ENERGY DEMAND IN POST HARVEST ACTIVITIES

:A CASE STUDY OF MAIZE

DILOKRUCH THANGSUPANICH

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Dilokruch Thangsupanich

Candidate

Chirapol Sintunawa, Ph.D.

Major Advisor

Sriwai Singhagajen, B.Sc.

Co-advisor

Narongsak Senanarong, M.Sc.

Co-advisor

Monthree Chulasamaya,M.D.,Ph.D.

Dean

Faculty of Graduate Studies

Raywadee Roachanakanan, M.Sc.

Chairman

Master of Science Program in Technology of Environmental Management

Faculty of Environment and Resource Studies

Thesis

entitled

ENERGY DEMAND IN POST HARVEST ACTIVITIES

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on

May 15, 1991

Dilokruch Thangsupanich

Candidate

Aurapin Eamsiri, Ph.D.

Chairman

Chirapol Sintunawa, Ph.D.

Member

Sriwai Singhagajen, B.Sc.

Member

Narongsak Senanarong, M.Sc.

Member

Monthree Chulasamaya, M.D., Ph.D.

Dean

Faculty of Graduate Studies

Aurapin Eamsiri, Ph.D.

Dean

Faculty of Environment and Resource Studies

BIOGRAPHY

NAME	:	DILOKRUCH THANGSUPANICH
DATE OF BIRTH	:	14 APRIL B.E. 2506 (1963)
PLACE OF BIRTH	:	BANGKOK, THAILAND
INSITITUTIONS ATTENDED	:	Ramkhamhaeng University, 1981-1983 Bachelor of Economics (Financial Economics) Mahildol University, 1986-1990 Master of Science (Technology of Environmental Management)

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ผู้วิจัย ดิลกรัชต์ ทังสุพานิช

ปริญญา วิทยาศาสตรมหาบัณฑิต (เทคโนโลยีการบริหารสิ่งแวดล้อม)

คณะกรรมการควบคุมวิทยานิพนธ์

จิรพล สินธุนาวา , Ph.D.

ศรีวัย สิงหะคเชนทร์ , B.Sc

ณรงค์ศักดิ์ เสนาณรงค์ , M.Sc.

วันที่สำเร็จการศึกษา 15 พฤษภาคม พ.ศ. 2534

บทคัดย่อ

เทคนิคการวิเคราะห์พลังงานได้ถูกนำมาใช้ในการศึกษาครั้งนี้เพื่อให้เกิดความรู้ความเข้าใจในขั้นตอนและขบวนการการใช้พลังงานในกิจกรรมหลังการเก็บเกี่ยวของการเพาะปลูกข้าวโพดเลี้ยงสัตว์ในประเทศไทย

ในการศึกษาครั้งนี้ การเก็บรวบรวมข้อมูลได้จากการสัมภาษณ์ เกษตรกรผู้ปลูก ข้าวโพดเลี้ยงสัตว์ จำนวน 400 ครัวเรือน โดยแบ่งเป็น ภาคเหนือ ภาคตะวันออกเฉียงเหนือและภาคกลาง โดยจำนวนที่สัมภาษณ์ในแต่ละพื้นที่นั้นแบ่งตามสัดส่วนของพื้นที่เพาะปลูกในแต่ละภาค โดยมีการเก็บรวบรวมข้อมูลในพื้นที่จังหวัดนครสวรรค์ เพชรบูรณ์ เลย นครราชสีมา สระบุรี และลพบุรี

จากการศึกษาในครั้งนี้พบว่า พลังงานที่ใช้ในกิจกรรมหลังการเก็บเกี่ยวการเพาะปลูกข้าวโพดเลี้ยงสัตว์นั้นมาจากการกระเทาะเมล็ด และกิจกรรมที่ใช้แรงงานมากที่สุดคือการเก็บเกี่ยวซึ่งพบว่าเป็นร้อยละ 81 ของแรงงานที่ใช้ทั้งหมด พบว่ามีการใช้พลังงานมากที่สุด305.7 เมกกะจูลต่อไร่ ในภาคเหนือ และน้อยที่สุด 246.2 เมกกะ-จูลต่อไร่ ในภาคตะวันออกเฉียงเหนือ การใช้แรงงานนั้นพบว่ามีมากที่สุดในภาคตะวันออกเฉียงเหนือจำนวน37.8 คน-ชั่วโมงต่อไร่ และน้อยที่สุดในภาคกลางเพียง 19.6 คน-ชั่วโมงต่อไร่ และพบว่ามีความแตกต่างกันของการใช้พลังงานรวมของทั้ง 3 ภาคด้วยระดับนัยสำคัญ 0.05 นอกจากนี้แล้วยังพบว่า ประสิทธิภาพการใช้พลังงานจะมีมากที่สุดที่ภาคตะวันออกเฉียงเหนือ คือ ใช้ 625.8 เมกกะจูลต่อตันของผลผลิต ในขณะที่ในภาคเหนือมีประสิทธิภาพของการใช้พลังงานต่ำที่สุดคือ ใช้ถึง 695.7 เมกกะจูล ต่อตันของผลผลิต การใช้พลังงานของเครื่องกระเทาะที่มีกำลังน้อยกว่าหรือเท่ากับ 65 แรงม้า จะสิ้นเปลืองพลังงานน้อยกว่าเครื่องกระเทาะที่มีกำลังมากกว่า 65 แรงม้า นอกจากนี้แล้ว เกษตรกรควรจะเก็บข้าวโพดผึ่งในยุ้งก่อนที่จะกระเทาะประมาณ 40-50 วัน ซึ่งจากการศึกษาพบว่ามีการสิ้นเปลืองพลังงานที่น้อยกว่าเมื่อเทียบกับช่วงเวลาอื่น

Thesis Title ENERGY DEMAND IN POST HARVEST ACTIVITIES :A CASE STUDY OF MAIZE

Name Dilokruch Thangsupanich

Degree Master of Science (Technology of Environmental Management)

Thesis Supervisory Committee
Chirapol Sintunawa, Ph.D.
Sriwai Singhagajen, B.Sc.
Narongsak Senanarong, M.Sc.

Date of Graduation 15 May B.E. 2534 (1991)

Abstract

The technique of energy analysis was employed to gain insights into the process of maize post-harvest activities in Thailand.

Data collection of households was carried out in 3 regions namely; the North, Northeast and Central. Four hundred households who had been growing maize for three consecutive cropping seasons were visited and interviewed.

Study results revealed that the major parts of energy inputs for maize post-harvest activities was shelling and the major parts of human labour use for maize post-harvest activities was harvesting. The pesticide was used in farm storage in order to protect maize from insect. It was found that the animal labour was used in farm transportation in the North and Central regions.

On the basis of this study, the highest of total energy use was 305.7 MJ per rai in the North and the lowest of total energy use was 246.2 MJ per rai in the Northeast. The highest human labour use was 37.8 man-hour per rai in the Northeast and the lowest human labour use was 19.6 man-hour per rai in the Central. The highest energy intensity of maize post-harvest activities was 625.8 MJ per ton output in the Northeast whereas the lowest energy intensity of maize post-harvest activities was 695.7 MJ per ton output in the North.

It was found that there were differences between the averages of total energy use in 3 regions at the significant level 0.05 and the real cost was also different. The sheller which has power greater than 65 horse power consumed the energy more than the sheller which has lower than or equal to 65 horse power. In addition, after harvesting the farmers should keep their maize for drying between 40 - 50 days before shelling.

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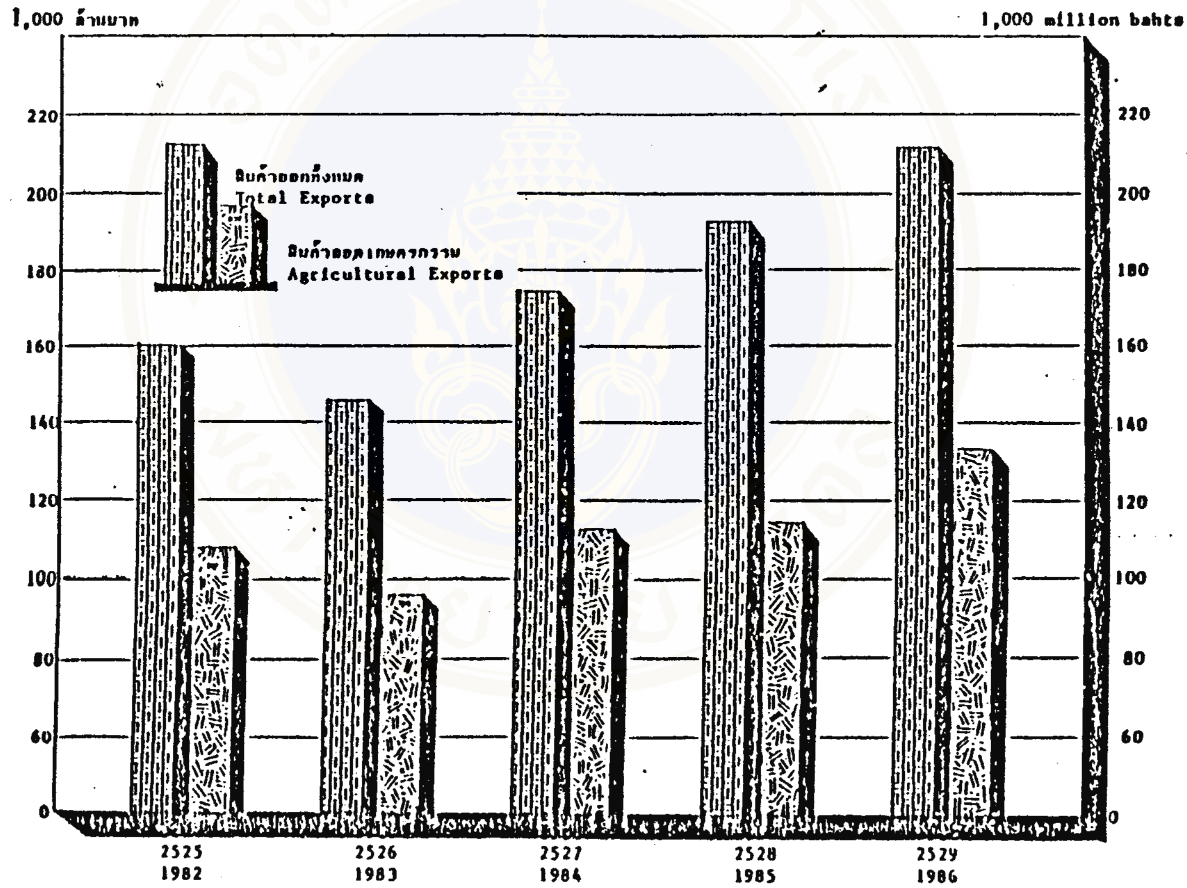
Introduction

1.1 Background

Agriculture is important for Thai economy since many years back. The value of agricultural goods and products for export is greater than 50 percent of total export as shown in Fig. 1.1. (1982-1986)



Source : Thai agricultural statistics in crop year 1987/88:P3-4

Fig 1.1 Value of agricultural and total exports, 1982 - 1986

Eventhough Thailand is one of the important export countries for agricultural goods and products, its trade balance is still in deficit as shown in Table 1.1

Table 1.1 Thai trade balance, 1980-1986 (million baht)

Year	Export	Import	Trade balance
1980	132.0	190.0	-58.0
1981	150.2	216.0	-65.8
1982	157.2	193.3	-36.1
1983	145.1	234.3	-89.2
1984	173.5	242.3	-68.8
1985	191.7	253.4	-61.7
1986	229.3	245.8	-16.5

Source : Research Center of Bangkok Bank P:652

Prices of agricultural goods fluctuate depending on the market demand and supply. In addition, Thai agriculture is dependent upon imported agricultural inputs. The cost of imported agricultural inputs rises in a greater proportion as compared to the price rise of the agricultural goods. This then causes the deficits in the trade balance.Thus, the government policy is to increase the agricultural products in order to achieve higher quantity of export for eradicating deficits. The new technologies have been introduced and encouraged to be used in farm for obtaining higher yield. In practice, more production and export will in turn result in the increase of imported agricultural inputs for usage in farms. It was found that as the quantity of agricultural production and export is increased, the trade balance deficits will also be increased gradually, but at an even greater proportion. This is due to the fact that many energy products such as fuel, fertilizer, and chemical substance etc. would have to be imported at a greater quantity.

Processing of agricultural products before distribution from farm consists of many stages as follow:

- Crop cultivation stage

  This stage starts from land preparation through maintenance.

- Crop Harvest

  In this stage, farmers will harvest their products if they knew that they are mature enough

- Crop Post Harvest

  The process of this stage involves activities done by farmers after harvesting, for example: transportation of products to market, shelling etc. This stage ends at the point of distribution from farm gate.

In every stage of agricultural production, the input factors such as human labour, fuel, etc. would be considered. These factors are transformed into energy unit, the value of energy are related to the activity. The study of energy analysis used in agriculture is useful in trying to understand agricultural system. This leads to the national policy such as product exports and alternatives for suitable production. In addition, this study should prove to be helpful in deciding what should be changed or improved in any of the above-mentioned factors and stages.

1.2 Problem statements

In the past, the agricultural production in Thailand was that of the old style using human and animal labour without advanced technological inputs. Now, considerable partion of technologies used are being imported and the demand rate has been increased gradually in the worldwide market. Thus it can be seen that Thai agriculture is somehow dependent upon the imported factors.

Not only the change occurs at the production stage but also at the activity, for instance, the method used for product transportation was changed from human and animal labour to the use of transporting machine. The shelling method is also changed as well. These changes in turn lead to a change in energy, eg., the energy use in term of fuel for operating the machines. It is thus interesting to carry out the study on energy demand for post harvest activity in order to see what should be improved to attain appropriate energy use and to benifit the development of alternatives to improve energy intensity of the post harvest stage.

1.3 Principles and Causes

1. Energy requirement in agricultural production via energy analysis helps to clarify the quantity of energy use at each stage and to quantify energy intensity of cropping system. This study approach would be beneficial to the improvement of energy use at each stage and at the whole.

   The difference between energy analysis and monetary/economic analysis is that the unit for energy analysis is in energy term while the unit of economic analysis is in monetary term. While the monetary term is changed dynamically depending on such factors as time, inflation etc. Energy unit remains unchanged since it is a physical unit unaffected by those factors. Thus, it would be much more feasible to do the study based on energy analysis rather than monetary/economic analysis.

2. Post harvest activities are those activities that farmers perform starting from harvest shelling, drying, dried field preparation etc. What happen after the post harvest activities end is that products are transported from farm gate. Throughout all the post harvest activities, energy is needed to carry out the tasks which is unlike the plantation activities solar energy is used as the main energy source. The solar energy is free and is in infinite supply. Crops can use and transform solar energy into bio-mass. However, for the post harvest activities, farmers inevitably import input factors such as fuel, farm machinery etc. from abroad. These input factors contribute to the increase in production cost. Considering the energy use during the production stage, it is found that the more energy is used, the more yield will be obtained. But during the post harvest period, yield is not found to be influenced by such input factors. The study was aimed to focus on only the post harvest activities in order to quantify energy use.

3. Economic crops which are important for Thai economy include the 6 following crops namely: rice, maize, cassava, sugar cane, soybean and sorghum. Thailand exports high volume of agricultural products to foreign

countries. The planted area of these 6 crops was about 77.8 percent of total planted area in crop year 1985/86 (10). In this study, maize was selected as the main focus because maize planted area have been more significant as compared to others as shown in Table 1.2.

Table 1.2. Planted areas of maize, soybean and sorghum (1980-1986). (Thousand rai)

Year	Maize	Sorghum	Soybean
1980	7534	1062	958
1981	9796	1749	797
1982	10494	1534	778
1983	10552	1657	1008
1984	11355	1838	1253
1985	12377	1935	1524
1986	12194	1212	1799

Source : The agricultural statistic in crop year 1986/87 P:30,62,68

1.4 Objectives

The main purpose of this study was to gain insights into the process and method of harvest of maize via energy analysis in order to use for energy planning on energy use in Thailand; especially on imported energy and also to recommend alternatives for further improvements. The objectives of this study can be described as shown below:

1. To gain insights into the type of activity and energy requirement in each stage of post harvest activities.
2. To quantify energy intensity of maize post-harvest.
3. To development appropriate recommendations for the improvement of energy intensity for maize post harvest.

1.5 Scope of study

1. Studied crop:-

   Maize was selected for this study.

2. Studied areas:-

   Maize production areas in the North, Northeast and Central was studied, the South was not included in this study due to its small planted area as compared to those in other geographical areas.

3. Data used in this study was collected from survey by visiting and interviewing farmers.(in crop year 1988/89 or B.E. 2531/32)
4. Solar energy was also not included in this study.
5. Tools:-
   a). Questionnaires were used for farm interviews.
   b). Field tests and measurements were conducted for checking by testing and measuring work rate, rate of use of agricultural inputs and rate of fuel consumption while farmers operated their farms.
   c). Computer softwares such as lotus-123 and statistical package were used for data analysis and calculation.

(Steps taken in completing this study:-)

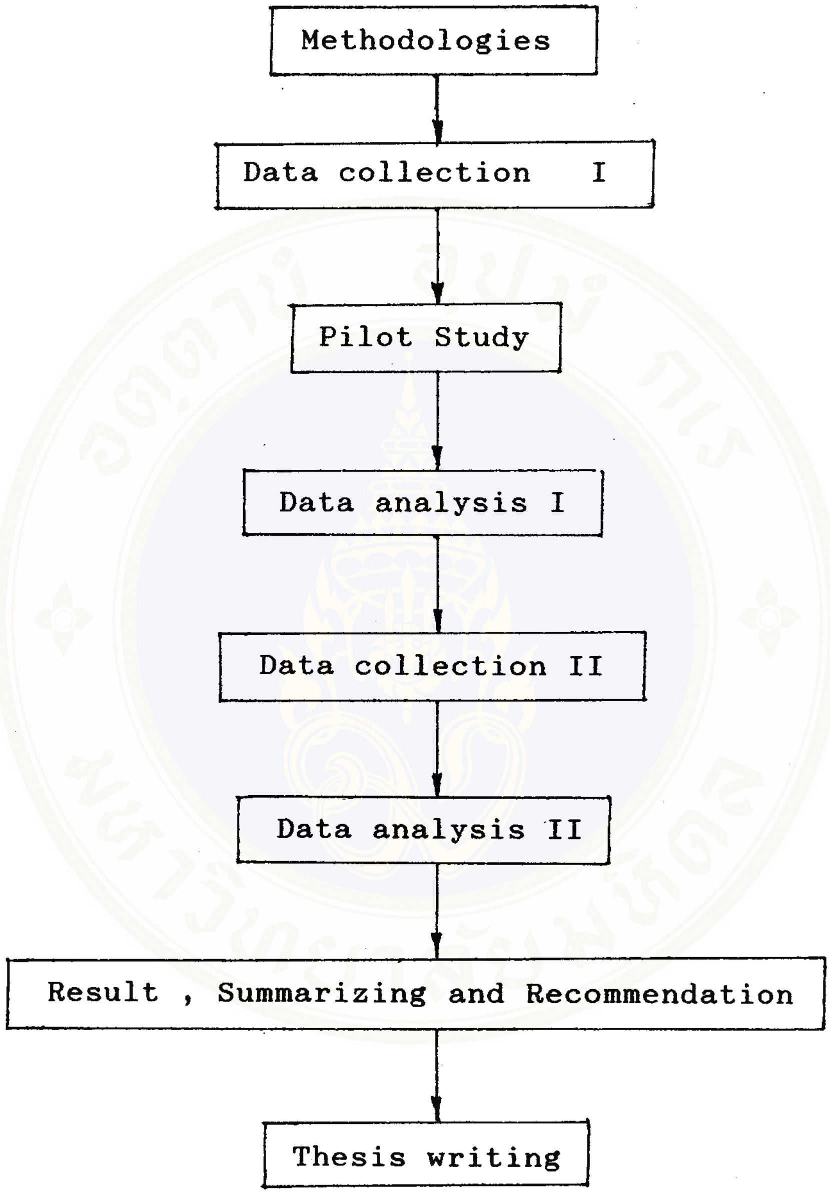


Fig. 1.1 Shows the steps taken in completing this study

CHAPTER II

MAIZE ENVIRONMENT AND CULTIVATION

2.1. Maize history

The origin of maize has been the source of much controversy, recent accounts express the three current tenable hypothesis, as follow: (21)

- present-day, teosinte is the wild ancestor of maize, or
- a primitive teosinte is the common wild ancestor of both maize and present-day teosinte, or
- an extinct form of primitive maize was the ancestor of maize; teosinte being a mutant form of the primitive type.

The earliest archaeological evidences were from caves in Techuacan valley, Mexico, dated about 7000 BC. It is possible that maize was introduced by the Portuguese to the West African coast in the early sixteenth century. There are some evidences which show that maize was introduced to Thailand by the Portuguese 400 years ago. In Thailand, the research done on maize was started since the year 1951.(27)

2.2. Taxonomy

The taxonomy of maize was classified as shown below:-(21)

Family : Graminae

Sub-family : Panicoideae

Genus : Zea

Species : mays

2.3. Climate and soil relations

Maize is adapted to a wide variety of soils in the tropics ranging from sands to heavy clays. Most maize is grown on well structural soils of intermediate texture (sandy loams to clay loams) which provide adequate soil water, aeration and penetrability. In the tropics as a whole Ovisol, Utisols, Alfisols and Inceptisols have the greatest potential for maize production. Maize is quite susceptible to flooding. Flooding to a depth of 5 - 15 cm for 48 hours at different growth stages reduces yield by 31-63%. Maize is also sensitive to water deficit at flowering. Maize in the tropics has low yield relative to temperate maize. It does best when the daily temperature ranges from 24 - 30 ^{o}c and the range of soil pH is between 5.5 - 8.0. Thailand is not highly suitable for maize plantation because of high temperature and precipitation. (28)

2.4 The classification of maize types

Maize can be classified into many types depending on the purpose. Generally, the classification can be done in the following manner:- (28)

1. DENT CORN:-

   At the end of its grain, it contains light powder and has white color because of the starch in the upper part of endosperms.

2. FLINT CORN:-

   The outer part of endosperms is hard starch.

3. SWEET CORN:-

   The grain of this type will be wilted and sweet taste because sugar is changed to starch in endosperms at slower pace as compared to other types.

4. FLOUR CORN:-

   Almost all starch of endosperms is soft type. When it gets old, it will be not pounded because soft starch of outer part of the endosperms will be shrunken equally.

5. POPCORN:-

   Endosperms contain high percentage of starch similar to that of flint corn. It is of smaller size but will bloom when heated (due to the force pushing from inside.) but it is smaller and when it is heated there will be the force inside and it will expand.

6. WAXY CORN:-

Starch of endosperms is like wax because this type of starch consists of amylopectin which is different from that of others.

2.5 Maize cultivation and production

In Thailand, there are 2 cropping seasons for maize:- the beginning of rainy season and the end of rainy season. For the beginning of rainy season, maize is usually planted in April-May; while for the end of rainy season, it is usually planted in July-August. Thailand has a total of approximately 320,696,888 rais of land in 4 areas in the Northeast, North, Central, and the South; each of which covers the area of 105,533,963, 106,027,680, 64,938,253, and 44,196,992 rais respectively. The largest planted area of maize in Thailand lies in Phetchaboon, which accounts for about 18 percent of the total planted areas, with a production of 774,753 tons in 1986/87. The areas where maize is grown in Thailand are shown in Figure 2.1 and Table 2.1.

Maize production in Thailand has increased from 1,677,000 tons in crop year 1977/78 to 4,309,000 tons in crop year 1986/87. The productivity averaged of 275 kilograms per rai in crop year 1977/78 and 380 kilograms in 1986/87. (10)

Table 2.1. Maize: Area, Production and Yield by agro-economic zone and province (crop year 1986/87).

Province	Planted Area(rai)	Production (1000 ton)	Yield (kg/rai)
Sakon Nakhon	3,643	1,450	409
Nong Khai	3,709	1,817	491
Udon Thani	331,699	112,970	341
Loei	983,325	420,042	429
Ubon Ratchathani	27,844	12,555	451
Kalasin	19,318	7,879	436
Khon Kaen	66,622	29,650	463
Buri Ram	52,773	13,619	373
Si Sa Ket	146,361	64,703	444
Chaiyaphum	365,498	88,178	292
Nakhon Ratchasima	1,282,727	296,638	284
Nakhon Sawan	930,648	1,229,509	370
Phetchabun	1,777,759	323,259	445
Uthai Thani	580,402	774,753	284
Lopburi	1,095,034	303,797	371
Saraburi	608,708	262,853	444
Kamphaeng Phet	513,257	194,912	380
Tak	272,437	90,956	349

Table 2.1 (cont)

Province	Planted Area(rai)	Production (1000 ton)	Yield (kg/rai)
Phichit	83,081	30,740	379
Phitsanulok	491,815	170,184	347
Nan	250,436	95,742	383
Phrae	115,754	42,641	368
Lampang	34,061	11,601	341
Sukhothai	102,860	34,913	345
Uttaradit	187,514	62,630	334
Chiang Mai	15,378	5,807	380
Chiang Rai	258,653	99,463	386
Mae Hong Son	6,500	2,080	320
Lamphun	5,000	1,500	300
Phayao	134,219	57,623	431
Chai Nat	33,439	7,959	253
Suphan Buri	87,576	23,882	310
Kanchanaburi	209,067	69,945	362
Prachuap Khiri Khan	50,663	19,631	335
Phetchaburi	82,441	22,638	289
Ratchaburi	162,032	39,064	242
Chachoengsao	27,156	11,878	443
Prachin Buri	597,196	289,256	485

Table 2.1 (cont)

Province	Planted Area(rai)	Production (1000 ton)	Yield (kg/rai)
Chon Buri	12,000	4,800	400
Rayong	2,812	1,181	420
Chanthaburi	170,908	71,105	426
Chumphon	7,003	2,185	313
Surat Thani	9,460	1,892	202

Source : Argicultural statistics in Thailand in crop year 1986/87

2.6 Utilization

Among all cereals grown in the world, maize is used for the industry rather than others. Almost all parts of maize such as stem, leave, cob and grains have economic value. The maize part that is used in highest percentage is grain. Almost all of the grain is endosperms (83%) and the rest are germ (11%) and hull (6%). The grains are used for many purposes which can be classified into 3 types as shown below:- (17)

1. **Animal feeding:-** Because starch is the main component in maize and there is little protein in

those grains, they can be used for animal feeding and also the price is low.

2. **Food.** Grain can be used for human food. Many people in some countries use maize grain for their staple food(eg.,bread). Those countries where maize grains are used for daily consumption are, for example, South America, Mexico, Spain, Italy etc.

3. **Industry:-** Besides food products, maize grain were used in many industries for other kinds of end-products such as alcohol, plastic, etc.

2.7 Post-harvest crop processing

Most crops need to be dried or processed into some other forms which are slightly different from the originals. Maize is one important crop for Thai economy and there are many stages involved in the post-harvest processing of maize.

Nowadays, the processing involves the use of new technologies such as machineries along with human labour; and machineries would need fuel to power the operations. The energy fuel is needed for farm transportation, shelling and sale transportation. Post-harvest maize processing can be classified into 3 different stages as shown below:-

2.7.1 Grain drying

In general, maize cob gets dried in the field by natural sunlight. Some farmers dry it in a prepared field, by turning around the cob so that all parts get exposed to sunlight. If there is not enough labour to accomplish this, the farmer will first store them in an appropriate place by transporting from the farm to a storage which is either a house or a farm area. The E-Than is a Thai truck and tractor with trailer are popular for farm transportation as shown in Figure 2.4.

2.7.2. Storage

The storage must keep the grain dry and free from insects or rodent animals. In some types of storage, where the grain may not be kept quite dry enough, ventilation factor should be considered. Some farmers use malathion or similar insecticide to dust the grain in order to protect it from insect attack, while other farmers use general rodent control measurement. There are many types of maize storage adopted in Thailand as shown in Figure 2.3 and they can generally classified into 5 types as follow:-

1. Raised-floor Storage

The type of storage is a permanent type. The floor is raised about 30 to 50 centimeters above the ground. The roof can be made out of many types of material, namely corrugated iron or certain kinds of tree-leaves, depending upon the affordability level each farmer has. The floor is made of wooden boards and usually bamboos or naths are used to construct storage and walls in such a way as to allow ventilation so that the moisture can be kept to minimum. The disadvantage of this type of wall construction, however, is that rainfalls cannot be prevented from wetting portions of the maize which will in turn cause fungi and are undesirable growth of maize seeds.

The losses occurred in this type of storage are usually caused by one or more of the following factors:- moisture, excessive heat, insects, fungi, birds, mouse, pets, and an undesirable seed growth.

2. The bolstered storage

The floor is constructed by placing wooden boards on bolsters or wooden poles so as to raise the floor level. The construction is made in a way that temporary disassembly of the floor for cleaning purpose can be achieved without much difficulty. The walls are usually built with bamboos by allowing spaces between columns for ventilation. Whenever needed, farmers could disassemble floors or walls for cleaning. If not, the floors could be dusted with mortar and the underfloors could also be dusted with DDT to eliminate termites. However, most agricultures tend to avoid all these troubles and just do simple cleaning around the storage area.

The causes for the loss in this type appear to be the same as those of the first type, but losses are greater in quantity in this case. Major contributors to the higher loss are excessive moisture and destructions by termites.

3. Concrete-paved Storage

The floor is permanently made with concrete. Main objective of this is to prevent termites. And the walls are built with bamboos or naths in such a way that allows good ventilation.

Overall loss in this case is loss than that of the "bolstered storage". Perhaps this is due to the fact that destructions by termites can be effectively controlled. However, as compared with the "Raised-floor storage", the loss id higher for the concrete-paved storage". This is because the moisture from the soil underneath tends to be absorbed through the concrete floor, and finally gets to the portion of maize which is next to the floor.

4. Under-house/Bolstered Storage

Storage of this type is constructed under the house, where the storage floor level is raised by placing wooden boards on bolsters. The walls are made out of either bamboos or naths in such a way that ventilation is allowed.

The causes for the loss in this case the same as those of types 1-3. The loss is higher as compound with type 1 and type 3. But when compared with type 2, the loss is lower. This may be because those measures taken to insure loss reduction (eg, rotation of maize or termite prevention) could be achieved more conveniently with the storage of this type.

5. Under-house/Concrete-paved Storage.

The floor is constructed with concrete, while other features are the same as those of type 4.

The loss associated with this type of storage is the highest. Especially when compared to type 3, the higher margin of loss becomes obvious. The reason for this may be the combination of all the previously-mentioned causes. For instance, moisture from soil underneath cannot be effectively prevented from being absorbed through the concrete floor; furthermore excessive moisture can also through the walls; and also destructions can be caused by insects, fungi, birds, or mouse.

From the analysis of associated losses and resulting quality of maize in the study. Singhagajen (33) reported that the concrete-paved storage (type 3) is found to be the one which could best preserve the maize quality as compared among all five types of maize storage.

2.7.3 Grain shelling

The shelling of grain for human and animal feed is one of the most basic of crop-processing requirements. In the past, maize shelling is a process which was handled by hand and thus took a long time to finish. Later on, there has been a development of grain-shelling machines which range from hand-held instruments through fuel-driven machines as shown in Figure 2.2.

Shelling takes place immediately after harvest if the grains are dry enough and the selling value of those grains are attractively high. Some farmers make arrangements with a middleman which the middleman will be responsible for providing the sheller and sufficient labor necessary for the shelling operation. The labor wages will be paid by the farmer or middleman depending on their agreement. On the other hand, if the maize harvest is not dry enough or the selling value is low, they will be kept in the storage until they are dry or can be sold at a higher price. However, some can not afford to wait simply because they need to pay back the loans (plus interest) to whomever they borrow from.

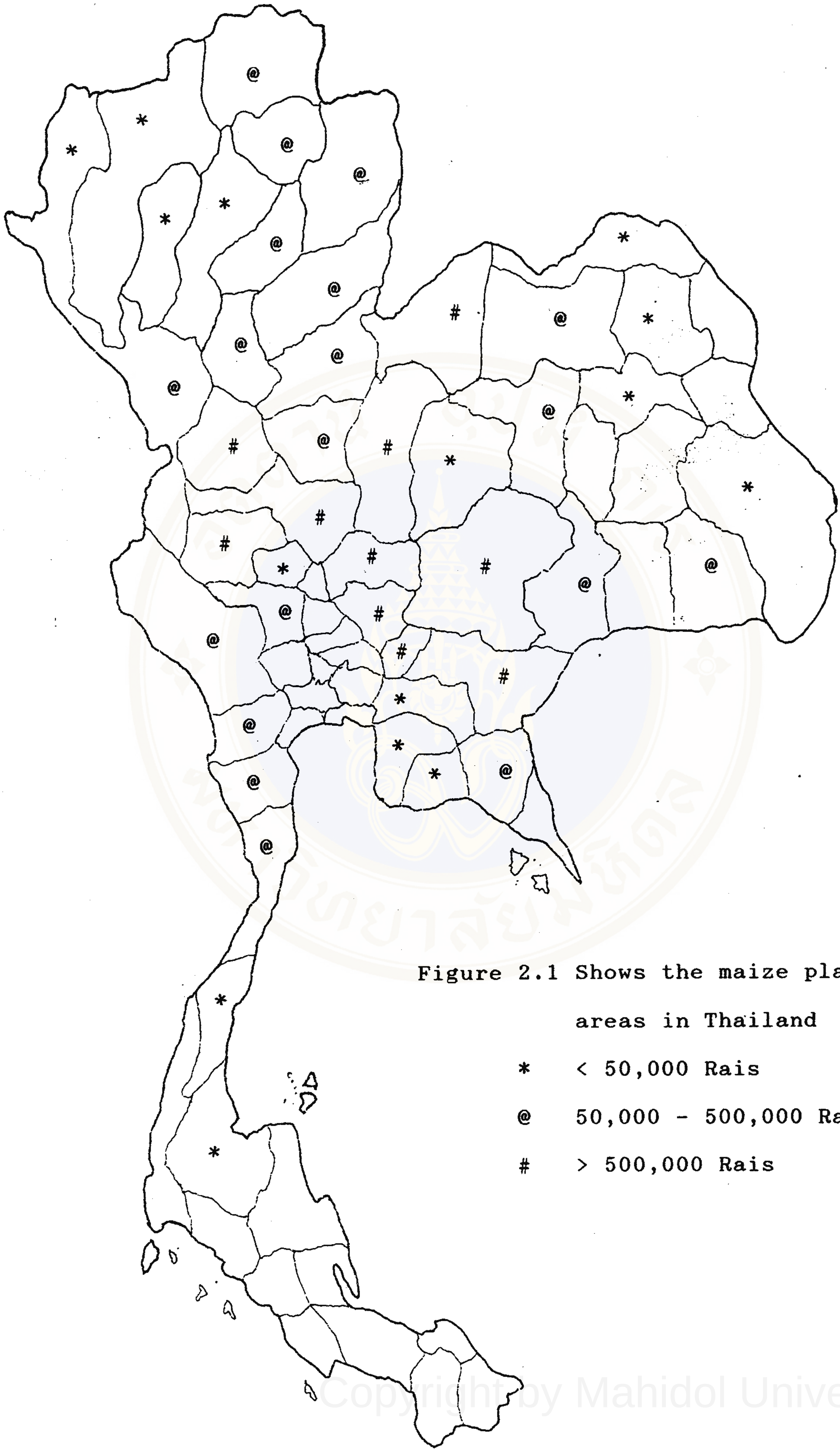


Figure 2.1 Shows the maize planted areas in Thailand

* < 50,000 Rais

@ 50,000 - 500,000 Rais

\# > 500,000 Rais

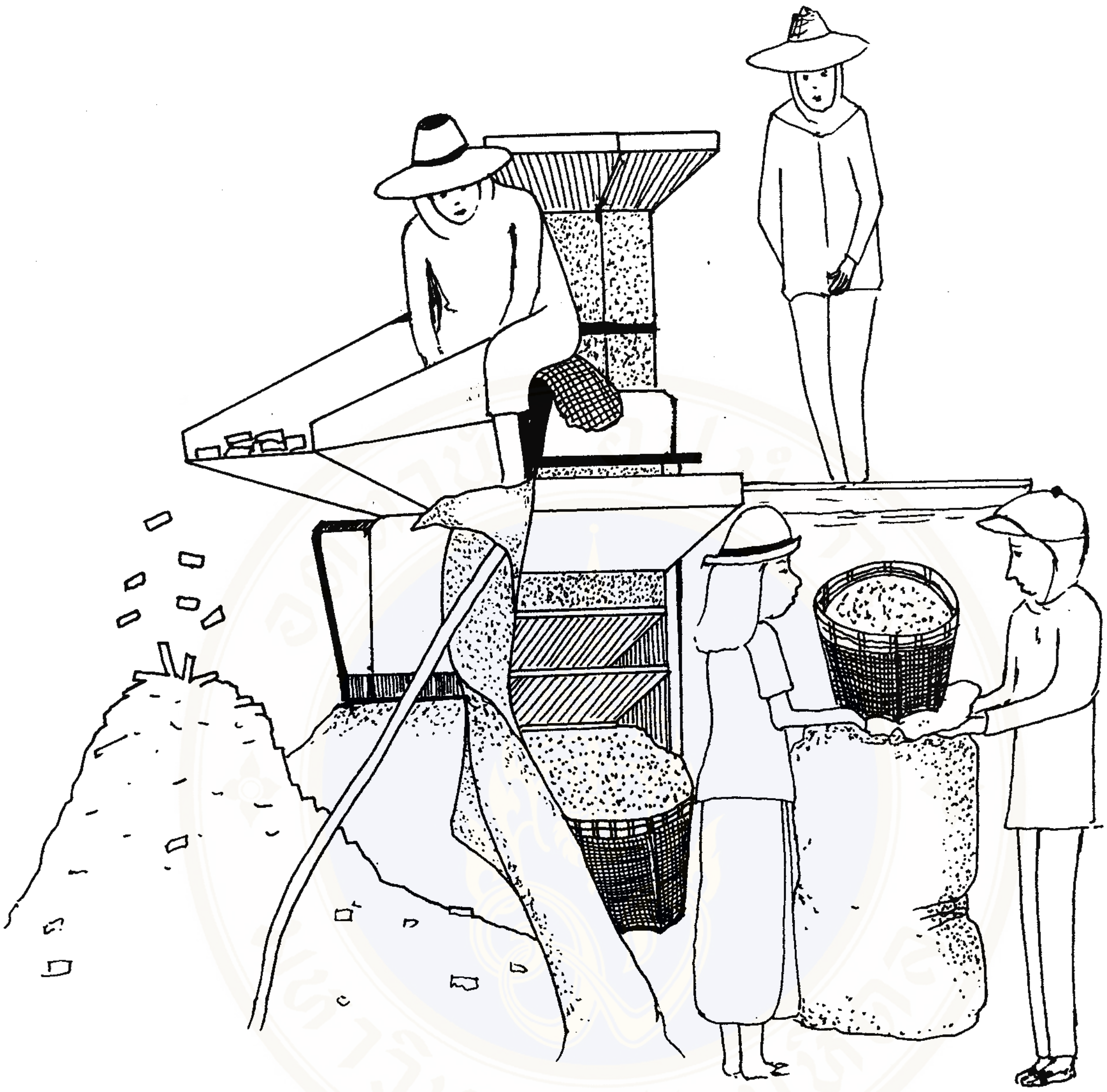


Figure 2.2 Maize shelling

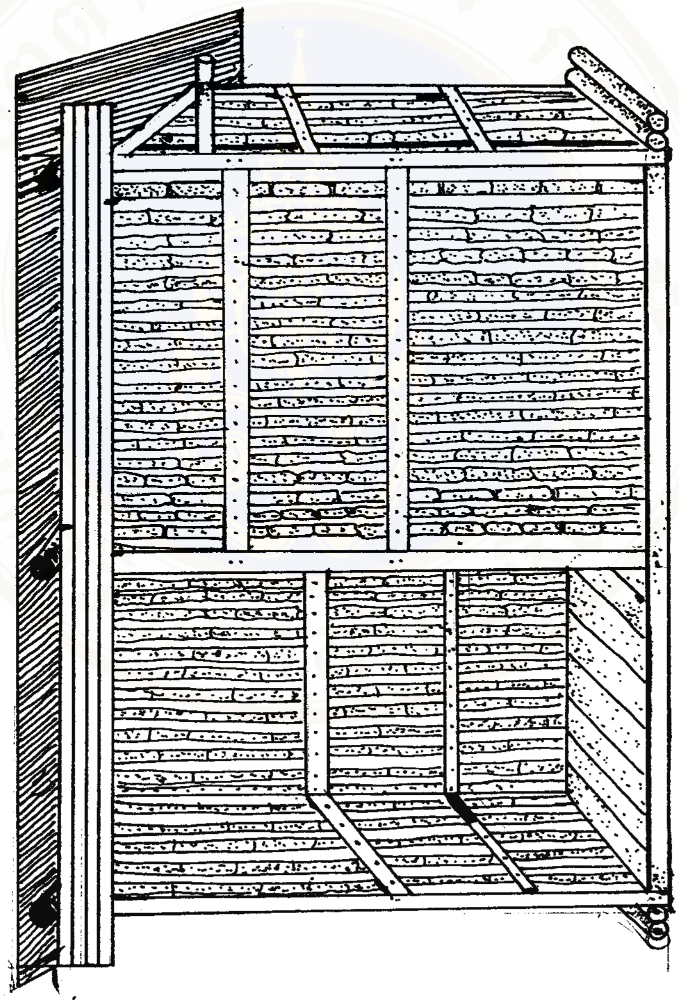


Figure 2.3 Storage

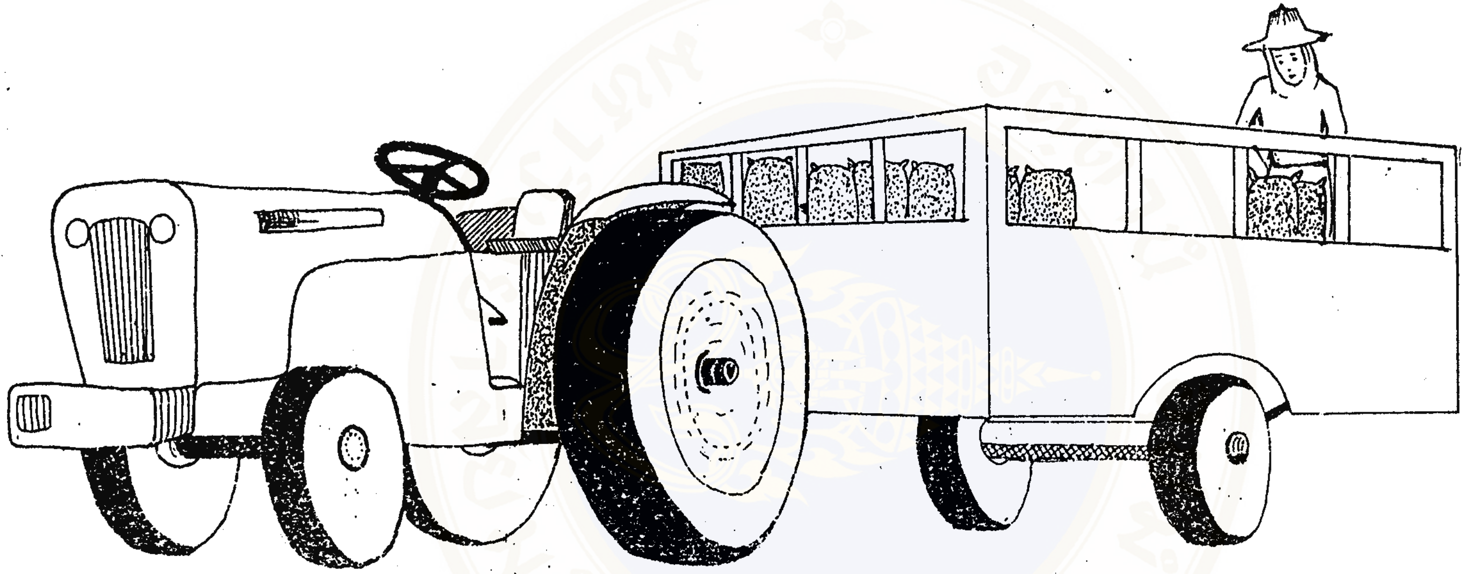


Figure 2.4 Farm transportation

CHAPTER III

METHODOLOGY

3.1 Data collection

In order to achieve the previously mentioned goals, two types of data collection were made in this study.

- Data collection I

This is the type that can be referred to as secondary data which is obtained from other reports, research and study of both government and private sectors from domestic sources and abroad.

- Data collection II

This method provided the main part of farm data which was carried out by interviewing farmers using questionnaires at farms. In addition, farm test and measurement were also conducted to compare rate of work, rate of consumption and use of each cropping activity.

3.1.1. Sample selection and areas.

There are 16 agroeconomic zones in the whole kingdom that are suitable for maize planting. The technique of stratified random sampling was employed for data collection. The 2 biggest planted areas in each region were tarketed for this study. The South was excluded due to a small existence of the maize planted areas in the region.

Thus, 6 provinces from the North , Northeast and Central were selected as studied area in this study. In crop year 1986/87, there was 12,193,581 rai of maize planted areas and the average area per household was 16.7 rais.(20) Hence, the approximate number of households planting maize in this cropping season was 730,155 households. For the calculation of sample size, representative of the population on Yamane's formula is as follow:-

$$n = \frac{N}{(1 + Ne^2)}$$

where n = the number of sample size

N = the total number of population

e = acceptable error (5 % was used in this study)

hence n = 730155/(1+730155*0.05^2)

= 400

3.1.2. Sample sizes in each studied areas.

The sample sizes in each studied areas were determined according to the areas in each provinces based on the report of the Office of Agricultural Economics in crop year 1986/87. The two provinces with the largest planted areas in each region were selected and only those farmers who had been growing maize for at least 3 years were interviewed. The final list of provinces and their relevant data used in this study are shown below.

Table 3.1 Provinces, and their maize planted areas in crop year 1986/87 along with sample sizes.

Region/province	Maize Planted areas	Sample size
North		
Nakhon Sawan	930,648	55
Petchabun	1,777,759	107
Northeast		
Loei	983,325	59
Nakhon Ratchasima	1,282,727	77
Central		
Lopburi	1,095,034	66
Saraburi	608,708	36

3.2 Energy System Analysis

At present, fossil energy is one of the major input for in agricultural production. In agricultural production fossil energy has a twofold uses; that is to is to power farm machines which directly and indirectly substitute human and animal labours. The other use is to produce all kinds of farm inputs including farm machines . The major inputs which increase crop yields include the energy used as fertilizers, pesticides and irrigation. (15)

3.2.1 Energy analysis

The International Federation of Institutes for Advanced Studies (IFIAS) convened an Energy Analysis workshop in Stockholm in 1974, the participants decided upon a definition that clearly was not broad enough to encompass the whole range of investigations. As reported by Peet in 1986 (22), " .. they agreed to define energy analysis as the determination of the energy sequestered in the process of making a good or service within a framework of an agreed set of conventions." The purposes of energy analysis are manifold as follow:

- The energy analysis may simply serve as an energy accounting procedure.
- To quantify energy requirements according to some stated set of conventions.
- To focus on identifying structural patterns and interdependencies of energy use.
- To evaluate the efficiency of energy conversion or use.
- To use energy flows as means for thinking ecological and economic systems.

3.3 Methods of energy analysis

There are 3 general approaches for energy analysis. The most common technique in energy analysis is generally referred to as Process analysis. The other two are Input-Output analysis and Hybrid energy analysis. (22)

3.3.1 Process analysis

The first stage in any energy analysis is to identify and quantify the direct flows of energy into and out of the process. Process analysis involves the systematic study of the numerical assignment of energy values to each input.

3.3.2 Input-Output analysis

This technique is adapted from economic input-output tables (which show transactions between disaggregated economic sectors in monetary term) giving the energy flows associated with production or provision of monetary worth of goods and service.

3.3.3 Hybrid energy analysis

In this technique, both of the above-mentioned energy analyses are combined. Process analysis is used in deriving gross energy requirements for goods or service as distinct from fuel requirements. The input-output analysis shows results in term of money. Measurement of physical quantities in term of monetary units introduces difficulties in data interpretation over time.

3.4 Energy calculation

The direct energy or fuel use can be calculated by taking into account working hour, horse power, and energy of diesel fuel (46.4 MJ/Litre). The indirect energy was analysed using the farmer's tractor price in 1984 in Thailand. The total energy is calculated by adding the direct energy and indirect energy. In this study, energy conversion factors from Sintunawa (1983) (33) were used, as shown in Table 3.2 below.

Table 3.2 Energy conversion factors.

Farm machine	Energy (MJ/HR)
7 HP	8.4
9.5 HP	10.1
16 HP	43.7
22 HP	44.9
30 HP	63.0
75 HP	113.9
78 HP	134.7
Sheller	3.9
Pesticides (MJ/Kg)	128.0
Diesel (MJ/L)	46.4
Gasoline (MJ/L)	42.7

Note : HP : Horse power

MJ : Meggajoule

Kg : Kilogrammes

L : Litre

HR : Hour

Source : Sintunawa, C., 1983 (33)

3.5 Cost Analysis

Cost estimation in this study was derived from the raw data obtained through the questionnaires in the field survey. Cost could be classified into two groups.

1. Real cost
2. Opportunity cost

The cost in post-harvest of maize includes labour, machine, pesticides and others which are used.

1. Real cost is the cost that incurs in any actual operation. For example, cost of hired labour, price of pesticides used, price of a loaned machine, etc.

2. Opportunity cost is determined from every other things used in the operation but do not need to be paid for; such as family labour, family-owned farm machine, etc. The lost opportunities of those things that could be productively used elsewhere at that time can be taken into account in various ways. For example, in the case of family labour, the opportunity cost could be thought of in terms of a standard wage rate in the area (baht per day or per rai). And in the case of family owned farm machine, the opportunity cost could be estimated by the standard cost of equipment loan in the area.

3.6 Statistical analysis

In this study, the statistical technique used for data analysis is ANOVA (Analysis of Variance) which is the way of mean differences of real cost, opportunity cost and total energy used in each region. This would include the mean difference of energy used for shelling between sheller which has power greater than 65 horse-power and the one with less than or equal to 65 horse-power. The other methods used for analysing data are percentage and mean.

CHAPTER IV

RESULTS

4.1 Farmer's Practice in Maize Post-harvest Activities

In general, the process of maize production starts from land preparation through products distribution from farm-gate to middleman or markets. The scope of the post-harvest activities covered all those activities which occur after the harvest stage. Different farming methods are used in different areas. For instance, some farmers allowed the maize to dry out in the fields while others harvest immediately as soon as the maize becomes mature. Many factors such as economics, time, labour could affect how farmers carry out their activities. Those farmers who borrow funds from outside sources would be under pressure to try to execute the activities as quickly as they could in order that the debt could be paid on time. At the same time, there are those who are fortunate enough to be able to finance those activities with their own funds. In this case, they would probably prefer to wait for good price on their harvest since the more the moisture is decrease, the better price they could ask for. Pesticide could be used to protect those products if they were to be kept in storage for a lengthy period. Maize post-harvest activities to be seen in every region in Thailand are of similar characteristics which can be concluded into a line diagram as shown below in Figure 4.1.

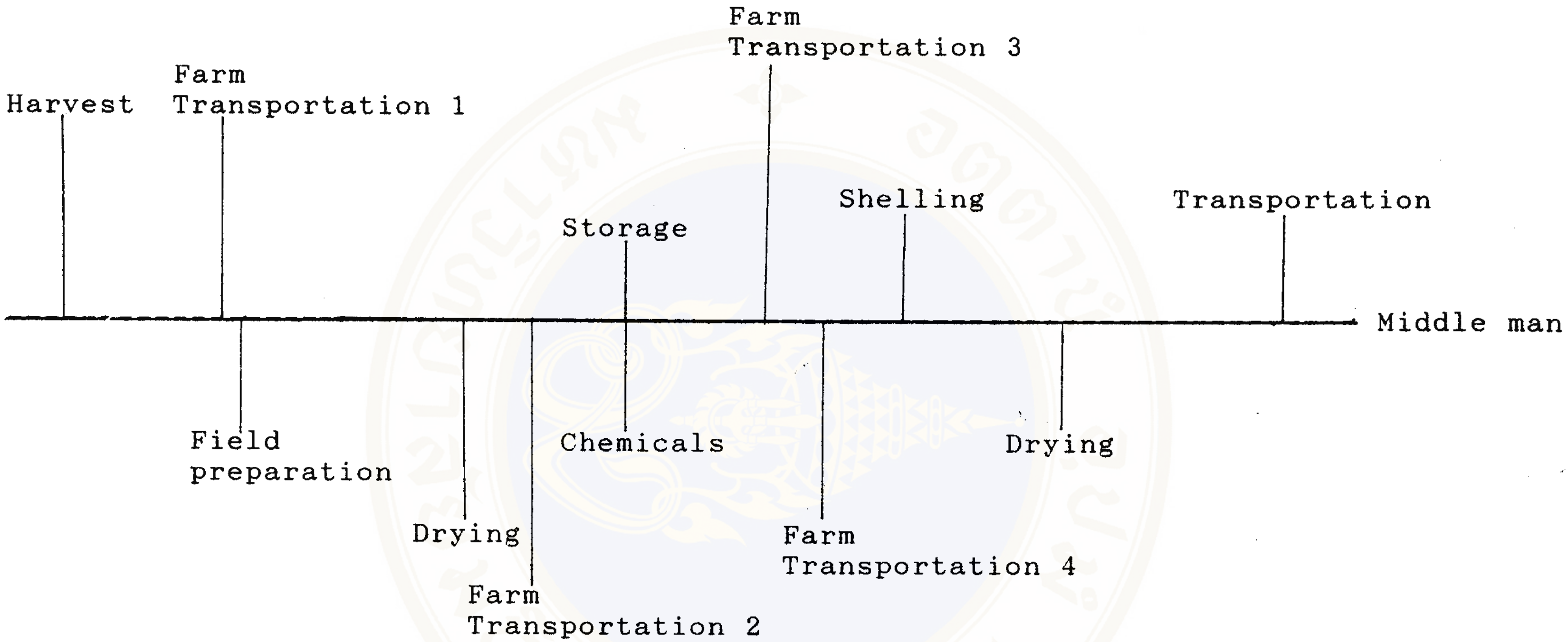


Figure. 4.1 Line diagram for post harvest of maize

4.1.1 Northern Region

Data was collected from Nakhon Sawan and Petchabun provinces. On the basis of this study (crop year 1988/89), farmers harvest their crops in June, August, September and October at a percentage of 13.6, 46.9, 34.6, and 4.9 respectively. Most farmers planted maize in the beginning rainy season (or first crop), then, they usually harvest in August. After harvest, 25 percent of the products were then transported from the field to storage. The means of transportation were either animal labours or farm-trucks such as "E-Than"(Thai-made trucks). The average distances from field to storage was estimated to be 1.3 kilometers. The storage which was built for maize usually lasted about 3 - 5 years. Some farmers stored their products by simply hanging on a large piece of string under the house. The average time for storing and letting the maize dry in order to obtain better price was about 51 days after harvest. Eight percent of farmers in this region shelled them immediately. The average area of storage was 98 m^3. Pesticides were used in their storage to protect the products from insects and rodents. The quantity of powder and liquid pesticides used were 0.226 kilograms per ton of products by 17 farmers, and 0.74 liters per ton of products by 7 farmers. Shellers with horsepower greater than 65 HP are used at a ratio of 26.0, while those with horsepower less than or equal to 65 HP were used at a ratio of 1.0.

After shelling, their products were then distributed to the middleman by trucks. The average distance for transporting the products to the center market was about 26 kilometers. Average yield was 439 kilograms per rai.

4.1.2. Northeast region

The farmers in Nakhon Ratchasima and Loei were visited and interviewed. Months of operations for harvest in this region were in January (11.7 per cent), June (11.7 per cent), September (18.2 per cent), October (1.57 per cent), November (11.7 per cent) and December (20.4 per cent). After harvest, they either shell them immediately or keep them for a few days. Pesticides were not commonly used in this region, however, the storage existed for the harvested maize to be kept. Average area of storage used in this region was 72.9 m^3. Average yield was 393.4 kilograms per rai. The average distance from field to storage was 2.6 kilometers which was longer as compared to that in the North; while the average distribution distance was 16.7 kilometers. Farm truck were used for farm transportation at the percentage of 27.9. It was found that animal labour was not used for transportation purpose in this region.

4.1.3. Central Region

The majority of farmers in this region harvested their crops in August (54 per cent of all interviewed farmers), while 19 per cent of farms in this region harvest in September as shown in Table 4.1 below. They always planted maize in the beginning of rainy season (April) and Sorghum in the late rainy season (August). Ninety one per cent of farmers hired labours for harvest. Some farmers built storage in their farms to facilitate the process of transporting their products from their large planted areas. After harvest, 86 per cent of farmers kept their products in the storage while 14 per cent of them shelled their products immediately. Thirty-three per cent of farmers in this region preferred to keep their maize for over a month to let it dry and thus became more valuable. Shellers with horsepower greater than 65 HP were most common. It was found that 23 per cent of farmers used pesticides in their storage areas to protect their maize from pests . Seventy-seven per cent of farmers asked the middleman to shell the products, and thus the sale price did not include the shelling and the associated labour costs.

Table 4.1 Months of operation for harvesting in each region in percentage term by survey in crop year 1988/89

Region\Month	Jan	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North	-	13.6	-	46.9	34.6	4.9	-	-
Northeast	11.7	11.7	-	24.8	18.2	1.5	11.7	20.4
Central	-	7.9	3.0	53.9	18.6	3.9	8.8	3.9

4.2 Cost

In this study, cost was categorized into 2 types:- "real cost" and "opportunity cost". "real cost" was the obvious expense which incurred to farmers, whereas "opportunity cost" could be determined by considering the hiring or renting rate in local areas as described in Chapter III. The following table illustrates a few example of REAL COST and OPPORTUNITY COST.

Table 4.2 Examples of "REAL COST" and "OPPORTUNITY COST"

Activities	Real cost	Opportunity cost
Harvest	- hired labour	- family labour
	- food and beverage	- cousin labour
	- labour transportation	- owner truck
	- fuel for truck	
	- labour who lift products	
Transportation	- sale transportation	- farmer own truck
	- farm transportation	
	- input factors transportation	
	- fuel	
	- hired labour	
	- food and beverage	
Shelling	- Sheller	
	- hired labour	
	- food and beverage	
Pesticides	- Pesticides cost	- free pesticides from government offices
	- hired labour	

4.2.1. Real cost

4.2.1.1. Norththern region

Major portion of the real cost was for harvest (40%). The next major item was shelling by means of sheller (20%). The ratios of hiring labour and using family labour in both harvest and sheller were 54 and 78 per cent respectively. The estimated cost for harvest was 79.6 baht per rai, whereas the cost for shelling was 39.3 baht per rai. The cost for storage maintenance was 3.1 bahts per rai. Fifty-two percent of farmers repaired their storage by using family labour. For the farm transportation, farmers paid at the average of 31.1 bahts per rai which 60 per cent of farmers hired others to transport their farm outputs at farm level. And for product distribution, the rate of hiring was 79 per cent with the cost of 40.7 baht per rai. The total real cost in this region was 193.8 baht per rai as shown in Table 4.3.

4.2.1.2. Northeast region

Labour cost in this region was lower than those the North and Central regions. The wage was in the range of 25 to 35 bahts per day. The major portion of the real cost was for harvest (42 per cent). The harvest cost was as high as 90.3 baht per rai. The next major item was shelling (4.3 baht per rai). The item with the lowest cost was farm transportation (23 baht per rai). Shelling and product distribution costed 27.6 and 23.5 baht per rai respectively. Only 54 per cent of farmers sold their products by themselves using hiring truck (41 per cent) or using their own truck (13 percent). The total real cost was about 168.7 baht per rai.

4.2.1.3.Central region

The biggest portion of real cost was for the harvest (75 baht per rai). The next major item was again shelling (18.1 baht per rai). The item with the lowest cost was storage maintenance (2.2 baht per rai). Farm transportation and product distribution costed 16.3 and 13.7 baht per rai respectively. Sixty per cent of total cost in post-harvest activity was harvest due to the existence of large planted areas; farmers had to hire outside labour to assist them in harvesting. Ten per cent of farmers shelled their products by themselves, while others sell their products to the middleman who are then expected to handle the shelling.

It was found that at the significant level of 0.05, it could not be accepted that the mean difference of real cost are not different. Then S-method(Scheffe) was used for testing the mean difference between 2 regions(North - Northeast, North - Central, and Northeast - Central). (Appendix C)

It was concluded that there was indeed a difference between the real cost in 3 regions as shown in Figure 4.2.

Table 4.3 The real cost for maize post harvest (Baht/rai)

Activities	Regions		
	North	Northeast	Central
Harvest	79.6	90.3	75.1
Storage maintenance	3.1	4.3	2.2
Shelling	39.3	27.6	18.1
Farm transportation	31.3	23.0	16.3
Sale transportation	40.7	23.5	13.7
Total	193.8	168.7	125.4

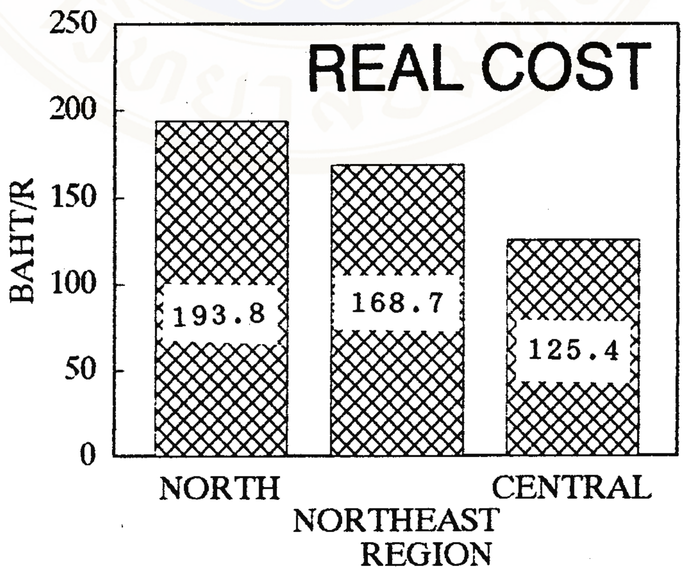


Figure. 4.2 The real cost of maize post-harvest

4.2.2. Opportunity cost

4.2.2.1. Northern region

The major portion of this opportunity cost was for harvesting (45%). The next major item was for transportation (27%). The cost for farm storage maintenance was the lowest (3.7 baht per rai), whereas harvest being the highest was at 46.2 baht per rai. The cost of shelling, farm transportation, and product distribution were at 14.7, 27.5, and 9.6 baht per rai respectively. The total cost in this region was around 101 baht per rai. (Table 4.4)

4.2.2.2. Northeast region

The major portion of opportunity cost here was spent on the harvest (59.6 baht per rai). The item with the lowest cost was for storage maintenance (12.3 baht per rai). Shelling and sale distribution activities costed 12.7 and 13.4 baht per rai respectively. The total opportunity cost was about 114.1 baht per rai.

4.2.2.3. Central region

Harvest accounted for 46 per cent of the opportunity cost here in this region at 24.1 baht per rai, which was the highest as compared to all the others. The lowest one was the process of product distribution which accounted for only 0.8 baht per rai. The cost of shelling, storage maintenance, and farm transportation were 10.1, 2.7 and 14.6 baht per rai respectively. Fifty five per cent of farmers maintained their products in storage, and 40 per cent of them use pesticides to protect maize. This cost was at the ratio of 1 to 2.4 of the real cost.

Table 4.4 The opportunity cost for maize post harvest (Baht/rai)

Activities	Regions		
	North	Northeast	Central
Harvest	46.2	59.6	24.1
Storage maintenance	3.7	12.3	2.7
Shelling	14.7	12.7	10.1
Farm transportation	27.5	16.1	14.6
Sale transportation	9.6	13.4	0.8
Total	101.7	114.1	52.3

Assumption of analysis of variance was that, in the hypothesis of mean difference, the variance test must not be differences in variance in the North, Northeast, and Central regions at the significant level of 0.05.

$$X^2 \ (2) = 272.56$$

$$X^2 \ 92)(0.05) = 124.34$$

Thus, it could be concluded that there was indeed a different in variance of opportunity cost. The average of opportunity cost in 3 regions are different as shown in Figure 4.3.

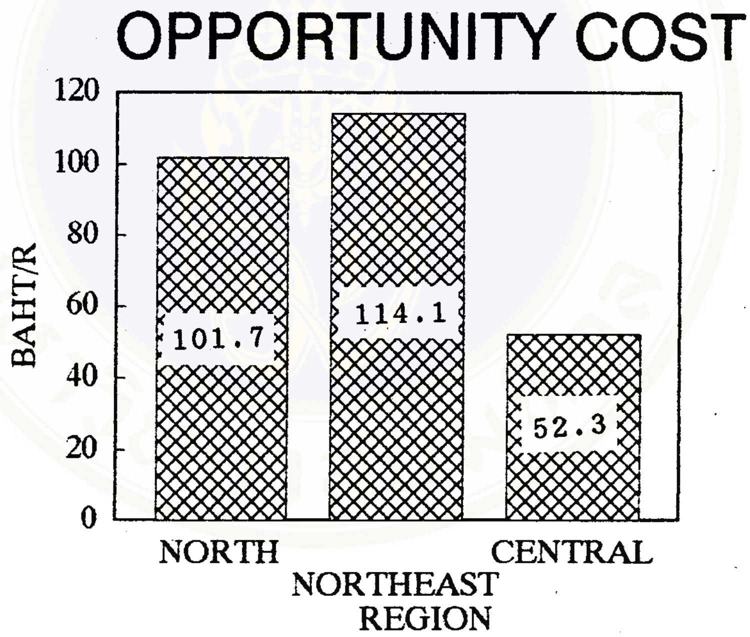


Figure. 4.3. The opportunity cost of maize post-harvest

4.3 Energy requirements

Fuel energy was needed to power farm machine(eg. sheller) and trucks. Direct energy used was calculated by multiplying the quantity of diesel oil with 46.4 MJ per litre (for diesel) or 42.7 MJ per litre (for gasoline). Indirect energy was estimated by the use of "energy conversion factors" (as shown in Table 3.2) depending on the type of machine used and the maize farm test (Appendix D). Total energy was determined by adding direct energy to indirect energy.

4.3.1. North region

The energy requirement for shelling, farm transportation, and products distribution were 1.0, 1.8 and 1.9 liters of diesel oil per rai respectively. The indirect energy used in the stage of farm transportation which was the highest (28.7 MJ per rai). Coming in second and third places were sale transportation (25.5 MJ per rai) and shelling (19.5 MJ per rai).

4.3.2. Northeast region

The energy uses in this region were mainly for operating the shelling machines, farm transportation, and products distribution. The direct fuel or diesel used in the stage of product distribution was the highest (1.6 liters per rai). Farm transportation and shelling came in second and third places respectively with 1.1 and 1.0 liters per rai. Large tractors with horsepower of more than 65 HP were used for sheller power. Four per cent of farmers in this region sold their products as maize cob. Average time taken to drive a sheller was 0.2 hour per rai.

4.3.3. **Central region**

The average diesel oil uses were 1.0 litre per rai for shelling, 1.0 liters for farm transportation, and 1.5 liters for the stage of sale transportation. Pesticides were used for storage maintenance at the average rate of 21.1 MJ per rai via human labour assitance. The total energy used was 252.3 MJ per rai or 5.4 liters of diesel per rai. Usage of large tractor for shelling purposes was also common in this region.

The details of total energy use for maize post harvest in 3 regions is shown in Table 4.5 and the fifference of total energy use is indicated in Figure 4.4.

Table 4.5 The total energy use for maize post harvest.
(MJ/Rai)

Activities	Regions		
	North	Northeast	Central
Pesticides	13.4	-	21.1
Shelling	64.5	69.5	66.4
Farm transportation	114.0	77.3	78.7
Sale transportation	113.8	99.4	86.1
Total	305.7	246.2	252.3

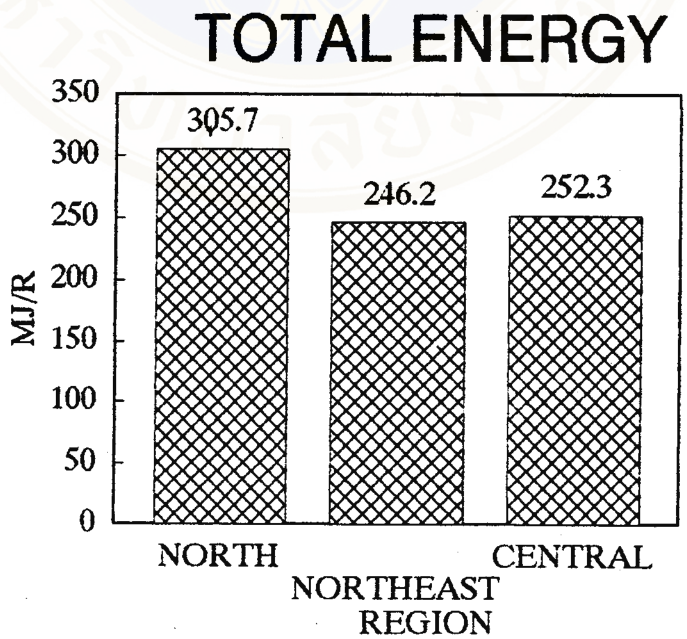


Figure. 4.4 Total energy use for maize post-harvest

On the basis of this study, it was interesting to note the difference in total energy usage depending on the duration of maize storage. It was found that the longer the maize was kept to be dried, the less energy was needed. This was mainly due to the fact that it took longer time to shell maize which contains moisture. In the situation where the maize was shelled immediately, the total energy used was estimated to be around 69 MJ per rai or 1.5 liters of diesel per rai. On the other hand, if the maize was first kept for more than 60 days before being shelled, the total energy usage would then be reduced to 55.2 MJ per rai. Table 4.6 contains detailed data to further illustrate different periods of time the maize was stored before shelling and the corresponding values of total energy usage in shelling.

Table 4.6 Number of days the maize was stored and corresponding energy usage in shelling

No. of Days	Total energy usage in shelling (MJ/rai)
Shelling immediately	69
1 - 10	69
11 - 20	68
21 - 30	62
31 - 40	57
41 - 50	47
51 - 60	55
> 60	55

By applying the method of analysis of variance, it was found that there was a difference in the average total energy usage in the 3 regions at a confidence interval of 95 percent.

Since it was confirmed by the above method that there was indeed a difference, it would be interesting to find out further which particular 2 regions were different. This would be accomplished through the application of Sheffe method since the sample sizes from those 3 regions were not equal. On the basis of this study, there were differences in the average total energy usage between the North and Northeast, North and Central, and Northeast and Central. (Appendix C)

Analysis of Variance (ANOVA) method could be applied further to determine whether there was any difference between energy use for shelling with sheller power greater than 65 HP as compared to shelling with sheller power less than or equal 65 HP at the same period of time. It was found that there was a difference at a significance level of 0.05. (Appendix C)

4.4 Human and Animal Labour Requirement

In this study, human and animal labour was not taken into consideration in the determination of total energy requirement. It was only determined in term of hours per rai. The difference of total human-labour use in 3 regions is shown in Figure 4.5.

4.4.1. Northern region

Highest effort of human labour in this region was directed toward the harvest stage at the rate of 22.2 man-hours per rai. The next highest was farm transportation (1.4 man-hours per rai) which involved the activity of transporting harvested maize to trucks. Human labour requirements for storage maintenance, shelling, and product distribution were 0.3, 2.0, and 0.4 man-hour per rai respectively.

In this region, animal labour was used for farm transportation at the rate of 24.7 percent and with the labour requirement rate of 1.2 animal-hours per rai.

4.4.2. Northeast region

Highest effort was directed toward the harvest process at about 82 per cent of the total human labour use in post-harvest activities. Farmers who owned small planted areas often harvested through the use of family labour, whereas in the case of those who owned larger planted areas, labour hiring becomes necessary. Wages was determined by number of bags per day or baht per day. The duties and the number of labour needed for each one are summarized in a simplified table as seen below.

Duties	Number
1. Machine controller	1
2. Maize conveying	3
3. Products measurement	2
4. Bag sewing	1
5. Person who put maize cob to the sheller	1

Exact number of labour needed for each activity vary depending on many factors (eg., existing labour, time remaining, etc...).

4.4.3. Central region

Major portion of human labour was concentrated toward the harvest process which accounted for 81 per cent out of the total effort; the labour requirement here was 16.3 man-hours per rai. The area which required the lowest labour effort was sale transportation (0.2 man-hours per rai). Animal labour was used in the stage of farm transportation at an average of 1.7 animal-hours per rai.

The details of human labour and animal labour are shown in Table 4.7.

Table 4.7 The human labour and animal labour use for maize post harvest in 3 regions

Activities	Region		
	North	Northeast	Central
Human labour(Man-hour/rai)			
Harvest	22.2	31.6	16.3
Storage maintenance	0.3	1.7	0.3
Shelling	2.0	2.1	2.3
Farm transportation	1.4	2.0	1.0
Sale transportation	0.4	0.4	0.2
Animal labour (Animal-hour/rai)	1.2	-	1.7

4.5 Energy Inputs, Cost, and Grain Yield

Total energy inputs required for maize post-harvest activities for 3 regions namely the North, Northeast, and Central were 305.7, 246.2, and 271.3 MJ per rai respectively. The average grain yield of maize for 3 regions are 439.4, 393.4, and 378.1 in the North, Northeast, and Central as shown in Figure 4.6. Energy intensity for maize production in these regions were 694.8, 625.8, and 717.5 MJ per ton of grain yield in the North, Northeast, and Central areas respectively.

The conclusion of energy inputs, ratios of energy use, and grain yield are summarized in Table 4.8 and Figure 4.8.

Table 4.8. The conclusion of energy inputs (Direct energy, Indirect energy and Total energy), costs (Real cost and Opportunity cost) and grain yield in the North, Northeast and Central.

Items	Region		
	North	Northeast	Central
Energy (MJ/R)			
Direct energy	218.6	172.8	162.6
Indirect energy	87.1	73.4	89.7
Total energy	305.7	246.2	252.3
Grain yield (KG/R)	439.4	393.4	378.1
Energy Intensity (MJ/TON)	694.8	625.8	667.3
Cost (B/R)			
Real cost	193.8	168.7	125.4
Opportunity	101.7	114.1	52.3
Total cost	295.5	282.8	177.7
Cost/Ton	672.5	718.9	470.0

Note : MJ : Magajoule

KG : Kilogram

R : Rai

B : Baht

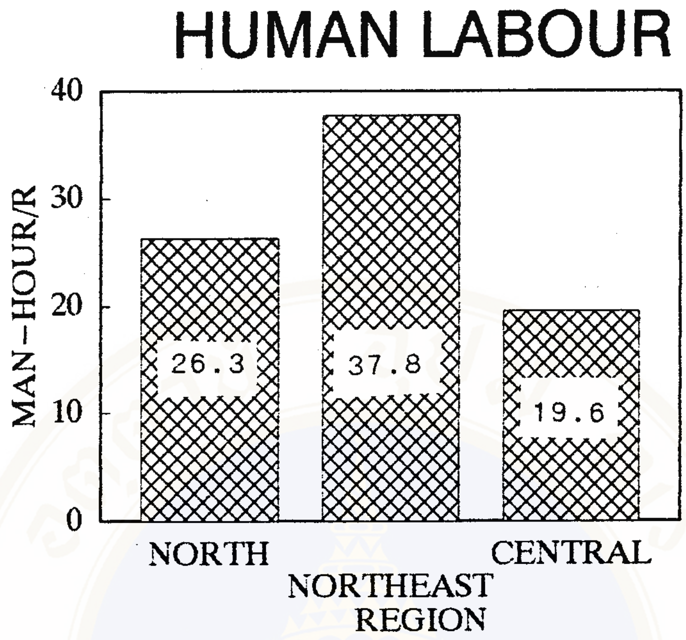


Figure 4.5 Human labour use for maize post-harvest

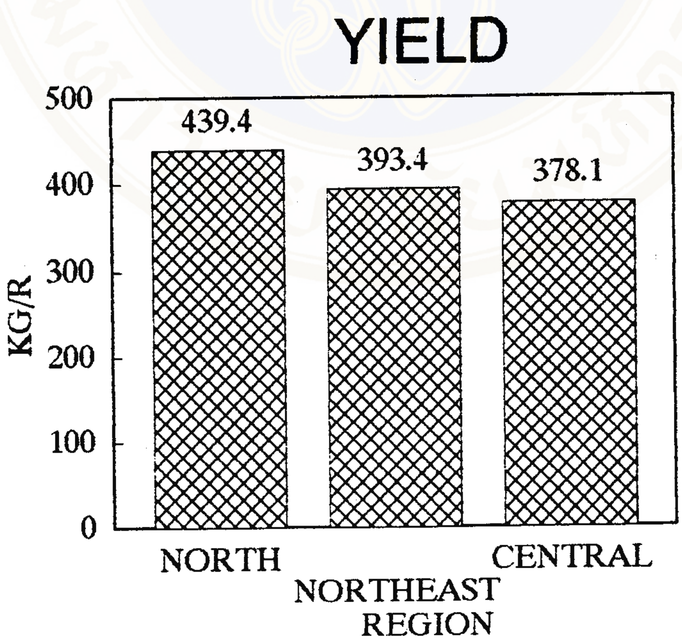


Figure 4.6. Maize yield

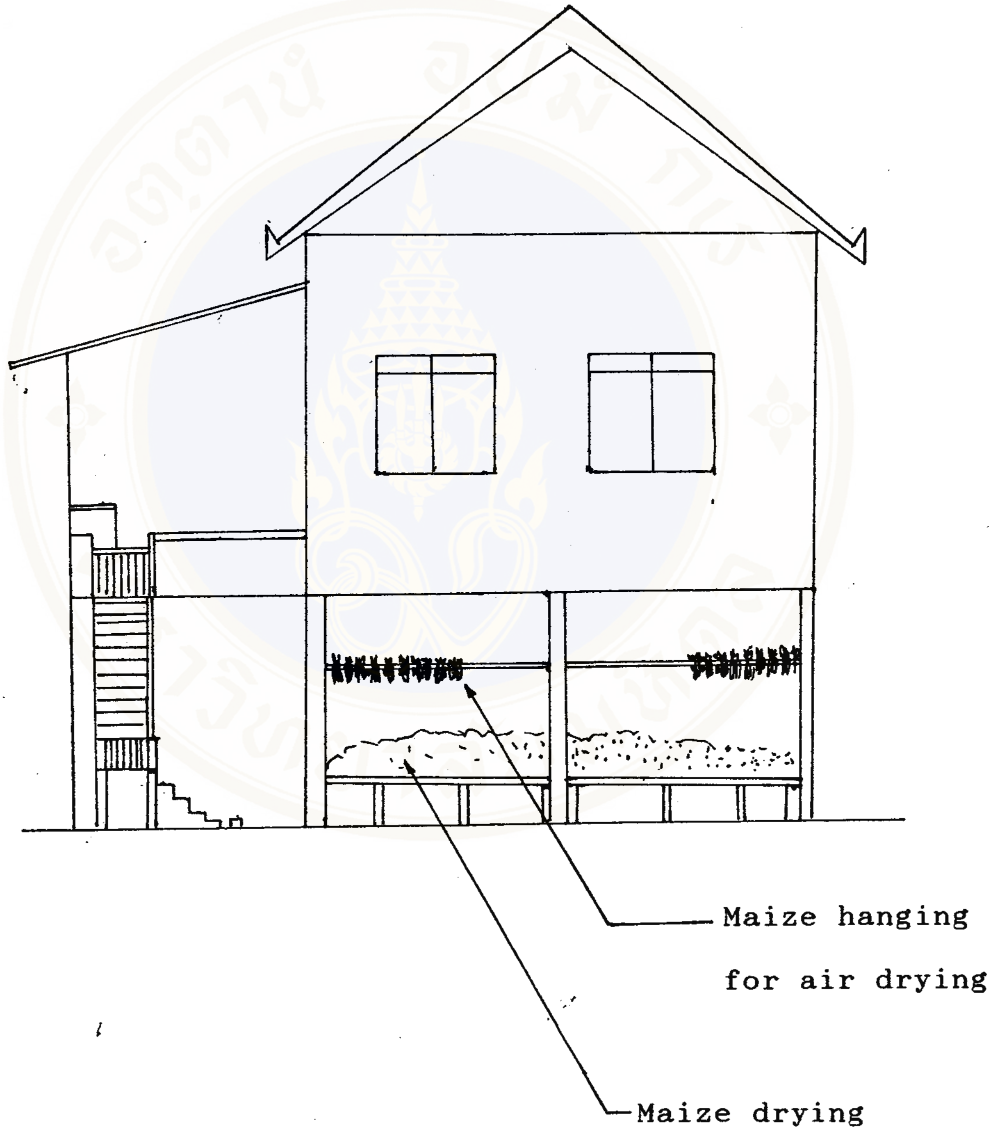


Figure 4.7. Maize storage under house

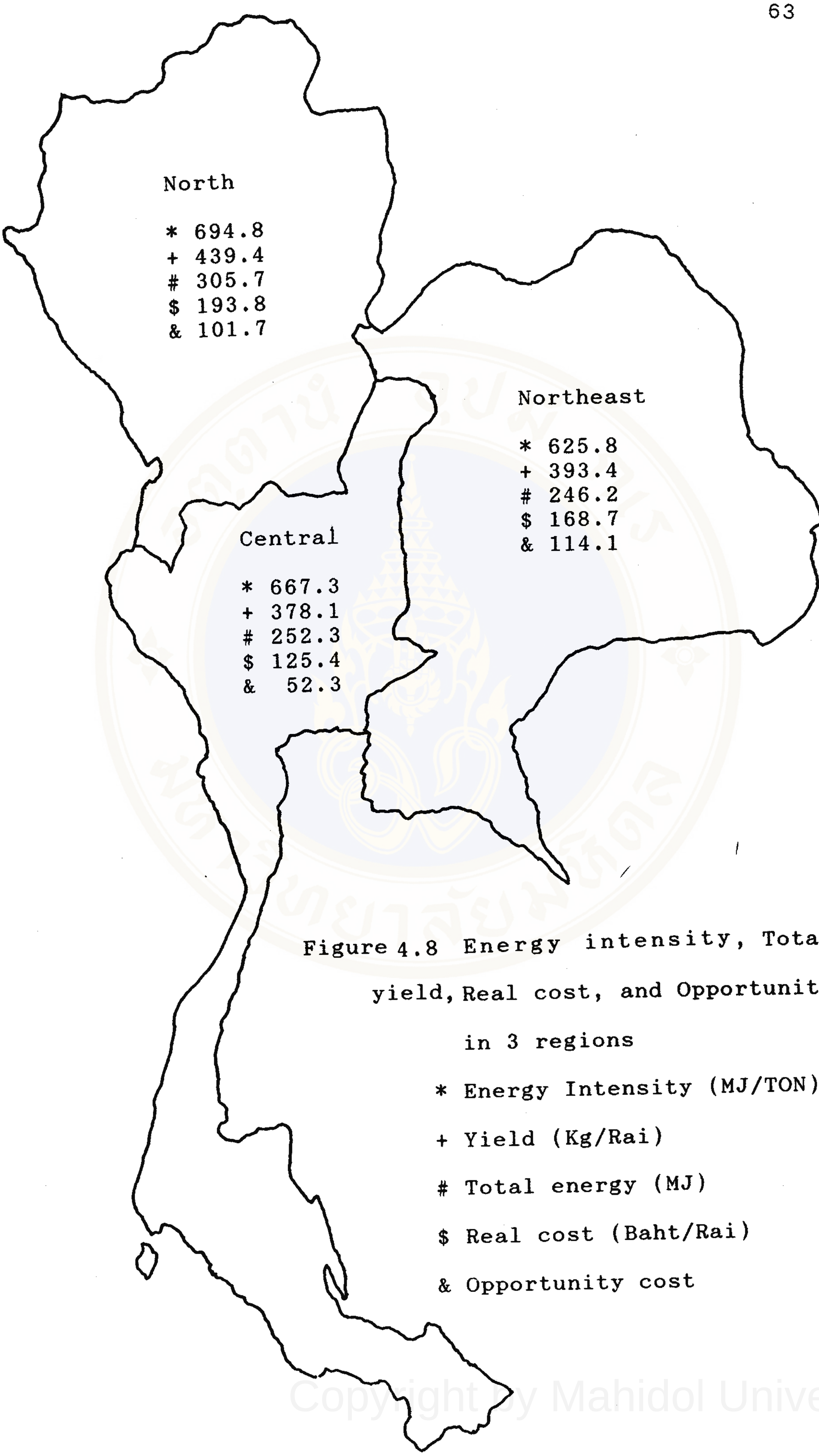


Figure 4.8 Energy intensity, Total energy, yield, Real cost, and Opportunity cost in 3 regions

* Energy Intensity (MJ/TON)

+ Yield (Kg/Rai)

Total energy (MJ)

$ Real cost (Baht/Rai)

& Opportunity cost

CHAPTER V

Discussions, Conclusions, and Recommendations

5.1 Discussions

All the available data used in the analysis was continuously collected during the years 1988 to 1989. The secondary data was collected from various sources in order to be able to conceptualize the most appropriate way to create questionnaires. Pilot study or pre-survey was performed in order to test those questionnaires so as to have them edited to assure completeness and consistency prior to data analysis. Data analysis was then conducted by first transforming those data obtained through the questionnaires onto data sheets before being analyzed through the use of LOTUS 1-2-3 and other statistical package. Those software facilitated the process of determining averages, standard deviations, and difference testings.

Testing to determine average energy use for wet shelling and dry shelling was not studied due to the difficulty in finding actual samples and also the moisture of maize could not be determined while shelling. However, with all the available data, it was possible to roughly summarize total energy usage against number of days in storage before shelling, as seen in Table 4.6.

The cost of transporting certain input factors (eg., pesticides, fertilizers, etc.) by bus or local bus was also not included in this study since buses were often shared by many parties and thus the actual cost of energy use was so minute that it could be disregarded.

5.2 Conclusion

The study involved the analysis of energy requirement for maize post-harvest activities in Thailand, and the determination of whether there was a significant difference of the average energy use and the cost in 3 regions, namely the North, Northeast, and Central. The total energy use was determined from many factors involved such as farm machines, fertilizers, pesticides, fuels, etc. The cost of maize post-harvest activities was divided into 2 main categories: - real cost and opportunity cost. The real cost was the obvious expense which incur to farmers, while the opportunity cost was the hidden cost.

On the basis of this study, the highest amount of energy use occurred in the North at the rate of 305.7 MJ per rai., while the lowest was in the Northeast with 246.2 MJ per rai. The highest yield was in the North with the value of 439.4 kilograms per rai, while the lowest was in the

Central with 378.1 kilograms per rai. The highest real cost occurred in the North with the value of 193.8 baht per rai, and the lowest was in the Central with 125.6 baht per rai. The highest opportunity cost was in the Northeast with 114.1 baht per rai, while the lowest was in the Central with 52.3 baht per rai. Energy ratio was calculated by dividing the value of total energy use by the value of yield. Thus, the energy intensity is considered to be a good indication for energy efficiency. It was found that the Northeast was the one with the highest energy efficiency, while the Central was the lowest.

Highest human labour requirement for maize post-harvest activities was 38.8 man-hours per rai in the Northeast, while the lowest was 20.1 man-hours per rai in the Central. The majority of human labour requirement was concentrated toward harvesting activity which accounted for 81.1 per cent of total human labour requirement in all 3 regions. Animal labour requirement was found in the North and Central regions handling the farm transportation activity. (Table 5.1)

Table 5.1 Total energy use, real cost, opportunity cost, and energy intensity.

Item	Quantity		
	North	Northeast	Central
Total energy (Megajoule/Rai)	305.3	246.2	271.3
Liters/Rai (of diesel)	6.6	5.3	5.8
Cost (Baht/Rai)	302.1	330.9	177.7
- Real cost	200.4	216.8	125.4
- Opportunity cost	101.7	114.1	52.3
Yield (Kilograms/Rai)	439.4	393.4	378.1
Energy intensity (Megajoule/ton)	694.8	841.1	717.5
Human labour (Man-hour/rai)	26.3	37.8	19.6
Animal labour (Animal-labour/rai)	1.2	-	1.7

By means of statistical analysis (ANOVA), it was found that there was indeed a difference of energy use among the 3 regions. The real costs incurred in these 3 regions were also found to be different. The study also showed that shellers with power greater than 65 HP consumed more energy as compared to the ones with power less than or equal to 65 HP in the same time. Moreover, it was found that the energy requirement would be less when farmers allowed the maize to be dried for certain period of time before shelling, as opposed to having the maize shelled immediately.

5.3 Recommendations

After having concluded this study, these are some of the relevant ideas for possible improvement on the next study which could be conducted in order to explore further into more details:

- Studied areas could be narrowed down so that more details could be considered. For example, perhaps only one region is selected to do the study on. In this case, it would be more convenient to elaborate the data collection to include much more details to enable the researcher to do the analysis at a much greater depth.

- The moisture of maize while shelling could be accurately measured in order to further determine the difference of the average energy use.

- The differences of energy requirement for maize post-harvest activities in early rainy season and dry season could be studied and compared.

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APPENDIX A

APPENDIX A

TABLE 1 THE DIRECT FUEL USE FOR MAIZE POST-HARVEST (LITRES/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
SHELLING	1.0	0.6	60	1.0	0.8	80	1.0	0.5	50
FARM TRANSPORTATION	1.8	3.2	177	1.1	1.7	154	1.0	1.2	117
SALE TRANSPORTATION	1.9	2.9	137	1.6	1.4	88	1.5	2.7	180
TOTAL	4.7			3.7			3.5		

TABLE 2 THE DIRECT ENERGY USE FOR MAIZE POST-HARVEST (MJ/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
SHELLING	44.9	25.4	57	45.6	36.9	81	46.6	26.1	56
FARM TRANSPORTATION	85.4	148.9	174	52.5	78.9	150	46.9	54.7	116
SALE TRANSPORTATION	88.3	123.3	140	74.7	65.2	87	69.1	126.9	184
TOTAL	218.6			172.7			162.6		

TABLE 3 THE INDIRECT ENERGY USE FOR MAIZE POST-HARVEST (MJ/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
PESTICIDES	13.4	15.2	113	-	-	-	21.1	33.3	158
SHELLING	19.5	11.4	58	23.9	16.8	70	19.8	11.0	56
FARM TRANSPORTATION	28.7	49.9	174	24.9	41.1	165	31.8	44.7	141
SALE TRANSPORTATION	25.5	39.4	155	24.6	81.0	81	17.0	28.9	170
TOTAL	87.1			73.4			89.7		

TABLE 4 THE TOTAL ENERGY USE FOR MAIZE POST-HARVEST (MJ/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
PESTICIDES	13.4	15.2	113	-	-	-	21.1	33.3	158
SHELLING	64.5	36.7	57	69.5	52.8	76	66.4	37.1	56
FARM TRANSPORTATION	114.0	197.9	174	77.3	107.4	139	78.7	150.0	190
SALE TRANSPORTATION	113.8	162.1	142	99.4	81.0	81	86.1	155.6	181
TOTAL	305.7			246.2			252.3		

TABLE 5 REAL COST FOR MAIZE POST-HARVEST (BAHT/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
HARVEST	79.6	77.0	97	90.3	77.6	86	75.1	40.9	54
STORAGE MAINTENANCE	3.1	4.0	132	4.3	5.7	133	2.2	2.6	118
SHELLING	39.3	25.7	65	27.6	25.0	91	18.1	16.1	89
FARM TRANSPORTATION	31.1	40.1	129	23.0	36.2	157	16.3	11.9	73
SALE TRANSPORTATION	40.7	33.4	82	23.5	18.0	77	13.7	5.6	41
TOTAL	193.8			168.7			125.4		

TABLE 6 OPPORTUNITY COST FOR MAIZE POST-HARVEST (BAHT/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
HARVEST	46.2	69.5	150	59.6	56.1	94	24.1	27.6	115
STORAGE MAINTENANCE	3.7	5.1	138	12.3	15.1	123	2.7	2.8	104
SHELLING	14.7	19.7	134	12.7	14.6	115	10.1	13.7	136
FARM TRANSPORTATION	27.5	25.3	92	16.1	21.2	132	14.6	13.2	90
SALE TRANSPORTATION	9.6	14.6	152	13.4	14.7	110	0.8	-	-
TOTAL	101.7			114.1			52.3		

TABLE 7 HUMAN LABOUR REQUIREMENT FOR MAIZE POST-HARVEST (MAN-HOUR/RAI)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
HARVEST	22.2	14.5	65	31.6	26.0	82	16.3	11.1	68
STORAGE MAINTENANCE	0.3	0.5	189	1.7	3.1	182	0.3	0.5	167
SHELLING	2.0	1.3	65	2.1	1.6	76	1.8	1.1	59
FARM TRANSPORTATION	1.4	1.8	129	2.0	2.8	142	1.0	1.4	140
SALE TRANSPORTATION	0.4	0.6	150	0.4	0.4	100	0.2	0.2	100
TOTAL	26.3			37.8			19.6		

TABLE 8 ANIMAL LABOUR REQUIREMENT FOR MAIZE POST-HARVEST(ANIMAL-HOUR/R) YIELD (KILOGRAMME/RAI), STORAGE AREA (M^3), STORING TIME (DAYS)

ACTIVITIES	REGION								
	NORTH			NORTHEAST			CENTRAL		
	mean	sd	cv	mean	sd	cv	mean	sd	cv
FARM TRANSPORTATION	1.2	1.1	92	-	-	-	1.7	2.5	147
YIELD	439.4	176.3	40	393.4	166.4	42	378.1	199.2	53
AREA	98.3	117.6	120	72.9	46.3	64	141.4	142.5	101
STORING TIME	51.2	38.8	76	-	-	-	48.4	75.9	157

APPENDIX B

APPENDIX B

QUESTIONNAIRE

CODE .... INTERVIEWER ....

DATE ....

INTERVIEWEE'S NAME ....

ADDRESS ....

....

PLANTED AREAS (RAI) .... PRODUCTIVITY ....

(KILOGRAMME/RAI)

---

1. How many years have you had experience on maize cultivation?

   .... years

   Have you planted maize continuously for last three years?

   1. yes 2. no (stop interviewing)

2. Will you plant maize in next year?

   1. yes 2. no (stop interviewing)

3. Were your maize plot used as public's demonstration plot last crop year?

   1. yes (stop interviewing) 2. no

4. Did you get any free material inputs for maize cultivation last crop year?

   1. yes (stop interviewing) 2. no

5. Which were your cropping pattern for maize?

   1. monocropping 2. crop rotation with ....

   3. Intercropping with .... (stop interviewing)

6. Plots of maize cultivation in crop year 1988/89 ...... plots total areas .... rais.

Plot no	Planted area(rai)	Variety	Crop/year	Location	Distance(kms)		
					1	2	3 *
1.							
2.							
3.							

* 1: Farm to house

2: House to market

3: Farm to market

7. Have you any own machineries or equipments?

1. yes 2. no (pass to question 8)

7.1 Water pumping: Centrifugal pump .... units.

Propeller pump .... units.

Type	Diameter / Lenght	Brand / H.P.	Type of fuel / Rate of consumption	Price / year	Used time before buy / Using time per year	Combine with	Repairation in 1988
Machine 1							
Pump 1							
Machine 2							
Pump 2							

7.2 Sprayer .... units.

Type	Type	Brand ----- H.P.	Type of fuel ------------ Rate of consumption	Price ----- year	Used time before buy ---------- Using time per year	Combine with	Repairation in 1988
Sprayer1							
Sprayer2							
Sprayer3							

7.3 Tractor, Sheller, Trailer and Other equipments.

Type Equip-ment	Brand ----- H.P.	Model ----- Number	Type of fuel ------------ Rate of consumption	Price ----- year	Used time before buy ---------- Using time per year	Combine with	Repairation in 1988
Tractor							
4-wheel							
machine							
structure							
2-wheel							
machine							
structure							
Equipement							
Blade							
Furrow							
Planting							

Type	Equip-ment	Brand / H.P.	Model / Number	Type of fuel / Rate of consumption	Price / year	Used time before buy / Using time per year	Combine with	Repairation in 1988
Mold board								
Sheller machine sheller								
Others								

8. Give the details of maize production on plot no ....

area .... rais Productivity .... kgs.

This plot was 1. Early rainy season

2. Lately rainy season

Maize variety .... Rate of seed use (plus repair) ...... kg/r.

Seed source

1. collected for ..... years. 2. bought from ...... price ....

chemical mixing for seed

1. unmixed 2. mixed (chemicals .... quantity ....)

seed droping by

1. using sharpen wood made holes. 2. using hoe made holes.

3. following the furrows 4. planting machinery

5. other ....

ACTIVITY	TIME	DISTANCE	BY	HP	RATE OF WORK			FUEL	EXPENSE	
					MHR	HR	AHR	USE	B1	B2
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.......										
11.......										
12.......										

Notes ....

....

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APPENDIX C

APPENDIX C

The analysis of variance to test the mean difference of real cost between 3 regions is shown in Table C-1.

Table C-1 Analysis of Variance Table showing mean difference of real cost between 3 regions.

SOV	SS	DF	MS	F	$F_{(2,392)(0.05)}$
Region	56959.43	2	28479.71	3.78	3.0
Error	2991628.61	397	7535.59		
Total	3048588.04	399			

Note SOV : Source of Variance

SS : Sum Square

DF : Degree of Freedom

MS : Mean Square

F : F Value from Calculation

Table C-2 The mean difference of real cost between 3 regions

Mean difference ($\hat{\psi}$)	$\hat{\sigma}_{\psi}$	$\frac{\hat{\psi}}{\hat{\sigma}_{\psi}}$
North - Northeast = -16.5	4.96	-3.3
North - Central = 74.9	4.56	16.4
Northeast - Central = 91.4	5.14	17.8

Table C-3 Analysis of variance for total energy usage in 3 regions

SOV	SS	DF	MS	F	$F_{(2,397)(0.05)}$
Region	12314728.93	2	6157362.97	5226.45	3.0
Error	467711.98	397	1178.12		
Total	12782437.91	399			

Table C-4 The result of Sheffe method for mean difference test

Difference ($\hat{\psi}$)		$\hat{\sigma}_{\psi}$	$\frac{\hat{\psi}}{\hat{\sigma}_{\psi}}$
North - Northeast	= 59.5	5.34	-11.1
North - Central	= 34.4	4.91	7.0
Northeast - Central	= -25.1	5.53	-4.5

Table C-5 ANOVA Table showing energy use in Shelling with 2 levels of sheller power

SOV	SS	DF	MS	F	$F_{(1,390)(0.05)}$
Region	35872.81	1	35872.8	20.44	3.84
Error	584581.19	390	1755.3		
Total	720454.0	391			

APPENDIX D

Appendix D

Table D-1 The results of maize farm test in the field in crop year 1988/89

	L/Hr	L/Hr/HP	T/Hr	Man
Shelling				
X	6.14	0.08277	5.72328	13.13
SD	2.15	0.02791	2.102497	3.76
n	30	30	30	30
C.V.	35	33.73	36.74	28.61
Transportation				
X	3.35	0.08778		
SD	2.9	0.1		
n	49	46		
C.V.	85.0	103.4		

L = Litres

Hr = Hour

HP = Horse power

T = Ton