.14	Can not	Can not	Can not	Can	Can
5	319,922.28	Can not	Can not	Can not	Can not	Can

5.2.1 The results of new design of transportation model with Weka

From the results of steps to analysis the CSC location without considering to the volume of cassava roots from farms with Weka, there have find out about the number of CSC locations in 5, 10, 15, 20, 25, and 30 locations.

From the data of Cassava Service Center (CSC) locations in the new design of transportation model by without considering in weight of volume of cassava roots in their farms with Weka in 30 location to collected the cassava roots from farms to cassava starch factory have shown in figure 5.10 (Another mapping of CSC location have shown in Appendix C)

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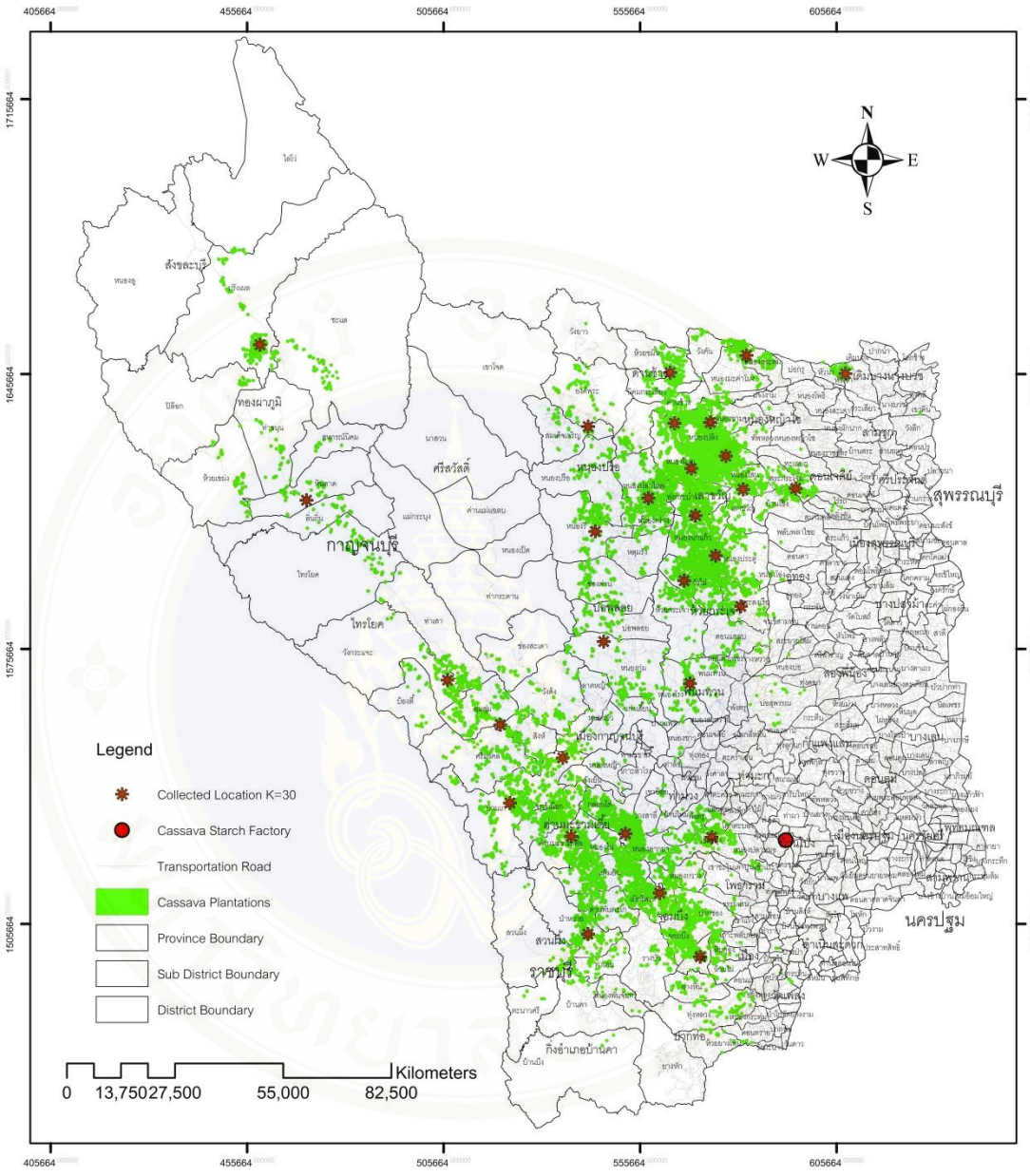

Figure 5.10 The 30 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka

From the step of analysis the distance of transportation process, there have used the dijkstra's algorithm and closest facility of GIS application to evaluate and establish the transportation routing with the same 2 steps like in the current state: from cassava farms accumulate to CSC 30 location centers and from 30 CSC locations to cassava starch factory. There are shown in figure 5.11 and 5.12, respectively. (Another mapping of CSC location have shown in Appendix C)

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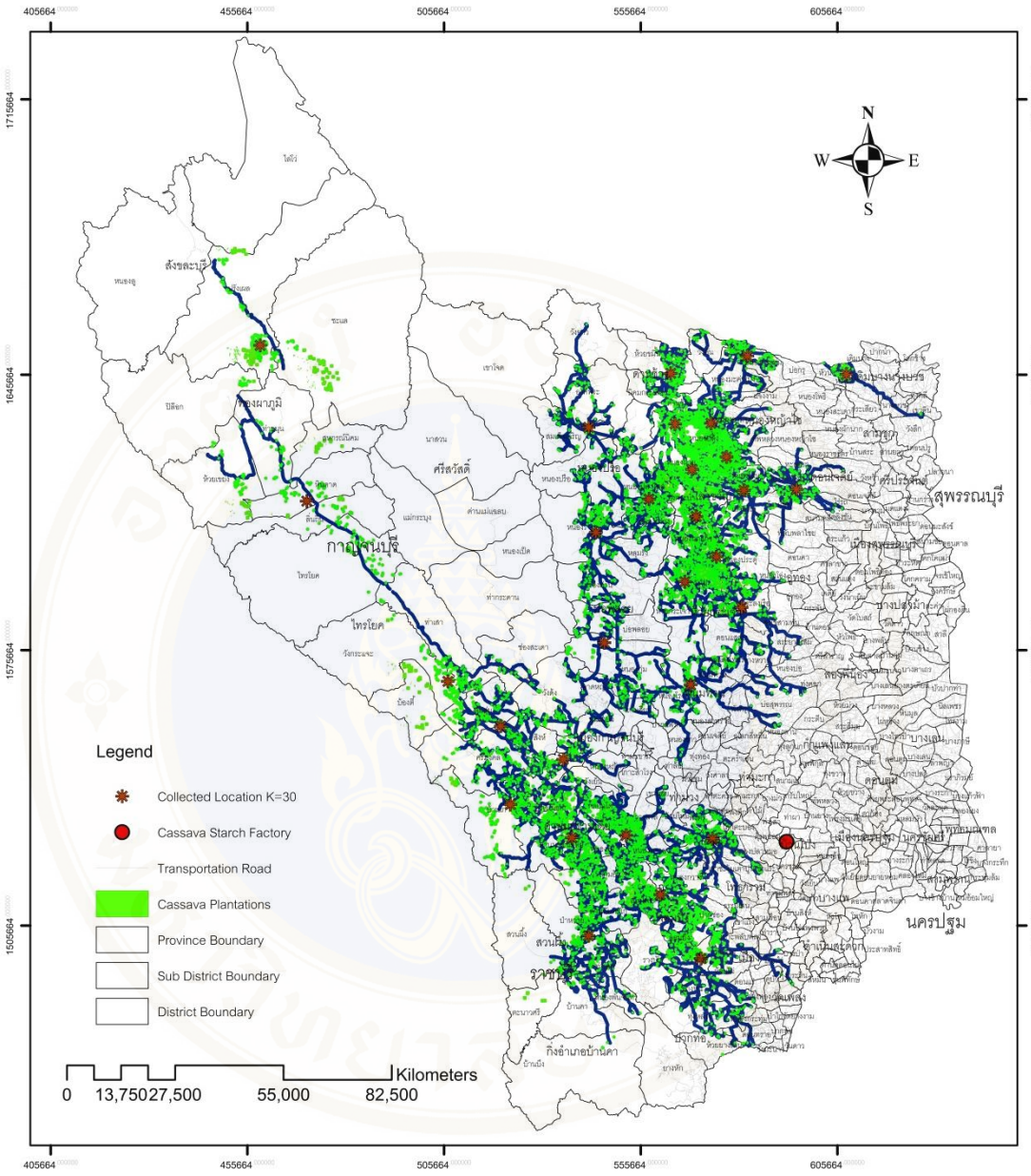

Figure 5.11 The 30 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka

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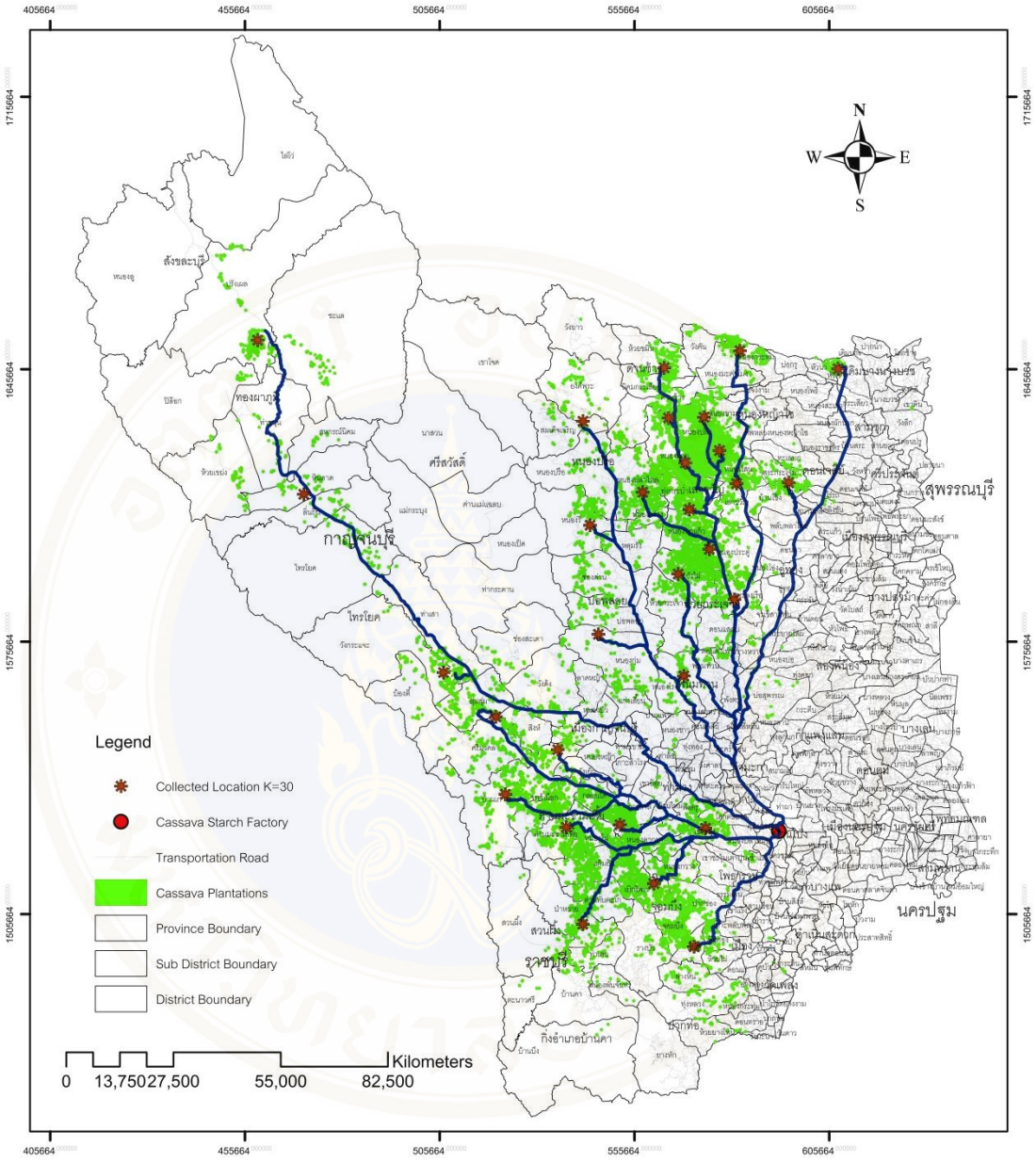

Figure 5.12 The 30 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka

The total distances after their got the CSC location and evaluates the distance from cassava farms to factory and there have multiply by the number of trucks to transport from each farm to CSC and CSC to factory (the total distance there have analysis from the distance direct from farms to SCS and SCS to factory, and multiply by the number of trips, calculate by capacity of farms divide by 21 tons that

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mean the truck can carry weight of cassava root per trip in 21 tons) with dijkstra's algorithm and closest facility of GIS application has shown in table 5.4

Table 5.4 The results of total distance from farms pass to CSC to factory with Weka

Unit: kilometers/year

Number of Centroids	Total Distance from Farm to CSC	Total Distance from CSC to Factory	Total Distance
30	707,223	6,705,315	7,412,538
25	778,861	6,718,139	7,497,001
20	963,362	6,662,467	7,625,830
15	1,100,210	6,718,972	7,819,182
10	1,271,557	6,728,986	8,000,543
5	1,732,073	6,710,167	8,442,240

From the table 5.4 have shown the distance from cassava farms to CSC locations and there are go to cassava starch factory. The results have shown about the distance has increasing when reduce the number of CSC location. However, there do not conclude it mean like when there got more CSC location, there were reduce the transportation cost and total cost. Because of the total cost in this research has including to consider about the investment cost. To the total transportation costs with Weka by ordinary k-mean clustering has shown in table 5.5 (the transportation costs was calculated from the fuel consumption of 10 wheel of trucks is 10 kilometer/lite and the diesel prices in situation of this research study is 30 baht/lite).

Table 5.5 The results of transportation cost of CSC location with Weka

Number of CSC locations	Average Capacity in CSC locations (tons)	Total Distance (km)	Total transportation cost (Baht)
30	53,320.38	7,412,538	22,237,616.96
25	63,981.72	7,497,001	22,491,004.71
20	79,980.57	7,625,830	22,877,490.58
15	106,640.76	7,819,182	23,457,547.51
10	159,961.14	8,000,543	24,001,631.66
5	319,922.28	8,442,240	25,326,722.48

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About the investment cost, there have analysis from the table of 5.2. The results from many CSC location type have shown in table 5.6 that their got the total investment cost plus to the total distance cost from cassava farms to factory by passing to the CSC locations.

Table 5.6 The results of total cost from number of CSC location analysis with Weka.

Unit: Baht/year

Number of CSC locations	the service area of CSC location (rai)				
	3	**5**	**7**	**10**	**20**
30	45,468,033.13	52,821,949.89	67,863,687.96	82,886,875.77	148,919,338.72
25	-	48,192,204.23	60,742,289.91	73,270,115.29	128,309,070.82
20	-	43,753,989.98	53,816,597.08	63,851,378.81	107,900,073.22
15	-	-	47,209,689.52	54,756,065.15	87,820,991.03
10	-	-	-	45,949,408.12	68,046,796.95
5	-	-	-	-	50,417,053.05

From the table 5.6, the results have shown about the total cost from cassava farms to CSC location and getting to cassava starch factory in finally. In the lowest cost are from the number of CSC location is 20 location, that have the total cost from transportation and investment cost in 43.7 million baht/year. And the number of iterations and sum of square error has shown in table 5.7 when there analysis by Weka (the results of CSC location in UTM scale has shown in Appendix 2).

Table 5.7 The results of number of iterations and sum of square error from analysis the ordinary k-mean clustering with Weka

Number of CSC locations	Number of iterations	Sum of square error
30	93	17.16908
25	60	20.44274
20	51	25.49823
15	37	39.37905
10	28	61.85386
5	19	110.0319

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5.2.2 The results of new design of transportation model with MATLAB

From the results of steps to analysis the CSC location with including to consider the volume of cassava roots from each farm by coding with MATLAB, there have find the optimal solution from the number of CSC locations in 5, 10, 15, 20, 25 and 30 locations.

From the data of Cassava Service Center (CSC) locations in the new design of transportation model by including to consider in weight of volume of cassava roots from farms with one parameter of k-mean algorithm to find the optimal solution of total cost with MATLAB in 30 location to collected the cassava roots from cassava farms to cassava starch factory have shown in figure 5.13 by plot the figure with MATLAB and 5.14 by plot in GIS program (Another mapping of CSC location have shown in Appendix B and D, respectively)

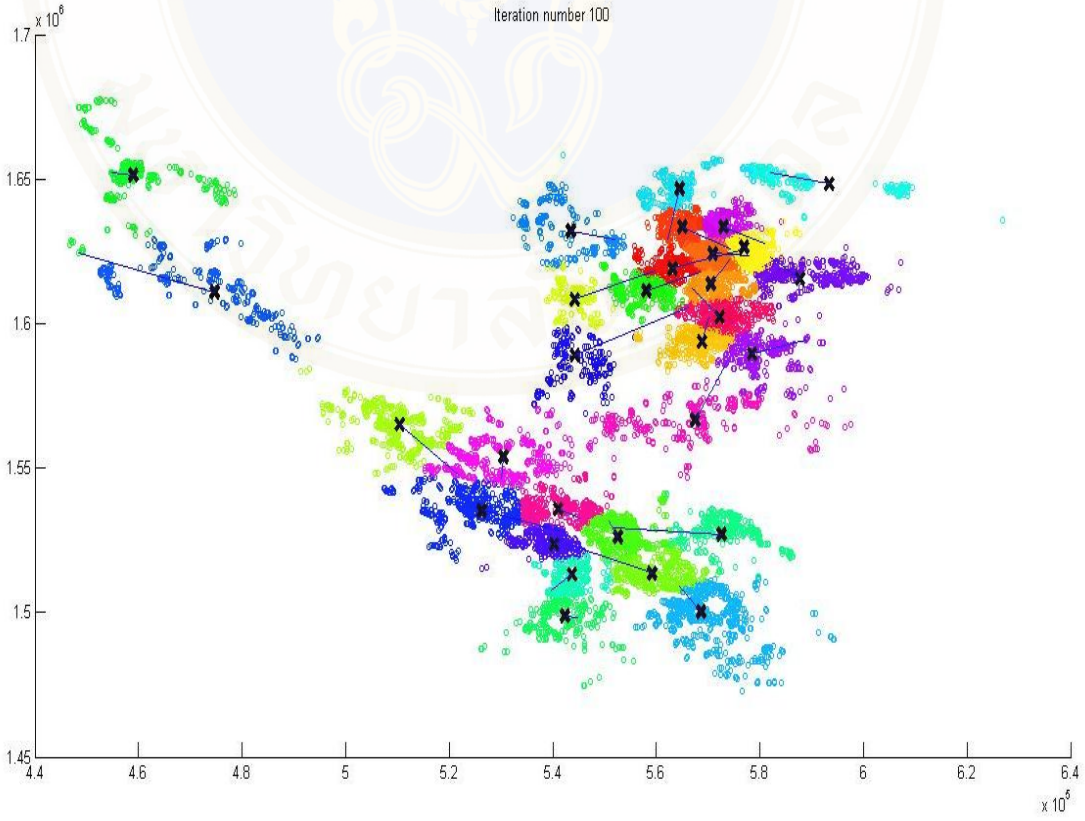

Figure 5.13 The 30 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with MATLAB

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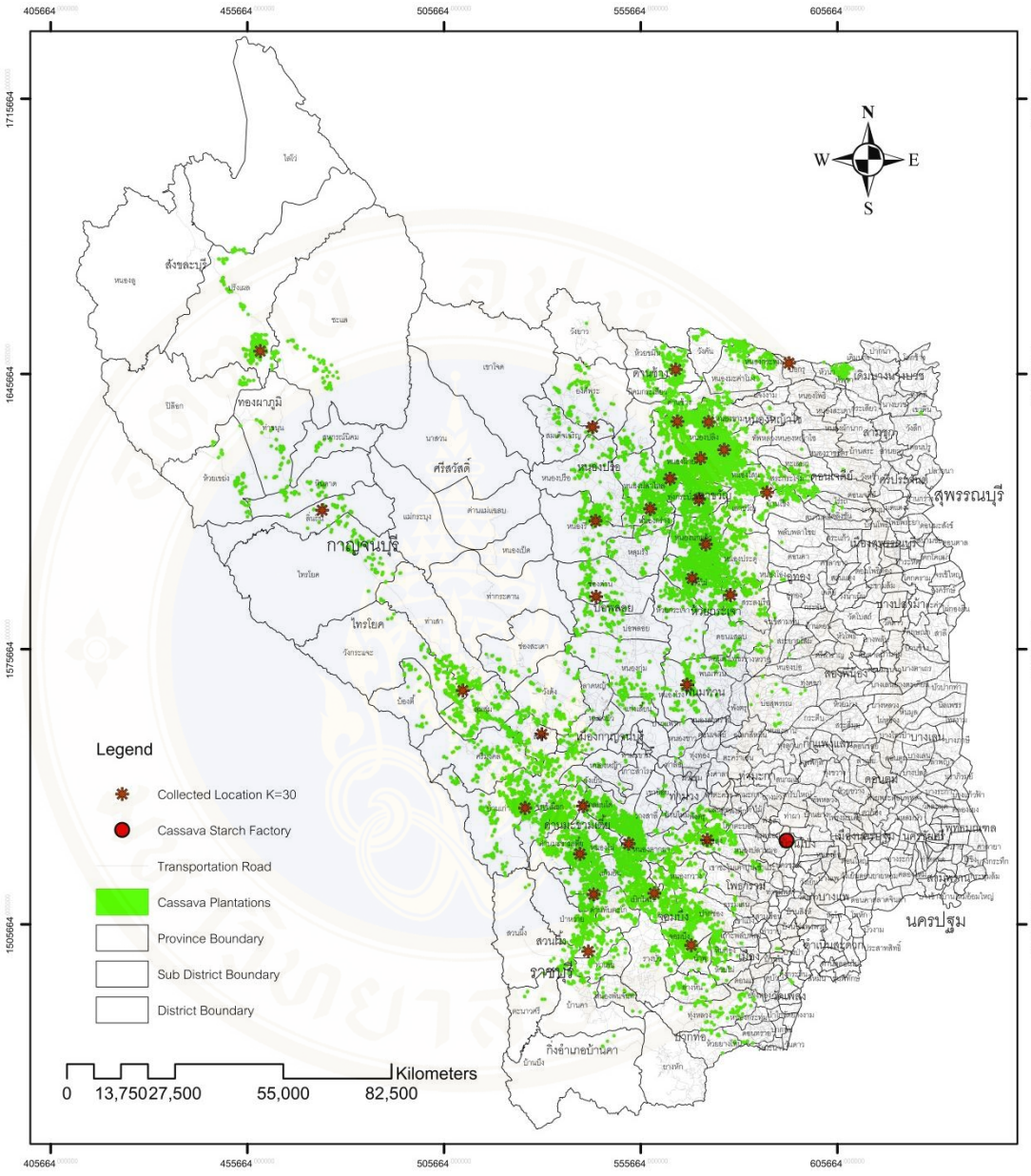

Figure 5.14 The 30 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with MATLAB and plotting with GIS program

From the step of analysis the distance of transportation process, there have used the dijkstra's algorithm and closest facility of GIS application to evaluate and establish the transportation routing with the same 2 steps like in the current state and new design with Weka: from cassava farms accumulate to CSC 30 locations and from 30 CSC locations to cassava starch factory by used weight of volume in cassava roots

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from farms to considering in k-mean algorithm. There are shown in figure 5.15 and 5.16, respectively. (Another mapping of CSC location have shown in Appendix 3)

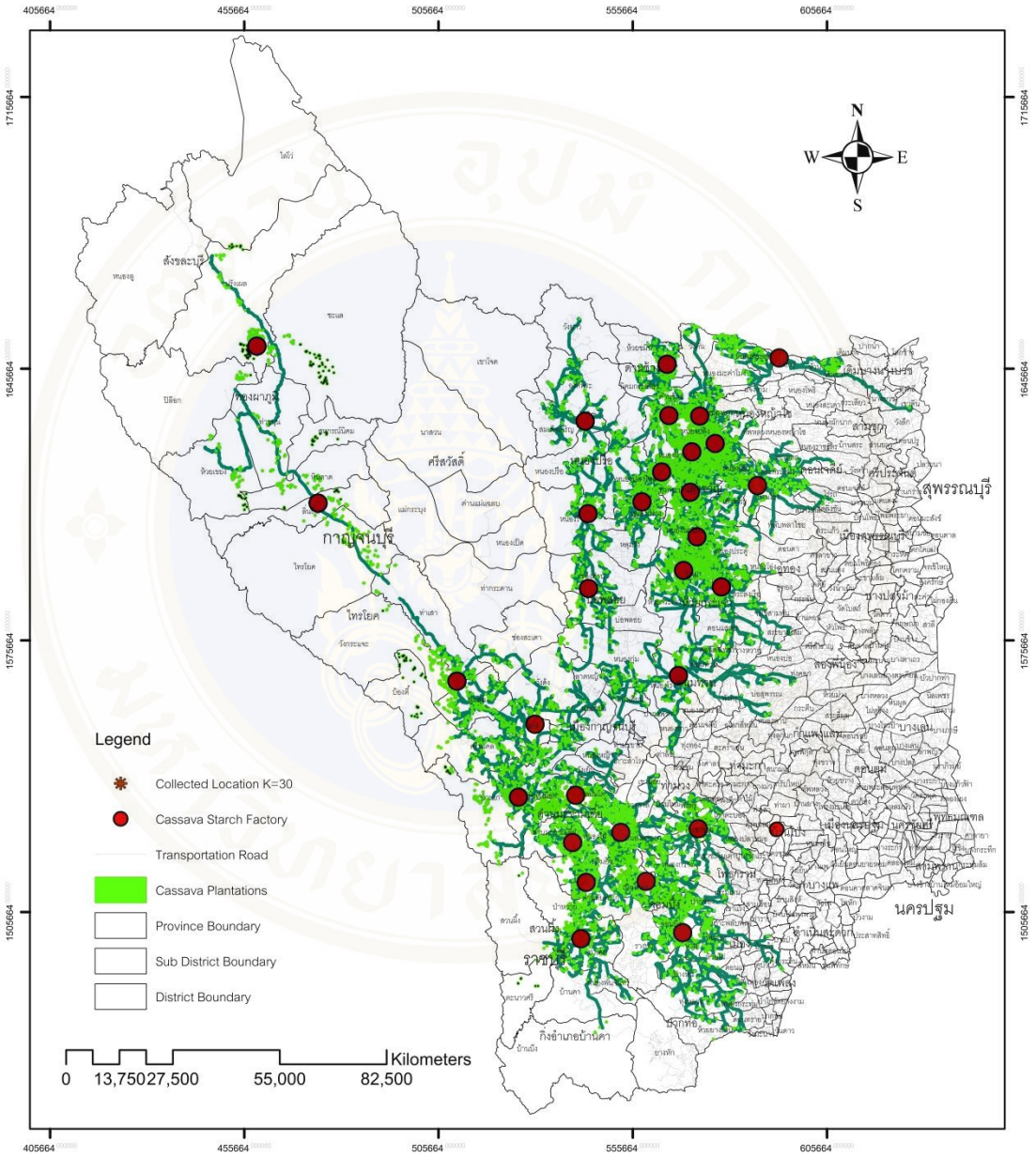

Figure 5.15 The 30 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with MATLAB

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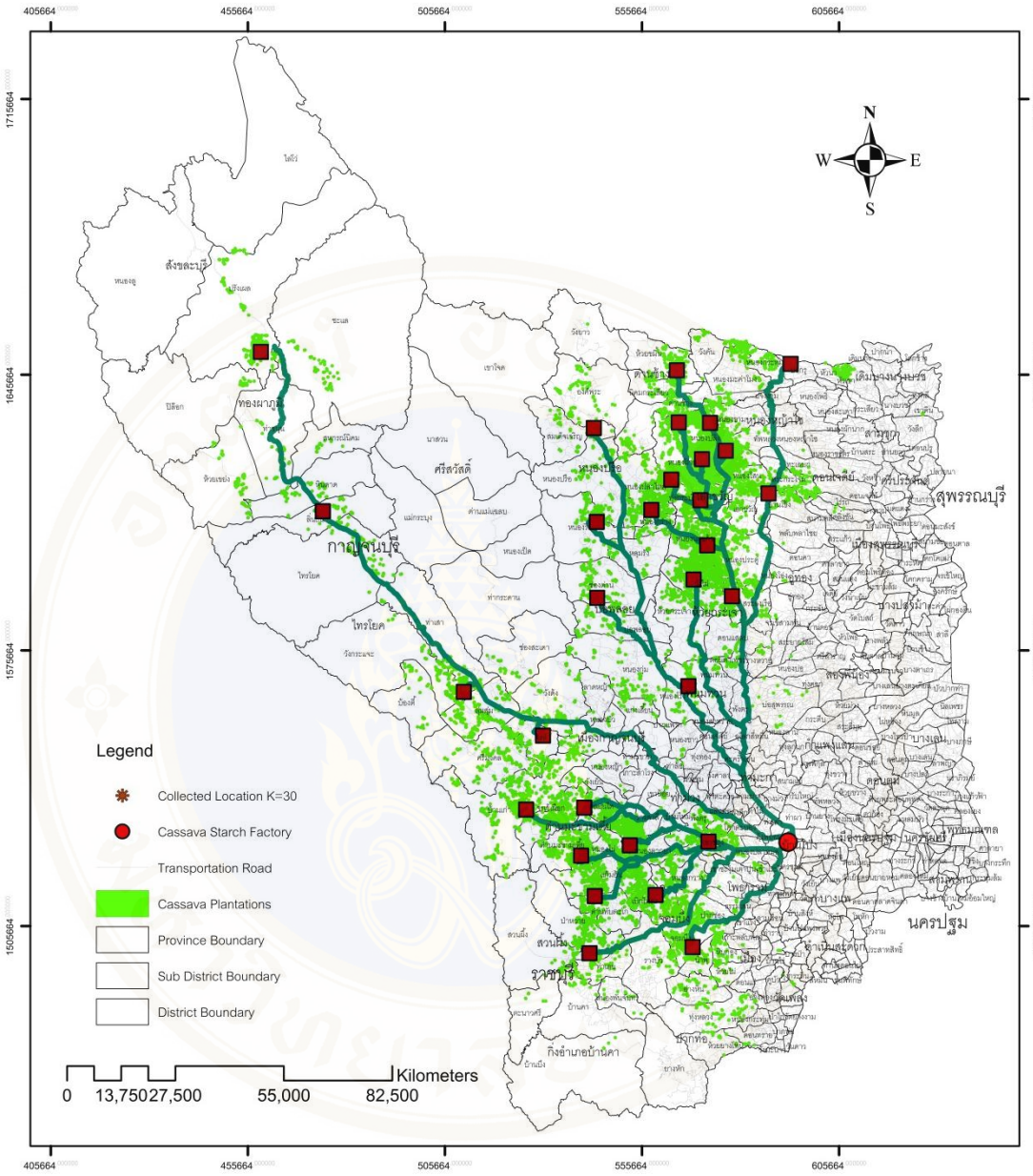

Figure 5.16 The 30 locations of Cassava Service Station (CSC) and routing from CSC locations to cassava starch factory by used modified k-mean algorithm with MATLAB

The total distances after their got the CSC location and evaluates the distance from cassava farms to factory and there have multiply by the number of trucks to transport from each farm to CSC and CSC to factory (the total distance there have analysis from the distance direct from farms to SCS and SCS to factory, and multiply by the number of trips, calculate by capacity of farms divide by 21 tons that

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mean the truck can carry weight of cassava root per trip in 21 tons) with dijkstra's algorithm and closest facility of GIS application has shown in table 5.8

Table 5.8 The results of total distance from farms pass to CSC to factory with MATLAB

Unit: kilometers/year

Number of Centroids	Total Distance from Farm to CSC	Total Distance from CSC to Factory	Total Distance
30	667,601	6,714,027	7,381,628
25	764,125	6,717,729	7,481,854
20	826,919	6,697,380	7,524,299
15	1,007,765	6,693,769	7,701,534
10	1,297,354	6,694,514	7,991,868
5	1,675,228	6,694,068	8,369,296

From the table 5.8 have shown the distance from cassava farms to CSC locations in many types and going to cassava starch factory. The total distances have increasing when the number of CSC locations has been decrease, and the total distance have affect distance from cassava farms to CSC location more than from the CSC location to cassava starch factory. However, these researches want to considering in total cost from transportation cost plus to investment cost. To the total transportation costs with MATLAB by modified k-mean clustering has shown in table 5.9 (the transportation costs was calculated from the fuel consumption of 10 wheel of trucks is 10 kilometer/lite and the diesel prices in situation of this research study is 30 baht/lite).

Table 5.9 The results of transportation cost of CSC location with MATLAB

Number of CSC locations	Average Capacity in CSC locations (tons)	Total Distance (km)	Total transportation cost (Baht)
30	53,320.38	6,714,027	22,144,883.82
25	63,981.72	6,717,729	22,445,562.10
20	79,980.57	6,697,380	22,572,897.22
15	106,640.76	6,693,769	23,104,602.33
10	159,961.14	6,694,514	23,975,604.57
5	319,922.28	6,694,068	25,107,887.73

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About the investment cost, there have analysis from the table of 5.2. The results from many CSC location type have shown in table 5.10 that their got plus to the transportation cost from cassava farms to factory by passing to the CSC locations.

Table 5.10 the results of total cost from number of CSC location analysis with MATLAB

Unit: Baht/year

Number of CSC locations	the service area of CSC location (rai)				
	3	**5**	**7**	**10**	**20**
30	45,375,299.99	52,729,216.75	67,770,954.82	82,794,142.64	148,826,605.58
25	-	48,146,761.62	60,696,847.30	73,224,672.68	128,263,628.21
20	-	43,449,396.63	53,512,003.73	63,546,785.45	107,595,479.86
15	-	-	46,856,744.34	54,403,119.97	87,468,045.85
10	-	-	-	45,923,381.03	68,020,769.86
5	-	-	-	-	50,198,218.29

From the table 5.10, the results have shown about the total cost from cassava farms to CSC location and getting to cassava starch factory in finally. In the lowest cost are from the number of CSC location is 20 location, that have the total cost from transportation and investment cost in 43.4 million baht per year. And the number of iterations and error by gradient descent has shown in table 5.11 when there analysis by MATLAB (the results of CSC location in UTM scale has shown in Appendix 2).

Table 5.11 The results of number of iterations and error by gradient descent from analysis the modified k-mean clustering with MATLAB

Number of CSC locations	Number of iterations	Error from gradient descent
30	100	5143.6
25	100	5886
20	100	6643.2
15	100	7849.6
10	100	10959
5	100	14230

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5.2.3 The comparison results of new design of transportation model with ordinary k-mean algorithm with Weka and modified k-mean algorithm with MATLAB

From the results of ordinary k-mean algorithm with Weka and modified k-mean algorithm with MATLAB, there are having the best solutions in the same type with the number of CSC location is 20 locations and the service area of location is 5 rai in each CSC location. However, this research not only to find the lowest cost to constructed the Cassava Service Center (CSC) but there want to know about the affecting from the weight of parameter from the volume of cassava root production in their farms to multiply with k-mean algorithm that could or could not be help to reduce the transportation distance from cassava farms to cassava starch factory. Thus, there are comparing between the cost and distance of transportation, and the total cost in the end of process model to find the best algorithm and solution that will give the best solution.

The total transportation distance that there were analysts with 2 methods: First, by using ordinary k-mean algorithm with Weka. And second, by using the modified k-mean algorithm that had multiplies by volume of cassava root in cassava farms with MATLAB. The results of 2 methods different has shown in table 5.12

Table 5.12 The results of total distance comparison between Weka and MATLAB

Unit: kilometers/year

Number of Centroids	Total Distance from Weka	Total Distance from MATLAB	The Different of Total Distance
30	7,412,538	7,381,628	30,910
25	7,497,001	7,481,854	15,147
20	7,625,830	7,524,299	101,531
15	7,819,182	7,701,534	117,648
10	8,000,543	7,991,868	8,675
5	8,442,240	8,369,296	72,944

From table 5.12 had shown the results of total distance with Weka and MATLAB method, and the different of total distance from total distance of Weka minus to total distance from MATLAB. The difference results have shown in positive

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value that mean the total distance results from Weka is much more than the total distance results from MATLAB. Therefore, from the inbound transportation analysis with modified k-mean clustering to multiply by one parameter from the volume of cassava farms can make the minimum total distance from farms to factory better than the ordinary k-mean clustering with Weka. The results of total distance between 2 methods had shown in figure 5.17, there were know about the gap different from the ordinary k-mean and modified k-mean clustering methods had much between the number of location in 20 and 15 locations.

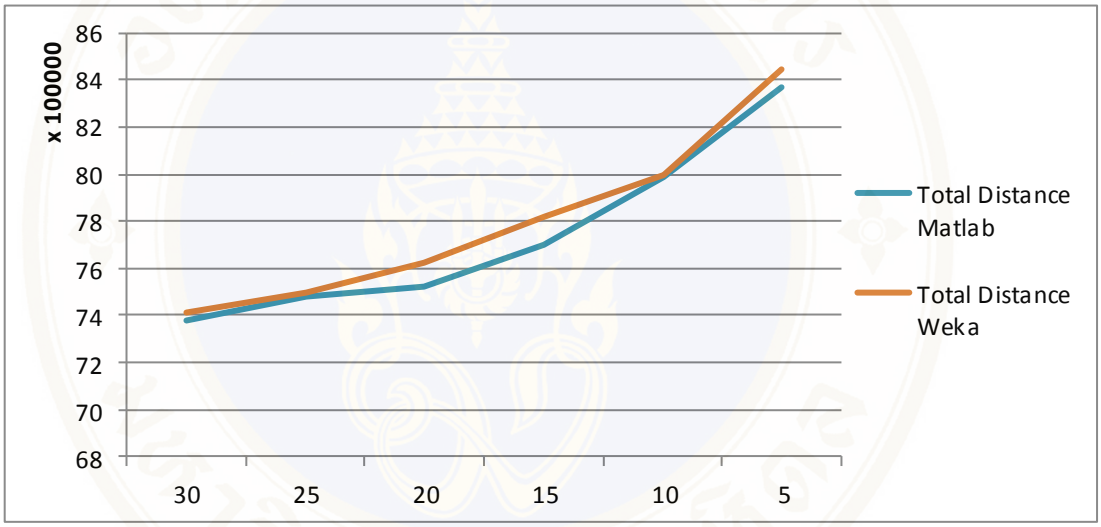

Figure 5.17 The results of total distance between 2 methods: Weka and MATLAB (Unit: kilometer)

Table 5.13 The results of transportation cost of CSC location with Weka and MATLAB

Unit: Baht/year

Number of CSC locations	Total transportation cost with Weka	Total transportation cost with MATLAB	Total transportation cost different
30	22,237,616.96	22,144,883.82	92,733.14
25	22,491,004.71	22,445,562.10	45,442.61
20	22,877,490.58	22,572,897.22	304,593.36
15	23,457,547.51	23,104,602.33	352,945.18
10	24,001,631.66	23,975,604.57	26,027.09
5	25,326,722.48	25,107,887.73	218,834.75

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From the results of total transportation costs from ordinary k-mean and modified k-mean clustering were shown in table 5.13. From this table, have shown the total transportation cost to using 2 algorithms between ordinary k-mean and modified k-mean clustering methods to analysis and results. There are assuring the results of transportation design by modified k-mean methods can help to reduce transportation cost and distance from cassava farms to factory. Finally, there have to compare the results of the best total cost from 2 methods at 20 CSC locations and the service area of CSC location is 5 rai.

Table 5.14 The results of total cost from number of CSC location analysis.

Unit: Baht/year

Number of CSC locations	the service area of CSC location in 5 rai
20 (Weka)	43,753,989.98
20 (MATLAB)	43,449,396.63

From the table 5.14, the best solution of total cost from the number of Cassava Service Center (CSC) location Analysis is the modified k-mean clustering to multiply by the volume of cassava root production in cassava farms with MATLAB, There results have total cost in 43.449 million baht per year. There are different from the results of ordinary k-mean clustering with Weka is 304,593 baht per year.

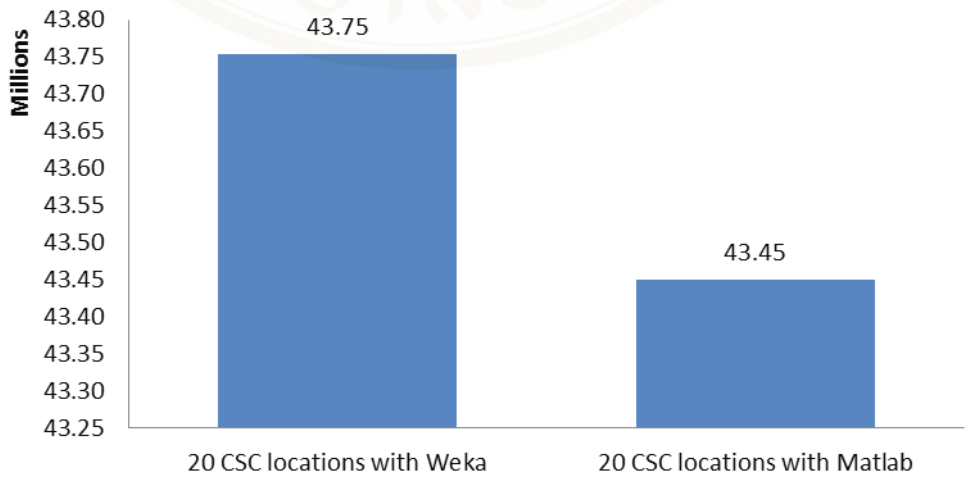

Figure 5.18 The results of total cost of 20 CSC locations between analysts with Weka and MATLAB (Unit: Baht)

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From the results of analysis the distance of transportation process in this research with modified k-mean clustering algorithm, the results of location of Cassava Service Center (CSC) in the best solution ad 20 CSC locations has shown in figure 5.19. The routing from cassava farms to CSC locations and routing from CSC locations go to cassava starch factory is shown in figure 5.20 and 5.21, respectively.

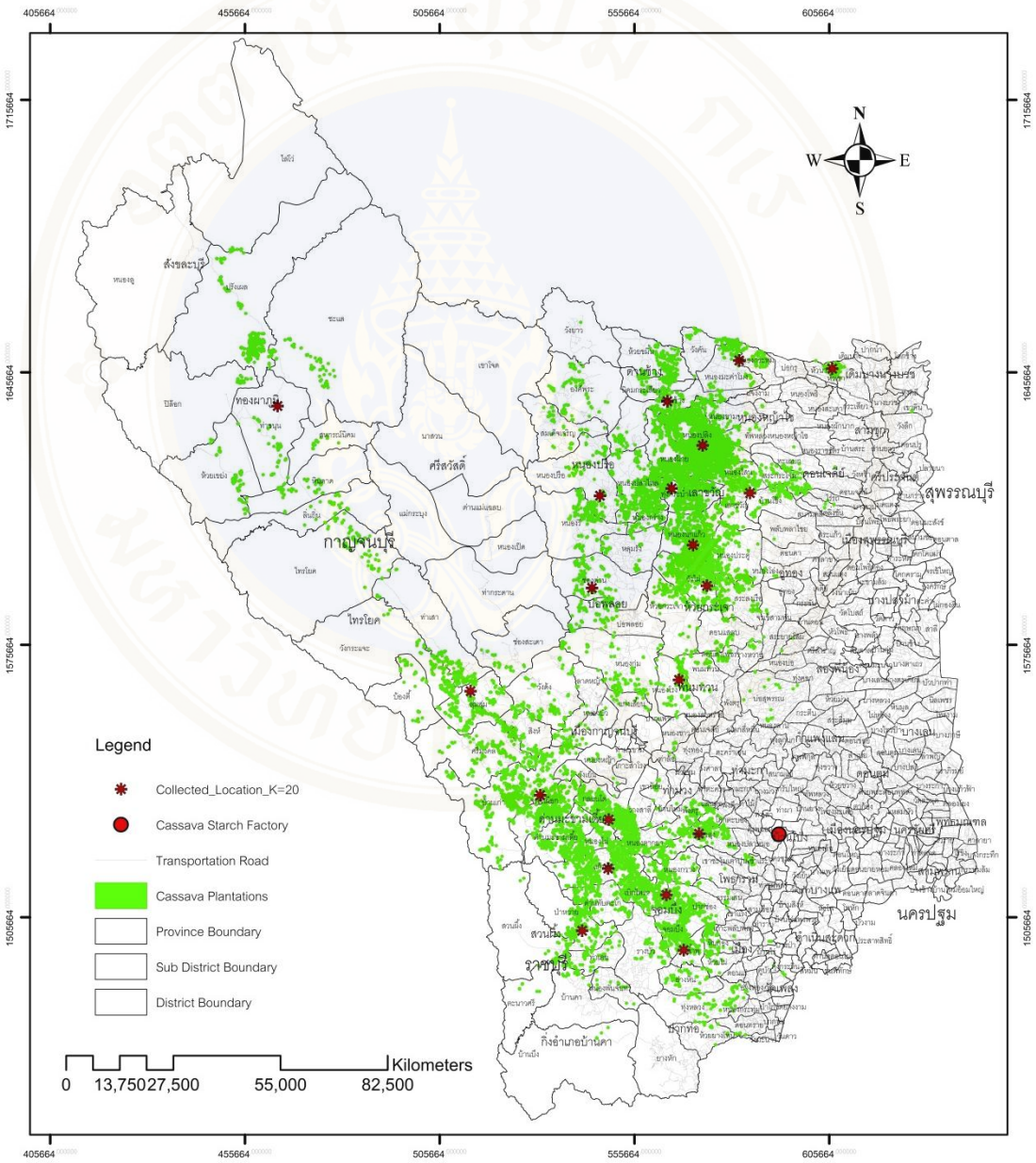

Figure 5.19 The 20 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with MATLAB and plotting with GIS program

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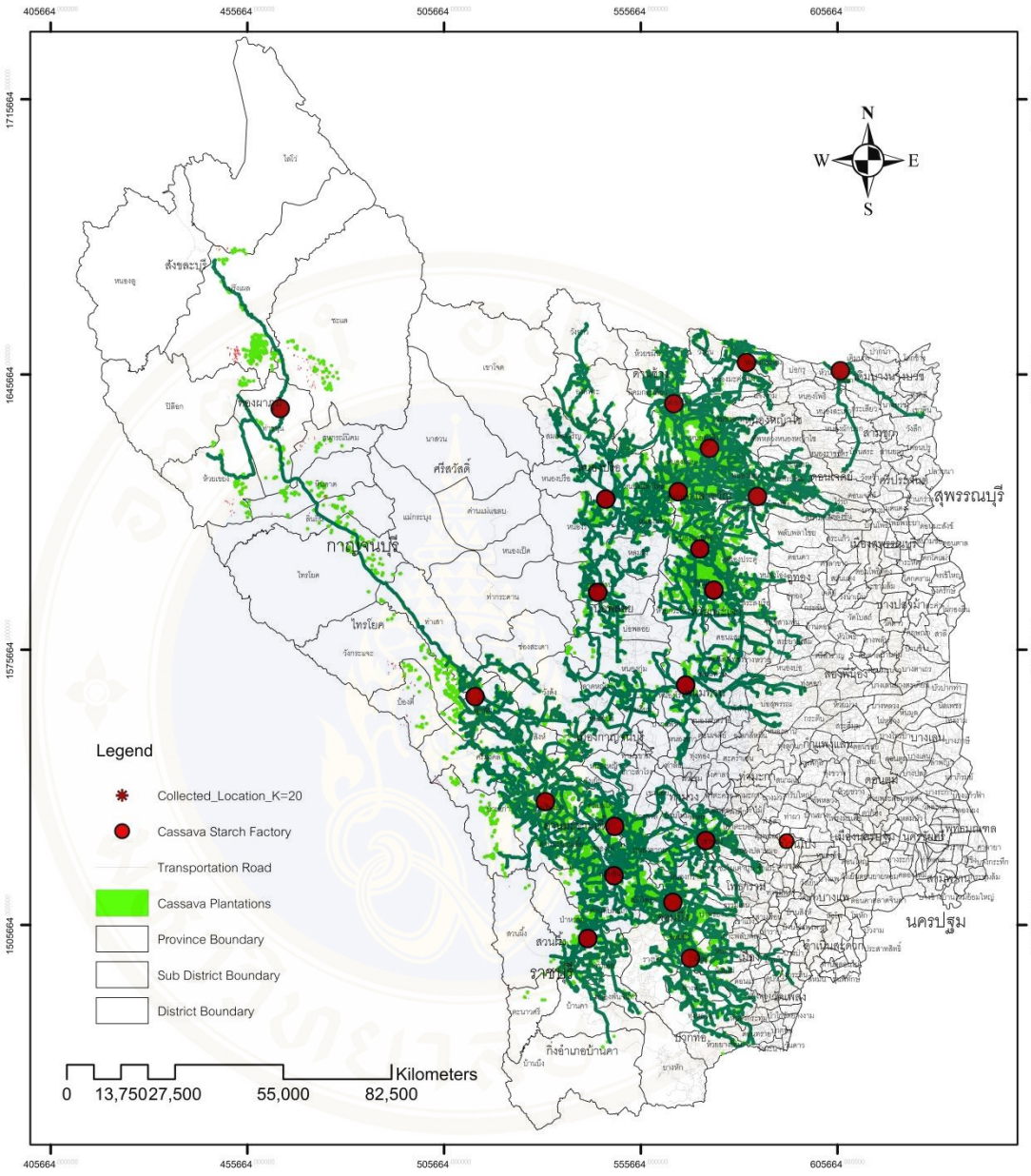

Figure 5.20 The 20 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with MATLAB

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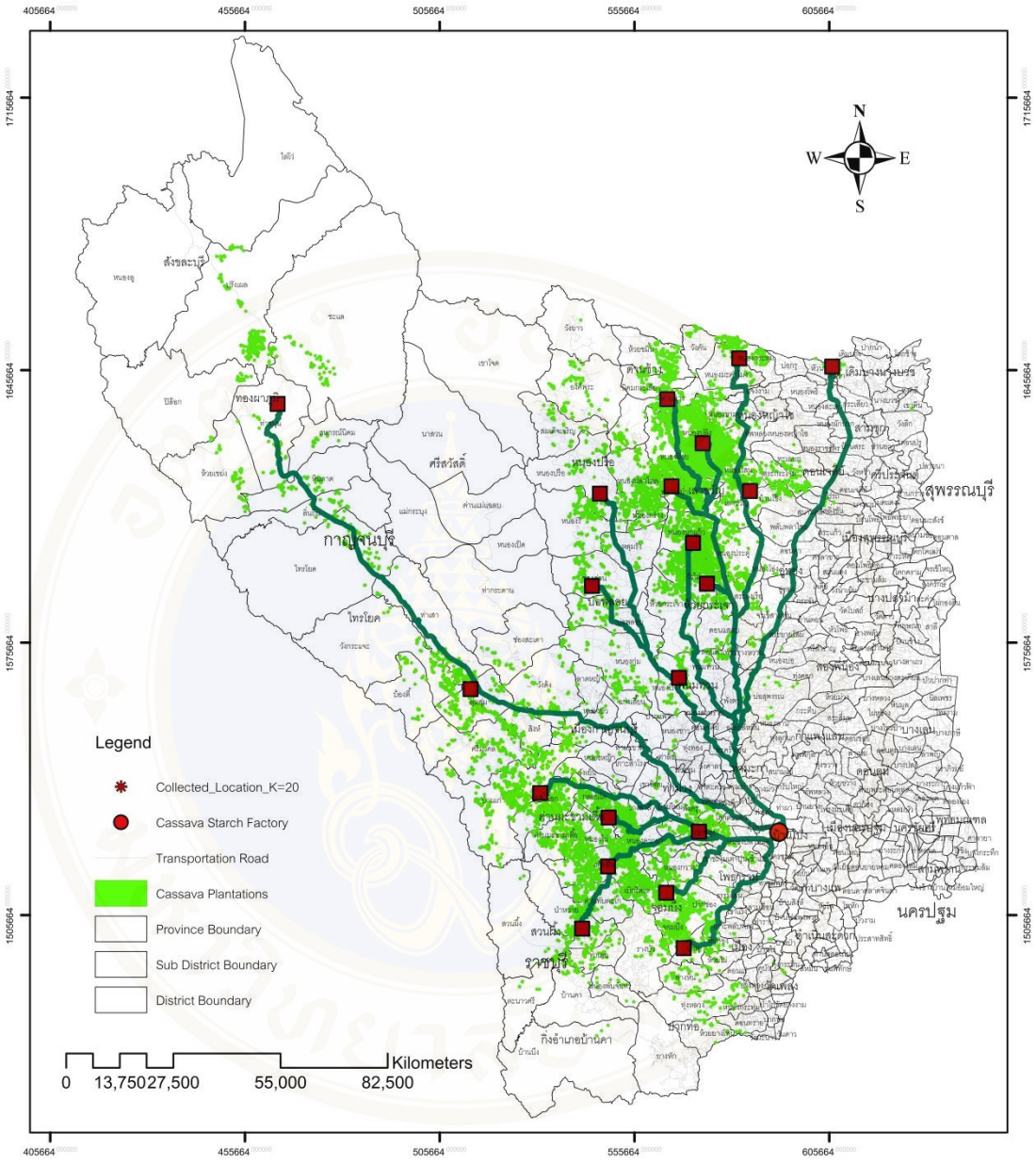

Figure 5.21 The 20 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with MATLAB

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5.3 The new business process model with value stream mapping (CSM) of cassava starch industry in future state (TO-BE Process)

Working on the gap areas identified by the value stream mapping of the current state of cassava starch manufacturing line, some modification are proposed as indicated in figure 5.22. The Kanban system brought the necessary schedule and delivery discipline. It is also observed that inventory was high in the store because of poor communication and a play-safe tendency. Electronic information flow is proposed for the suppliers. It helped in reducing order quantity and inventory at raw material stores. This also helped in making whole supply chain lean and flexible.

From the future state map of value stream mapping for the cassava starch manufacturing process has shown from below. That have the activity as the same the current state of cassava starch manufacturing process but there has change and improve the process line, relationship, and add the activity of the accumulate center in the inbound logistics and change the relationship process with the Kanban system and Pull processing. From the cassava starch factory has changed their schedule planning to send to the cassava farms and accumulate center to help the planning schedule of the logistics inbound of cassava starch manufacturing system.

Before to harvest the product of cassava roots, their farmers was contract the factory and harvest the product in the schedule plan of factory which plan was made from the schedule of farmer to cultivate the cassava plantation and were suitable to harvest in time, this process their call contract farming, when the cassava farmer had suitable production then their farmer must take to harvest the production to factory in time. After that the production of cassava roots was transport to the accumulate center or Cassava Service Center (CSC) and have to cleaning the cassava roots. After then their got to cleaning the cassava roots, there had to transport to factory when the factory has send the Kanban card to the accumulate center. Therefore, the inbound logistics and lead time before the process line was decrease from 6 day to be 1 day that also helpful to decrease the lead time of supply chain system in cassava starch industry.

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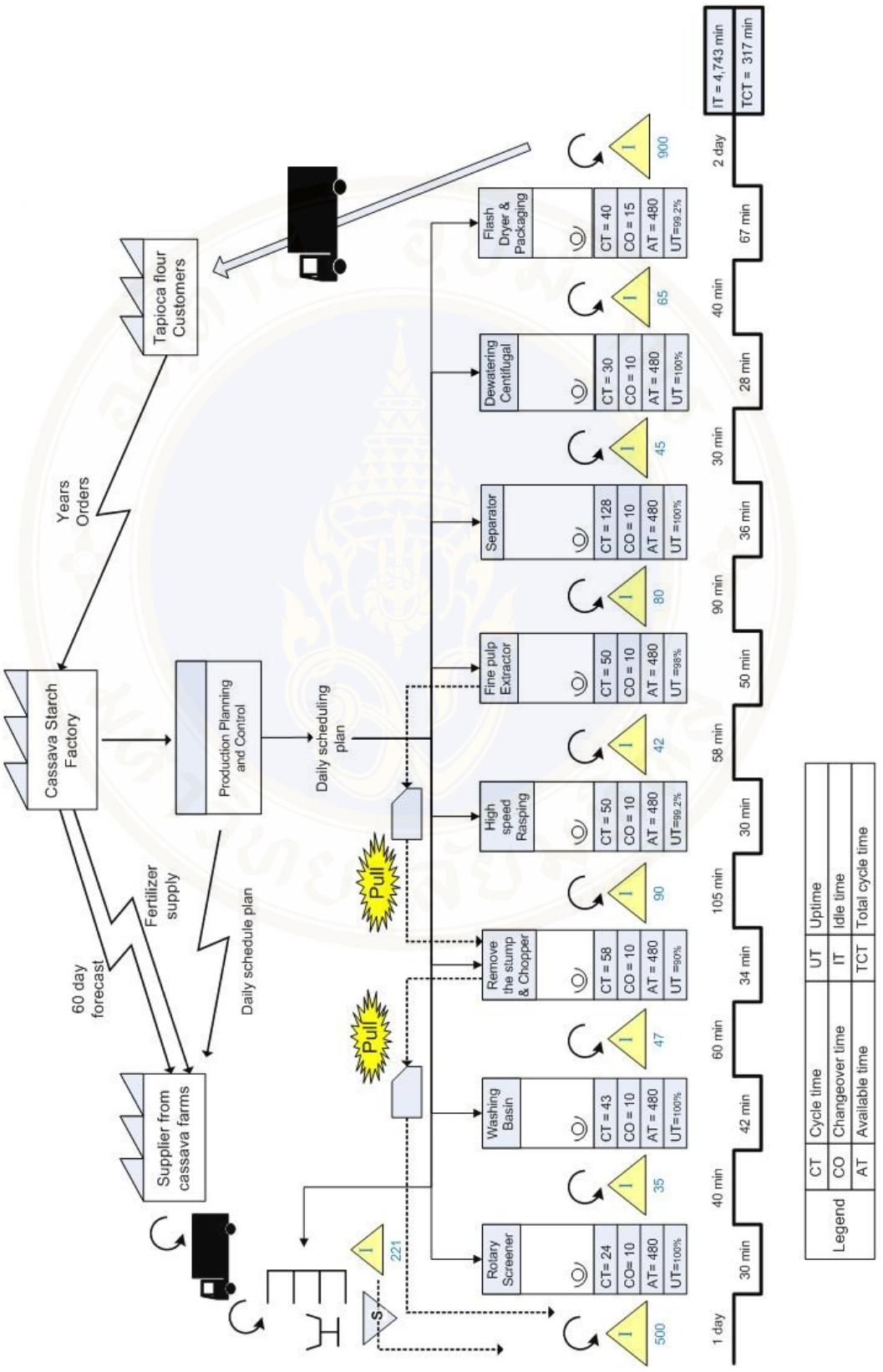

Figure 5.22 The value stream mapping of the future state in supply chain of cassava starch industry in Thailand

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CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This research was studies and focused on the business processing of the supply chain process in cassava starch industry, which the Integrate DEFinition for function modeling (IDEF0) and used the value stream mapping to identified the business process activity and supply chain process of cassava starch industrial. The problem of cassava production in supply chain was being the same in the other agriculture in supply chain processing about the transportation lacking, traffic jam in the front of factory, shortest or over stock of inventory and etc.

From the research to study and analysis of potential suitability of cassava service centers to collect the cassava roots from many farms to cassava starch mill at Western region in Thailand. Compare with the cassava yards location in situation about investment cost and transportation distance to minimize in objective function of this area. The improved of business process was added to the Cassava Service Center (CSC) locations to help and make the efficiency to collected cassava roots from farms to cassava starch factory, and reduces the stock in manufacturing process with operating and management in logistics inbound and transportation system. The methods to design and analysis there got to 2 types: ordinary k-mean clustering with Weka program, and modified k-mean clustering to multiply by the volume of cassava roots in their farms from coding with MATLAB. To finding the best solution that reduce to distance and total costs from transportation and investment cost in the number of locations at 5, 10, 15, 20, 25 and 30 locations.

For the consequence, the new design model of transportation that there has got the suitable accumulate center, or cassava starch center (CSC), has showed the best results that used to 20 location in the service area is 5 rai, from the total costs is 43,753,989.98 baht per year, by using modified k-mean clustering to multiply by the volume of cassava starch from their farms for the cassava plants to collected,

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preprocessing and transport to factory had the results better than the current state of transportation model and other new design process that used to.

After there was study and solve the problem in this case study, to find the suitable location of Cassava Service Center (CSC). There have to evaluate and establish with dijkstra's algorithm and closest facility of geographic information system application. In the value stream mapping, there have to improve the information system and network and the Kanban system that been so important to get the business process time to decrease and get more efficiency in the supply chain process to be better.

6.2 Recommendation for Future Research

The recommendation of using the improved business process analysis tools is to apply them in process analysis for identifying business processes of the system. However, this research only to identify the material and information of the cassava starch supply chain system by using IDEF0 and Value Stream Mapping (VSM). It needs to analyze in the other field of case study, for identifying the general required information in the system analysis, and identified the problem of business process in other industry.

About the clustering and transportation methods of this research has been difficult to analyst, evaluate and establish in one step. There have analysis to find clustering location with k-mean algorithm, to evaluate and establish by dijkstra's algorithm and closest facility of GIS application. For the future research, there might be using linear programming or quadratic programming to find out the location and evaluate the routing results in the final state will be faster and efficiency on it.

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APPENDICES

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APPENDIX A
MATLAB CODE USED TO DETERMINE CENTROID LOCATION WITH K-MEAN CLUSTERING ALGORITHM

This appendix provides the MATLAB code that was used to determine the Cassava Service Center (CSC) locations by k-mean clustering algorithm.

Main Program

```
%% Main program to analysis with k-mean clustering algorithm.
clear ; close all; clc
fprintf('\nRunning K-Means clustering on example dataset.\n\n');
load X.txt
K = 30;
max_iters = 100;
initial_centroids = kMeansInitCentroids(X, K);
[centroids, idx] = runkMeans(X, initial_centroids, max_iters, true);
fprintf('\nK-Means Done.\n\n');

fprintf('Program paused. Press enter to continue.\n');
pause;
```

kMeansInitCentroids.m

```
function centroids = kMeansInitCentroids(X, K)
%KMEANSINITCENTROIDS This function initializes K centroids that are to be
%used in K-Means on the dataset X
% centroids = KMEANSINITCENTROIDS(X, K) returns K initial centroids to be
% used with the K-Means on the dataset X

% You should return this values correctly
centroids = zeros(K, size(X, 2));

% ============================================================

randidx = randperm(size(X, 1));
centroids = X(randidx(1:K), :);

% ============================================================

end
```

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runkMeans.m

```
function [centroids, idx] = runkMeans(X, initial_centroids, max_iters, plot_progress)
%    RUNKMEANS runs the K-Means algorithm on data matrix X, where each row of X  is a single example

% Set default value for plot progress
if ~exist('plot_progress', 'var') || isempty(plot_progress)
   plot_progress = false;
end

% Plot the data if we are plotting progress
if plot_progress
   figure;
   hold on;
end

% Initialize values
[m n] = size(X);
K = size(initial_centroids, 1);
centroids = initial_centroids;
previous_centroids = centroids;
idx = zeros(m, 1);

% Run K-Means
for i=1:max_iters

   % Output progress
   fprintf('K-Means iteration %d/%d...\n', i, max_iters);
   if exist('OCTAVE_VERSION')
      fflush(stdout);
   end

   % For each example in X, assign it to the closest centroid
   idx = findClosestCentroids(X, centroids);

   % Optionally, plot progress here
   if i==max_iters
      plotProgresskMeans(X, centroids, previous_centroids, idx, K, i);
      previous_centroids = centroids;
      fprintf('Press enter to continue.\n');
      %pause;
   end

   % Given the memberships, compute new centroids
   centroids = computeCentroids(X, idx, K);
end

% Hold off if we are plotting progress
if plot_progress
   hold off;
end

end
```

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computeCentroids.m

```
function centroids = computeCentroids(X, idx, K)
%COMPUTECENTROIDS returs the new centroids by computing the means of
the data points assigned to each centroid.

% Useful variables
[m n] = size(X);

% You need to return the following variables correctly.
centroids = zeros(K, n);
cent = zeros(K, n);
load w.txt


% ====================================================================
id = eye(K);
post = id(idx,:);
num_points = sum(post,1);
J = 0;
for i =1:K
    d = 0;
    if (num_points(i) > 0)
        for j=1:m
            if post(j,i)==1
                cent(i,:) = cent(i,:) + w(j)*X(j,:);
                d = d+w(j);
            end
        end
        cent(i,:) = cent(i,:)/d;
        for j=1:m
            if post(j,i)==1
                J = J+w(j)*sum((X(j,:)-cent(i,:)).^2).^0.5;
            end
        end
    end
end
centroids = cent;
J=J/sum(w)
% ====================================================================
end
```

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findClosestCentroids.m

```
function idx = findClosestCentroids(X, centroids)
%FINDCLOSESTCENTROIDS computes the centroid memberships for every
example

% Set K
K = size(centroids, 1);

% You need to return the following variables correctly.
idx = zeros(size(X,1), 1);

% ====================================================================

ndata = size(X,1);
n2 = (ones(K,1)*sum((X.^2)',1))'+...
    ones(ndata,1)*sum((centroids.^2)',1)-2.*(X*(centroids'));
if any(any(n2<0))
    n2(n2<0) = 0;
end
[Y,idx] = min(n2,[],2);

% ====================================================================

end
```

plotDataPoints.m

```
function plotDataPoints(X, idx, K)
%PLOTDATAPOINTS plots data points in X, coloring them so that those
with the same index assignments in idx have the same color
%   PLOTDATAPOINTS(X, idx, K) plots data points in X, coloring them
so that those with the same index assignments in idx have the same
color

% Create palette
palette = hsv(K + 1);
colors = palette(idx, :);

% Plot the data
scatter(X(:,1), X(:,2), 15, colors);

end
```

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plotProgresskMeans.m

```
function plotProgresskMeans(X, centroids, previous, idx, K, i)
%    PLOTPROGRESSKMEANS is a helper function that displays the
progress of k-Means as it is running. It is intended for use only
with 2D data.
%    PLOTPROGRESSKMEANS(X, centroids, previous, idx, K, i) plots the
data points with colors assigned to each centroid. With the previous
centroids, it also plots a line between the previous locations and
current locations of the centroids.

% Plot the examples
plotDataPoints(X, idx, K);

% Plot the centroids as black x's
plot(centroids(:,1), centroids(:,2), 'x', ...
     'MarkerEdgeColor','k', ...
     'MarkerSize', 10, 'LineWidth', 3);

% Plot the history of the centroids with lines
for j=1:size(centroids,1)
    drawLine(centroids(j, :), previous(j, :));
end

% Title
title(sprintf('Iteration number %d', i))

end
```

drewLine.m

```
function drawLine(p1, p2, varargin)
%DRAWLINE Draws a line from point p1 to point p2
%   DRAWLINE(p1, p2) Draws a line from point p1 to point p2 and holds
the current figure

plot([p1(1) p2(1)], [p1(2) p2(2)], varargin{:});

end
```

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APPENDIX B

THE FIGURE RESULTS OF CASSAVA SERVICE CENTER (CSC) LOCATION BY USED THE MODIFIED K-MEAN CLUSTERING ALGORITHM AND PLOTTING WITH MATLAB

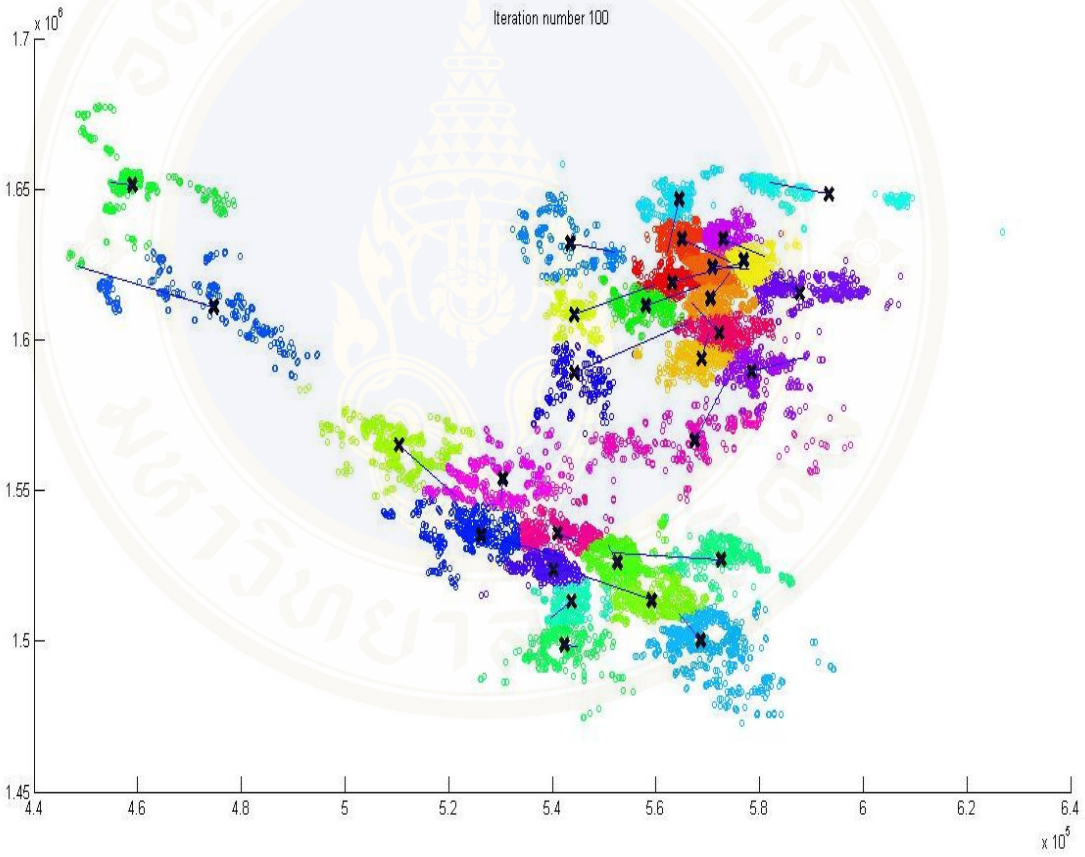

Figure the 30 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

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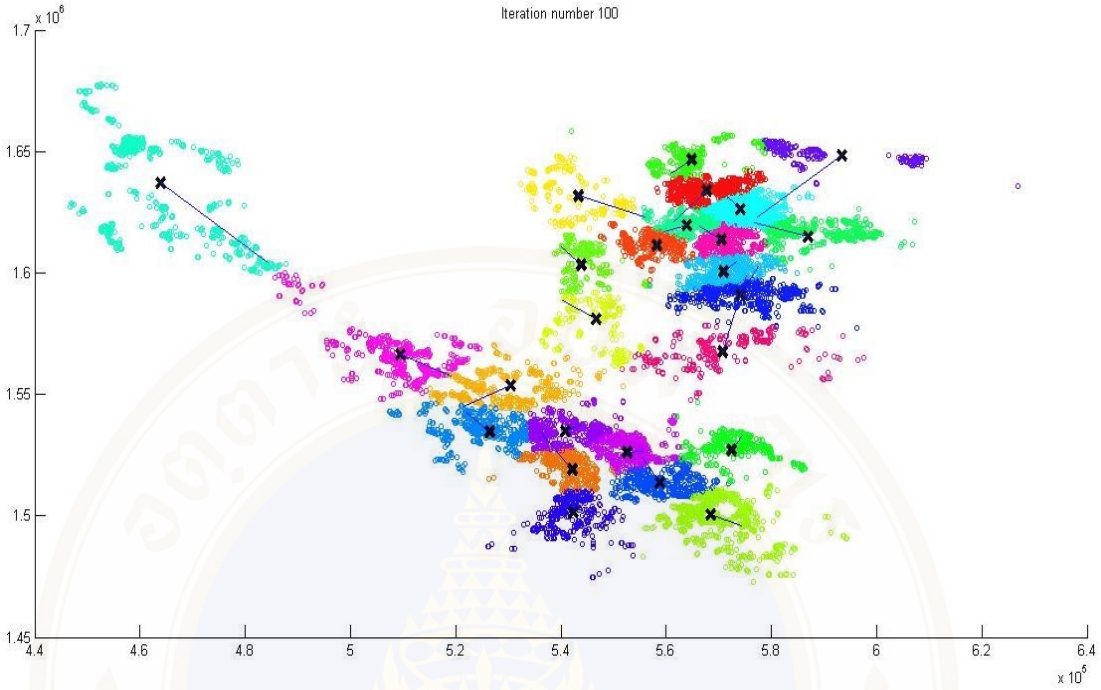

Figure the 25 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

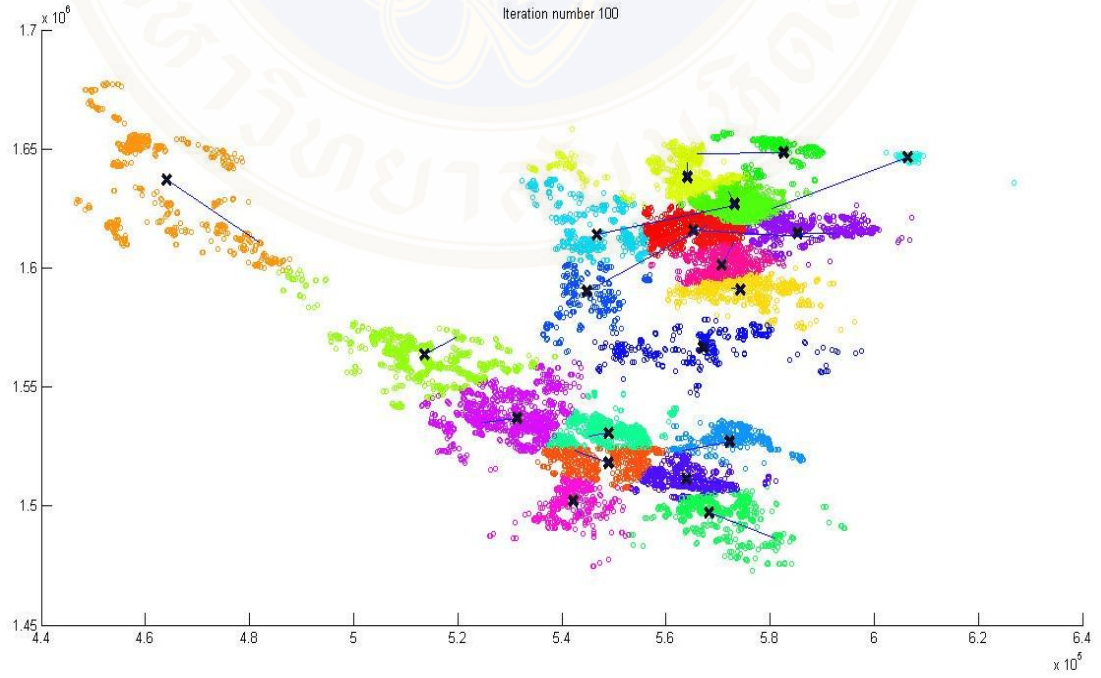

Figure the 20 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

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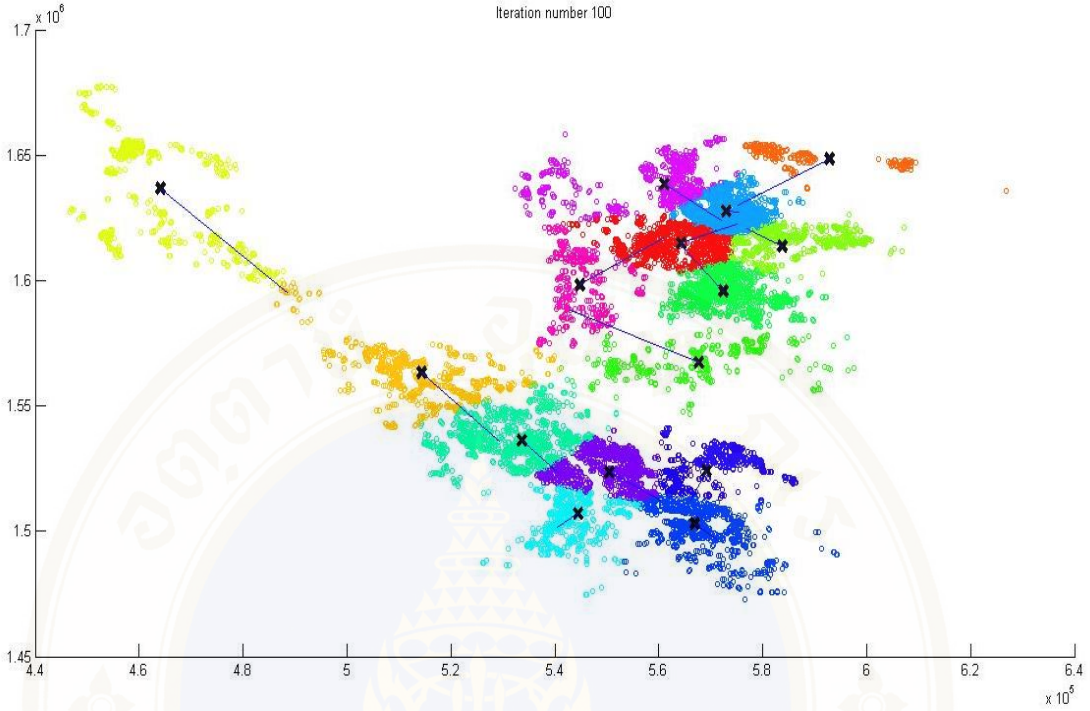

Figure the 15 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

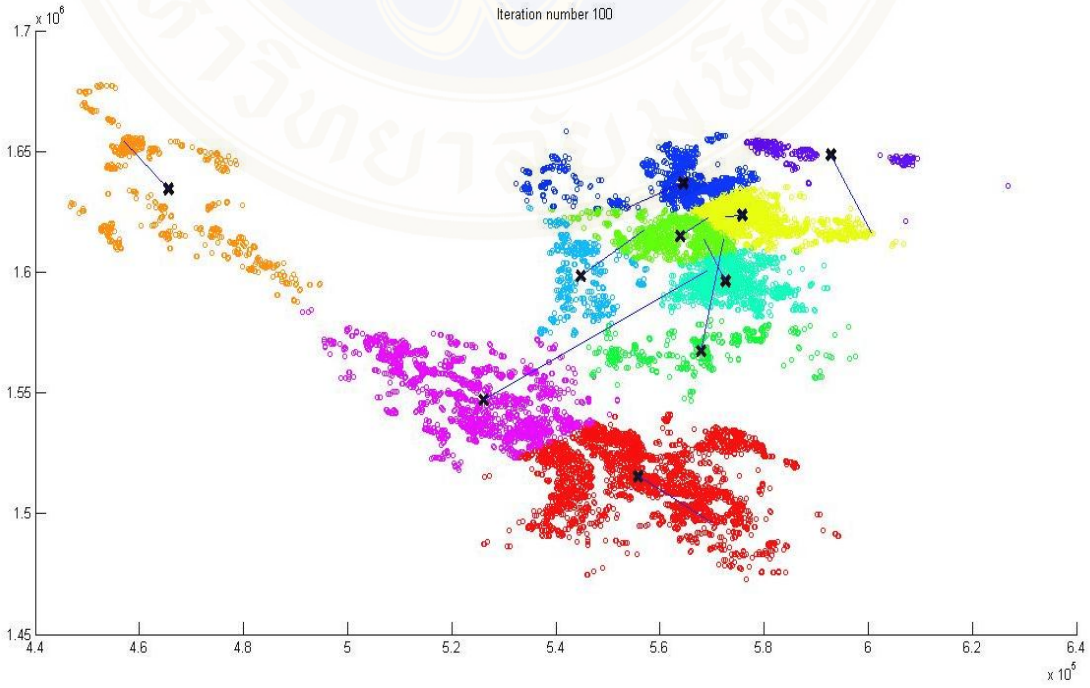

Figure the 10 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

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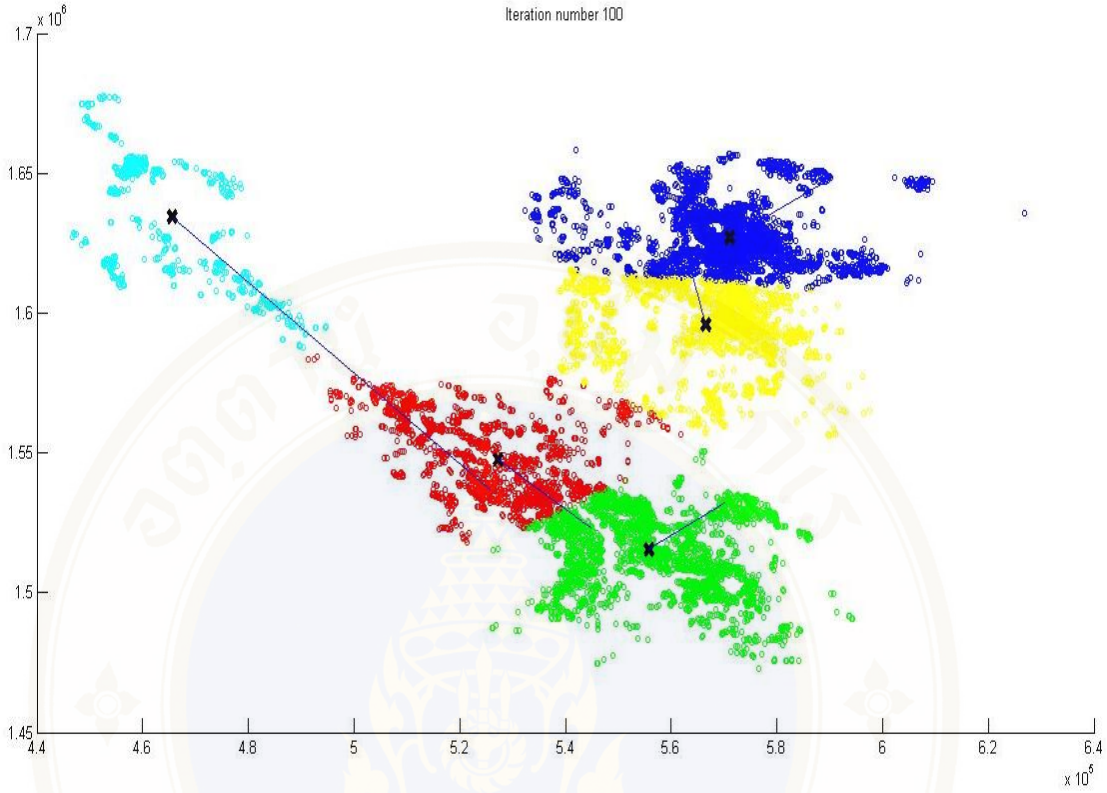

Figure the 5 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm and plotting with Matlab

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APPENDIX C

THE FIGURE RESULTS OF CASSAVA SERVICE CENTER (CSC) LOCATION BY USED THE ORDINARY K-MEAN CLUSTERING ALGORITHM WITH WEKA AND PLOTTING WITH GIS

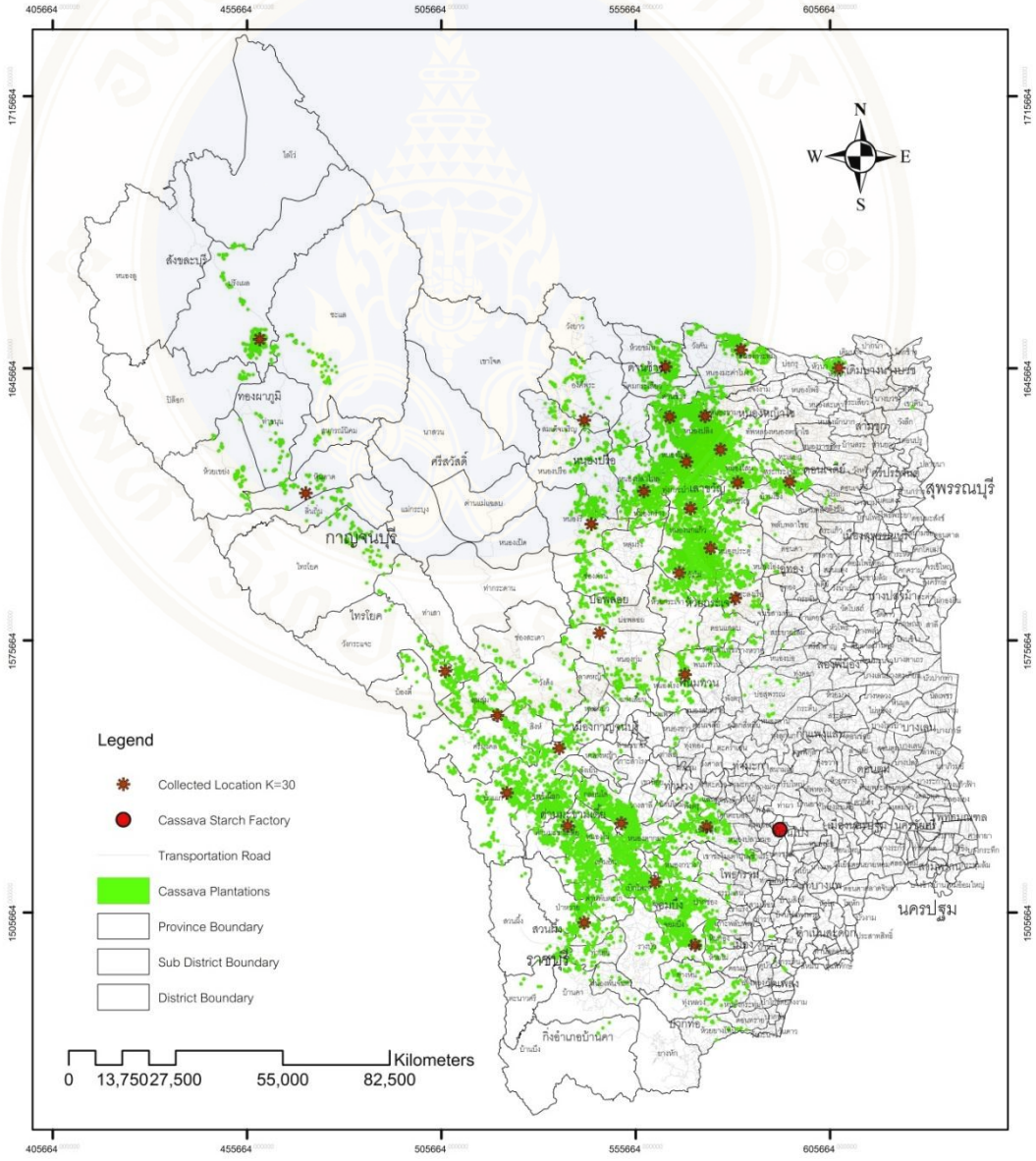

Figure the 30 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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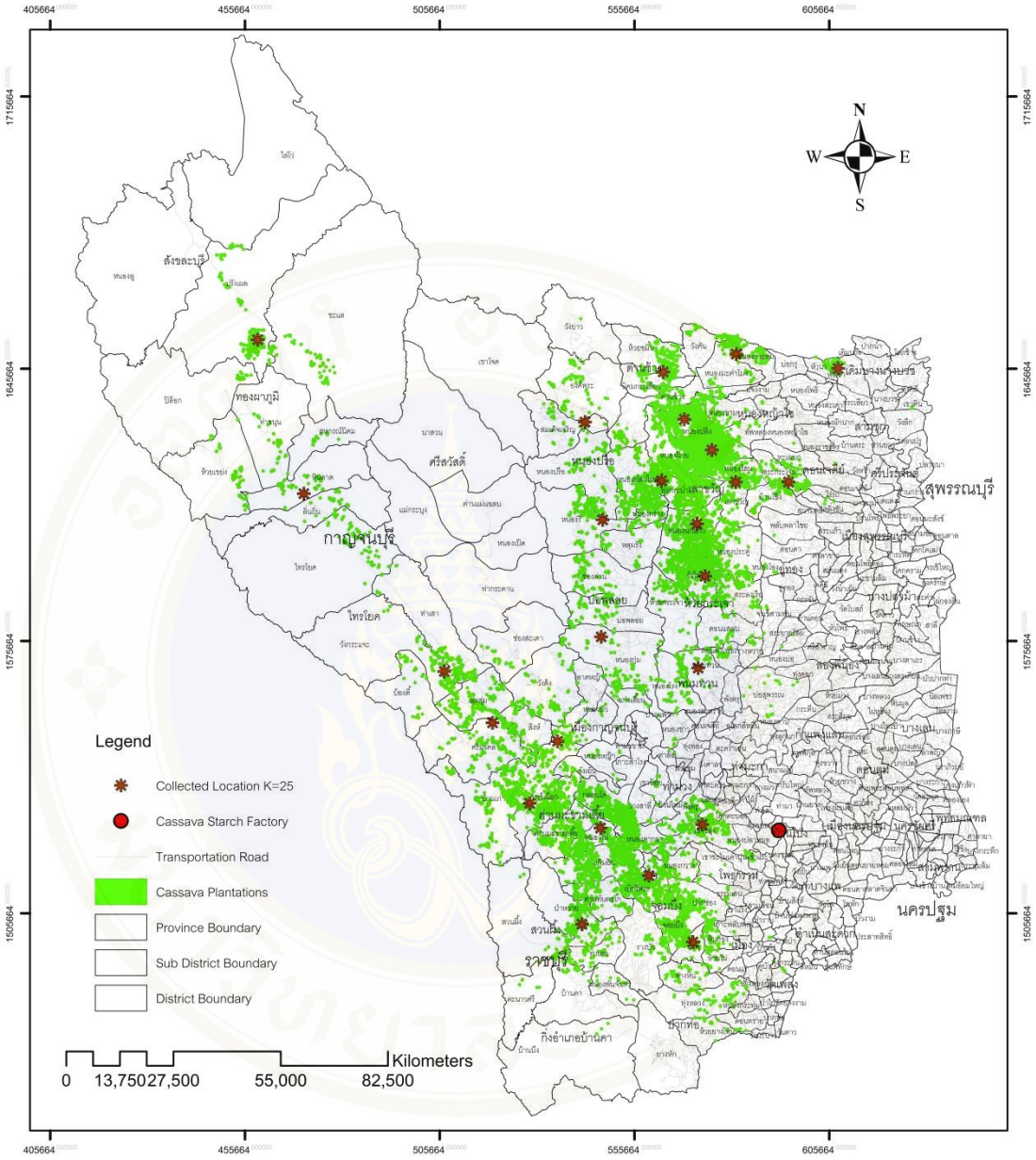

Figure the 25 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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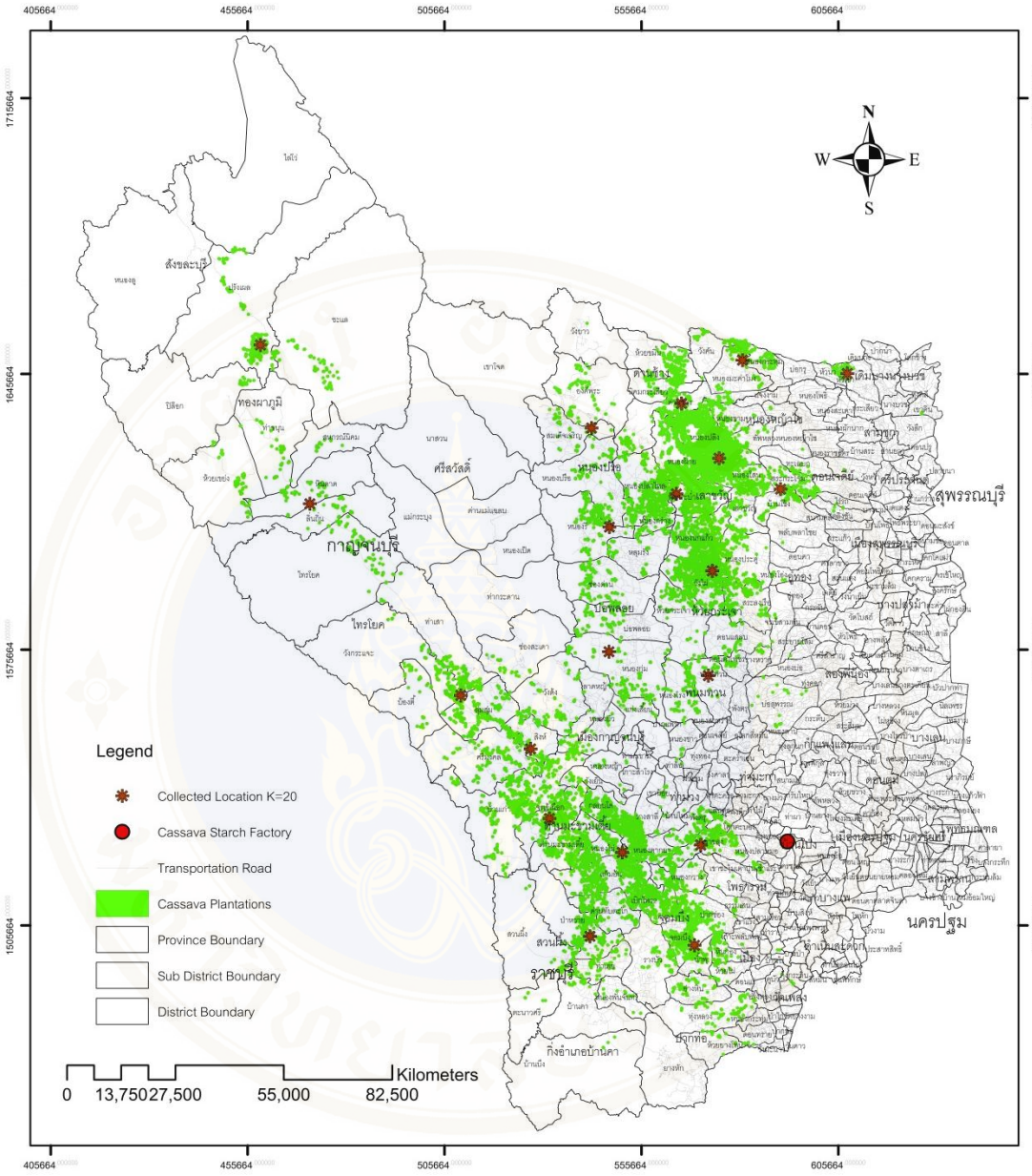

Figure the 20 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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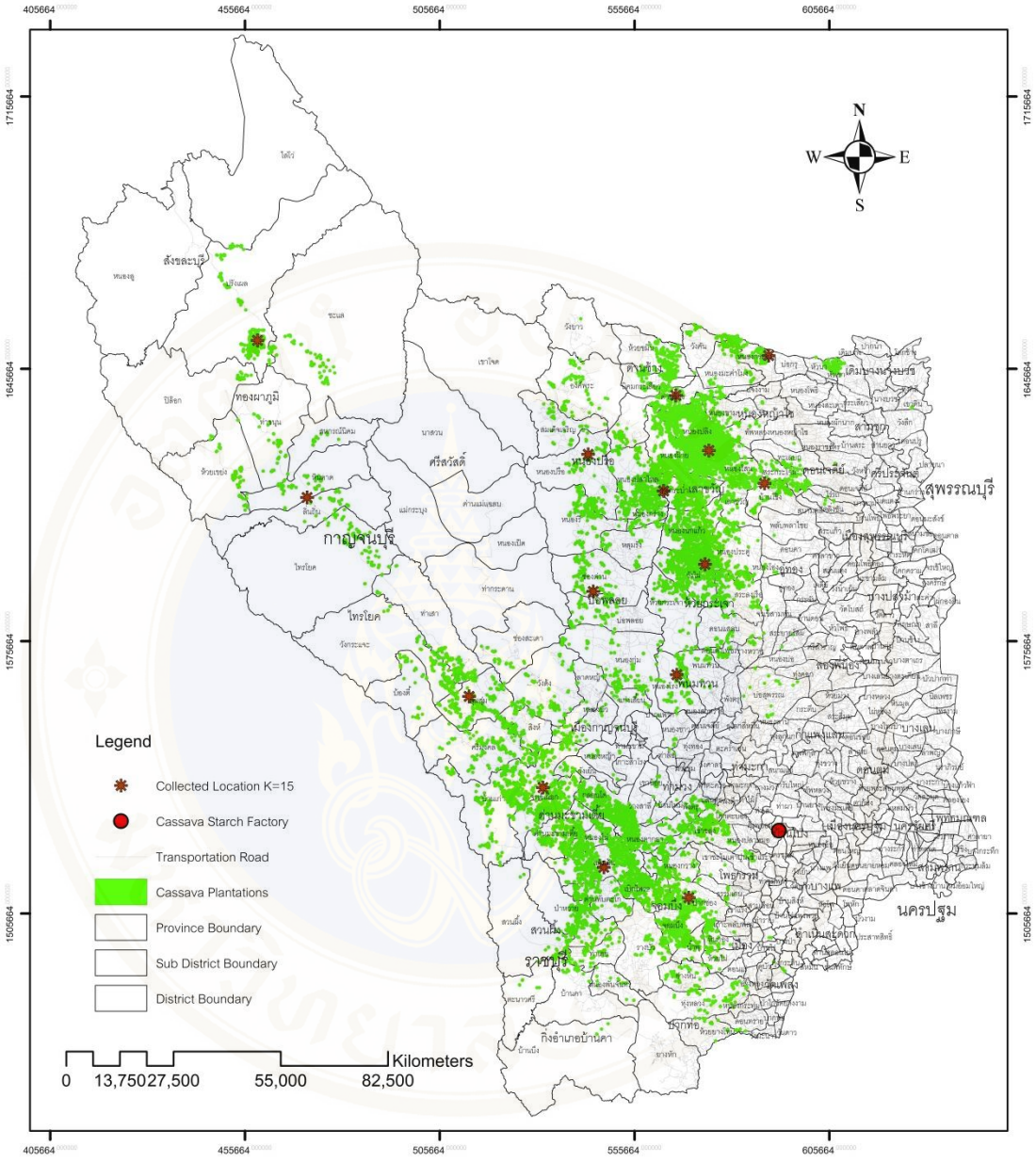

Figure the 15 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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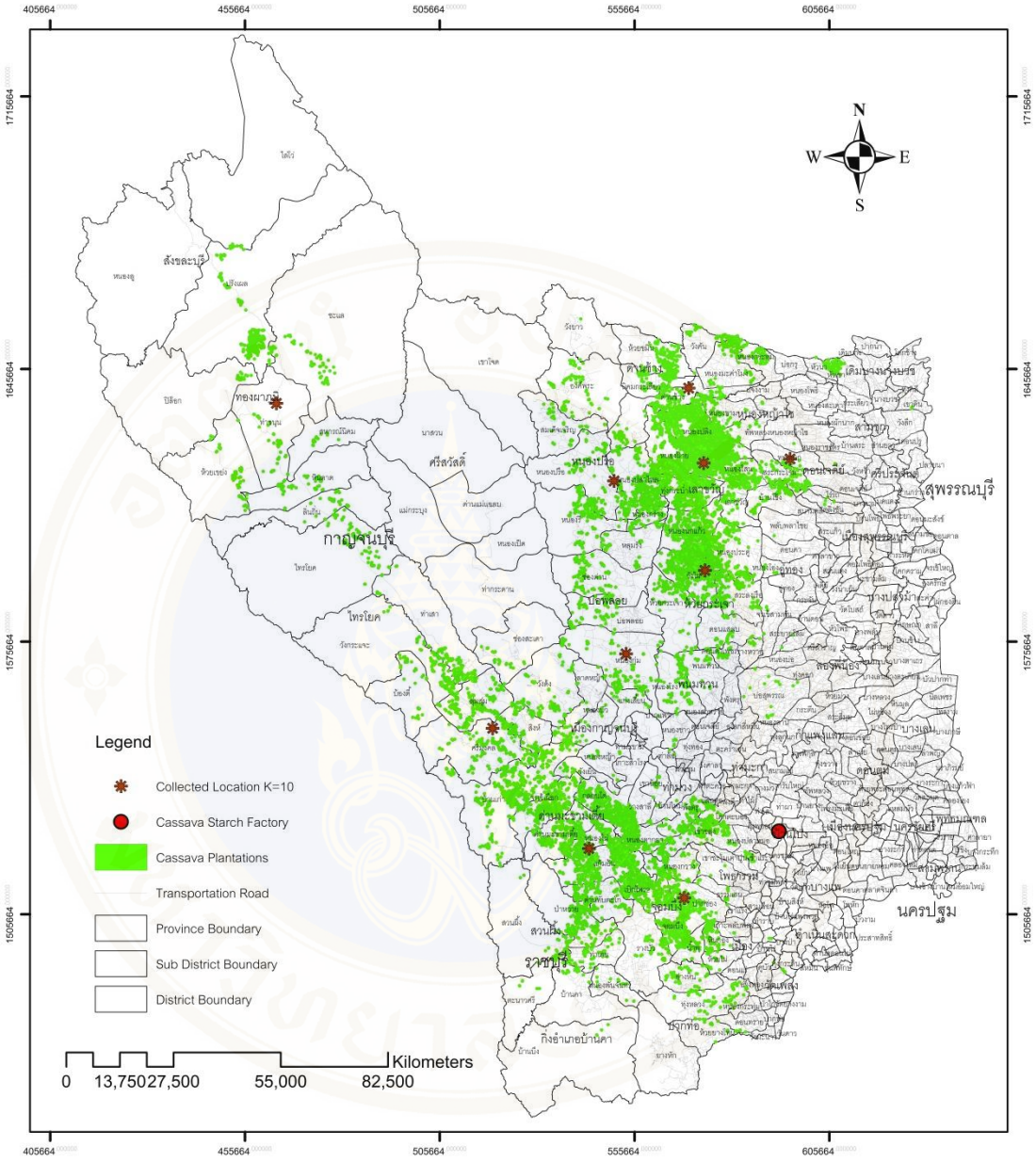

Figure the 10 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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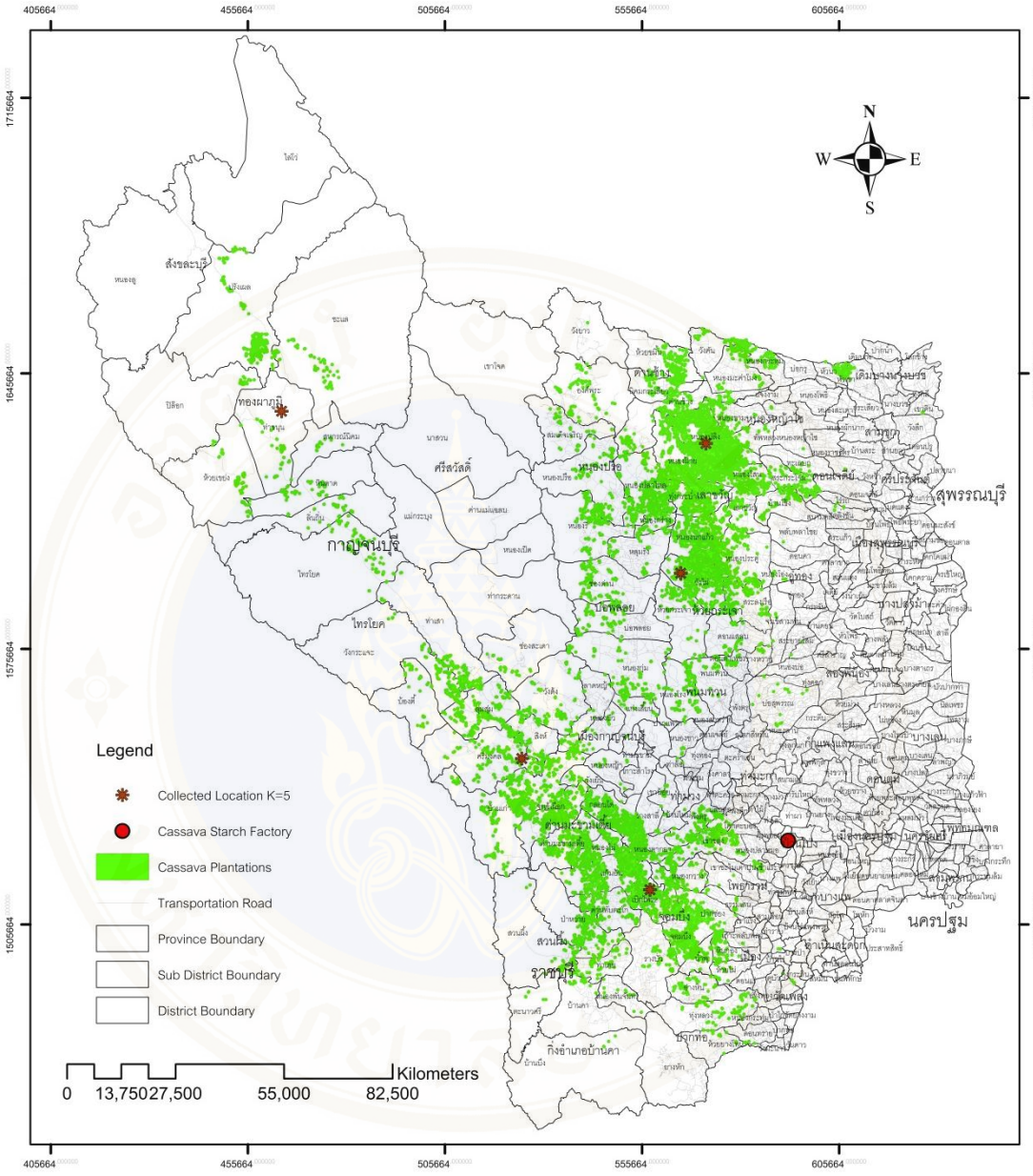

Figure the 5 location of Cassava Service Center (CSC) location by used ordinary k-mean algorithm with Weka and plotting with GIS program

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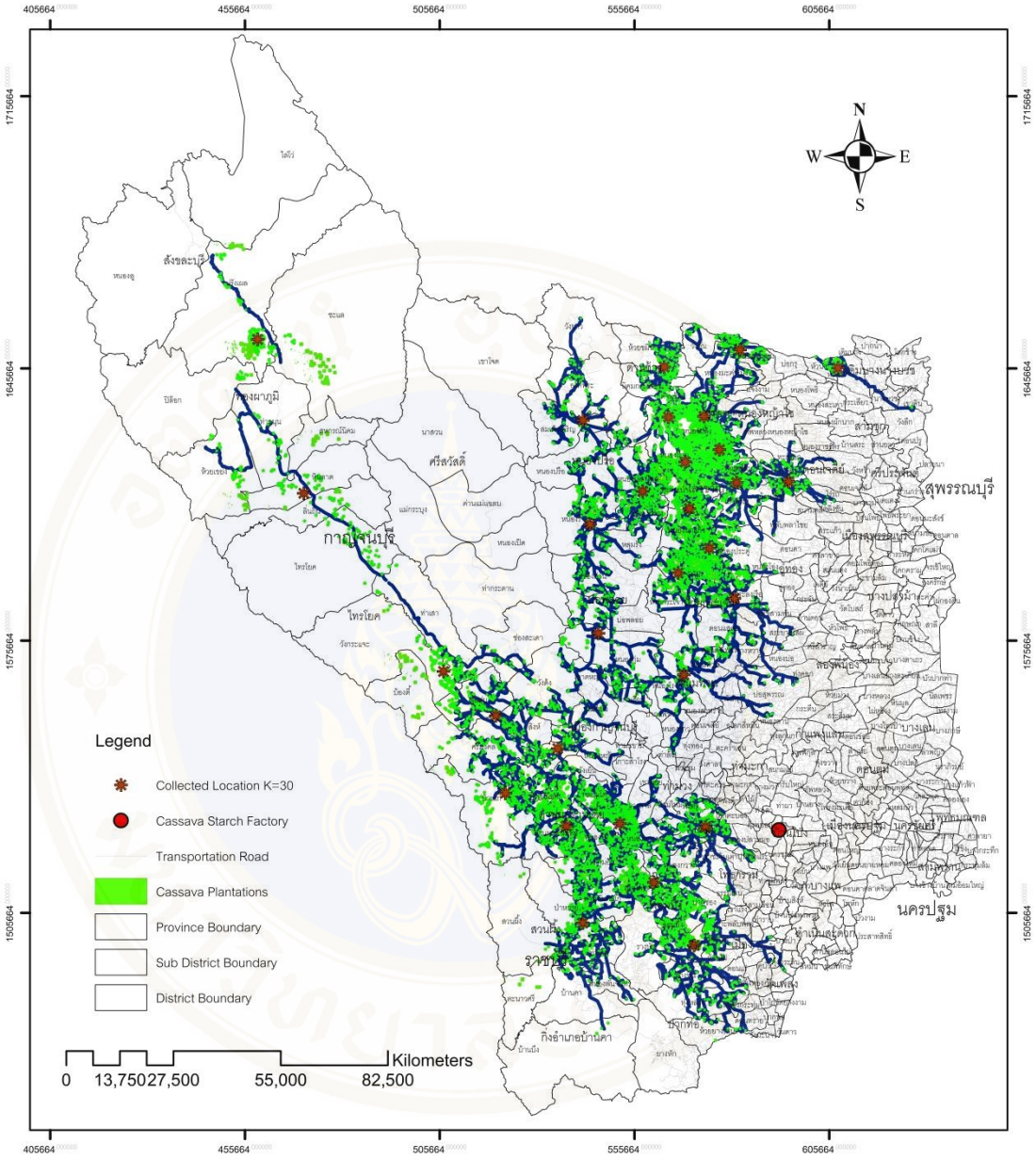

Figure the 30 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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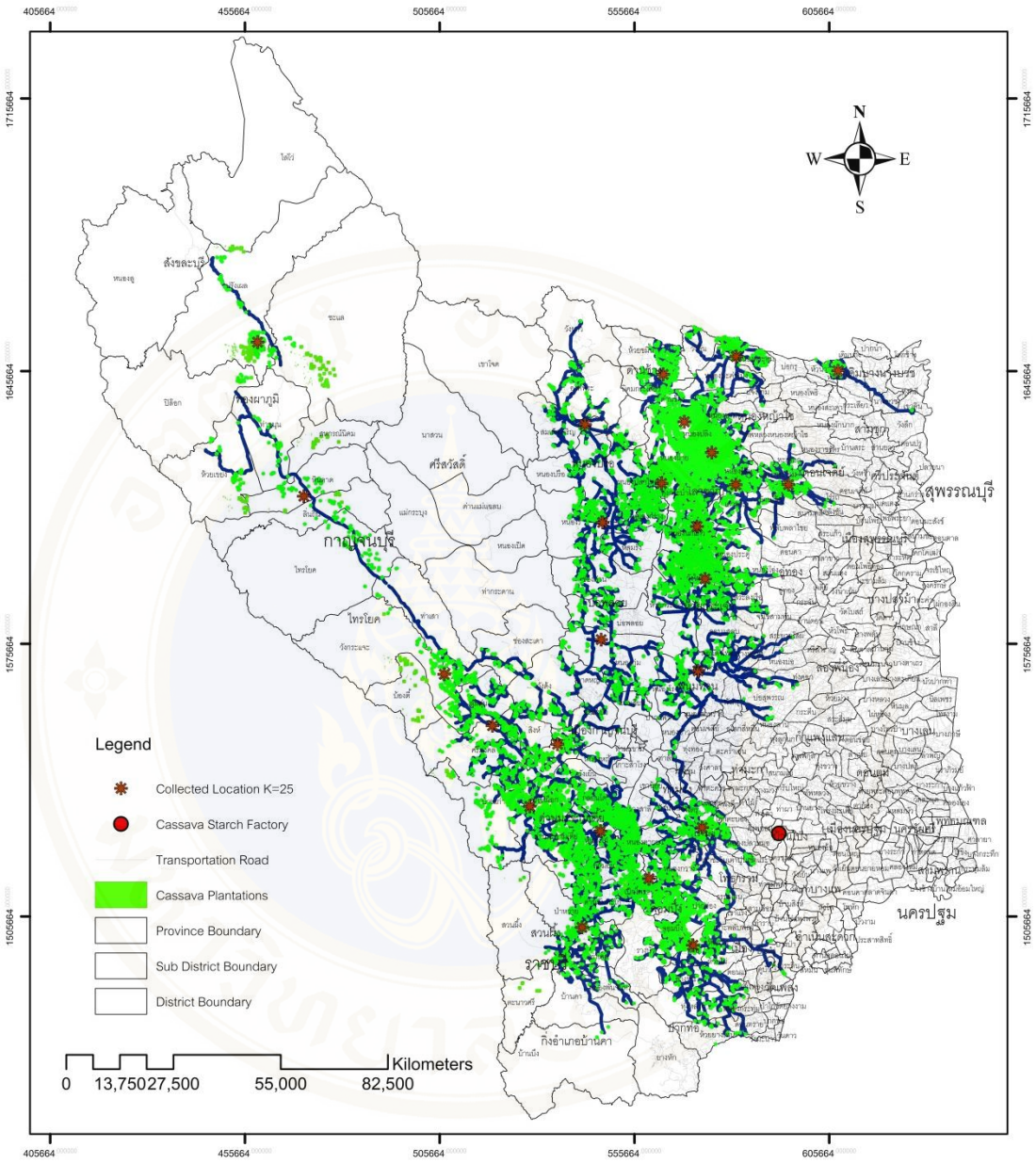

Figure the 25 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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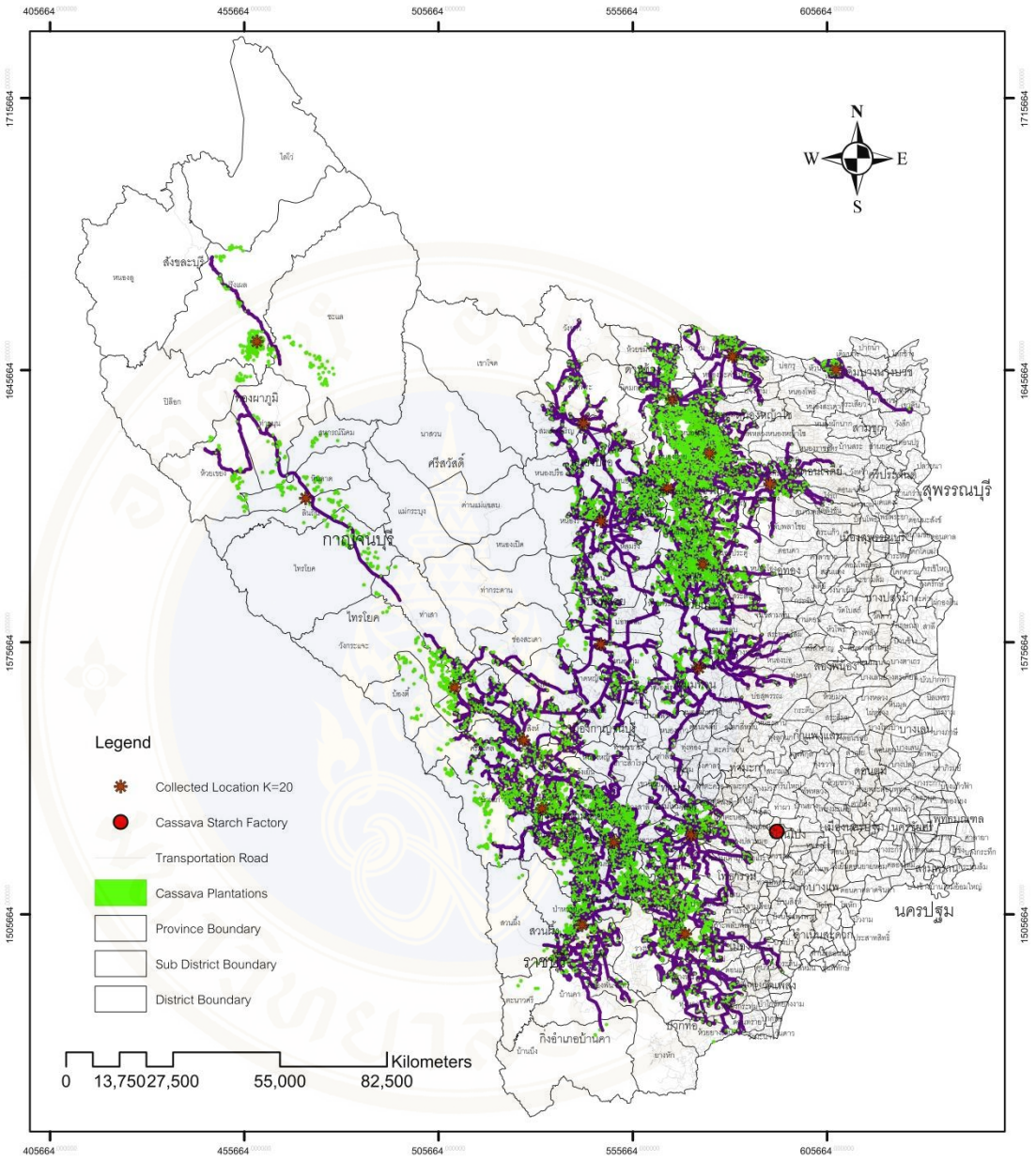

Figure the 20 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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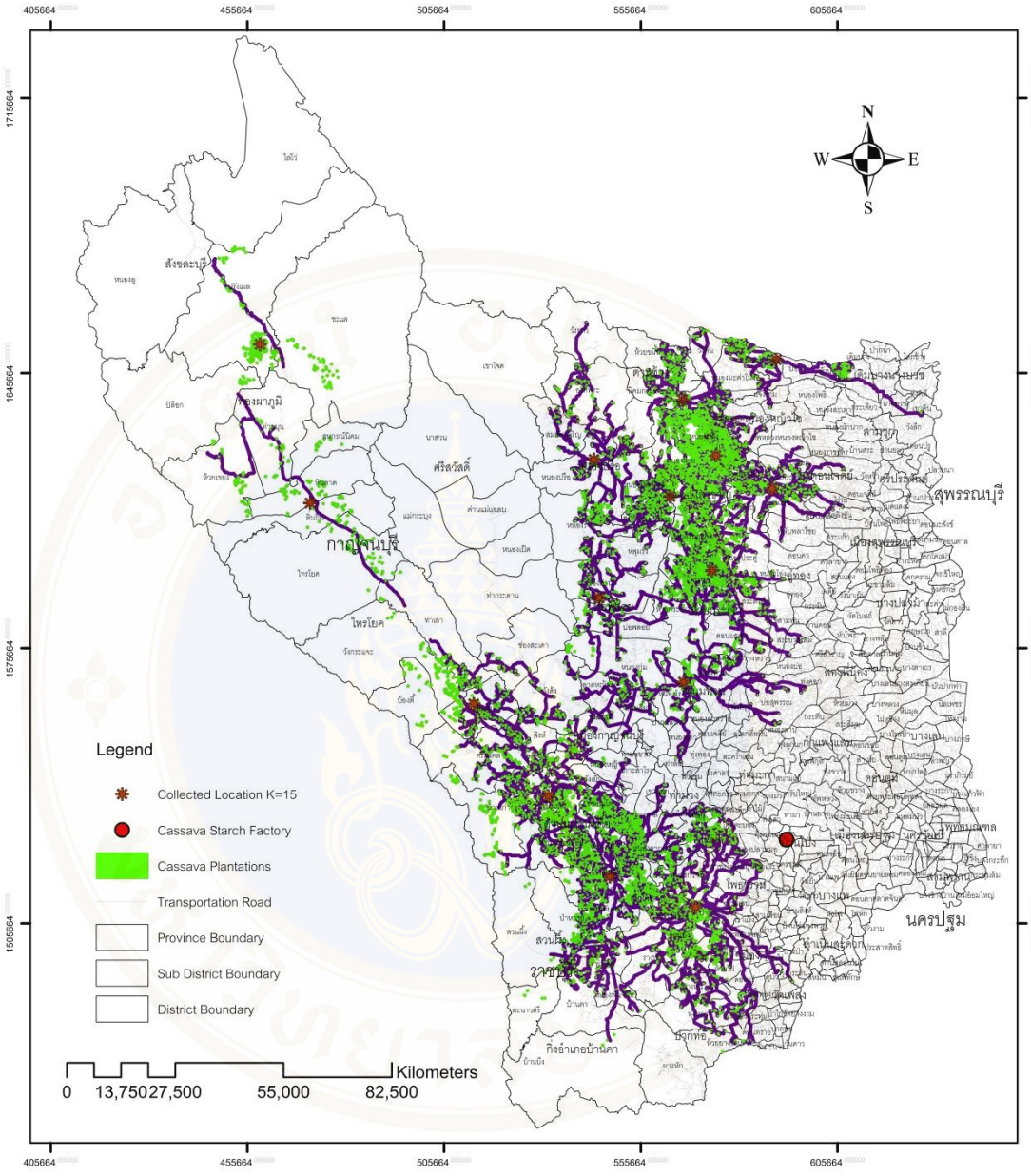

Figure the 15 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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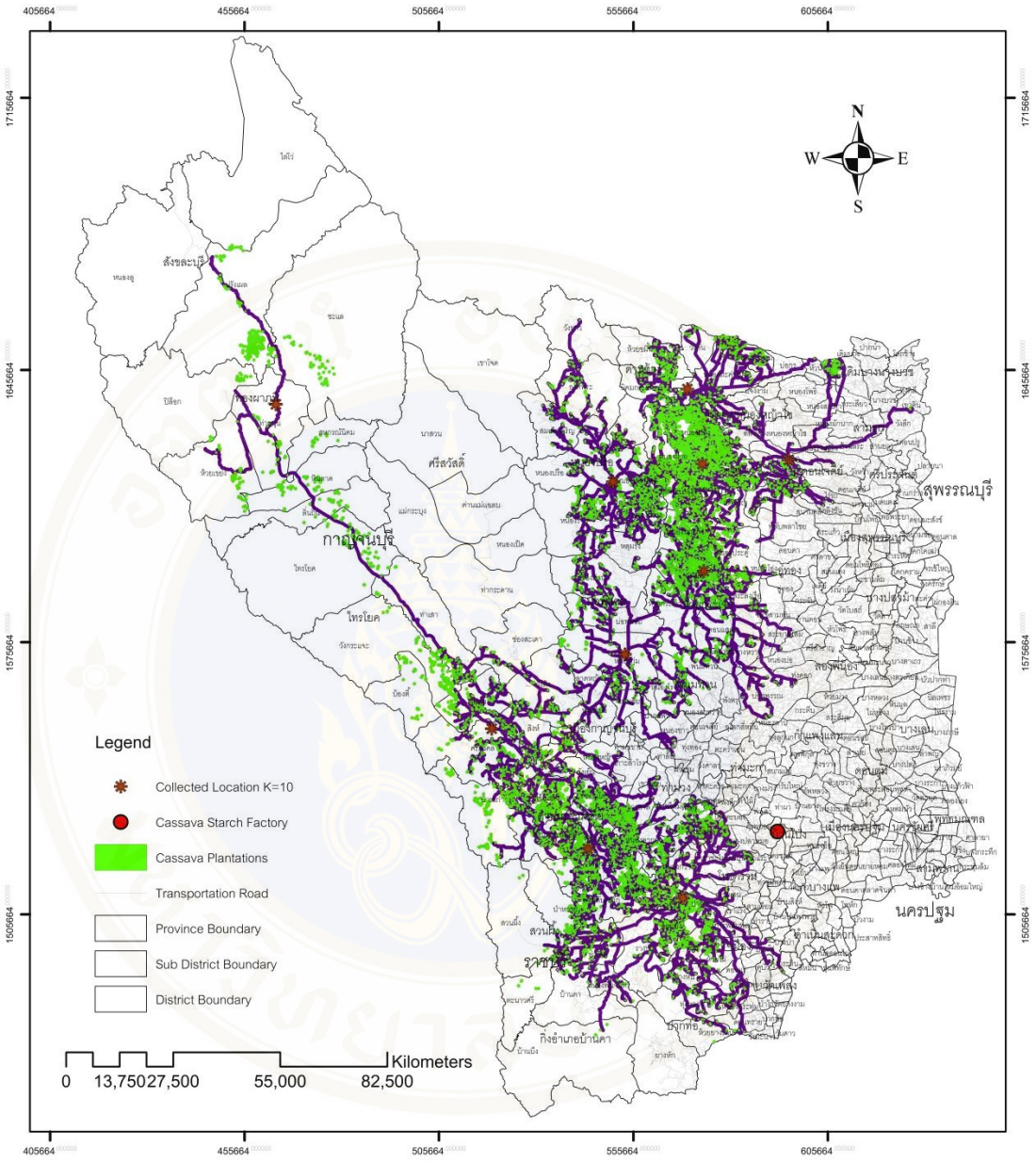

Figure the 10 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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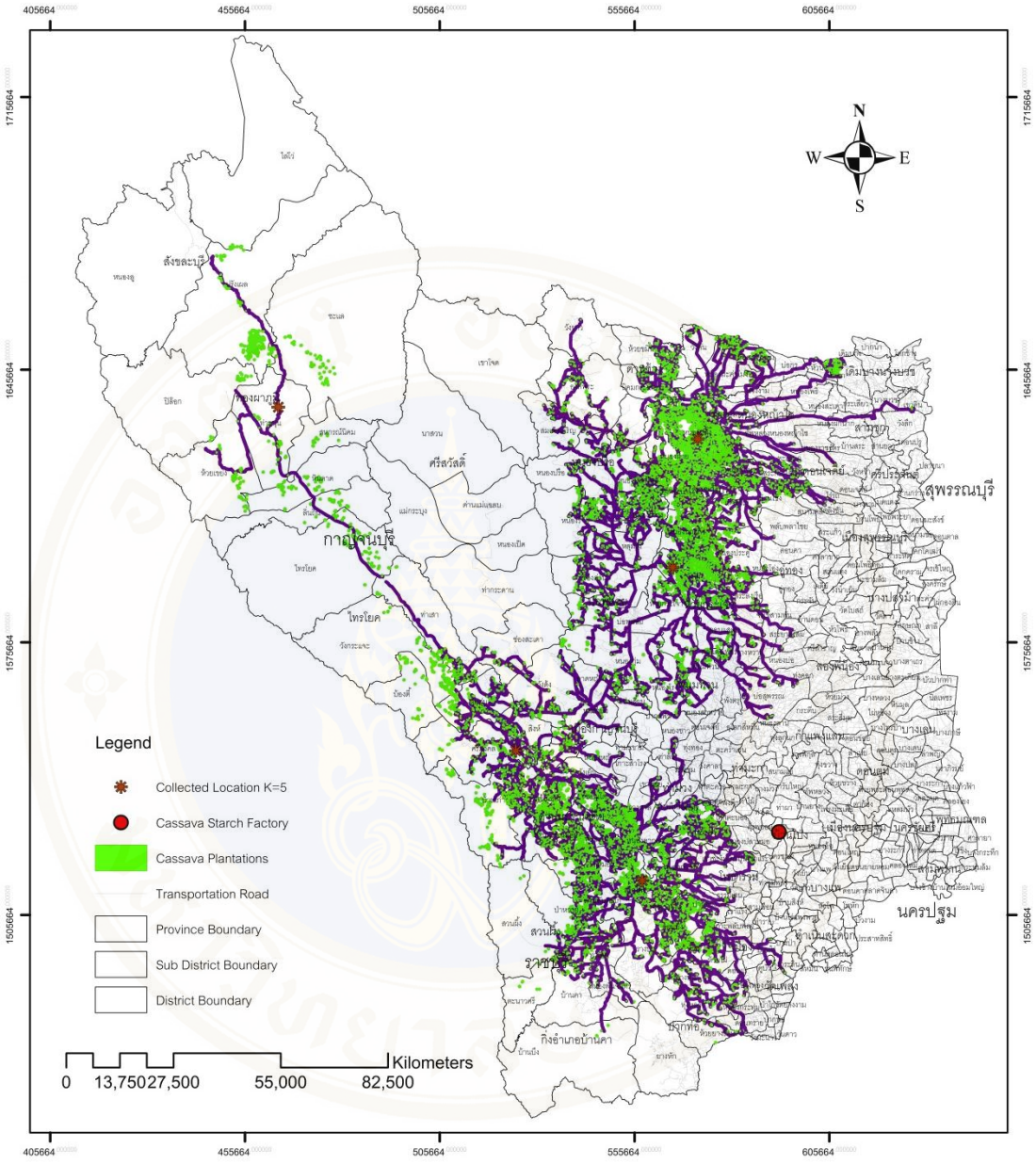

Figure the 5 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used ordinary k-mean algorithm with Weka and plotting with GIS program

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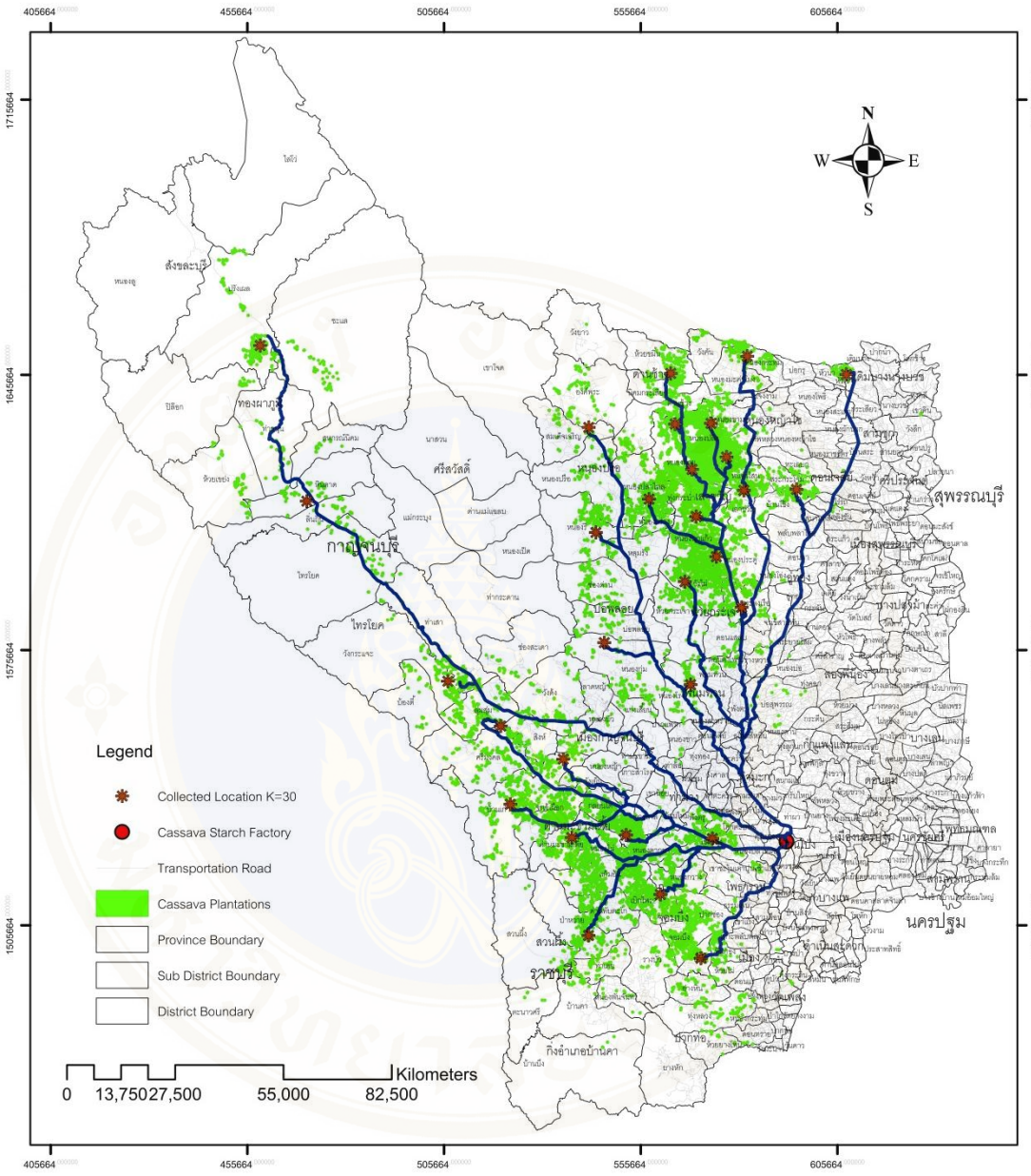

Figure the 30 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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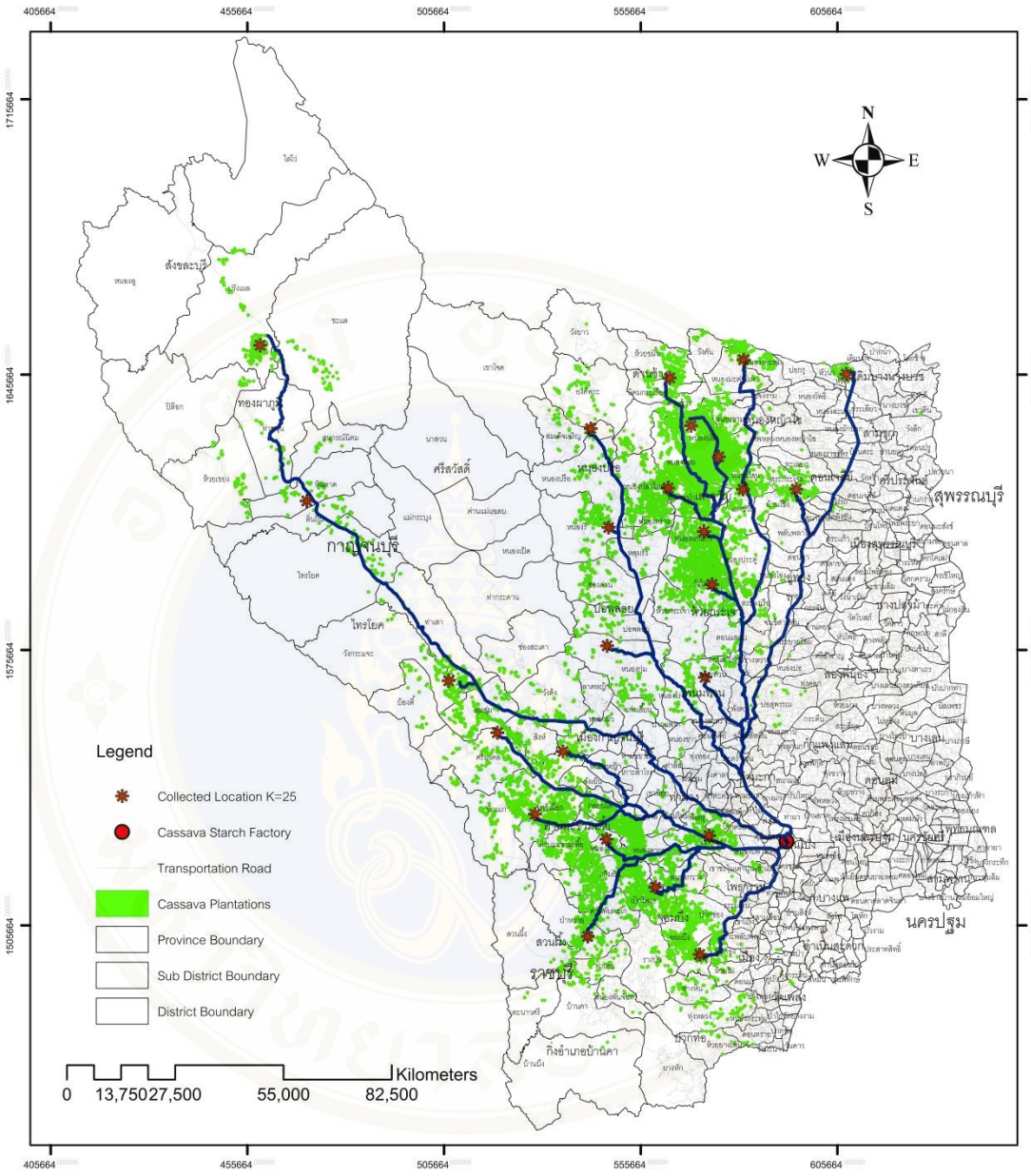

Figure the 25 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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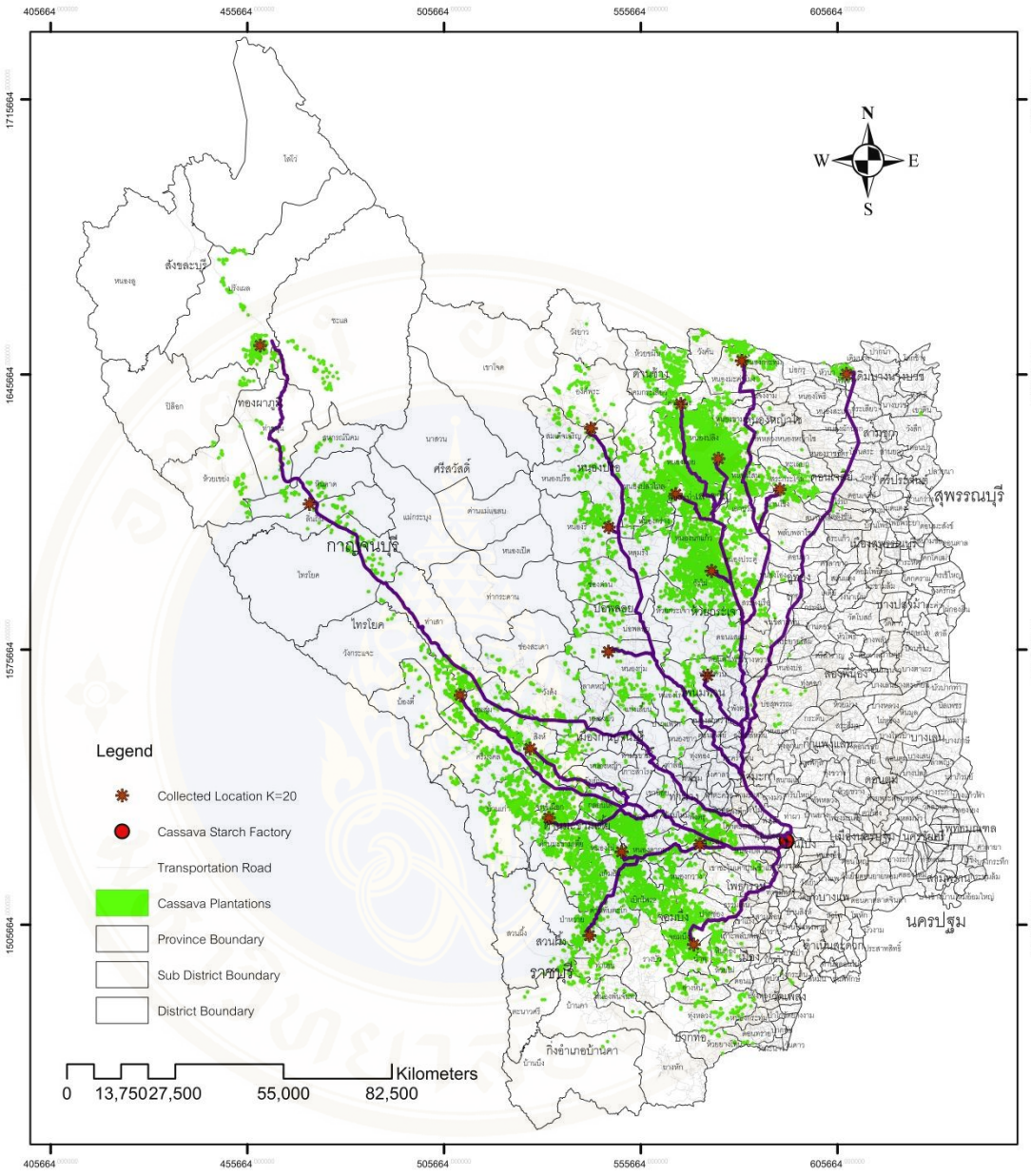

Figure the 20 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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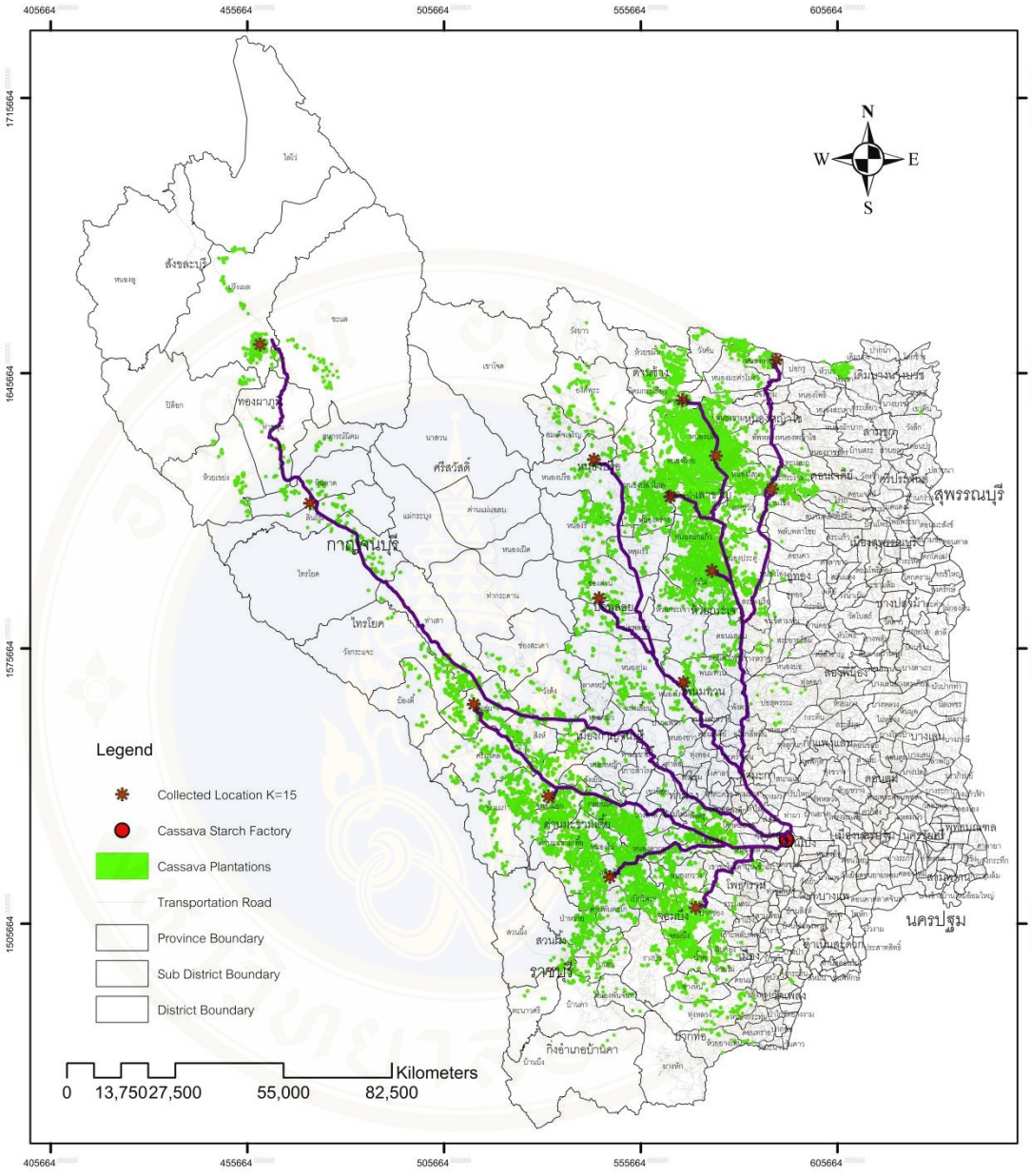

Figure the 15 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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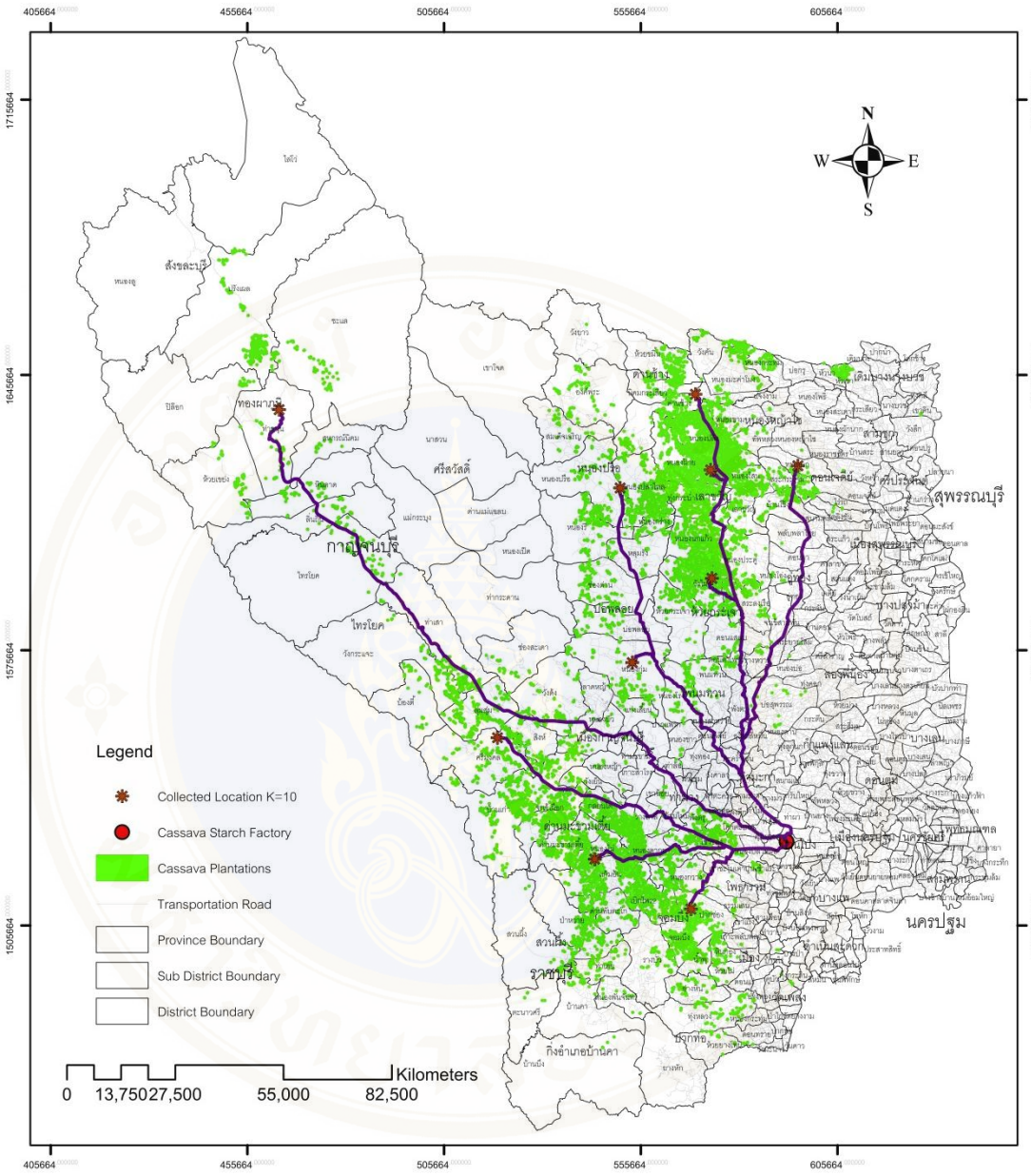

Figure the 10 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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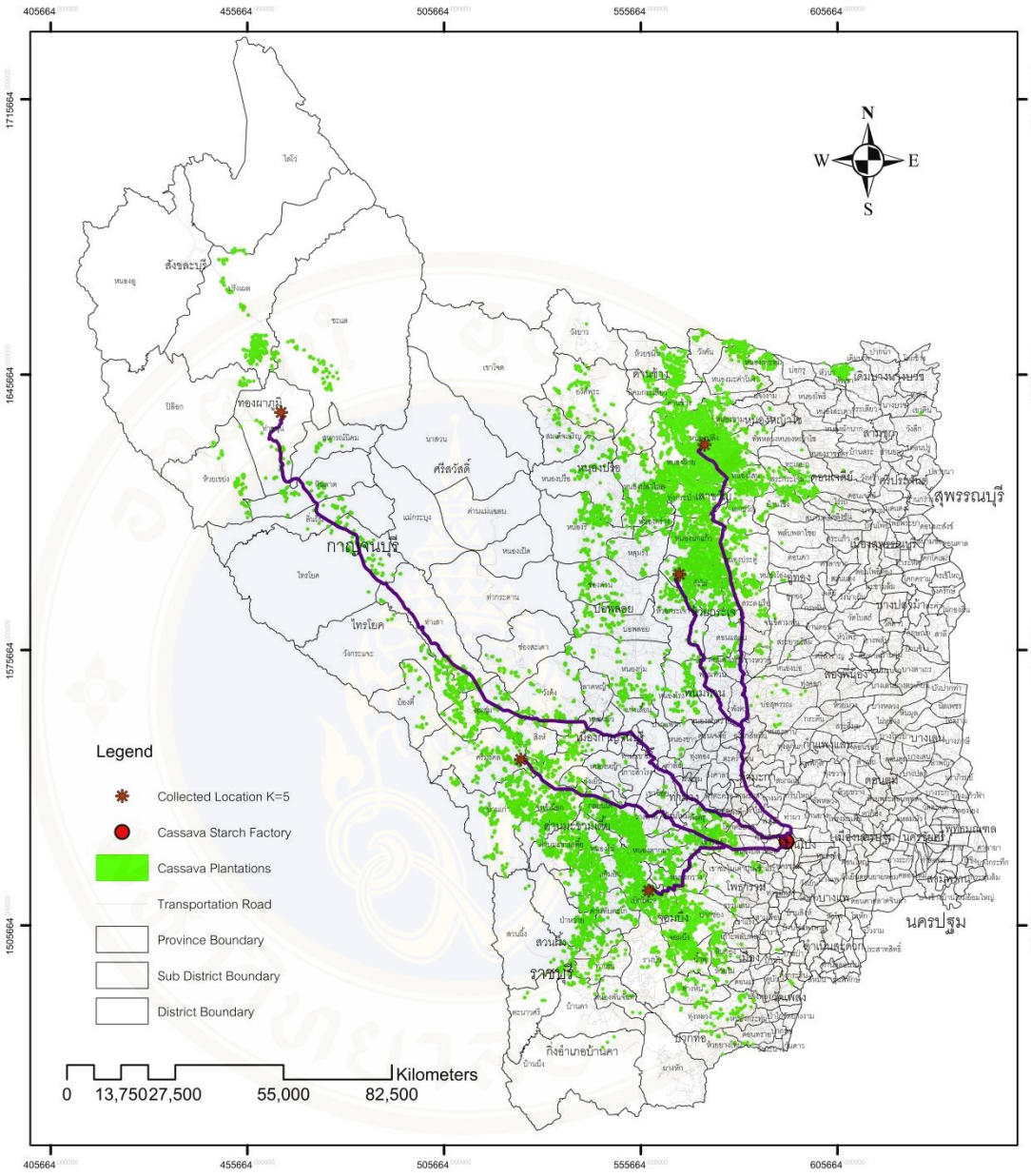

Figure the 5 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used ordinary k-mean algorithm with Weka and plotting with GIS program

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APPENDIX D

The figure results of Cassava Service Center (CSC) location by used the modified k-mean clustering algorithm with MATLAB and plotting with GIS

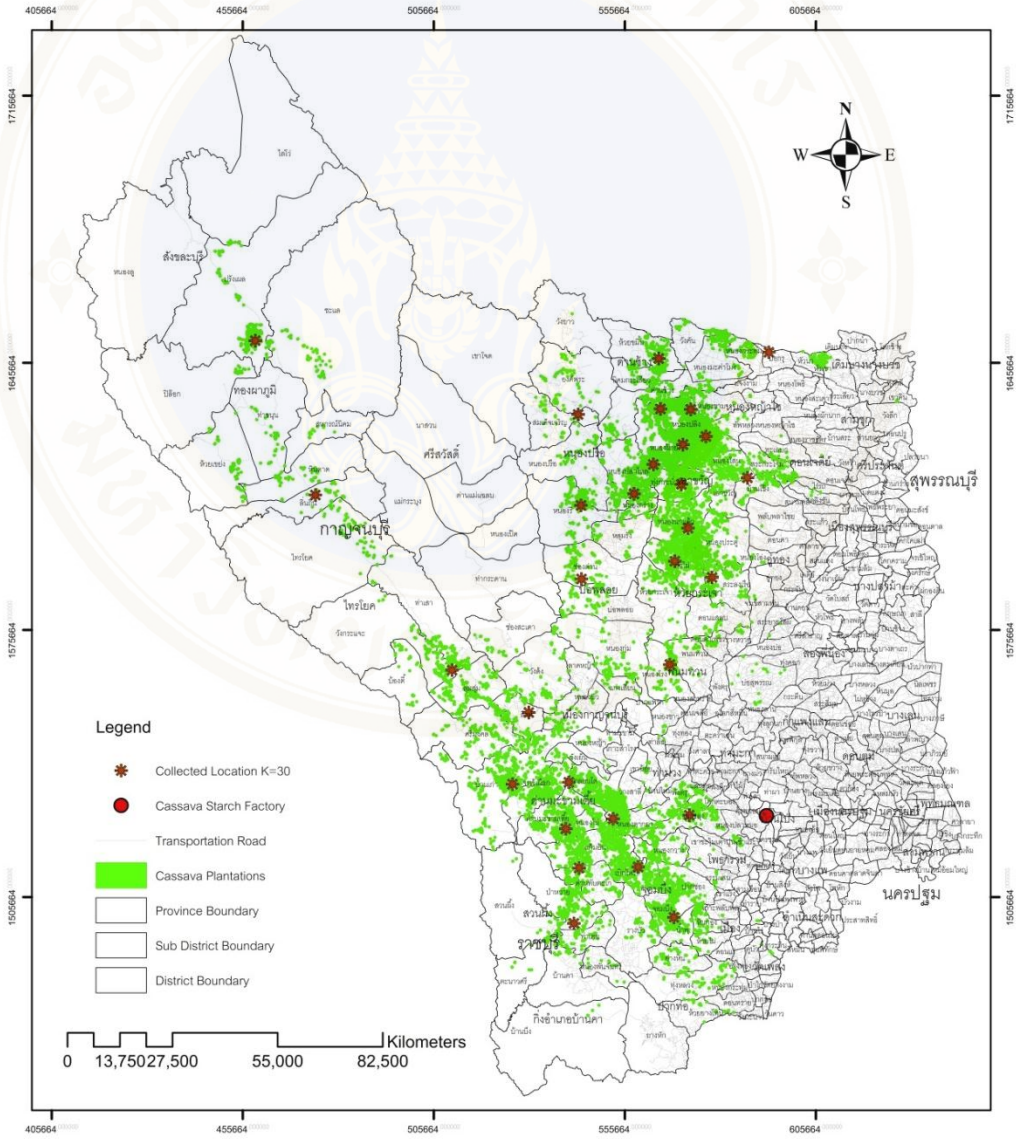

Figure the 30 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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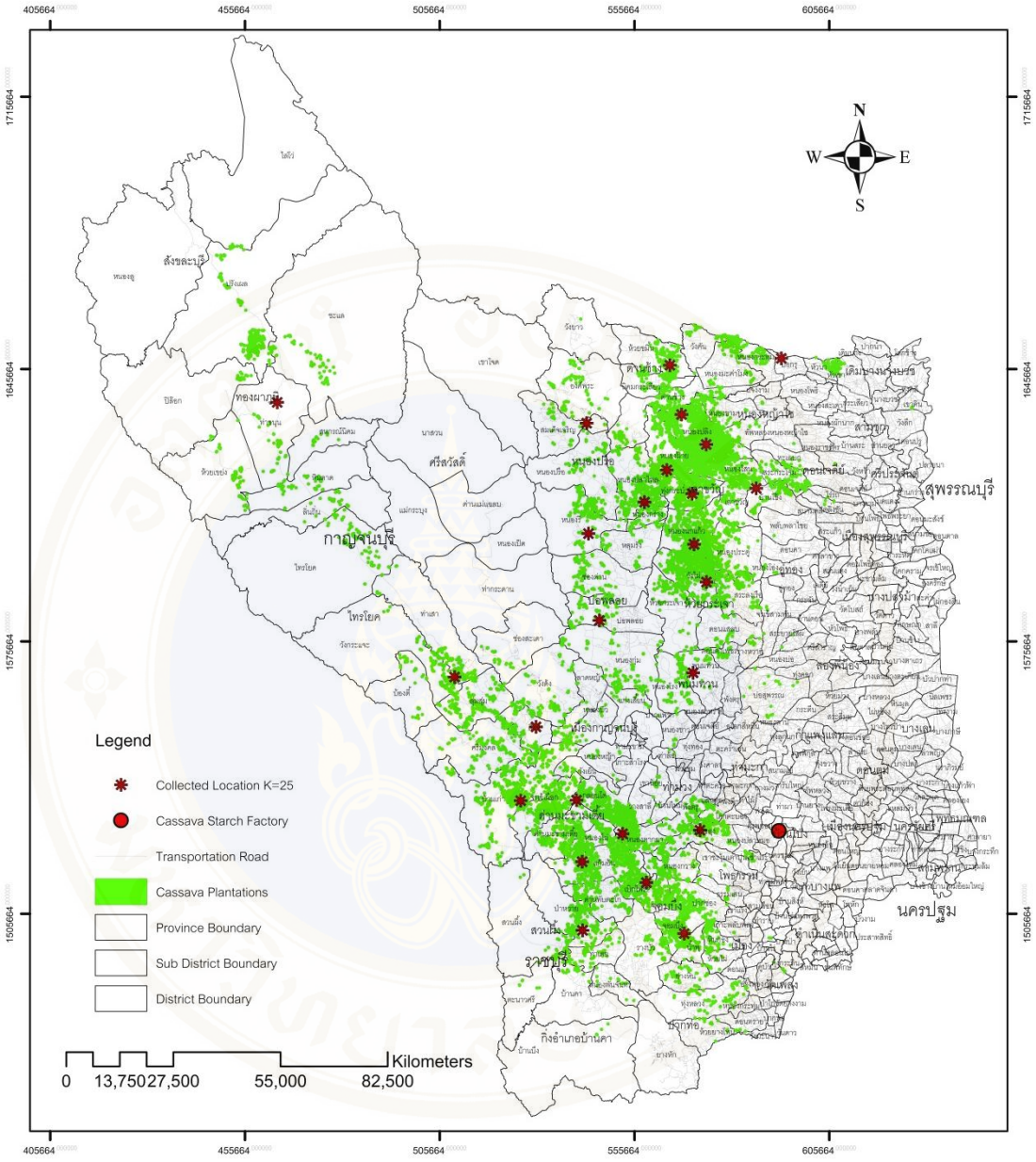

Figure the 25 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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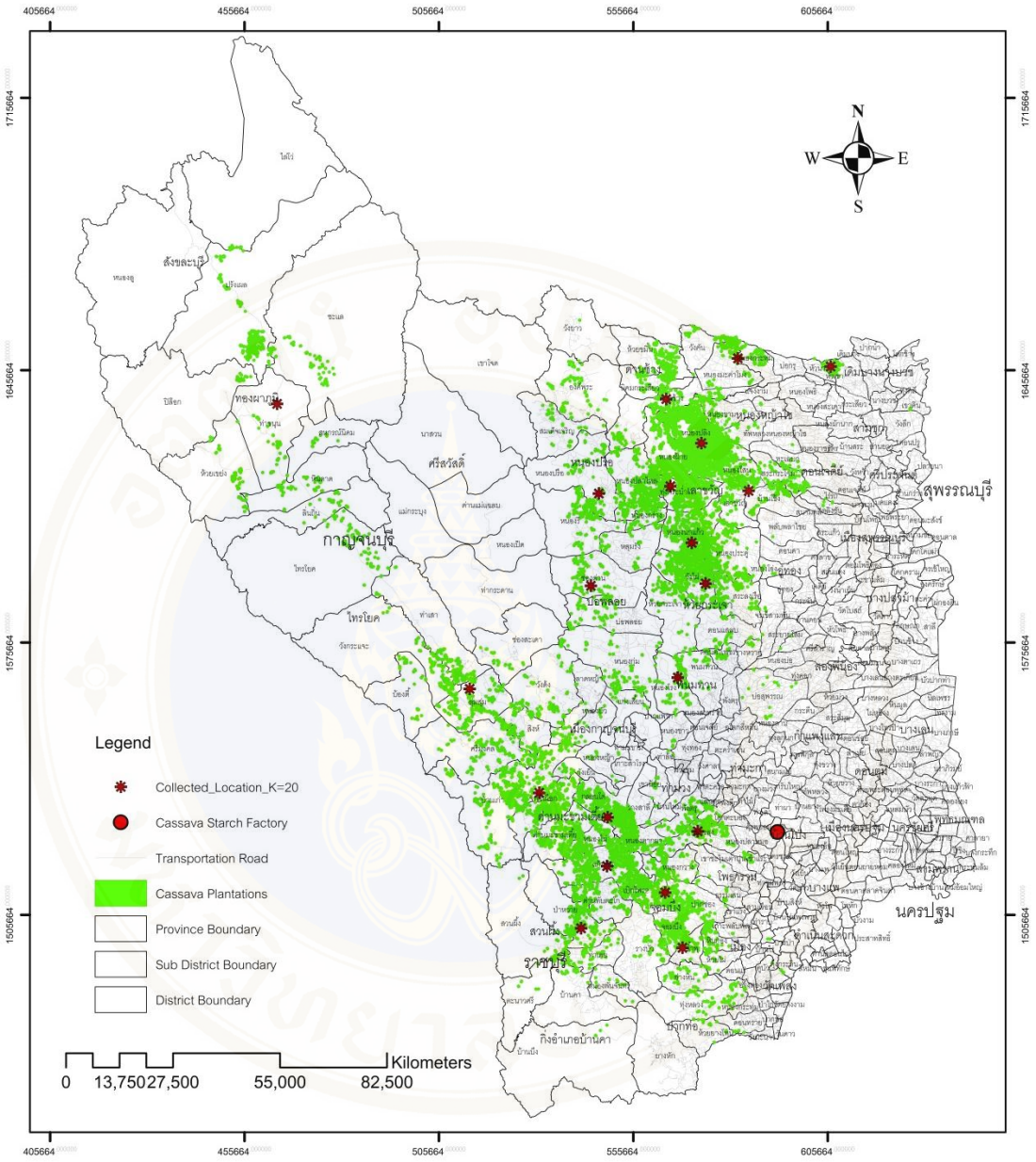

Figure the 20 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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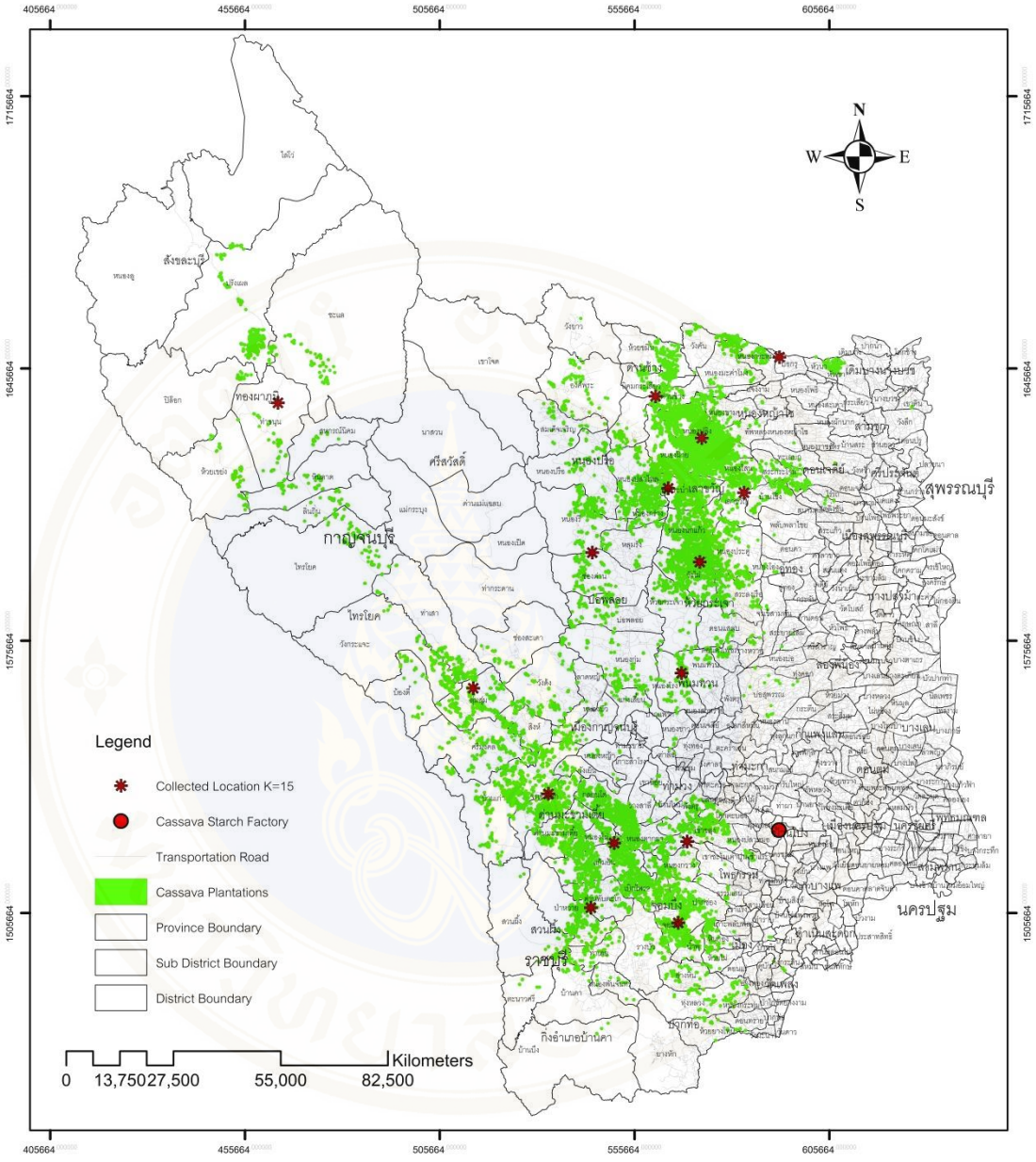

Figure the 15 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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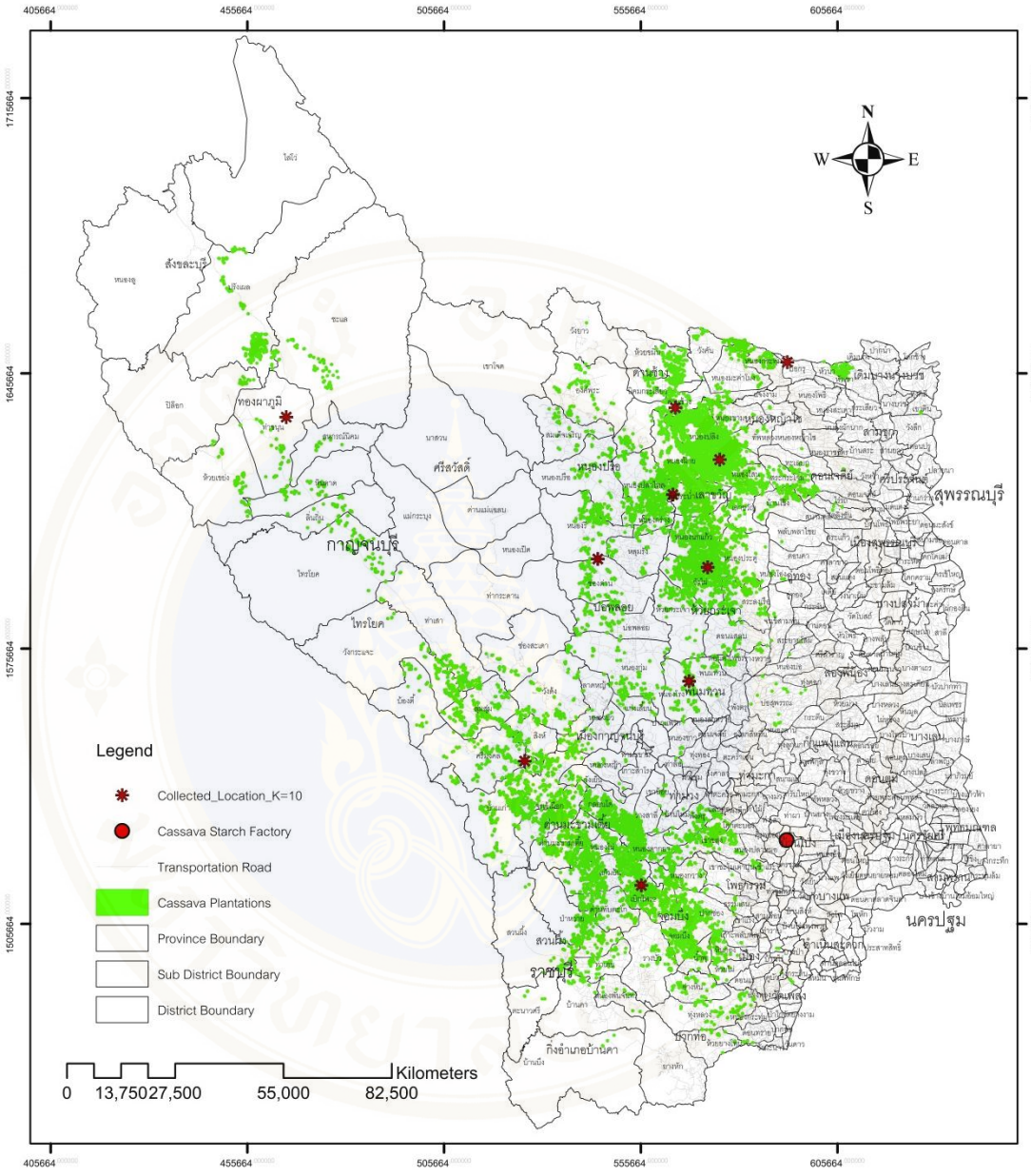

Figure the 10 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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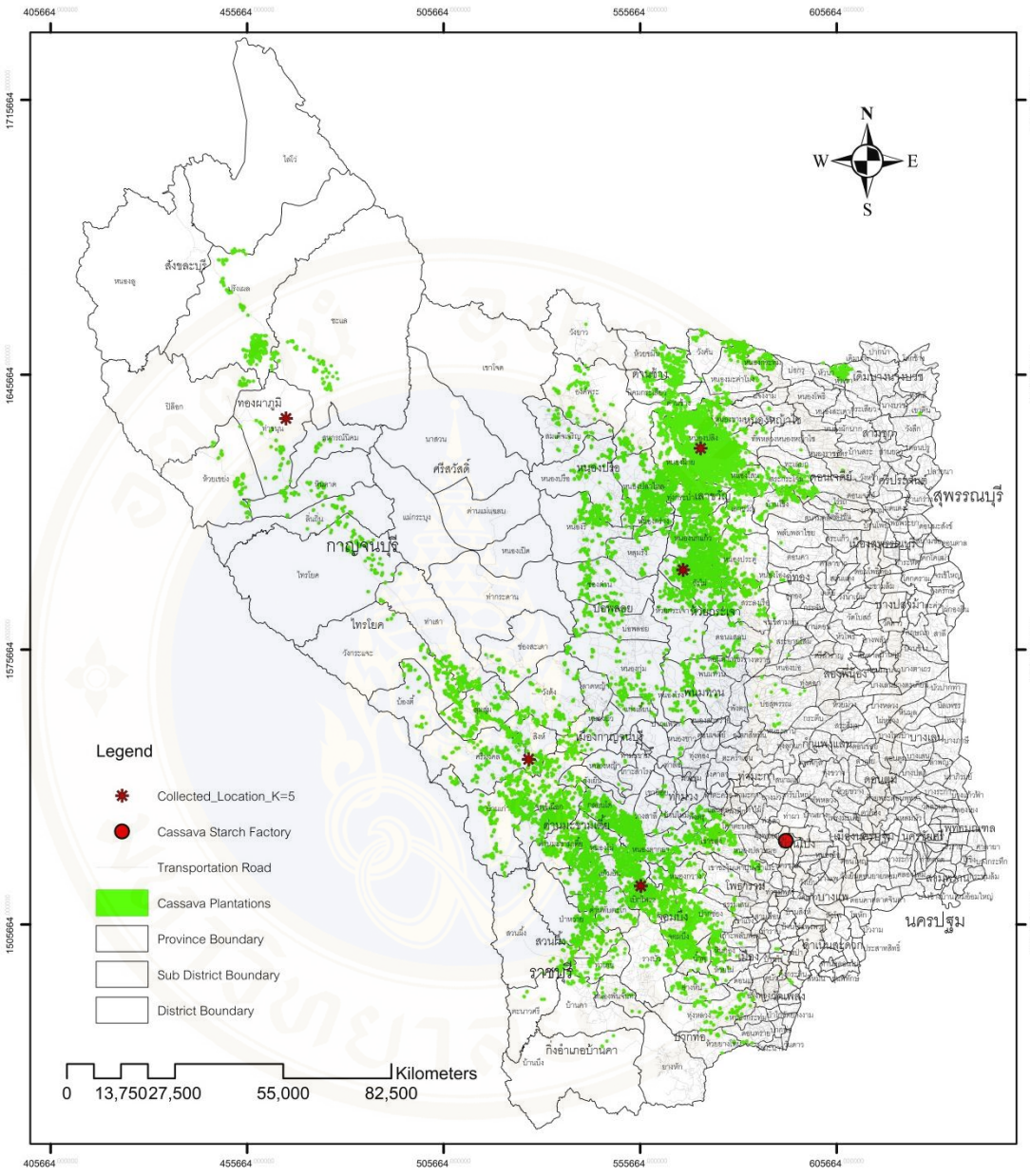

Figure the 5 location of Cassava Service Center (CSC) location by used the modified k-mean algorithm with Matlab and plotting with GIS program

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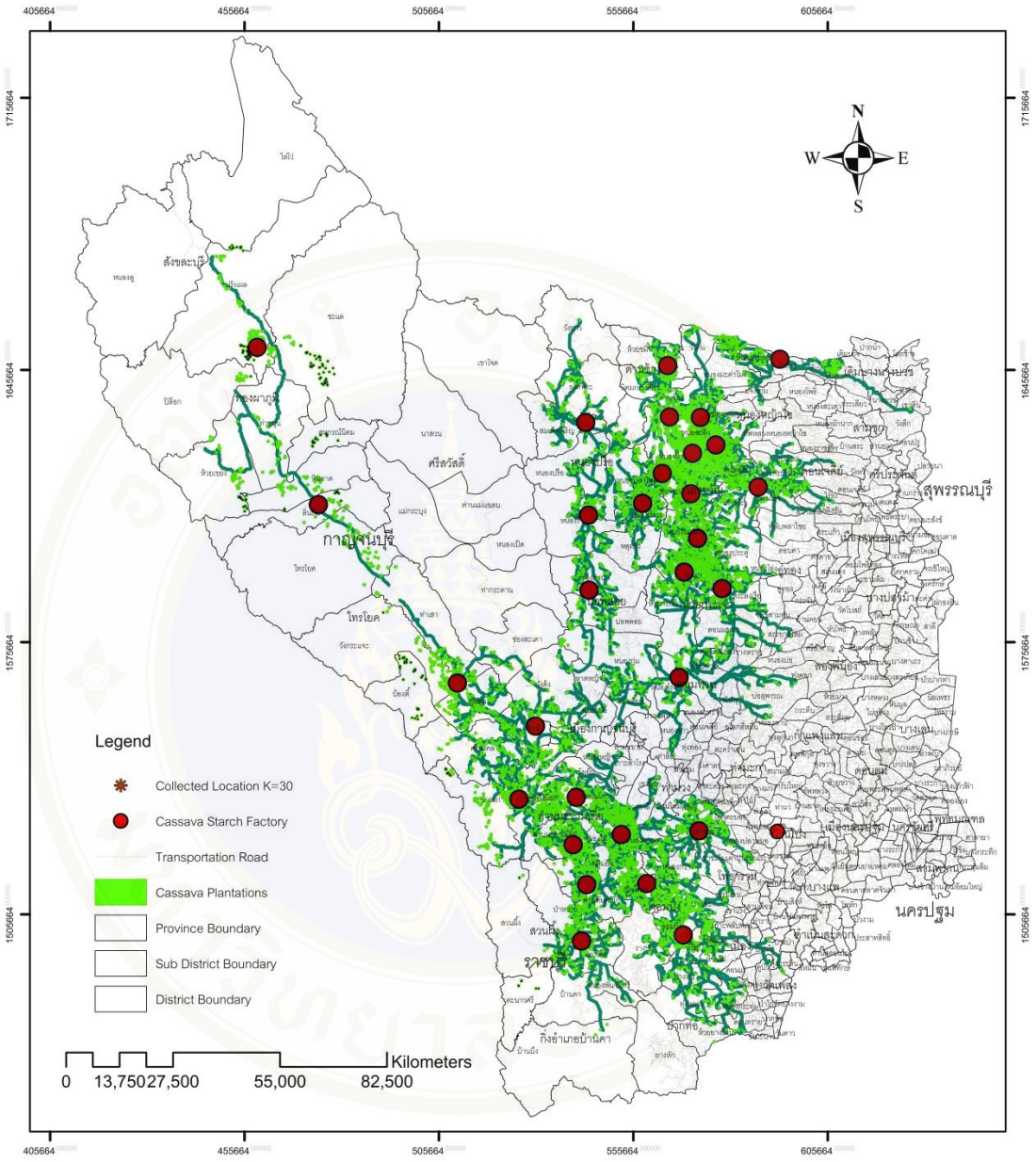

Figure the 30 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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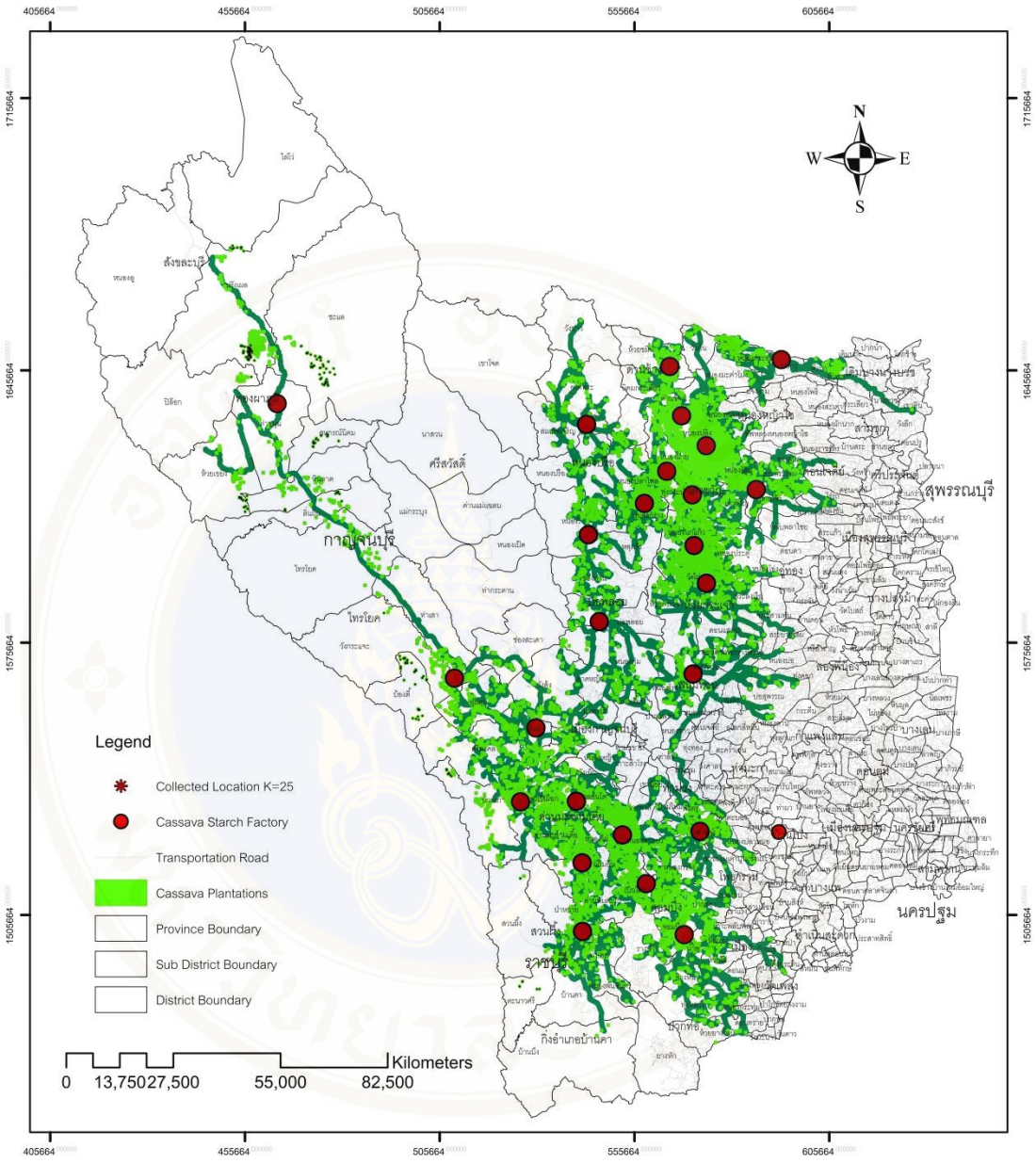

Figure the 25 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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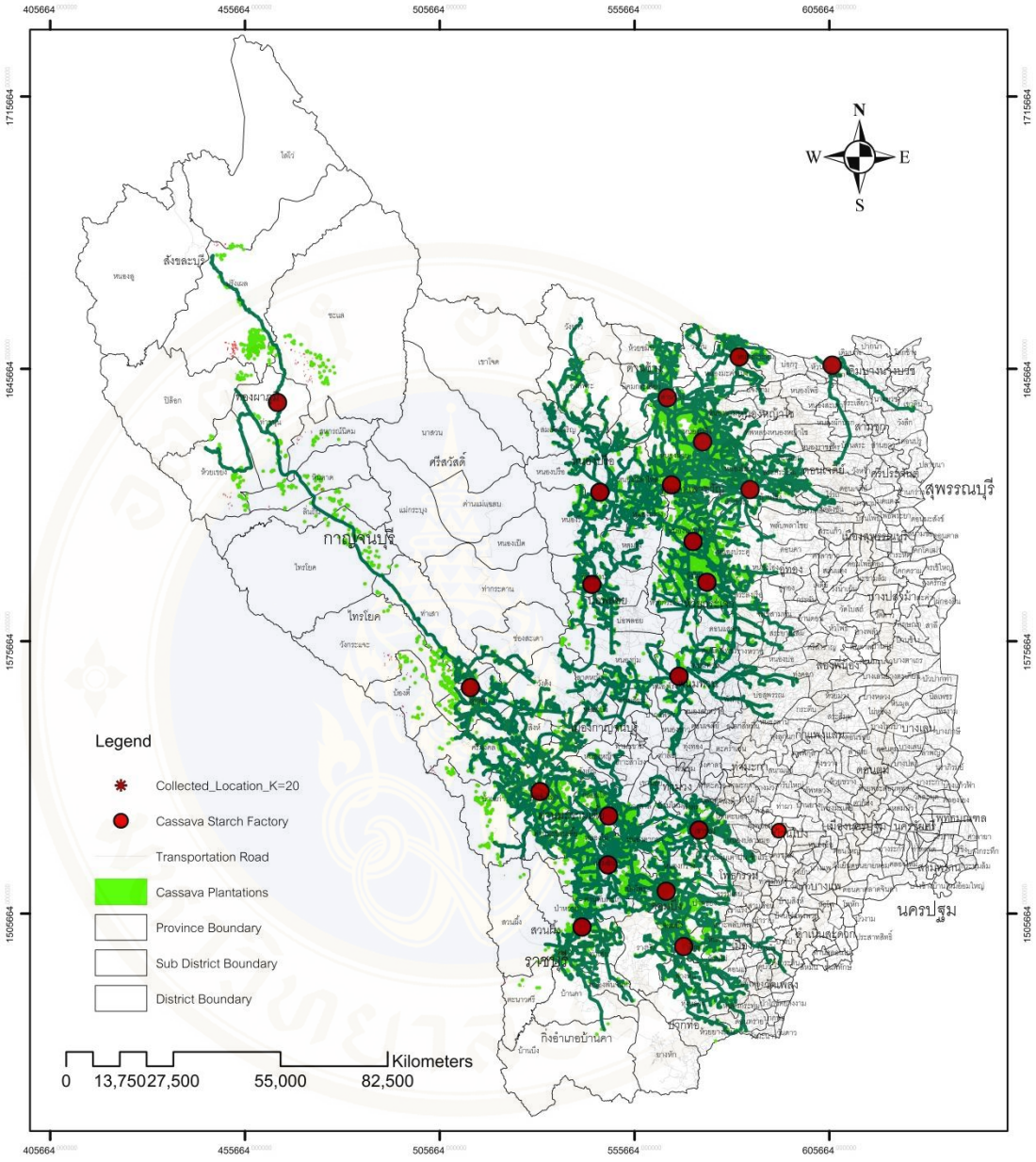

Figure the 20 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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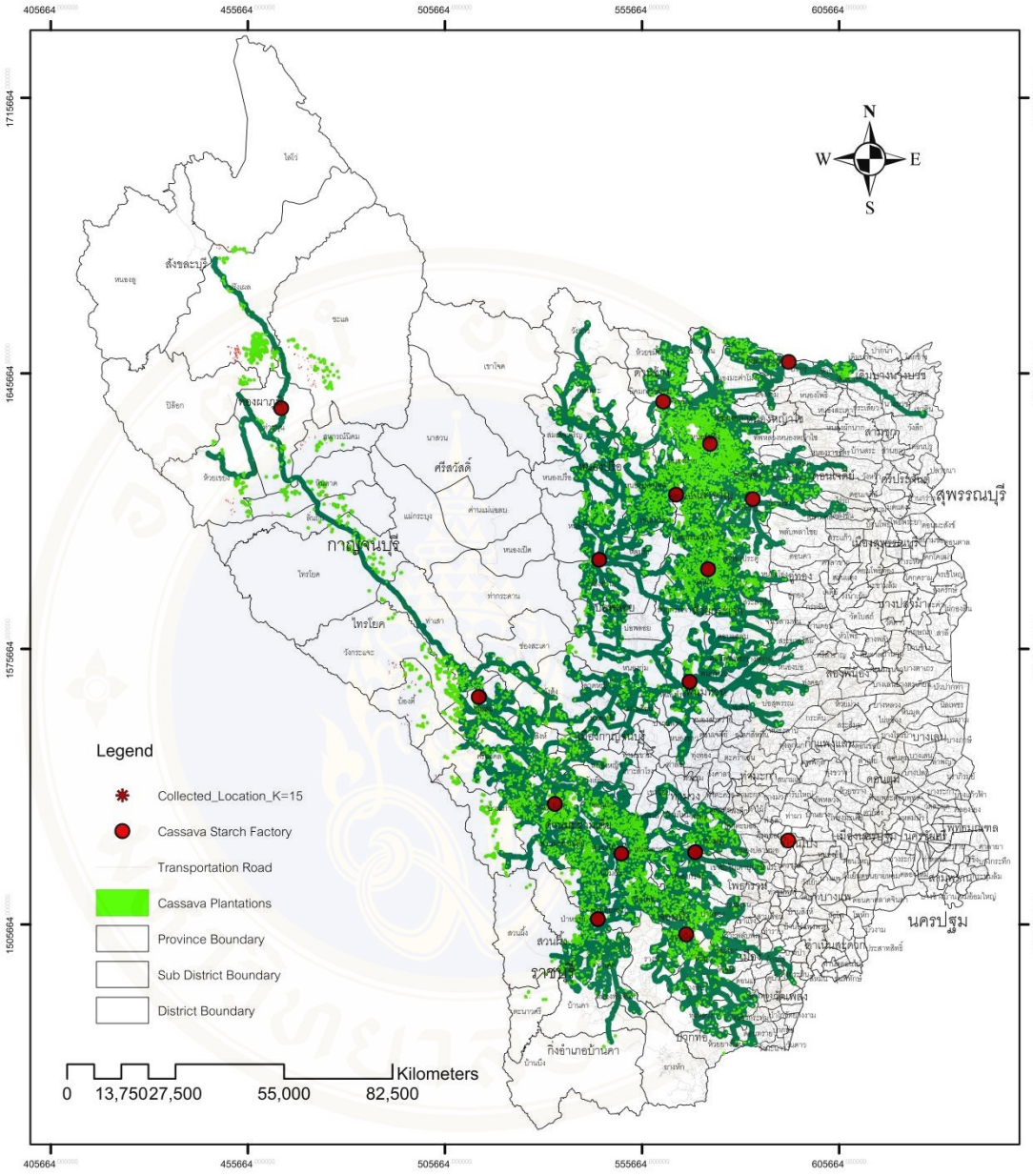

Figure the 15 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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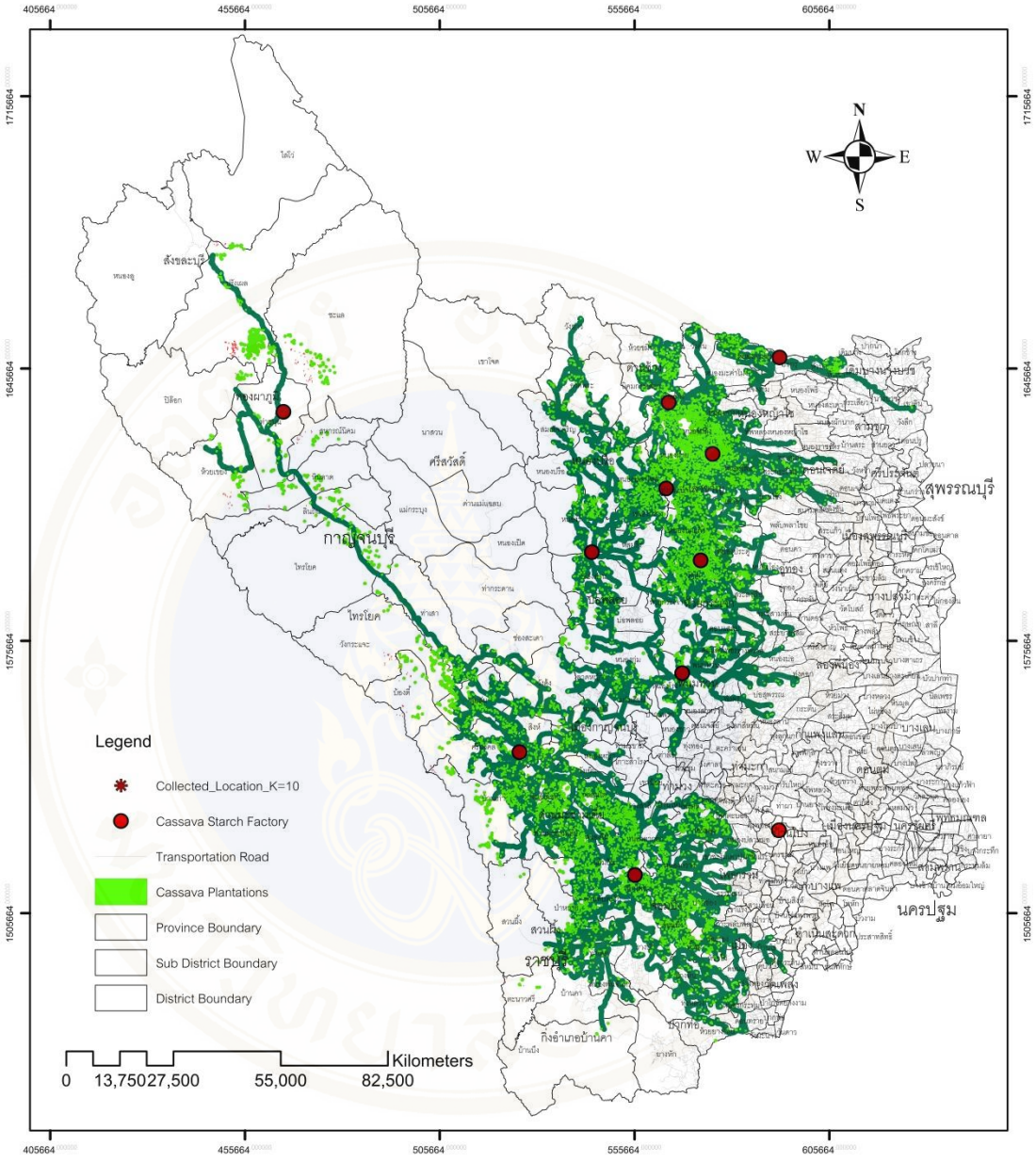

Figure the 10 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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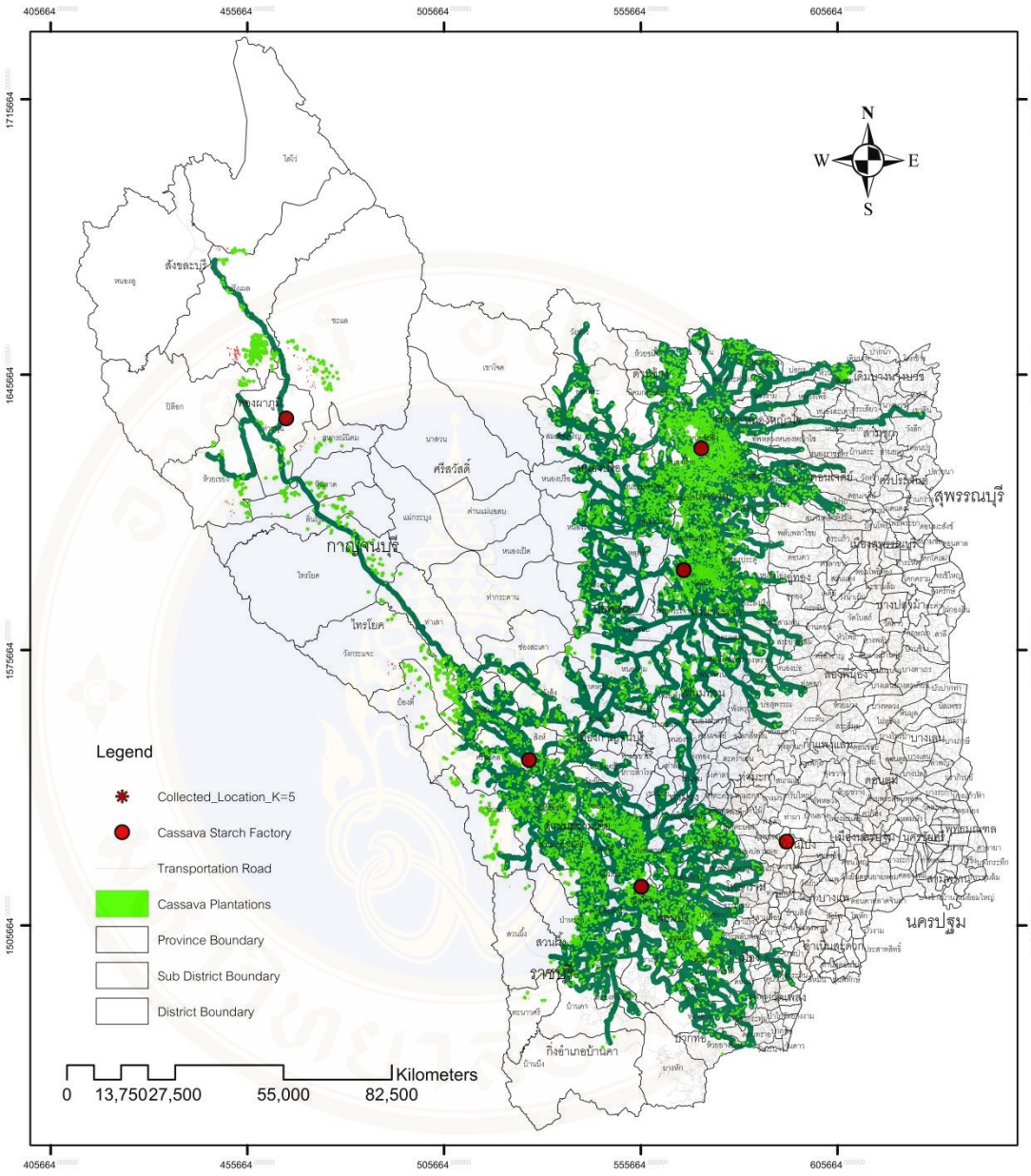

Figure the 5 locations of Cassava Service Station (CSC) and routing from cassava farms to CSC locations by used modified k-mean algorithm with Matlab

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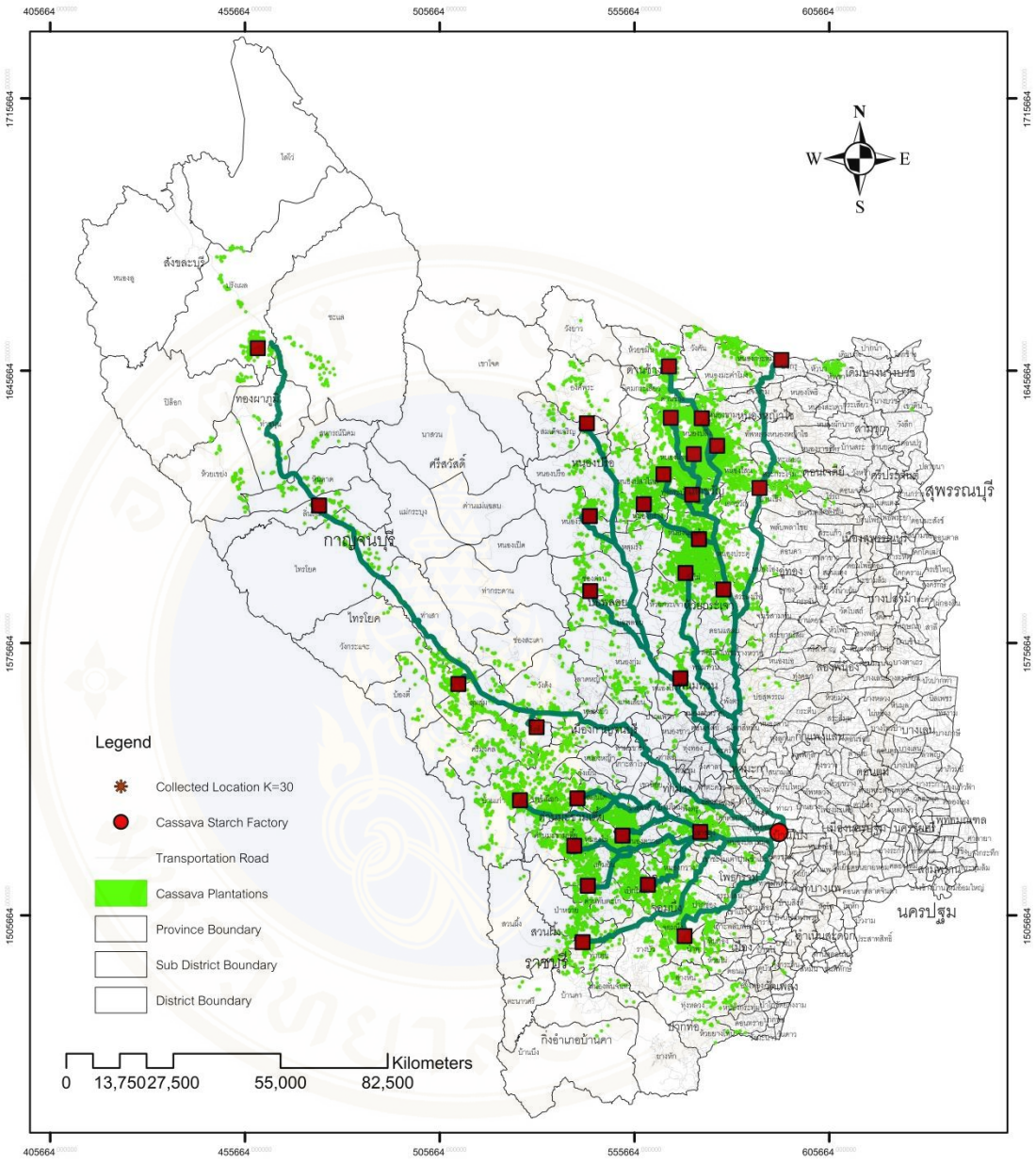

Figure the 30 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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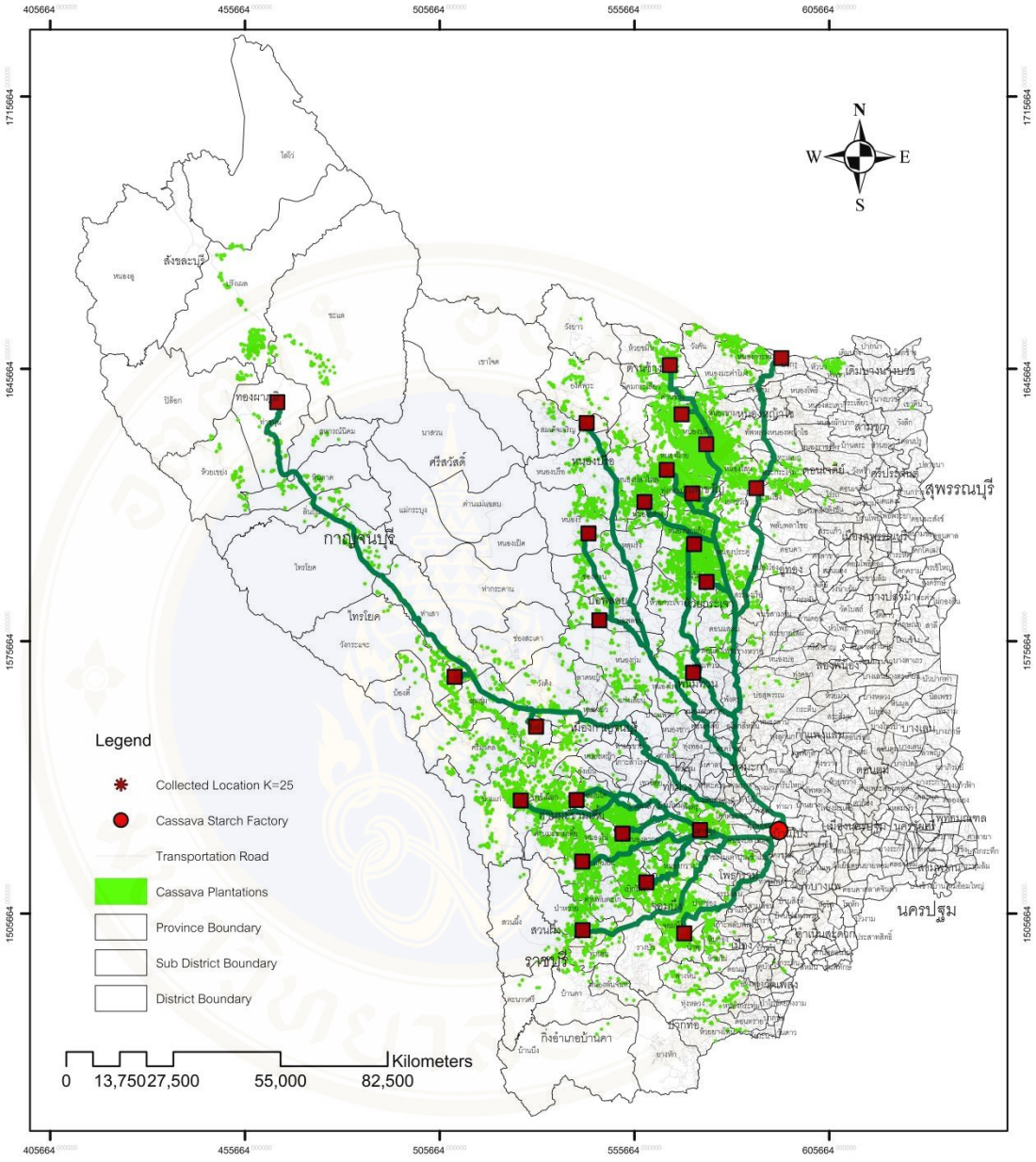

Figure the 25 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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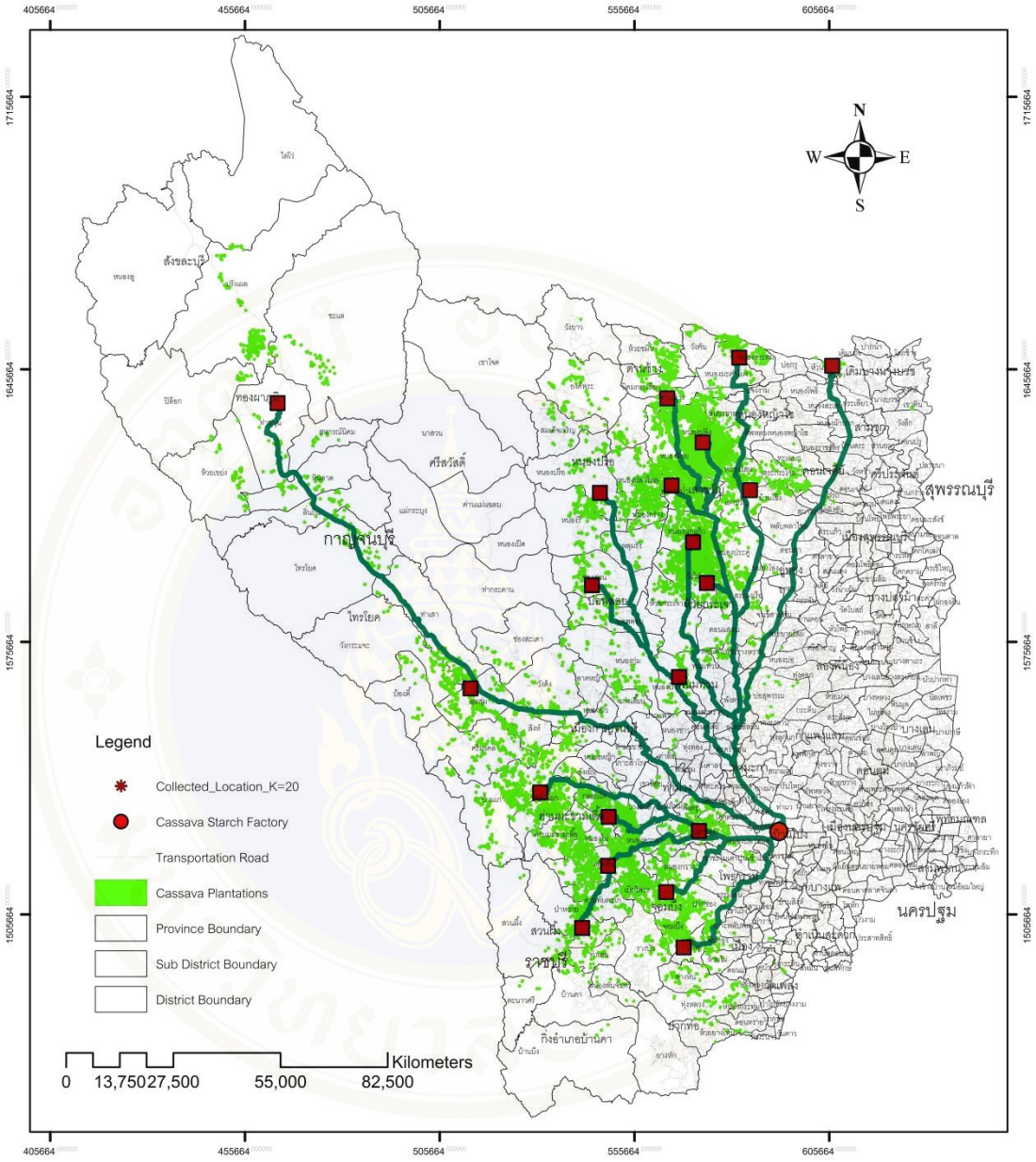

Figure the 20 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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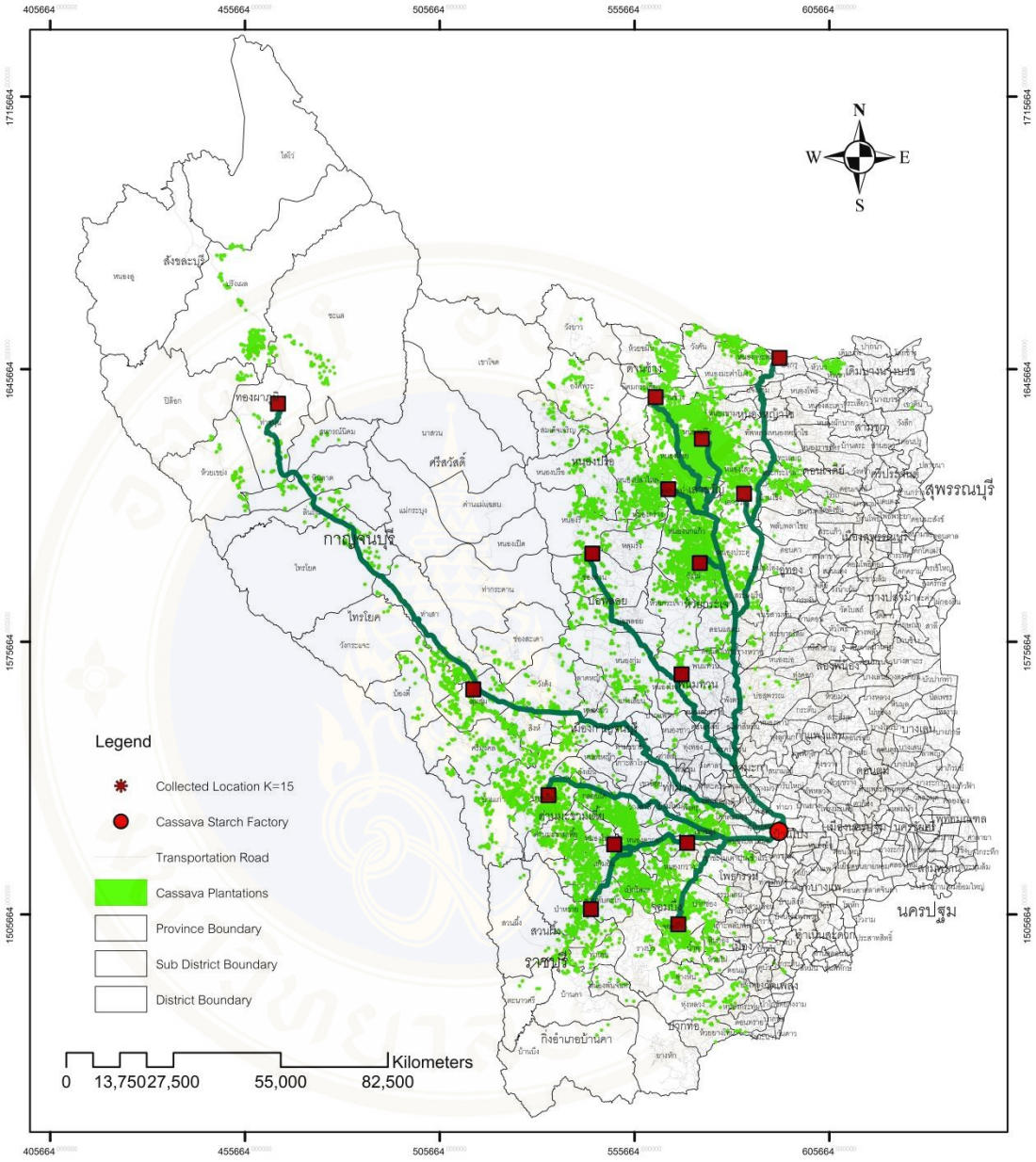

Figure the 15 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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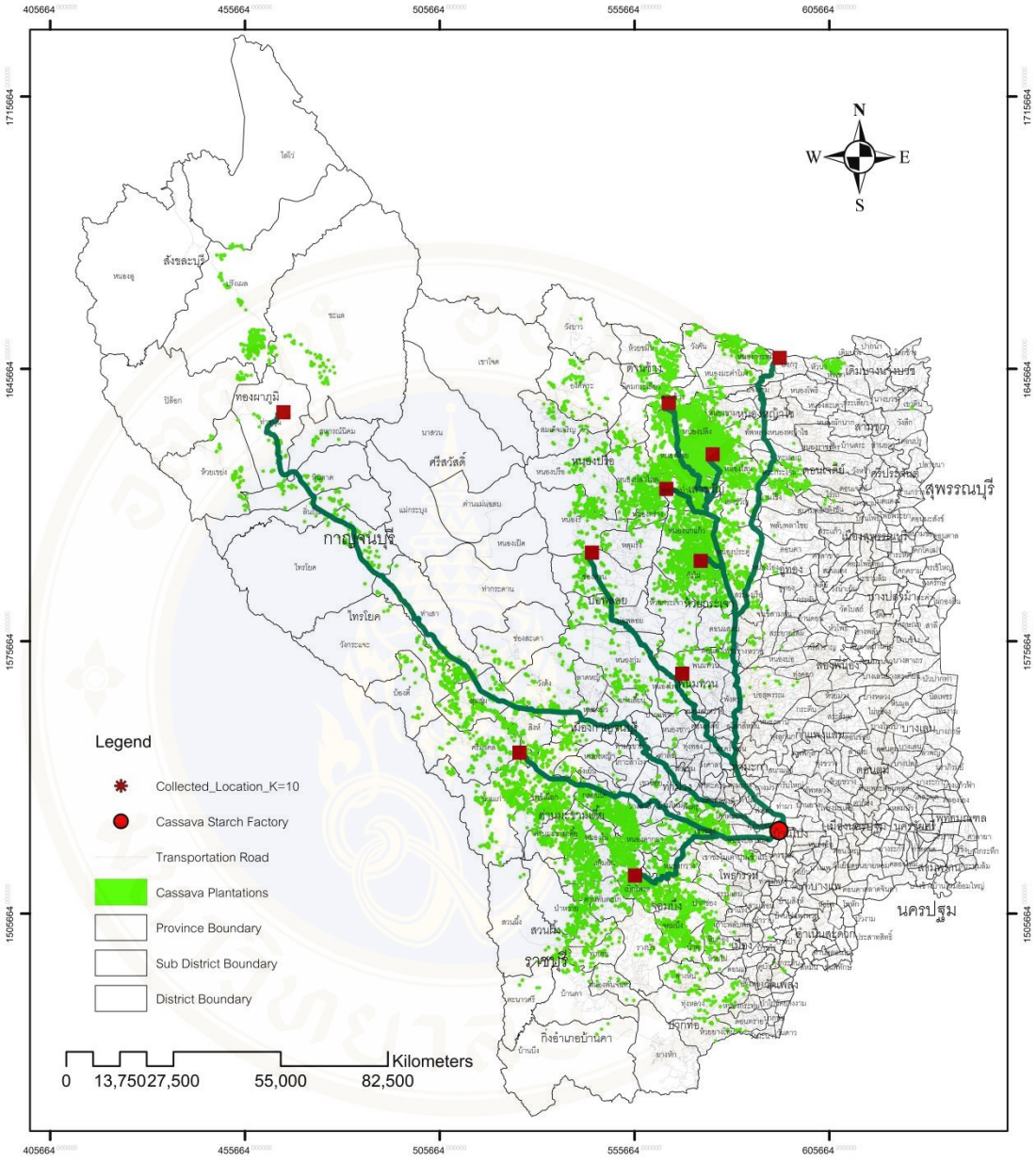

Figure the 10 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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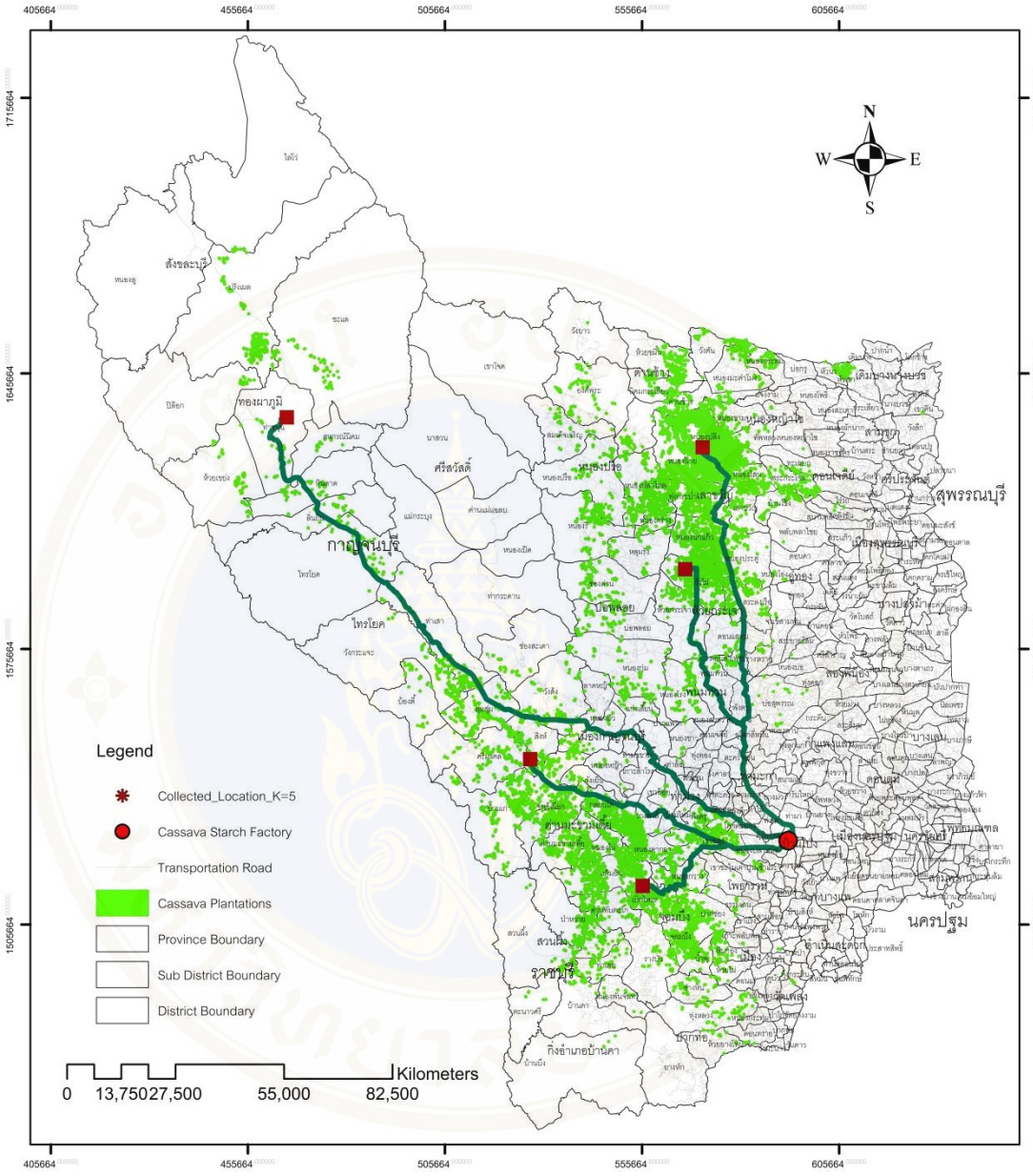

Figure the 5 locations of Cassava Service Station (CSC) and routing from CSC locations to Cassava starch factory by used modified k-mean algorithm with Matlab

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