MECHANIZATION OF SMALL-SCALE RICE FARMING AND SMALL FARM MACHINERY OPERATIONS IN RIAU PROVINCE, INDONESIA

インドネシア・リアウ州の小規模稲作における機械化と
小型農業機械の運用について

UJANG PAMAN

2016

MECHANIZATION OF SMALL-SCALE RICE FARMING AND SMALL FARM MACHINERY OPERATIONS IN RIAU PROVINCE, INDONESIA

A THESIS SUBMITTED TO THE UNITED GRADUATE SCHOOL OF
AGRICULTURAL SCIENCES, KAGOSHIMA UNIVERSITY, JAPAN
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in Agricultural Science

BY

UJANG PAMAN

MS AGRICULTURAL INFORMATION SCIENCE
(SAGA NATIONAL UNIVERSITY, JAPAN)

2016

鹿児島大学大学院連合農学研究科
The United Graduate School of Agricultural Sciences
Kagoshima University

21-24, KORIMOTO 1- CHOME, Kagoshima 890 - 0065, JAPAN

The dissertation entitled "MECHANIZATION OF SMALL-SCALE RICE FARMING AND SMALL FARM MACHINERY OPERATIONS IN RIAU PROVINCE, INDONESIA" prepared and submitted by Ujang Paman in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY is hereby accepted.

Prof. Dr. Hiroyuki CHO
Chairman,
Examination Committee
Saga National University

2016. 1. 8
Date

Prof. Dr. Yoshiharu SHIRATAKE
Member,
Examination Committee
Saga National University

Prof. Dr. Masami UENO
Member,
Examination Committee
University of the Ryukyus

Prof. Dr. Munehiro TANAKA
Member,
Examination Committee
Saga National University

Prof. Dr. Koichi IWASAKI
Member,
Examination Committee
Kagoshima National University

Preface

It seems really quite amazing to be at the point of finishing this dissertation. It is a result of hard work and a contribution of a number of people who were involved. This dissertation is my recent empirical research on the mechanization of small-scale rice farming and small farm machinery operations in Riau Province, Indonesia. The mechanization is the most important single and evitable factor in the modernization of rice farming system.

This dissertation is organized in five main chapters; Chapter 1 is a general introduction. Chapter 2 describes the review of literature; Chapters 3 explain the research methodology; and Chapter 4 shows the results of the study and discussion. Conclusions and recommendations of this dissertation work are presented in Chapter 5.

The work outlined in this dissertation was carried out at Laboratory of Agricultural System Information and Technology, Department of Agricultural Science, Saga University of Japan, over the period from 2004 to 2014. This dissertation is the result of my work and includes nothing which is the outcome of work done in collaboration, except for a few instances which are stated in the text.

The results of this research work have mostly been published in nine international scientific journals which are included in Chapter 4. The publications covered all major points of this study. Thus, this dissertation on the one hand and the scientific publications on the other contain to some extend complementary information. Of course any mistakes that go into the final publication and a dissertation are my own responsibility.

Ujang Paman

要旨

農業機械の使用は稲作の近代化や小規模農場経営において重要さを増している。この研究では、小規模農場の稲作における作業時間・労働および費用に関する必要量を調査、農業経営のための費用、耕耘機の故障に関する問題および毎年の修繕費に大きな影響を与える要因の明確化、合理的な修繕費モデルの開発を目標とした。さらに、耕耘機の共同管理を実施している農家が実施する耕耘機レンタル事業・事業提供領域・季節毎の作業域における経済性について明らかにするとともに、リアウ州の小型農業機械を使用・管理する農家における経済的有効性、さらに稲作による農業経営に対する機械化推進状況についての評価も目標とした。研究に供試したデータは、本目的に合致するリアウ州の４つの団体であるクアンタンセンギンギ・ローカンフル・シアクおよびカンパーを対象としてあらかじめ準備した質問事項をもとに聞き取り調査を行って取得した。取得したデータは一次および二次データから構成されている。単純な記述や統計的手法およびコスト集計の手法を用いて解析した。調査の結果は以下の通りであった。稲作農家における平均的な機械動力は1ヘクタール当たり0.31馬力と、かなり低い値であった。2006年から2013年において農業に対する機械化の進捗状況はたった20.6%に留まった。稲作における全作業に必要な労力は1ヘクタール当たり83.26人・日であったが、これを機械化した場合、1ヘクタール当たりたったの7機械・日であった。稲作に必要な作業時間の合計は、平均して1ヘクタール当たり851時間に達した。それに必要な全費用は7,895,830インドネシアルピア（877米ドル）となった。この全費用は大半が人件費となるため、比較的高かった。耕耘機の故障は、作業者のミス・質の低い燃料や潤滑油の使用・圃場状態の悪さ・機械のメンテナンス不足および不適切な設計・乱暴な使用法・整備されていない農道での使用などの要因で発生している。技術力が不足している修理拠点・交換部品の欠如・その地方における整備員の不足は、修理期間の延長を招くとともに高い経費の要因となる。毎年の修理費用は機械の使用時間・使用圃場の広さ・馬力および操作者の技術によって影響されることが修理費用モデルにおいて統計的に判明した。その反面、所有者の違いおよび製造会社の数はこのモデルにおける説明変数としてさほど重要ではなかった。耕作を依頼した作業請負は高含水率圃場に対するものが大部分であった。耕耘機の所有者は毎年平均23.13ヘクタールの請負で926,000インドネシアルピア（以下IDRと表記）（109米ドル）の収入を得ていた。しかし、機械の維持に毎年348,000IDR（41米ドル）の費用が掛かっていた。実際に営農集団が管理している機械の数は請け負う面積をカバーするには十分ではなかった。稼動中の機械の限られた数・１シーズンあたりの作業日の不足・作業面積の限定・低い作業能力は、１シーズンにおける請負える面積を限定してしまった。浮上式耕耘機は３種の耕耘機中、作業能率・運用コスト・採算性で最も優れていた。農業における機械化発展計画は適期・短時間で実施する完璧な農作業と機械の普及の増大に不可欠である。機械の動力の点からも農家への更なる機械の提供が求められる。操縦者や整備員を教育するプログラムは、機会の運用やメンテナンスを成功させるのに是非とも必要である。また、機械所有者に対する耕作依頼は、リアウ州における農業機械の普及を加速させると確信している。

Abstract

The use of farm machines becomes increasingly important for mechanizing small rice farming and modernizing the production system. The objectives of this study are to determine the mechanical power availability, mechanization capacity, time and labor requirements, and costs for small rice farming operations; to examine the specific problem associated to tractor breakdowns, the factors affecting on repair costs, and develop a reasonable repair cost model; to know the economic potential of tractor hire businesses, the coverage, and seasonal working areas of the tractor hire services managed under farmer groups; to compare the working performance and cost for three types of power tillers; and to recommend improvement measures associated to small machinery operations. Data were based on a field survey from four purposively selected regencies: Kuantan Sengingi, Rokan Hulu, Siak, and Kampar in Riau Province. Interviews were conducted using questionnaires. The collected data consisted of primary and secondary data. Simple descriptive and statistical techniques and cost accounting method were used. Results show that the average mechanical power available to rice farmers is very low at about 0.31 HP/ha. The mechanization capacity increased at relatively low at around 20.6% during 2006-13. The labor required to complete rice farming operations was 83.26 man-days/ha, whereas the mechanical power was only 7 machine-days/ha. The total time required for rice farm operations was 851 h/ha on average. The total cost of rice farming operations was IDR 7,895.83 (US $877) thousand/ha. This overall cost is relatively high because of the large human cost. The tractor breakdowns were caused by operators' mistakes, inferior fuel and oil uses, poor field conditions, poor maintenance, intense usage, and poor farm roads. Inadequate repair shops, lack of spare parts, and shortage of local mechanics caused the repair to take longer and higher costs. The annual repair costs were statistically affected by age, use, horsepower, and operator skill, while ownership and manufacture variables were not significant explanatory variables in the repair cost model. A reasonable model was proposed to predict the annual repair costs. Majority of tractor hire services is profitable under operating in wetland paddy. Tractor owners received profit IDR 926 (U.S. $109) thousand/year on average under annual use of 23.13 ha and service charge of IDR 348 (U.S. $41) thousand/year. The number of machines managed by groups was not sufficient to work the entire coverage area owned by the group members. The limited number of available machines, short working days/season, small paddy field areas, and low working capacities caused the small seasonal working area. Hydro tiller was the best in terms of working performance, operational cost, and profitability. The mechanization development programs should be directed to increase mechanization capacity and complete farm works in timely and short time. The mechanical power available must be increased by providing more farm machines for farmers. Machine operators should be well-trained and supporting facilities and training programs must be made available for successful operation and maintenance machinery. The use of farm machinery for custom hiring should be encouraged to develop machine ownership in the province.

Acknowledgments

I would like to express my sincere gratitude and profound appreciation to the following people who gave me a valuable help to successful completion of this dissertation and achieve my Doctor's degree.

I am grateful to my supervisor, Dr. Susumu Uchida, Professor of Saga University and The United Graduate School of Kagoshima University, for his kindness, guidance, and encouragement during my study at The United Graduate School of Kagoshima University and completing this dissertation. Thanks also to Prof. Dr. Takayuki Kojima, former supervisor, for his insightful advice to my study and writing of my dissertation.

My special gratitude and acknowledgment to Dr. Shigeki Inaba, Associate Professor Saga University, for his continuous support and assistance to complete this dissertation and preparation for submission process to The United Graduate School of Kagoshima University. I owe a debt of gratitude to Prof. Dr. Tokumi Fujiki, former supervisor, for his patience and generosity, and valuable background in research. He also provided thoughtful guidance and encouragement for being inspirational, and for teaching me the importance of using curiosity as the driving force behind the research.

In addition, I wish also to acknowledge Prof. Dr. Hiroyuki Cho for his willingness to serve as a Chairman of Examination Committee and help for submission process to The United Graduate School of Kagoshima University. Similar gratitude and appreciation are also extend to Prof. Dr. Yoshiharu Shiratake, Prof. Dr. Munehiro Tanaka, Prof. Dr. Masami Ueno, and Prof. Dr. Koichi Iwasaki as examination committee members for their valuable comments and suggestions in the dissertation draft.

The work described in this dissertation would not have been possible without the generous financial support. Therefore, I would like to express my gratefulness to the Minister of Education and Science, Japan for their contributions towards my scholarships during master's course and the first year of doctor's course.

I am greatly indebted to the Faculty of Agriculture of Saga University and The United Graduate School of Agricultural Sciences, Kagoshima University, for allowing me to pursue my master and doctoral studies in Japan.

I would also like to say thank to my parents, family, and friends for always applying love, support, and faith. I have always been challenged to do my best and to never give-up. You were always there to congratulate me when I would succeed and to console and support me when I had failed. Thank you for everything.

During my stay in Japan for master and doctor courses, friendship was made my life here meaningful and fruitful. I would like to address my sincere gratitude and appreciation to many people in Saga City, laboratory's colleagues as well as Indonesian friends in Saga who always helped me whenever I need.

Finally, I wish to extend my appreciation to my wife and son for their many sacrifices and patience during my study in Japan.

Ujang Paman

Map of Indonesia

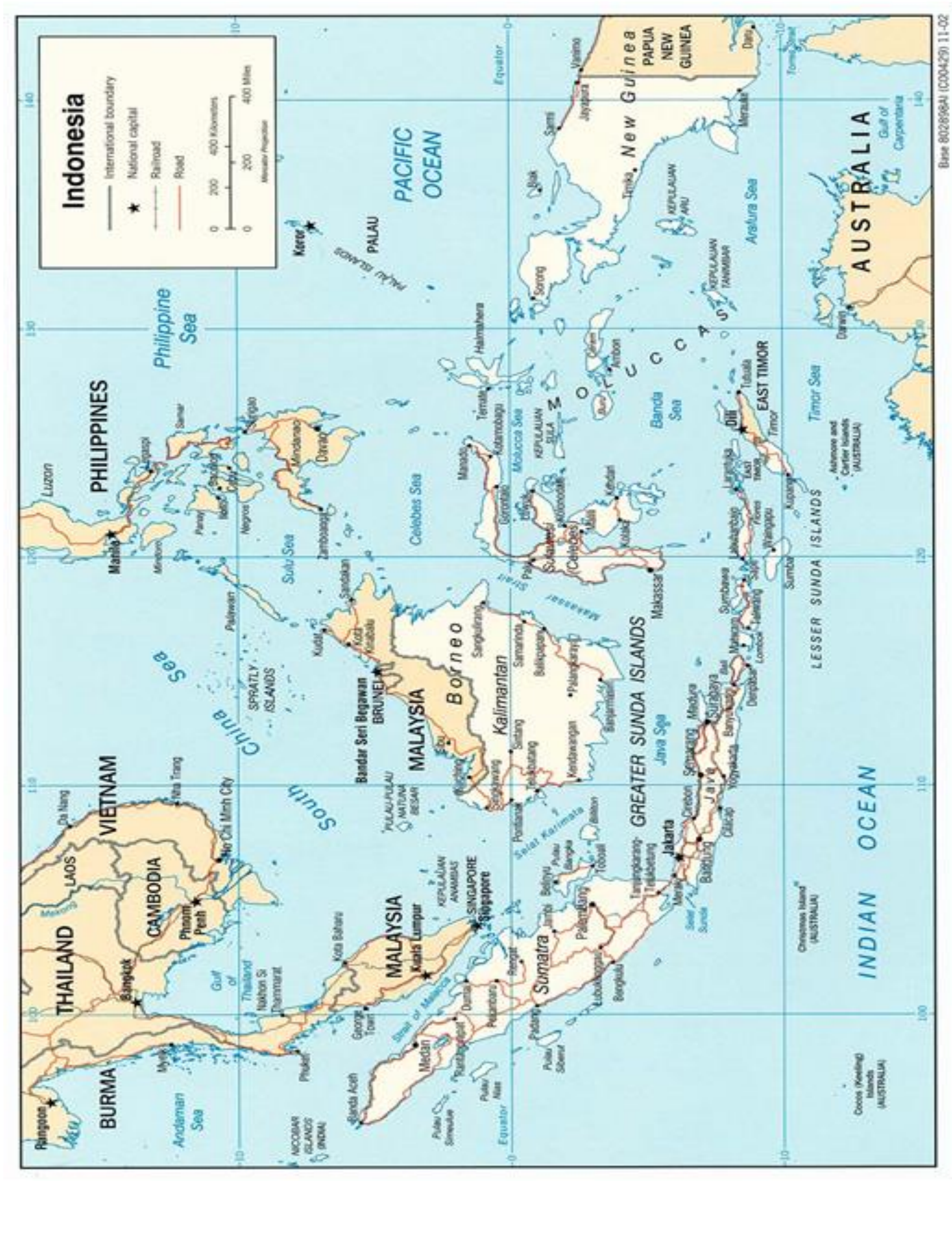


Table of Contents

.

List of Tables

Table | Page

List of Figures

List of Appendixes

List of Publications

U. Paman, S. Uchida, S. Inaba, T. Kojima. A survey on Causes of Tractor Breakdowns in Riau Province, indonesia A Case Study of Small Tractor Operations. Applied Engineering in Agriculture 2007; 23(1): 43-48. DOI: 10.13031/2013.22329

U. Paman, S. Uchida, S. Inaba, T. Kojima. Factors Affecting Repair Costs of Small Tractor Use in Riau Province, Indonesia. Tropical Agriculture 2008; 85(2): 142-148.

U. Paman, S. Uchida, S. Inaba. Economic Potential of Tractor Hire Business in Riau Province, Indonesia: A case study of small tractors for small rice farms. Agricultural Engineering International: CIGR Journal 2010; 12(1): 135-142.

U. Paman, S. Uchida, S. Inaba. Operators' Capability and Facilities Availability for Repair and Maintenance of Small Tractors in Riau Province, Indonesia: A Case Study. Journal of Agricultural Science 2012; 4(3): 71-78.

U. Paman, S. Inaba, S. Uchida. Determining Mechanization Capacity and Time Requirement for Farm Operations: A Case of Small-Scale Rice Mechanization in Riau Province, Indonesia. Applied Engineering in Agriculture 2012; 28(3): 333-338. DOI: 10.13031/2013.41486

U. Paman, S. Inaba, S. Uchida. Farm Power Status and Requirement for Small-Scale Rice Farm Operations: A Case in Riau Province, Indonesia. Tropical Agriculture 2013; 90(2): 79-86.

U. Paman, S. Inaba, S. Uchida. Farm Machinery Hire Services for Small Farms In Kampar Regency, Riau Province, Indonesia. Applied Engineering in Agriculture 2014; 30(5): 699-705. DOI: 10.13031/aea.30.10276

Ujang Paman, Shigeki Inaba, Susumu Uchida. The mechanization of Small-Scale Rice Farming: Labor Requirements and Costs. Engineering in Agriculture, Environment and Food 2014; 7: 122-126. DOI: 10.1016/j.eaef.2014.03.001

Ujang PAMAN, Shigeki INABA, Susumu UCHIDA. Working Performance and Economic Comparison of Three Power Tiller Types for Small-Scale Rice Farming in the Kampar Region of Indonesia. Journal of the Japanese Society of Agricultural Machinery and Food Engineers 2015; 77(5): 363-37.

CHAPTER I
INTRODUCTION

1.1. Background

Indonesia is a huge archipelago and predominantly an agricultural country. It consists of 13,667 islands with a total land area about 1.92 million sq. km or around 37% of a total land surface of 5.19 million sq. km. Approximately 17.19% of the total land area is cultivated area which is encompassed plantation area (4.08%), lowland (4.07%), dry land (2.83), and shifting cultivation (6.21%). Most lowland agriculture in Indonesian is irrigated, while upland agriculture is predominantly rain-fed.

The population of the country, according to the 2010 national population census is 237.6 million with annual growth of 1.49% and around 58% live in the island of Java which has only 7% of the total land area (Sidik, 2004). Approximately 70% of the Indonesian population live in the rural area which accounts for about 80% of the total land area and engage in agriculture sector and allied activities for their livelihood.

Agriculture has played an important role in success of Indonesia's economic development. In 2010, contributing for around 17% of Gross Domestic Product (GDP) (CBS, 2011) and the second highest after manufacture industry, and about 6% of country's export come from the agricultural sector. Furthermore, approximately 46.4% of total work forces engage in agriculture with low income. The ratio of agricultural income to non-agricultural income is about 1 : 6. Handaka (2009) reported that landless farmers and households with less than 0.5 ha had disposable incomes of US $250 and US $300 per month, respectively. Farm households with landholding from 0.5 ha to 1.0 ha and more than 1.0 ha had incomes of US $350- US $400 per month. Non-agricultural households had incomes between US $400 and US $500 per month, while the urban households had income more than US $900/month.

Like most developing countries, Indonesian agriculture is characterized mainly by small operational farms and subsistence level in production primarily in the production of food crops. Based on Agricultural Census of Indonesia in 2003, small farmers with land holding less than 0.5 ha reached 13.7 million in 2003 and this number increased from 10.8 million in 1993 or about 2.4% per year on average (CBS, 1994; 2004). Mechanization of this small farm can be achieved by introducing a small type of farm machinery with matching equipment.

In the case of rice, the most important grains in Indonesia and is the staple food for the majority of the people, is grown predominantly by small farms with difference of mechanization levels. In order to modernize agriculture and increase rice production, the agricultural development programs, such as the government's adoption of credit programs and the use of high yielding varieties, have been started since the 1960s (Priyanto, 1997) and focused on increasing production to achieve self-sufficiency (Djojomartono and Pertiwi, 1998). In the late 1960, there was an increase in tractor utilization, especially in rice production through the government mechanization programs in order to modernize agriculture and increase rice production.

Mechanization involves the use of machines ranging from simple hand tools to complex machines, and their associated power sources (Inns, 1995). The early mechanization system in Indonesia started from introducing rice milling in the 1950's and hand tractor in 1960's. Its development up to 1970's did not run well due to anxiousness on a shift of human labor and it was developed through protection and subsidy, so that it was kind of an artificial growth (Haeruman, 1998).

Currently, agricultural machinery has become increasingly important to carry out farm works instead of hand tools and drought-animal implements, which has been well established as the traditional farming technology of small farmers in most farming areas throughout Indonesia. The mechanization has played a significant role in increasing agricultural production by completing farm operations in time reducing cost of production and increasing crop intensity. It is because the major objectives of mechanization are to increase labor productivity by substituting mechanization for labor; to increase land productivity by removing bottlenecks which hamper higher land productivity, and to decrease costs of production by reducing expenditures for labor and draft animal and by more efficient operations (Rijk, 1986).

In addition, multiple objectives of farm mechanization in Indonesia are to increase productivity through intensification, to reduce post-harvest loss, to increase added value, and maintain the quality of farm products (Handaka, 2005). In addition to those multiple objectives, the ultimate goals are to increase of farm household welfare and to create employment opportunity in the rural area.

A recent study in Indonesia shows that the level of mechanization is relatively low to high, ranging from 10% – 90% depends on the intensity of the farming system and the common figure indicated the average level of 30% (Handaka, 2005). While in 1984, Indonesian farming is still mainly dependent on animal and human power with limited use of power tillers and mechanical threshers (Singh, 1984). Four individual technologies:

hand hoes, draft animals, two-wheel tractors, and four-wheel tractors, are available for land preparation for food crop production with different levels of application.

Agricultural mechanization in Indonesia is in its early stage of development based on stage of the mechanization process by Herdt (1983). The total number of small tractors on the farm increased at about 6% per year, from 84,178 in 1998 to 103,446 in 2002. In case of rice farming, adaptation and utilization of farm tractors for land preparation was about 62% for manual and animal, and 38% of mechanical power (tractors). The increasing use of the farm machinery in Indonesia is a result of government intervention by supporting the mechanization process. The intervention was made through its farm mechanization scheme, including direct tractor assistance and credit loan with low interest rate. The development of agricultural mechanization has focused on rice farming in order to transform from subsistence farming to the commercial farming system.

Rice in Indonesia is grown in a widely diverse production environment, including wetland (irrigated lowland), and dry land (rain-fed lowland and upland). In a few cases, paddy is also cultivated on dry land swamp areas. The main area for rice production in Indonesia is a wetland (irrigated lowland). Since 1999, it covers more than 11 million hectares. Indonesia became self-sufficient in rice production for a brief period during the mid-1980s. Self-sufficiency in rice has long been initiated by the Indonesian government as a national objective since early 60's. However, production growth slowed during the late 1980s and early 1990s, before stagnating at a very low average level from the late 1990s, which made Indonesia, had to import large quantity of rice annually to provide food security as a result of increasing population. Development of harvested area, production, and productivity of rice in Indonesia during the last ten years (2005 – 2014) is presented in Table 1.1.

Table 1.1. Harvested area, production, and productivity of rice in Indonesia

Year	Harvest area (million ha)	Production (million tonnes)	Productivity (t/ha)
2005	11.84	54.15	4.56
2006	11.79	54.46	4.62
2007	12.15	57.16	4.71
2008	12.33	60.33	4.89
2009	12.88	64.40	4.99
2010	12.12	63.02	5.20
2011	12.17	62.53	5.14
2012	12.28	65.19	5.31
2013	12.67	67.39	5.32
2014	12.46	66.19	5.31
Growth (%)	0.61	2.31	1.72

Source: Central Bureau of Statistics, 2015

The harvested area increased annually at about 0.61 percent on average during a period of 2005 - 2014, from 11.84 to 12.46 million ha during the period. The rice production increased annually at about 2.31 percent on average, from 54.15 to 66.19 million tonnes during the same period, while the rice productivity increased only about 1.72 percent on average, from 4.56 to 5,31 t/ha. An inadequate number of the farm machines on a farm may cause an insignificant effect of them on rice productivity. Moreover, the inadequacy of farm power and machinery with the farmers is one of the major constraints of increasing agricultural production and productivity (Kulakarni, 2009).

In order to increase cultivated area and rice yields, farming operations must be performed accurately and timely (Jain, 1979) by improving the use of farm power, especially mechanical power. Adequate and appropriate farm power is a key element to increasing agricultural output and labor productivity (Rijk, 1986) as well as an important input to achieve self-sufficiency in food production (Mondal et al., 2008).

Riau is one of provinces in Indonesia and situated in the center of Sumatra Island about 1500 km northwest of Jakarta, the capital of Indonesia. The total land area of Riau Province, approximately 89.16 thousand sq. km or about 4.6% of the Indonesia's total land area and has about 45.66 thousand sq.km cultivated area for food crops. Like national conditions, Riau agriculture is also characterized by small farm holdings, especially for rice production and other food crops, such as soybean, corn, ground nut, sweet potato, and vegetables. Of the 77,055 rice farmer households (16.09% of total agricultural households), about 40.34% of them have land holding less than 0.5 hectares (CBS, 2004).

The mechanization of rice farming in the province remains the primary concern of the provincial government because of the importance of rice as a source of livelihood in terms of providing staple food, employment, and household income. Farm power used in the small rice production system varies widely from hand tools, drawn animal implement to mechanical power for land preparation, although currently draught-animal power was not used anymore. Recently, the use of farm machines is increasingly becoming important and significance, especially among small rice farmers. The use of farm machines in rice farming is increasingly taking over from human labor, especially for power-intensive operations such as land preparation, irrigation, threshing, and milling. The use of farm machines in rice fields in Riau Province has shown a much progress since the 2004s (Table 1.2).

Table 1.2. Farm machinery condition in Riau Province during 2004-2013

Year	Large tractor		Small tractor		Water pump		Power thresher		Dryer		RMU	
	Good condition	Broken	Good condition	Broken	Good condition	Broken	Good condition	Broken	Good condition	Broken	Good condition	Broken
2004	24	4	648	93	643	84	1026	154	84	16	975	109
2005	33	4	697	122	665	104	767	144	139	31	986	83
2006	44	13	632	139	896	73	746	136	58	22	944	79
2007	39	8	579	165	869	79	576	170	40	23	870	99
2008	39	8	579	165	889	92	576	170	40	23	890	97
2009	41	8	966	330	606	271	841	259	54	11	718	171
2010	23	8	882	200	902	182	636	163	40	5	678	86
2011	28	7	1,505	477	4,359	315	811	298	39	11	750	177
2012	17	7	985	388	1156	275	958	323	39	12	648	170
2013	22	7	1,359	362	2583	327	1,690	505	11	1	807	188

Source: Food Crop Service of Riau Province, 2005 - 2014

The management of farm machinery in small-scale farming is often under capacity and economical. The use of the small farm machines for custom hire service which has widely been practiced in many developing countries (Chancellor, 1971, 1986; Kolawole, 1972; Wattanutcharya, 1983; Duff, 1986; Balangkari and Salokhe, 1999) has also become one of the popular methods adopted by small farmers in Riau Province. Because such method enables the owners to utilize full machine capacity and justify the economic level of the ownership of the farm machinery. The other very important benefits in the future is that custom hire services can be the main way to make farm machines available for other farmers without buying the machines and are potential to make someone's livelihood from the business. Therefore, there is a need to evaluate the economic potential of such operation method in Riau Province.

Ideally, the use of farm machines instead of hand tools and animal-drawn implements requires special management ability and skills as well as adequate service support facilities. However, farm machines in the Province have been promoted without making adequate program for training farmers and agricultural extension officials, and without providing the institutional support service and farm infrastructure to adequately support the efficient and economic use of the farm machinery at farm level. It is possible that failure of providing the service support system for effective use of farm machines leads to a large number of the machines in the Province remaining unserviceable (broken) (Table 1.2.). Moreover, the average life of a machine can, therefore, be reduced because it is difficult for farmers to repair tractors when they break down.

In addition, operators and mechanics should ideally be well trained and furnished with suitable maintenance and repair facilities. The manner in which the tractor is treated is also an essential factor to keep it in operating condition. These are the main problems in hand tractor operation in Riau Province. If these conditions do not pay attention, it could cause the whole mechanization process unsustainable and eventually waste machinery investment. Therefore, this research becomes significantly important to achieve mechanization goals; successful mechanization process and modernization of rice farming system in Riau Province.

1.2. Statement of the Problems

The main problems associated with using farm machinery for rice production system in Riau Province are: (1) the number of farm machinery available remains insufficient to completely mechanize rice farming operations in the province; (2) the mechanization capacity (level) which is determined greatly by the successful development process remains low in the region; (3) high frequency of farm machinery breakdowns and shortage of repair and training facilities; (4) high repair cost and difficulty to predict the cost; (5) most farmers have a difficulty to find an economic scale of their tractors; (6) problems facing machinery hire service groups to provide services for group members; and (7) difficulty to determine the best performance and lowest cost of three types of power tillers for tillage operations of small-scale rice farming. These problems will be examined by establishing some objectives and designing methodology to answer and solve the above problems.

1.3. Objectives of the Study

The objectives of this study were:

1. To determine the availability of mechanical power and the mechanization capacity (level) of rice farming in Riau Province.
2. To examines the working time and labor requirements and costs for small-scale rice farming operations.
3. To uncover specific issues associated to the breakdown's problems for hand tractor by investigating the causes of the tractor breakdowns on field operations.
4. To examine factors effecting annual repair costs and to develop a reasonable repair cost model for small tractors.
5. To evaluate the economic potential of farm machinery hire businesses to create economic advantages for the owners.
6. To determine the coverage and seasonal working areas of machinery hire services operated by farmer groups.

7. To compare the working performance and cost of three types of power tillers for tillage operations of small-scale rice farming.
8. To recommend improvement measures associated to small farm machinery operation and management in Riau Province.

1.4. Definition of Terms

For the purposes of this study, the following terms and definitions were used.

1. **Farm mechanization** is the process of developing agricultural machines and substituting this machine power for human and animal power in agricultural production practices.
2. **Farm machinery** is a vehicle specifically designed to deliver a high attractive effort (or torque) at slow speeds for the purposes of performing works in agriculture.
3. **Small tractor** (for this study is also called hand tractor or power tiller) is a small vehicle specially designed to land preparation of small farms with less 15 hp.
4. **Small farm** which is often used interchangeably with smallholder is a unit of land which under given agro-climatic conditions cannot afford to invest in the elements of modern production technology with having less than 2 hectares of cropland and low asset base.
5. **Mechanization capacity (level)** is the ratio of multiplying available machines by potential working capacity per year to the total operation expressed as a percentage.
6. **Power** is the work performed during a specific period of time and it is measured in horsepower (hp).
7. **Mechanical power** is power generated by machines like engines, muscles, levers or pulleys or the rate at which work is done.

8. **Breakdowns** are field stoppage due to sudden failure of the machine parts and implements.

9. **Repair** is a correction of a defect through the replacement or adjustment of defective component or assemblies, or through workshop procedures.

10. **Machinery hire service** is a commercial enterprise in which the tractor is used full-time on hire to people other than the owner.

11. **Custom hire service** is a farm machinery business that is managed by either a group or an individual to provide service for performing rice farm operations.

12. **Hire service group** is a group managed farm machines on farm level to providing machinery services for farmer groups as a group member.

13. **Fixed costs** (also called ownership costs) are incurred regardless of the number of acres or hours of use annually. Fixed costs include depreciation, interest (opportunity cost), insurance, shelter and, in some cases, taxes.

14. **Depreciation** is a cost resulting from the loss in value of a machine due wear, age and obsolescence. Machines depreciate each year regardless of the hours of use. Therefore, depreciation is considered a fixed cost. The change in a machine's value divided by the number of years of ownership can be considered annual depreciation

15. **Interest of investment** is a cash cost when you borrow money or an opportunity cost when you buy machinery with money that you've saved. Since interest cost does not vary with machine use, it is a fixed cost.

16. **Variable costs** (also called operating costs) vary with the hours of machine use. They include fuel, lubricants, repair and maintenance, and labor.

17. **Repair costs** include maintenance (adjusting for wear, daily service and lubrication, etc.) as well as the cost of all parts and the labor to make repairs.

18. **Revenue** is the value received from service given to others farmers in performing tillage works on paddy field.

19. **Profit** is the value received from deference between revenue and total costs when revenue exceeds costs.

20. **Break-even point (BEP)** is how much a machine needs to work to justify economically its possession.

1.5. Scope of the Study

This study focuses on mechanizing small-scale rice farming and operating small farm machinery operations. The survey location is limited only in four regencies in Riau Province with considering the rice production condition and farm machinery application level. The samples selected are divided into three categories: farmers, hand tractors and hire service groups associated with research purposes. This study highlights specifically the technical and economic aspects of small farm machinery utilization managed by individual as well as farmer groups. This study also evaluates managerial performance of small farm machinery operations managed hire service groups.

1.6. Significance of the Study

Study on mechanization of small rice farming and small machinery operations will be importance and significance. This study will uncover some empirical evidences of mechanization process and problems, especially the use of small farm machinery in Indonesia as one of developing countries. Therefore, this research will enrich the literature and extend the knowledge base that currently exists in the area of mechanization. The mechanization capacity model resulting from this research can assist planners and local government in evaluating the current status and level of mechanization and farm power availability on farm. This study will also present the estimation of farm machinery costs and a reasonable repair cost model which will help persons involved with operation machinery -machinery manager and custom operators- for making management decisions such as formulating machinery budget, establishing custom hiring charge, and determining machinery replacement time. Moreover, this research will also offer important recommendations on how to provide adequate repair and maintenance facilities, improve machinery management procedures and increase operator skill in order to make effective machinery operation and management. And importantly, the study will serve as a future reference for researchers on the subject of mechanization of small rice farming system, especially the using of small farm machinery.

CHAPTER II
REVIEW OF LITERATURE

The review of past literature has been made to pertain and establish a theoretical framework to the present study. Researches were reviewed in order to support the objectives of the study and were divided into five topical sections. The sections include important role of mechanization for agriculture, historical evidence of mechanization in Indonesia, overview of small farm mechanization, technical aspects of farm machinery operations, economic aspects of farm machinery operations, and related research of tractor effects on small farms.

2.1. Important Role of Mechanization for Agriculture

Agriculture is becoming increasingly mechanized throughout the world today (McCauley, 2003) since the development of machines began in the 1890's when the first steam tractor and combine were made in California USA (Meij, 1960). The mechanization of farming in developing countries has been very uneven. In country where farming system is beginning to be mechanized, power tillers and tractors are still restricted to tillage and a few other operations (Binswanger, 1986). As industrialized nations had a complete mechanization, many developing countries are also making significant shifts toward mechanized farming (McCauley, 2003). It is evidence that the number of tractors (as one of the major power sources) and other farm machines show an increasing trend for all Asian countries (Salokhe and Ramalingan, 1998). Mechanization in most of these countries is associated with rice production as the main crop and staple food for a majority of their population.

Agricultural development can be witnessed with rapid technological changes, ranging from new ways of intensive cultivation, use of high yielding variety seeds, fertilizers and pesticides, and improved water availability and later companied by farm mechanization technology. Technological changes in agriculture have been classed into two broad categories, i.e., land augmenting technological change and modernization of agriculture through farm mechanization (Maggu, 1982). Tractors and farm machinery are important samples of the modern technology (Xinan et al., 2005). The farmer is those which increase the productivity of land i.e., the use of high yielding variety seeds, fertilizers, irrigation, etc. and these are preconditions for farm mechanization and introduction of mechanical power inputs.

Mechanization has been a fundamental factor in the development of agricultural production from early times – the first agricultural hand tools were probably made from selected timber, bone or stone and use for soil preparation (Inns, 1995). Agricultural mechanization covers the complete range of technology for the application of mechanical aids to agriculture, from hand tools through animal equipment to engine power (FAO, 1992). While Pechon et al. (2007) and Vatsa1 and Saraswat (2008) mentioned that mechanization was started from the development of the animal drawn implements and other farming tools such as plows, weeders, harrows and other farming tools. A change from the use of draught animals to tractors as the source of motive power in agriculture is brought about because of perceived economic and human benefits (Spoor et al., 1983).

Agricultural mechanization includes three main power sources: human, animal, and mechanical (Kic and Zewdie, 2013). General purpose of farm mechanization is to replace human and animal power with mechanical power (Saegusa, 1975). Power is needed on the farm for operating different tools, implements and during various farm operations (Karale et al., 2008). Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handles the crop produce to reduce losses (Singh, 1997).

There was a need to make more efficient use of the labor, therefore, the mechanical power were developed. Pingali et al. (1987) argued that field tasks, particularly land preparation, are usually the most power-intensive. Therefore, the most power-intensive operations are usually the first to be mechanized. So, initial mechanization transitions from human power to higher form of either animal or engine powered mechanization occurred in land preparation.

Mechanization is one of major input which facilitates the increase of agricultural production (Igbeka, 1984). Agricultural mechanization embraces the utilization of all type of tools, implements, machines and equipment for agricultural land development, farm production, and crop harvesting primarily processing (Sinding, 1985; Gifford, 1992; Rijk, 1986, 1989; Clarke, 2000). It involves various power sources, including human, animal, mechanical, electricity and renewable energy (Sahay, 2004).

The farm mechanization is dependent mainly upon the sources and availability of farm power (Lohan et al., 2015). Srivastava et al. (2006) stated that the power for early farming operations was primarily human labor and later draft animals were used as the source of power. Horses, buffalos, oxen, camels, and even elephants were usually used as power sources. Based on these power sources, the major levels of mechanization technology have been broadly classified into hand-tool technology, draught-animal technology, and mechanical-power technology (Rijk, 1986; Gifford, 1992; Sims and

Kienzle, 2006). Each level and degree of technology has different technical, financial, economical, and social consequences (Rijk, 1985). The use of the modern technology during later decades resulted in rapid growth of farm production (Bakht et al., 2008).

Farm mechanization continues to be a contentious component of modernization in developing countries (Donovan et al., 1986). Kolawale (1974) stated that mechanization is often called as the most important single and evitable factor in the modernization of agriculture. It is also one of the important inputs for modern agricultural production system (Chamsing and Singh, 2000) or for any farming system (Sims and Kienzle, 2006). Therefore, modern agriculture is heavily dependent on mechanization, that is the tools, implements, power sources, and related management processes used in the production of food and nonfood products (Leiva and Morris, 2001). Furthermore, the modernization of agriculture as a primary industry through farm mechanization is the base to support the development of all other domestic industries (Sakai, 2013).

Priyanto (1997) stated the modern agriculture is agriculture which oriented to market, efficient and effective in using production inputs (seed, fertilizer, tool and machinery, etc.) to achieve a maximum productivity, quality and profit In addition, the modern agriculture aims to produce the high quality food and raw materials in sufficient quantity for a wide range of customers (Munack and Speckmann, 2001).

Bell and Johnson (1986) also mentioned that the agricultural mechanization is one of many complementary inputs available to farmers who wish to increase production and profitability. Therefore, the mechanization plays an essential role in agriculture and assures timely completion of farm operations as well as less expenditure per unit area (Vatsa and Saraswat, 2008). Agricultural modernization has also a positive effect on both measures of economic growth and human development (Self and Grabowski, 2007).

In many parts of the world, the agricultural mechanization has made a significant contribution to agricultural and rural development. Levels of production have increased, soil and water conservation measures constructed, the profitability of farming improved, the quality of rural life enhanced, and developments in the industrial and service sectors stimulated (Bishop, 1997). Mechanization of agriculture is also an important factor in reducing labor demands for farming and making it available to develop other industries (Srivastava et al., 2006). The factors affecting agricultural mechanization on farms were reported by Rasouli et al. (2009).

In developing counties, agricultural mechanization is a special importance in increasing agricultural yields as it improves the quality of work, enables carrying out work on schedule, and reduces labor peaks (Gego, 1986). A study conducted by Binswanger (1978) has shown that farm mechanization allows for more efficient farm operations which, in turn, positively effects yields as well as allows for greater intensity of land use. This implies that farm mechanization may alleviate the food problem that is commonly found in most developing countries (Sison et al., 1985). Furthermore, the mechanization gives a major benefit to the increased agricultural output generated from larger harvested area and higher yields resulting from deeper plowing and better cultivation practices (Herdt, 1983).

The important roles of the mechanization in agriculture process can be summarized as follow; to increase land and labor productivities, serving to extend agricultural area, improving product quality, reducing hard work and drudgery, improving timelines of agricultural operation, creating attractive job for men and women to prevent rural exodus, and increasing farm income (Wanjun, 1983; Duff, 1986; Rijk, 1986; Krause and Poesse, 1997; Salokhe and Ramalingan, 1998; Raid et al., 2003; Sahay, 2005; Sims and Kienzle, 2006, Srivastava et al., 2006; ASAE, 2006; FAO, 2008, Mehta and Pajnoo, 2013).

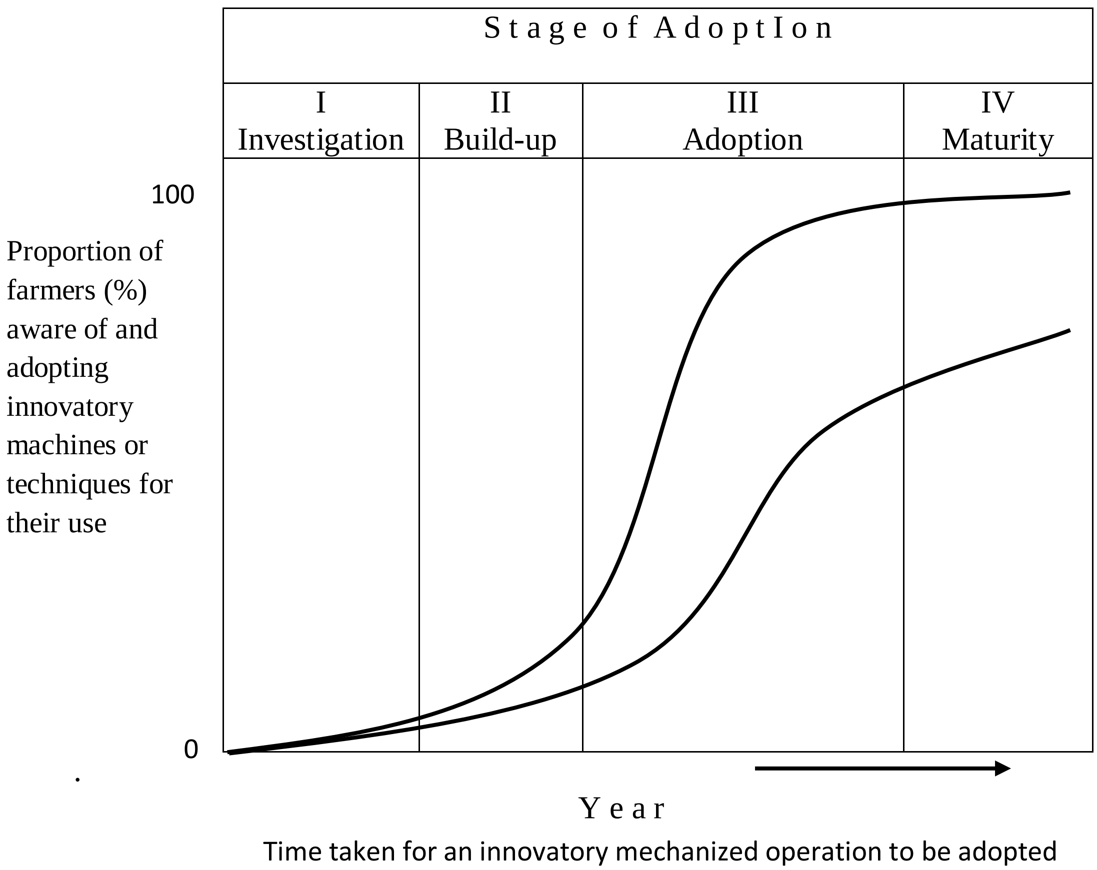
Herdt (1983) postulated four-stage mechanization process, i.e., introduction (only a few tractor available for experimentation); early adoption with about 2.5 hand tractors/1000 ha; take-off with 20 hand tractors/1000 ha and about 20% of arable land served; and full mechanization with 100 hand tractors/1000 ha and a variety of other equipment. In addition, mechanization in any area is characterized into three levels; low, fair, and high. Low mechanization level means that manual power used exceeded 33%. Fair means that animal power utilization ranges from 34% to 100%. The high mechanization level means that mechanical power utilization ranges from 67% to 100% (Rudolfo et al., 1998).

Within the historical and economic contexts, agricultural mechanization has seven stages of evolution (Rijk, 1986; Speedman, 1992) as follow: (1) Stationary power substitution, where mechanical power is substituted for human power used in stationary process; (2) Motive power substitution, where operation systems previously based on human power are replaced by mechanical power; (3) Human control substitution, where emphasis is placed on mechanizing operations previously controlled by human decision making; (4) Adjusting cropping systems to the requirements of mechanization (cropping system adaptation); (5) Adjusting farming systems to the requirements of mechanization (farming system adaptation); (6) Adjusting plant physics to the requirements of mechanization (plant adaptation); and (7) Automation, where operations in agricultural production are fully automated.

Based on the above agricultural mechanization process, in most Asian countries, mechanization is still in stage I (Rijk, 1986). In Indonesia, agricultural mechanization is in its early stages of development in the 1980s (Sing and Siswasumarto, 1988) and the current stage and practice of agriculture mechanization is still characterized by low level of distribution and utilization of farm machinery and associated implements for farm operations. A worldwide study has concluded that for optimum yield, there is a need for a power input of at least 0.8 hp per hectare (Jain, 1979).

The mechanization level can be determined in terms of power availability per hectare (kW/ha), number of hand tractors/1000 ha, ha/tractor, mechanical power/total power, and equipment weight/tractor (Ozmerzi, 1998). Such approaches were commonly used and practiced in many researches (Hert, 1983; Singh, 1984; Farrington, 1985; Mancebo; 1986; Chamsing, and Singh, 2000; Kaneko et al., 2000; Viegas, 2003; Mondal et al., 2008; Sharabiani and Ranjbar**,** 2008; Karimi et al., 2008). The level of mechanization can also be expressed by an index which represents the percentage of machine work to the sum of manual and machine work, expressed in energy units (Singh, 2006; Singh and Dee, 1999; Andrade and Jenkins, 2003; Ramírez et al., 2007; Olaoye and Rotimi, 2010). Furthermore, the degree of farm mechanization is the ratio of mechanized operations to the total operations (Karimi et al., 2008; Sharabiani and Ranjbar**,** 2008; Ghadiryanfar et al., 2009). The mechanization degree can be also expressed as the average energy input of work provided exclusively by human power (labor) per hectare (Olaoye and Rotimi, 2010).

Agricultural mechanization takes place in a specific process (Bagheri and Moazzen, 2009) and adoption stage. According to Inns (1995), awareness and adoption of mechanization-related innovations may be expected to follow *S-curve* of general form shown in Fig. 2.1, where the horizontal axis represents the time scale over which an innovatory machine or technique is taken up by potential beneficiaries and the vertical axis represents the proportion of the farming population who have benefited by that particular time.



Source: Inns (1995)

Figure 2.1. Stages in the introduction and adoption of innovatory machines or techniques in mechanized agricultural production and processing

In order to successfully achieve the mechanization process, it needs to strengthen of mechanization program that will include testing and supply of suitable farm machinery, development of traditional farm implement to increase efficiency, establishment of regional workshop to provide maintenance and repair facilities, training of mechanics, operators and farmers, and ensuring a regular supply of spare parts (Singh, 1996). In addition, Priyanto (1997) stated that application of agricultural mechanization requires some elements, such as professional personnel in management, technician and mechanist, operator, availability of workshop, fuel, lubricant, and spare parts, and other infrastructures. It is also important to note that each technology shift has implications for management of the system (Bell and Cedillo, 1999).

Inns (1995) stated that the development of agricultural mechanization depends on the farmer's willingness and ability to identify opportunity for achieving sustainable benefits by improved and/or increased use of power and machinery, selecting the most worthwhile opportunity and carrying it through to successful implementation. An agricultural machine must be suitable to the specific conditions of the region where it is used, including natural conditions, farming system, scale of production, economic and technical level, etc. Therefore, the agricultural machines, in order to appeal the farmers, must be suitable to local needs, simple and easy for operations and maintenance, reliable and durable, and inexpensive (Wanjun, 1983).

Furthermore, success in mechanization requires the highest level of management and operational efficiency, readily available fuel and lubrication, and low cost repair services. In practices, these prerequisite for success have seldom been met, so large number of tractors and machines purchased with public, commercial, and private funds have suffer premature breakdown and degradation; and this breakdown taken place very early in the machinery's anticipated working life. Surveys indicated that, in many developing countries, up to 30 percent of tractors are lying idle through want of replacement parts and the reliable index is less than 50 percent (FAO, 1990). In addition, achieving effective agricultural mechanization not only involves making available equipment but having the framework as well as the technology and well trained personnel to effectively use them (Bani and Dorvlo, 2013).

Sarker and sarker (1979) concluded that agricultural mechanization will only be possible if the following important services are developed simultaneously: 1) Establishment of service center with adequate repair and maintenance facilities and skilled mechanics in the rural area; 2) Establishment of training and vocational centres, imparting training to agricultural engineers, extension workers, technicians, operators, mechanics, and farm workers, providing educational facilities for the rural masses; 3) Creating job opportunities for the displaced labor by establishing industries and agro-based factories; 4) Manufacture of multi-purpose small implements and machinery should be encouraged in the country; and 5) Government must provide service facilities for successful implementation of mechanization.

Crossley (1979) added that the success introduction of a small tractor would be dependent upon the existence of or early potential for repair and maintenance, extension, credit arrangements, and marketing system. The pattern of production, the ownership of resources, participation by household members in farming, gender division of labor, and the profitability of farm enterprises influences the range and scope of agricultural mechanization (Bishop, 1997). To make mechanization profitable, farmers may have to consolidate landholdings or cooperatives may have to be formed to realize the economies of machinery (Lim, 1985).

It is evidence that mechanization schemes have been successful in many developing countries in Africa, particularly when coupled with irrigation. Agricultural mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labor and often to achieve results well beyond the capacity of human labor. This includes the use of tractors of various types as well as animal-powered and human-powered implements and tools, and internal combustion engines, electric motors, solar power and other methods of energy conversion (FAO, 2008).

2. 2. Historical Evidence of Farm Mechanization in Indonesia

It has been more than half of century agricultural mechanization introduced to support agricultural production, particularly food production. The definition and role of agricultural mechanization in Indonesia was formulated in a national symposium held in Ciawi - Bogor in 1967. The term agricultural mechanization was defined as a discipline of science that explores natural resources and energy for the development of human creativity in agriculture for the prosperity of human being. By the definition, the roles of the agricultural mechanization were formulated as follows: 1) to increase the efficiency of man labor; 2) to elevate the status and living standard of farmers; 3) to assure the increase in quality and quantity of agricultural production; 4) to enable the development of farming type from subsistence to commercial; 5) to accelerate the transition of economical nature from traditional to industrial based agriculture (Setiawan et al., 2006).

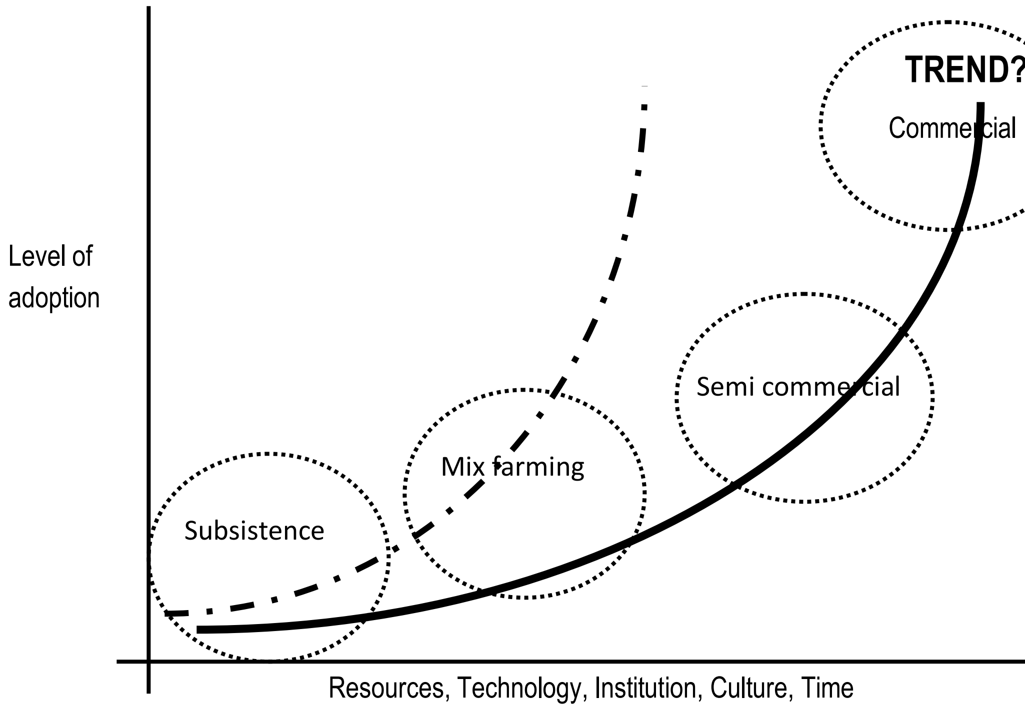
Agricultural mechanization in Indonesia was initiated by introducing rice milling in the 1950's and hand-tractor in 1960's (Haeruman, 1998; Rahmad and Hendiarto, 1998). Furthermore, Haeruman (1998) stated that its development up to 1970's did not run well due to anxiousness on a shift of human labor and it was developed through protection and subsidy, so that it was a kind of an artificial growth. However, farm machinery, particularly tractors, has been promoted in several densely populated locations in Jawa and Bali and the sparsely populated outer island of south Sulawesi (Maamun, 1991). In addition, Sihombing et al. (1984) argued that there are four development stages with regard to the characteristics of the evaluation of agricultural mechanization in Indonesia. The stage can be explained as follow:

1. The first stage of mechanization transfer in agriculture, perhaps, started in the yearly 1950's and continued until 1960/1961. The introduction of agricultural mechanization was based upon industrial impact of diffuse technological hypothesis. Progressive agriculture in industrialized countries was greatly influenced by industrial products, which were regarded as agricultural production function (fertilizer, pesticides, and big machineries). The application of big tractor, water pumps, and processing unit, operated by government of semi-government enterprise to help small farmers, should contribute great increase in food production. Unfortunately by the end of the decade 1950 – 1960, there was no significant increase in agriculture and yet almost of big machineries disappeared.

2). The second stage (1960 – 1970) was characterized by technical correction and ownership or management adjustment. Size and degree of sophistication of farm machinery were scaled down toward smaller and less sophisticated machineries. Ownership and operation of these machineries were more spread over to private sectors and farmers themselves. Government efforts were stressed on extension activities. In this decade, plant protection equipment number in used was drastically increased and small rice milling unit gradually replaced the functions of big rice mill. Field and laboratory experiments, field trials, and testing were intensively undertaken to generate more reliable information for extension works. The expansion of small farm machinery utilization in this decade was still dependent to foreign imported machineries.

3. The third stage (1970 – 1980) run into reverse theory of agricultural mechanization development that was agricultural impact to industrial development. It was recognized that the steady increase of nominal agricultural contribution in the national economic drove or induced to private sector to transplant design for local manufacturing, governmental for more research and extension and loan provided by rural bank. In the end of this third phase of technological transfer it was clearly noted that there was strong real demand for agricultural machinery, but locally produced machinery could not be sold due to heavy market competition and inappropriateness of machinery design related to farmers need.
4. The fourth stage started in 1980. This stage is started where the operation of selective agricultural mechanization policy was evaluated through area test at provincial level. Farm system research approach was used to identify the need of agricultural mechanization and suggest possible alternate solution for specific problems. Farmers' specific need and perception are considered as determinant factors in this bottom up planning rather than based on technological approach. Those combinations of the results of evolution process and farm system research were regarded as feedback inputs for policy reorientation in the present mechanization development. Local manufacturers were more encouraged to produce machineries to meet farm requirements which were: (1) simplicity in design, usage and maintenance; (2) made of locally available raw materials; (3) effective enough; and (4) low price. In this phase of development government purchase for agricultural machineries is directed to help domestic

manufacturer products.



Source: Handaka (2005; 2009).

Figure 2.2. Evolutionary process of farming system and farm mechanization in Indonesia

The Indonesia's agricultural mechanization program was then divided into six fields: 1) Agricultural machinery which studies the utilization of power and equipment in agriculture; 2) Soil and water engineering which studies water uses in agriculture and soil conservation; 3) Agricultural structures and environment which studies the problems in the utilization of agricultural buildings, infrastructures, and related environment; 4) Agricultural electrification which studies the problems of utilization of electrical energy in agriculture; 5) Agricultural product processing machinery which studies the problems in the utilization of machineries in conditioning and processing of agricultural products to be stored or be consumed directly; 6) Food processing machinery which studies the problems in the utilization of machinery and pre-condition requirements for food processing (Setiawan et al., 2006).

The farm mechanization is a process of technological evolution. The evolutionary process of mechanization technology has been figured by Handaka (2005, 2009) as presented in Fig. 2.2. He stated that a farm system moves from the subsistence to the commercial farm stage along a sustainable path. The development stages illustrate the technology adoption capacity that moves from one stage to another, influenced by variables such as infrastructure, cultural endowment, resources endowment, institutional arrangement, technology innovation, economy, and cultural behavior. The farm system's capacity to improve productivity is dependent upon its capacity to adopt, adapt and manage technology, institution, capital and other resources.

Machinery investment requires high costs, so it is difficult to small farmers for buying machine themselves. Therefore, joint ownership model such as cooperative or group was developed for small farmers. Farm machinery ownership in Indonesia is divided into three, namely food crop services, farmer group, and tractor contractors (tractor hire services) (Friyatno, 1997). According to Simatupang et al., (1995), the ownership tractors vary between provinces. For example, 96 percent of tractor in West Java were owned by farmers, and 4% is owned by food crop service (government). While, 32 percent of tractor in Centre Java was owned by farmers and 68% was tractor contractor. For producers, landowners, or farm managers who do not have the capital, time, or desire to perform machinery operations themselves, hiring a custom operator to perform machinery operations is an alternative method of obtaining machinery services (Beaton et al., 2003).

2.3. Overview of Small Farm Mechanization

Term of small farms (also called peasants) is indeed difficult to give a precise definition. The definition can vary depending on the conditions in different countries. The most obvious measure is farm size, and several sources define small farms as those with less than 2 hectares of cropland (Work Bank, 2003; Hazell et al., 2007; Hoering, 2008). Hoering (2008) added that in Latin America, for example, family farms are often considerably larger. In Brazil, farms with less than 50 ha are considered as “small”, while in India farms with more than five ha are seen as almost estates.

Wapenham (1979) defined a small farmer as an agricultural producer controlling no more land than he can farm without the permanent employment of non-family labour. FAO/RAFE (1978) defined small farmers, small fishermen and peasants in broad terms, including the low-income producers of agricultural, livestock and aquatic products. Steenwinkel (1979) included in his definition all people in the rural areas in developing countries who do not have the means to provide for their basic needs or are living in constant fear of losing their means.

A definition that could be easily applicable is that, a small farms is a unit of land which under given agro-climatic conditions cannot afford to invest in the elements of modern production technology particularly in respect of lumpy resources (Kuyembeh, 1986). Another definition is that small-scale agriculture is often used interchangeably with smallholder, family, subsistence, resource poor, low-income, low-input or low-technology farming (Heidhues and Brüntrup, 2003).

The traditional small farm scenario is characterized by low capital input; limited access to resources; low level of economic efficiency; diversified agriculture and resource use; and conservative farmers who are illiterate, living on the threshold between subsistence and poverty, and suffer from an inability to use new technology (Devendra and Thomas, 2002). The key elements in all of the above definitions are subsistence, low income and illiteracy. However, studies have shown that small farms tend to be more efficient and more productive than large-scale farms (Ong'wen and Wright, 2007). Research by Heltberg (1998), for example, found higher outputs per unit of land from small-scale farming systems.

Gifford (1992) found that, in general, the agricultural sector in developing countries is dominated by small scale farms, many of which are less than two hectares, consist of scattered fields or plots, and have limited access (i.e., roads, lanes, entrances, etc) and for most Asian farmers have less than 0.3 ha in traditional farming district and hilly areas (Sakai, 1999).

Chancellors (1986) claimed that Asia's agriculture is based on a multitude of small-scale farming unit on which operators and their families make managerial decision. Small holder agriculture plays a very important part in the economy of most developing countries; a large proportion of their population is engaged in the production of food and feed. Their contributions to agricultural production are even on the increase, for grains, milk, and meat.

Ong'wen and Wright (2007) claimed that small-scale farming has long made enormous contributions to society. The role of small-scale farming systems is multifunctional. That is, they have the potential to contribute to the realization of our social, economic, and environmental goals. Small farmers have been responsible for the development of the world's major food crops and have nurtured agro-diversity through generations. They continue to play a central role in food provision, employment, economic development, and environmental sustainability. Small farmers have also the potential to meet our food security needs and promote poverty alleviation.

Nobody knows exactly how many small-scale family farms exist in the world. There are estimates in the literature of between 500 million farms with two billion people. Such small farms account for an estimated 80 per cent of the land used for agriculture. With small fields, worked under difficult conditions and with scarce means, these farms contribute nearly half the food that feeds the world, partly for subsistence, partly for markets (Hoering, 2008).

Farm size is one of the most important aspects of land use in Indonesia. Size has economic meaning, in the sense that a certain area of land can most economically be used in a certain way: if it is below or above a certain size, the owner may have to farm in a different way. The Basic Agrarian Law imposed a limit in the size of agricultural land holdings, with a minimum and maximum size of 2 and 20 ha, respectively. In 1983, almost half of Indonesia’s farm households (48.9%) had a land holding of less than 0.50 ha, and only 5.8% of farm households had 3.00 ha or more. Of the farm households with less than 0.50 ha, 63.1% resided in Java (Pakpahan, 1995).

The issue of mechanization in small farms has been the center of controversy since the 1960’s (Sison et al., 1985). Kolawole (1974) stated that one of the basic problems facing developing countries associated to small farm mechanization is what type and level of mechanization and how best to introduce it to an agriculture characterized by small scale of operations, fragmented and odd shape farms. Another question is how the advantages that mechanization provides best can be made available to the small scale farmers (Gifford, 1992). The level, appropriate choice and subsequent proper use of mechanized agricultural inputs have a direct and significant effect on achievable levels of land productivity, labor productivity, the profitability of farming, and ultimately the farmers' quality of life (Clarke, 2000).

The main criteria which should be considered during the development of the mechanization are that these machines should be suitable for use in small farms, easily repairable and maintainable, inexpensive, and environmentally friendly. The word "appropriate" should be interpreted as appropriate to the farmers in terms of their needs and affordability (Salokhe, 2003). The small farmers will do better if simple improved tools, both manually operated and motorized, made available to them (Yohanna et al., 2011).

According to Kuyembeh (1986), appropriate mechanization for small farmers must fulfill the following criteria: 1) It should provide incentive to small farmers for its adoption, that is, it should bring adequate economic return to them, 2) It should be within the purchasing power of small farmers, 3) The new technology should also be made available to small farmers preferably at or near their farms, 4) It should be appropriate to the size of the land holding, 5) It should be dependable and should not involve fewer risks, 6) It should be simple to operate, easy to understand and does not require much change in the existing farming system, 7) The adoption of the technology would meet the needs of the farmers, and 8) The introduction of an appropriate technology would demand, as a complement to it, the availability of other agricultural inputs. Therefore, hand tractor are quite handy to use and can attain higher working efficiency and accuracy than four-wheel tractors (Sakai, 1999).

Depeng (1983) stated that there are many factor affecting the use and development of farm machinery, such as agricultural conditions, farming requirements, management scale, economic conditions, technical level of manufacture, and farmer's experience. In case of farm tractors for small farms, which characterized by small size of the land holdings, small type of farm machines (tractors) are more adaptable. Sutter (1974) argued that the introduction of mechanization on small farms in Southeast Asia, without consideration of local custom and economic conditions, is likely to be ineffective and may often have a negative effect.

Tewari et al. (2004) stated that small tractors (power tillers), which is one of small machine types, are usually used in developing countries for land preparation in dry and wet land condition and they are practically suitable for small size field. In Indonesia, the machines are generally used for land preparation with very little use in other farm operation (Salokhe and Hendriadi, 1995). In the same cases, the small farmers were not keeping any tractor on their farms because it was not economical (Nehta, 1982).

There are four reasons small tractor applicable for small farm conditions, namely: 1) Small tractors are suitable to agricultural condition and farming requirements in most area; 2) Small farmer are suitable to the economic conditions and management scale in most area; 3) Small tractors are suitable to the level of mechanical knowledge and management in rural area; and 4) Less investment and quick return in the production of small tractors (Depeng, 1983).

A small-sized farm is a big issue when it comes to mechanization because this is against the principle of economies of scale (Paras and Amongo, 2005). The majority of small scale farmers in developing countries cannot justify ownership of mechanical power technology for exclusive use on their farms (Gifford, 1992). Therefore, for mechanical power technology to be available to the majority of small-scale farmers, it must be through some forms of multi-farm use of power and related implements or equipment.

Kruzt et al. (1980) argued that a small farm had tendency to have a greater machinery capacity per unit area. The range of tractor power provisions per hectare in England is 0.87 – 2.98 kW, while in Indiana (U.S.A) it averages 0.9 kW. Toro and Hansson (2004) also stated that small- and medium-scale farms face difficulties in meeting the cost of up-to-date technology. On option for them is the multi-farms utilization of machinery in order to spread fixed costs over a larger area, as well as to reduce labor costs by using higher capacity machinery. Such cooperation may include neighbor help, hiring, leasing, machine syndicates, machine rings, contractor or other cooperative arrangement.

Machinery multi-farm use system in the private or quasi-public sector include: 1) pooling of individually owned machinery by informal and formal group; 2) Joint ownership such as cooperatives; 3) commercial enterprises operated part-time by farmer-contractors or full-time by machinery service contractor; and 4) hiring, renting or leasing schemes offered by machinery dealers or cooperatives (Gifford, 1992).

Custom hiring which is practiced in developing countries (Chancellor, 1971; Kolawole, 1972; Wattanutcharya, 1983; Yogatama et al., 2002; Hutabean et al., 2005) is one of ways to obtain the use of machinery without purchasing it. It may be a good alternative for operators who have acreage so small that fixed costs per acre of owning machinery are high relative to the cost of hiring (Kadlec, 1985).

2.4. Technical Aspects of farm machinery Operations

Management of farm machinery is one of the important branches of farm management ((Afsharnia et al., 2013). Operations are the portion of machinery management concerned with optimum adjustment and use of individual machines. The specific adjustment required for a specific machine is described in details by the manufacture's operating manual. Proper operation of specific machines can contribute to the economy of the farm enterprise just as much as other aspects of good machinery management (Hunt, 1983).

Transition from hand labor and animal traction to mechanization is somewhat difficult and needs time because it involves a number of technical, economic and social problems (Sakai et al., 1986). Low efficiency and substandard machines are common problems in agricultural mechanization in most developing countries (Pechon et al., 2007). Improper management and lack of competent personal, for example, can result primarily excessive time loss due to repairs (Alabadan and Yusuf, 2013).

The most appropriate machinery and power source for any operation depends on the work to be done, cultural settings, affordability, availability and technical efficiency of the options. Therefore a socially beneficial agricultural production is determined based on a wide range of social, economic and ecological factors. These factors determine whether a technology is practicable, beneficial and sustainable in an area (Olaoye and Rotimi, 2010).

Tractor ownership should be managed so that the tractor can work effectively for long periods without breakdown and thus provide a benefit to its owners. A tractor that breaks down and must be prematurely replaced incurs large expenses and wastes the investment. As an example, in developing countries approximately 53% of total machine expenses have gone to repairing machine breakdown as compared to 8% in developed countries (Inns, 1978). It is important to remember that the economic benefits from a tractor depend upon the efficient manner of its use (Rahmoo et al., 1979). The success of the investment depends greatly on operating costs, which, in turn, are influenced greatly by the quality of service and maintenance. The effectiveness of a tractor working system depends on the quality of its operation, maintenance, and repairs (Kumar and Ahmad, 1996).

Tractors breakdowns are the main factor often found in the field operations. Breakdowns are field stoppage due to sudden failure of a part and probability for and the lost time due to breakdowns can be considerable (Hunt, 1983). Hafsah and Bernstent (1983) stated that the tractor breakdowns reduced the available working time during the peak season and this problem also made tractor ownership was not economically viable. Chancellor (1971) reported that the breakdown problems caused about 26% and 15% of the potential working time in the main season were lost in Thailand and Malaysia, respectively.

The breakdowns are even more than a nuisance; it may jeopardize all or a part of the farmer's income (Liang and Link, 1970). Machine breakdowns also consume resources: manpower, spare parts, and lost production (Dodson, 1994). Furthermore, the breakdowns become the important problem because the breakdown of an individual farm machine is an annoyance and while the repair may be costly, the cost of the delay is potentially much greater than the cost of repair (Hunt, 1971). Bukhari and Soomro (1984) also stated that machine breakdowns can be very costly not only from stand point of repair expenditures but also the effect on crop yield as well. Therefore, it is of great importance to avoid the failure of a system during actual operation when such an event is costly and/or dangerous. In such situations, one important area of interest in reliability theory is the study of various maintenance policies in order to reduce the occurrence of system failure (Jhang and Sheu, 1999).

A number of studies have reported the causes of a high breakdown frequency and a high repair rate (Kolawole, 1972; Inns, 1978; Bukhari, 1982; Kuyembeh, 1982; Jacob and Harrell, 1983; Bukhari et al., 1984; Aneke, 1994; Adekoya and Otono; 1990; FAO, 1992; Babatunde, 1996). The authors found that unskilled operators, poor operation and maintenance practices, and lack of spare parts were the main contributing factors. Inadequate skills and technical know-how on the part of machinery owners lead to high operational costs, making investment in mechanization expensive and less attractive (FAO, 2007). Untrained operator was also a major cause of high repair and maintenance costs in Pakistan (Bukhari, 1982), and improper handling by tractor operators caused frequent breakdowns in Nigeria (Kolawole, 1972). On the other hand, the ability of the operator to drive efficiently is affected by experience and attentiveness, and by field and weather conditions (Palmer et al., 2003). Furthermore, failure of the regular supply of replacement parts for machinery and equipment in developing counties has often led to large numbers of agricultural machines remaining unserviceable for long periods (FAO, 1992).

Tractors breakdowns require repairs and to keep tractors in good condition needs maintenances. Repair is the action of fixing or replacing substandard or damaged components to include required repairs, recommended repairs and upgrades. Maintenance is the action of performing routine activities to include making minor repairs or replacements to continue proper performance of the system (Lesikar et al., 2006). Every agricultural tool and implement will need to be maintenance by replacing lubricant and worn or broken parts (Campbell, 1986).

A tractor properly maintained or tune up will enable to get work done in time (Bukhori, 1982). Butterworth (1984) has reported that the broken down tractor is caused by improper and poor maintenance that has a major effect on likely breakdowns and repair costs. While, Adekoya (1990) stated that tractors work for a long periods without breakdowns if they are maintained and with good maintenance, the cost of repairs and wear can be reduced. Bukhari and Soomro (1984) argued that properly operated and well maintained modern machines will operate for a long periods and do a great deal of work before major repairs are required.

An adequate supply of replacement parts is essential in maintaining agricultural machinery in reliable working condition. Without the necessary parts, even routine maintenance is neglected, leading to breakdowns and inoperable machinery. In some countries 30% of all tractors of working age are unusable and many more are unreliable (FAO, 1992). Thousands of tractors were procured and recent investigations shows that over 50 percent of these tractors have either broken down or are unserviceable due to various reasons including; lack of spares, poor operation and maintenance, and the unhealthy national macro-economic trend which has affected adversely tractor and equipment prices (Babatunde, 1996; Ajav, 2000).

In most cases, the management of tractors in small-scale farming is often under capacity and uneconomical. As reported by FAO (1992), most farmers in developing countries cannot justify ownership of the tractor for exclusive use on their own farms due to small farm scale owned. Since tractors are not possible to utilize to their full capacity, small farmers are forced to look for a collective use of the tractor such as private contractors, machinery cooperative, machinery ring, national machinery station and tractor hiring (Gego, 1986).

The use of the small tractor for custom hire services has widely been practiced in many developing countries (Chancellor, 1971, 1986; Kolawole, 1972; Wattanutcharya, 1983; Duff, 1986; Balangkari and Salokhe, 1999) and are attractive for small-scale farmers with limited investment capital or those with seasonal requirements (Edwards, 2009). Small-scale farmers can make their cultivation practices more efficient by using custom hire services (Sims et al, 2011) that can fulfill their requirements of farm equipment at a low cost (Chancellor, 1971) or at a cost lower than owning and operating such equipment (Patterson and Painter, 2011). Thus, hiring machines (mostly tractors) is more economical for small farmers (Henderson and Fanash, 1984).

The method has also become one of the popular methods adopted by small farmers in Indonesia as being practiced by farmers or farmer groups in Jogjakarta (Yogatama et al., 2002), West, Centre, and East Java (Friyatno, 2003), West Java (Arininsih and Tarigan, 2005), and Centre Sulawesi (Hutabaean et al., 2005). Because such method enables the owners to utilize full tractor capacity and justify economic level of the ownership of the tractors.

The other very important benefits in the future are that custom hire services can be the main way to make tractors available for other farmers without buying the machines and are potential to make someone’s livelihood from the business. As reported by Balangkari and Salokhe (1999) in Coimbatore District India and Kolawale (1974) in Savanna Zone of Western Nigeria, for example, the farmers hired tractors to other farmers to earn extra income. For others, the custom hiring may be a method to spread fixed costs of machinery over more acres, reducing per unit costs and increasing cash flow (Beaton et al., 2003).

2.5. Economic Aspects of Farm Machinery Operations

The economics of farm machinery operations has been studied at some length in a number of countries primarily associated with costs of using the machine. Bond and Beard (1997) revealed that the estimation of costs of farm machinery is important to persons involved with agricultural production – farmers, custom operators as well as researchers. Individual farmers can use estimated machinery costs to help formulate enterprise budgets that are useful in planning and controlling production on their farms. Custom operators need farm machinery costs information to establish rates charged for performing custom work.

Tractor ownership represents a considerable amount of capital investment in agricultural production. For modern farming, it makes up as much as 40% of the total investment (Henderson and Guericke, 1985). Furthermore, machinery costs are often more than half of total crop production costs for Kansas producers and substantially affect farm profitability. Besides affecting fundamental machinery buying and trading decisions, machinery costs affect profit-maximizing crop and rotation selection, thus long-run farm profitability (Kastens, 1997).

The cost of using farm machinery continues to gain in significance and importance (Fairbanks et al., 1971). A not too erroneous rule-of-thumb is that one third of the expense of growing a crop will be vested in land, one third in supply such as seed and fertilizer, and one third in machine operating expense (Kampe, 1971). For some crops, machinery operating and ownership costs can represent more than half of crop production costs (Ward et al., 1985; Wu and Perry, 2004).

Machinery ownership and operating costs represent a substantial portion of total production expenses for South Dakota producers (Pflueger, 2005). Surveys proved that agricultural machinery may represent up to 40 – 50% of total production cost in deferent countries (Ruiyin et al., 1999) or 35 to 50% of the costs of agricultural production when excluding the land (Anderson, 1988). Operating costs are likely to be at least twice the cost of use in developed countries due to cost of repair and poor serviceability (Inns, 1978). Therefore, having an accurate estimate of farm machinery costs is important in the decision-making process for producers (Dumler et al., 1998).

Generally, farm machinery costs are broadly divided into two categories: fixed (ownership) and variable (operating) costs (Rahmoo et al., 1979, Bukhari et al, 1988; Larson et al., 1960; Kampe, 1971; Fairbanks et al., 1971; Inns, 1978; Kepner et al., 1980; Jacobs and Harrell, 1983; Hunt, 1983; Kastens, 1997; Pflueger, 2005; Srivastava et al, 2006; Khodabakhshian and Shakeri, 2011). The ownership costs, which do not depend on amount of use or output of the equipment, include charges for depreciation, interest of investment (opportunity cost), taxes, insurance and housing facilities. The operation costs, which depend on the amount of use or output of the equipment, include repair and maintenance, lubrication, fuel and oil consumption, and labor. Ownership, operating, and total machine costs can be calculated on an annual, hourly, or per-hectare basis (Srivastava et al., 2006).

A different term of machinery costs categories was revealed by Wattanutchariya (1983) who divided them into cash and non-cash costs. Lazarus (2009) categorized machine costs into time-related and use-related categories. Use-related costs are incurred only when a machine is used. They include fuel, lubrication, use-related repairs and labor.

Time-related costs, also often referred to as overhead costs, accrue to the owner whether or not a machine is used. Overhead includes time-related economic costs: interest, insurance, personal property taxes, and housing.

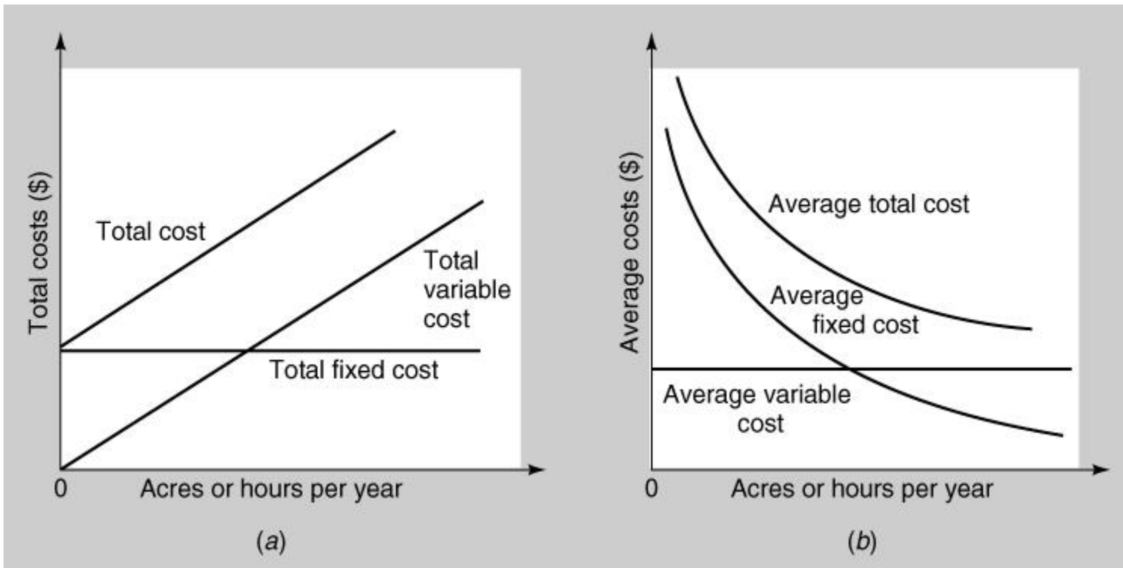


Figure 2.3. Relations between total and average machinery costs

Annual costs of operating a machine can also be divided into fixed cost and running costs. Fixed costs are constant per annum and will thus increase per hectare as the annual use of a machine increase. The running costs are constant per hectare and thus increases in proportion to the annual use (Butterworth and Nix, 1983; Bardaie, 1986). The fixed costs consist of depreciation, interest on capital, insurance, housing and road taxes. The running costs comprise repair and labor, together with fuel and tractor use. The division between fixed and running costs and the relationships are illustrated in Fig. 2.3.

One of the most important inputs of a modern machinery management system is an accurate and detailed cost estimate for each machine (Bower and Hunt, 1970). Agricultural engineers and economists use a variety of engineering and economic principles in calculating a machine's costs. A number of approaches have been used to determine costs of the farm machinery (Kampe, 1971; Fairbanks et al, 1971; Audsley and Wheeler, 1978; Henderson and Fanash, 1984; Chancellor, 1986; Ward, 1990; Yuanjuan and Chunjiang, 1999). For example, Kampe (1971) analyzed machinery costs based on a grouping of factors to provide input to basic decision on operator, while Cross et al. (1998) developed a computer program to estimate the economic costs of owning and operating farm machinery and equipment which was called Machinery Cost Calculator (MCC).

Audsley and Wheeler (1978) revealed method to determine an annual cost for owning and operating a machine calculated using actual cash flow. Yuanjuan and Chunjiang (1999) used a mathematical model to calculated machinery costs. The costs of farm machinery are determined by their yearly use, which is determined by the area to be worked, the machine capacity and available working hours. Other factors determining cost are the purchase price, maintenance and repair cost, fuel prices, interest rate and cost of labor (still) associated with the farm operations (Goense, 2005)

More special calculation has been always given to depreciation because the cost is often the largest cost of farm machinery (Langemeier and Taylor, 1998) and the decline in value of an asset over time because of age, physical wear, technical obsolescence, and change in market supply and demand for asset (Dumler et al., 1998). Depreciation measures the amount by which the value of a machine decreases with the passage of time where used or not. It means that depreciation is more likely a function of time for machines having small annual use (Hunt, 1983). Cross and Perry (1996) stated that depreciation is a significant cost associated with farm equipment ownership. Depreciation can be expressed as dollar per year, percent of new cost per year, dollar per acre, and percent of new cost per

100 acres (Huber, 1967).

Depreciation cannot be observed, so it is estimated (Cross and Perry, 1996). Many approaches have been used in order to estimate depreciation cost. Standard Budgeting techniques such as straight line, declining balance, or sum-of-the-year's digits were commonly used (Larson et al., 1960; Bloome et al., 1975; Kepner et al., 1980; Jacobs and Harrell, 1983; Hunt, 1983; Kay and Edward, 1994; Riggs et al., 1998; Panneerselvam, 2007, Lazarus, 2009). Another is to estimate the market value of used equipment at one or more points in the equipment's life, such as capital cost recovery (Watt and Helmest, 1981) and change in market value (Reid and Bradford, 1983, Perry and Nixon, 1990).

Functional relationship to estimate depreciation is also used, such as linear, Cobb-Douglas, or exponential (McNeill, 1979; Leatham and Baker, 1981; weersink and Stauber, 1988; Hansen and Lee, 1991; Crew and Kleindorfer, 1992). Bowers (1994) and Kastens (1995) used the formula developed by the American Society of Agricultural Engineers. The most comprehensive estimates of equipment depreciation functions are revealed by Perry et al. (1990); Cross and Perry (1995, 1996) and Wu and Perry (2004). One method by which fixed costs per unit of production have been minimized is through the increase of farm size (Cervinka and Chancellor, 1975).

The second significant cost of the machinery ownership is interest on the investment. The interest on investment in a farm machine is included in operational cost estimates. Even if the investment money is not actually borrowed, a charge is made since that money cannot be used for some other interest-paying enterprise (Bakht et al., 2008).

The most important cost item of machinery operating costs is repair and maintenance of farm machinery. Repair and maintenance costs are an important item in costs of owning and operating farm machinery (Ward et al., 1985; Al-Suhaibani and Wahby, 1999; 2001; Bakht et al., 2008). The costs are usually about 10% of the total cost; as the machine age increases the cost increases until it becomes the largest cost item of owning and operating of farm machines (Rotz and Bowers, 1991). Repair costs usually include both the material and labor required to make the repair (Larson, 1960).

Repair costs are difficult to estimate because amount of use, nature of use, and the maintenance and care given the machine influence repair needs (Larson, 1960; Kepner, 1980; Langemeier and Taylor, 1998). Fairbanks et al. (1971) also stated that repair cost difficult to estimate because both the amount and the nature of use and the kind of maintenance and care given the machine vary with each operator and influence repair needs.

Repair costs occur because of routine maintenance, wear and tear, and accidents. Repair costs for a particular type of machine vary widely from one geographic region to another because of soil type, rocks, terrain, climate, and other conditions. Within a local area, repair costs vary from farm to farm because of different management policies and operator skill (Edwards, 2001).

Repair data is available for different classes of machinery, but any one specific machine may vary greatly from the average due to maintenance practices, types of usage, and other factors (Langemeier and Taylor, 1998). Beppler and Hummeida (1985) also claimed that the costs of maintaining and repairing farm machinery are highly variable and unpredictable. The best source of information for repair costs is the record book for the machine (Jacobs and Harrell, 1983).

Agricultural engineers have done many studies regarding repair and maintenance of farm machines. Several studies were conducted in both developed and undeveloped countries either to develop models to determine the cost during a certain period or to get absolute numbers to represent owning and operating certain equipment (Bowers & Hunt, 1970; Fairbanks et al., 1971; Farrow et al., 1980; Ward et al., 1985; Rotz, 1987; Rotz & Bowers, 1991; Gliem et al., 1986; Gliem et al., 1989). Most studies depended on surveys to collect the necessary information due to the lack of accurate records with the users of farm machines.

Bowers and Hunt (1970) collected information from several farms in Illinois and Indiana in the United States as part of their study. This included ten types of agricultural machines in addition to tractors. Models were derived from the collected data and these were used as a reference for other studies. Fairbanks et al. (1971) made an extensive survey on 114 farms in Kansas and two models were derived. One model to calculate the cost of repairing diesel tractors and the other model calculated the cost of repair for combines. These models had the same format as given by ASAE (1993), but differed in their parameters. The accumulated cost of R&M was estimated to be 30% of the purchase price by the end of the economic age.

Ward et al. (1985) made an extensive study of 10 years of government records for repair costs of 4-wheel and 2-wheel drive tractors and derived a cost model for each type of tractor. This study agreed with other studies regarding the difference existing between the two types of tractors. Rotz (1987) derived a model based on equipment price and operating hours. The testing of the model showed that the costs were more realistic when the area worked was considered instead of the operating hours. Rotz and Bowers (1991) made an attempt to collect information from companies and experts, but limited response was received. They revised the models published by ASAE regarding repair and maintenance costs. They noticed that the repair and maintenance costs varied with operating conditions. Lips (2013) found that high annual utilization combined with short length of service measured in years has the effect of reducing the accumulated repair and maintenance costs.

Some studies conducted in undeveloped countries regarding repair and maintenance of farm machines have been reported in the literature (Inns, 1978; Henderson & Fanash, 1984; Beppler & Hummeidah, 1985; Konda & Larson, 1990; Abdelmotaleb, 1993). The operating costs of the farm machines in undeveloped countries were estimated using the models of developed countries (Inns, 1978). It was found that the R&M costs in the undeveloped countries were double that in the developed countries. It was mainly due to the high costs of spare parts and the lack of preventive maintenance. Bukhari (1982), for example, reported that in developing countries the cost of repairs was 150% as compared to 120% in United States due mainly to higher prices of spare parts and sometimes to a lack of knowledge of proper operation and maintenance.

Henderson and Fanash (1984) conducted a study in Jordan on the cost of tractor use. This study showed that there was a proportional increase of repair costs with tractor use. They proposed a model to estimate the repair cost of the tractor/hour/acre based on the Jordanian currency. Beppler and Hummeidah (1985) indicated that the available information in undeveloped countries were very limited and some of the studies conducted in Asia and Africa showed that R&M costs ranged from three to five times that in Europe and America. Konda and Larson (1990) performed a study in Burkina Faso. The study was done on machines used by a company for sugar production, and models for tractors, generators and irrigation pumps were developed. Abdelmotaleb (1993) conducted a study to test the ASAE models under Egyptian conditions. The required information was collected from farmers and mechanized agricultural stations. The analysis showed that the ASAE models were improper for Egyptian conditions as they under predicted costs.

Other studies have been conducted to determine repair costs of tractor (Puzey and Hunt, 1968; Hunt and Fuji, 1976; Henderson and Panash, 1984; Ward et al., 1985; Beppler & Hummeidah, 1985; Morris, 1988; Adekoya and Otono, 1990; Rotz and Bowers, 1991; Al-Suhaibani and Wahby, 1999; Ahmad et al., 1999). The general formula for expressing accumulated repair costs were developed by Larsen and Bower (1965) and Bower and Hunt (1970). In general, the costs other than those for repair and maintenance usually decrease with increasing usage, but the reverse is true with respect to repair and maintenance costs (Ward et al, 1985). Repair costs per hour of use increase with age but tend to level off as a machine becomes older (Kepner, 1980).

As the machine grows older, there is a tendency for maintenance and repair costs to increase and for the quality and quantity of output to decrease (Peterson and Milligan, 1976). Operating costs are likely to be at least twice the cost of use in developed countries due to cost of repair and poor serviceability (Inns, 1978). The high repair costs occurred due to high cost of spare parts, material and service charges (Bukhari et al., 1988). Therefore, the economic benefit from a tractor depends upon the efficient manner of its use, including repair and maintenance process (Rahmoo et al., 1979).

Information on the repair costs of farm equipment suggests strongly, however, that aged equipment requires much more repair (Liang and Link, 1970). Repair cost increases primarily as a consequence of more frequent failures. Equipment failure occurs in the middle of a working day and in the busiest part of the season is more than a nuisance, it may jeopardize all or a part of the farmer's income.

In addition, understanding repair patterns will greatly aid the wise farmer-manager in determining whether to repair or replace his machine (Puzey and Hunt, 1968). It is because there is a gradual increase in repair costs until eventually it becomes uneconomical to continue making repair (Kepner et al., 1980). Peterson and Milligan (1976) stated that the decision for replacement of the existing machine should be based on the economic life which is generally shorter than the physical life because as the asset grows older there is a tendency for maintenance and repair costs to increase.

Research conducted by Khodabakhshian and Shakeri (2011) on prediction of repair and maintenance costs of farm tractors by using of preventive maintenance confirmed that there are considerable variations in R&M costs among tractor models as well as individual ones. Also, based on the results the using preventive maintenance is more useful for replacement decisions than annual charge method.

Accurate machine costs are necessary for some management decisions Pflueger (2005). The costs of owning and operating machinery in the farm business are important to the farm owner or farm manager when making a decision on whether to buy or lease machinery or to hire work done by custom operators and one of the components in making this decision is the cost of repair and maintenance (Finner and Straup, 19850; Adekoya and Otono, 1990). Because of repair costs tend to increase with the age of a machine, so an accurate estimate is an important criterion for determining the optimal time to replace a machine (Calcante et al., 2013). Peterson and Milligan (1976) stated that the decision for replacement of the existing machine should be based on the economic life which is generally shorter than the physical life because as the asset grows older there is a tendency for maintenance and repair costs to increase.

Break-even analysis is a very useful cost accounting technique and widely used for financial studies (Riggs et al., 1998). The break-even is used to give answers to questions such as what is the minimum level of sales that ensure the business will not experience loss (Tsorakidis et al., 2014). While, break-even point (BEP) is the point at which the total revenue is exactly equal to the total costs and at this point no profit is made and no losses are incurred (Kamboj, et al., 2012). Calculation of break-even point is important for farm machinery operation because it tells machine owners and managers how much use are needed to cover all fixed as well as variable expenses of the machine operation or the volume of use after which the business will start generating profit. The alternative and applicative approach to break-even analysis is graphically depicted in Fig. 2.1. (Butterworth and Nix, 1983).

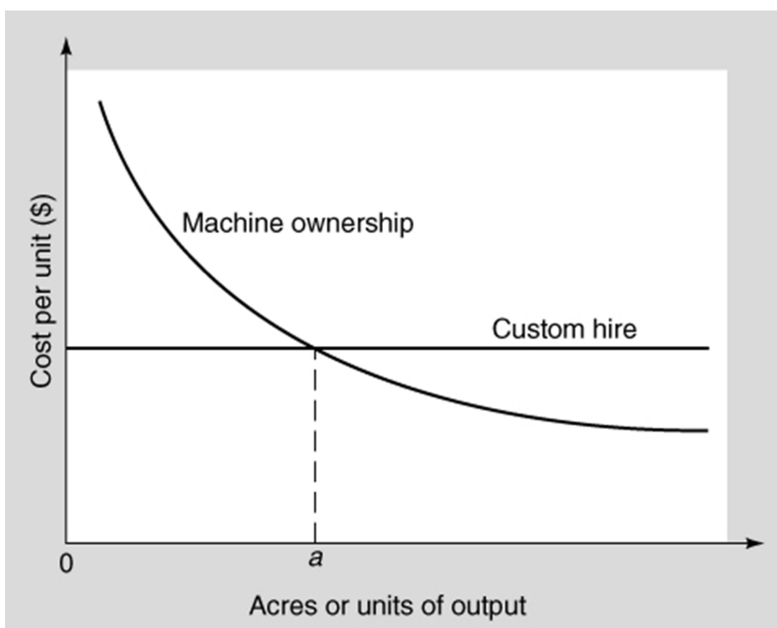


Figure 2.4. Break-even analysis: machine ownership versus custom hiring

2.6. Related Research of Small Farm Mechanization.

In the Asian countries, mechanization development is low progress in which about 30% of total cultivated land is cultivated by human labor, 30% by draught animals, and 40% by tractors (FAO, 2007; 2008). Singh and Siswasumarto (1988) argued that agricultural mechanization process in the country was in its early stages of development. Presently, the level of mechanization primarily in rice production system varies from low to high, ranging from 10% to 90% of cultivated land depends on the intensity of the farming system and common figure indicates its average level of 30% of cultivated land (Handaka, 2005).

The adoption of farm mechanical power as a substitute for manual and/or animal power poses a paradox (Sison et al., 1985). However, tractor is one of the most important power sources in Agriculture today (Bakht et al., 2008; Ghadiryanfar et al., 2009). The tractor is also the most important single item of farm machinery for selective farm mechanization in developing countries (Rahmoo et al., 1979). Tractors represent a considerable amount of capital investment in agriculture enterprise (Babatune, 1996), therefore, they must give benefit. The tractors also require doing the job economically (Peterson and Milligan (1976).

Effect of tractor power on agriculture is considerable (Singh, 2006). Tractor effects on small farms could be viewed in terms of cropping area and intensity, labor use pattern, and yields. .Some researches which provide evidence of the benefits of the mechanization on agriculture from across the courtiers have been reported. For rice farms, research conducted in central Mindanao Philippines was found that the power tillers had the highest cropping intensity and highest production per hectare resulting in the highest gross as net income per ha (Singh and Yadao, 1979).

The tractor has helped increase agricultural productivity by expanding new cultivated area and speeding up cultivation (Wattanutchariya, 1983). In Pakistan, Ahmad (1983) reported that tractor farms allocated more area to cash crops as compared to bullock farms where food crops (45.5%) and fodder crops (18.7%) were occupying larger areas. Thus, the gross income and total cost per farm acre were higher by 37.5% and 10.3% on tractor farm as compared to bullock farm. Sukharomana (1983) found that land preparation by buffalo in Thailand, costs more per hectare than land preparation by a two-wheel tractor, but no imported input are required.

Research conducted by Lockwood et al. (1983) in Pakistan showed that although there is an evidence of high returns to farmers on investment in tractors and attachments, there is a little evidence of appreciable social benefits. Tractors do not appear to have contributed to significant increases in farm productivity, either by bringing uncultivated land into production or by increasing the intensity of cultivation and crop yields.

Statistical analyses showed that the major effect of mechanical power adoption is significant reduction in labor input requirements of farms in Philippines using two-wheel tractors for land preparation and family labor requirements and hired labor employment as well. In addition, although the statistical analyses indicated that the mechanized farm realized higher level of rice output than non-mechanized farms, these results are not conclusive as far as attributing the difference solely to mechanization due to the fact that mechanized farms apply higher levels of fertilizer and chemical which may also account for the higher yields attained by these farms (Sison et al., 1985).

It was found that tractors helped in enhancing 26.96% more area for agriculture purpose at the farm in Palampur India (Singh et al., 2991). In Sub-Saharan Africa was reported that a typical farm family which is reliant solely on human power can only cultivate 1.5 ha per year and this will rise to more than 4 ha per year if tractor power is available (Sims and Kienzle, 2006). It is because mechanization is generally a labor augmenting technology, increasing output per worker rather than output per unit of land (Wanjiku et al., 2007).

Kobayashi (2003) found that the modernization of the agricultural machinery from human work to machine work, from a walk-behind to a riding type, from a small horsepower to a large horsepower machine has contributed to reduction of working hours per hectare from 1739 hours in 1960 to be 330 hours in 2000. From Bangladesh was reported that the increase in the productivity of labor with the adoption of power tillers was 20% for Boro and 18% for Aman, but they had little impact on rice yields (Saker and Barton, 2006).

On the other hand, survey conducted by Biswanger (1978) in India, Pakistan and Nepal revealed that there is not an evidence for substantial increase in intensity, yield, timeliness, and gross returns by using tractor. Similar result was also reported by Panin (1995) which refutes any economic justification for the current use of tractors in area by the small holding farmers in Botswana. The result shows that the use of tractors has a significant negative impact on crop production income and household labor economy. The current system of hiring a tractor for plowing has no impact on total cultivated area, crop yields, and total crop output.

Aguilar et al. (1983) stated that, in general, the labor required for a farm operation was reduced significantly whenever mechanized power was used. Their comparison researches conducted on small rice farm in Philippines revealed that the difference in total labor use between mechanized and non-mechanized farms was statistically significant in land preparation for both family and hired labors, but for both cropping intensity and yield had no significant difference. Sarker and Barton (2006) also reported the impact of power tillers on small farms as follow: a reduction in the cost of production, higher gross margins, greater labor productivity, and increased demand for hired labor but measurable increases in opportunities for sharecropping. Efficient machinery helps in increasing productivity by about 30% in India (Kulakarni, 2009).

Morris (1975) estimated that land preparation time in Indonesia was higher using animal than power tiller. With power tiller (12 hp), the time required to field preparation was 17 – 24 hours per hectare including travel time, compared to 160 hours by animal and 440 hours using manual methods.

Field studies carried out in Kavre, Parsa, Bara, and Chitwan districts in Nepal revealed that productivity of major crops in tractor/power-tiller farms is higher by 3.4% to 15.7% compared to bullock farms. The use of mechanical power technology has reduced the cost of production by 3.8% to 13.3%. The cropping intensity in tractor/power-tiller farm is higher by about 5% compared to bullock farm. The overall human labor employment is 4.5% to 6.1% higher in tractor/power-tiller farm compared to bullock farm (Pariyar et al., 2001).

Consequences of small rice farm mechanization on land preparation were also reported by Saefudin et al. (1983) and Maamum et al. (1983) in West Java and South Sulawesi in Indonesia, respectively. The results of preliminary analysis from the studies indicate that mechanization had more significant effect on reduction of labor use, particularly family labor, while the impact of the mechanization on cropping intensity and cultivated especially irrigated area were not clearly found and required further detailed analysis. Also in West Java, Indonesia, Singh and Siswasumarto (1988) reported that the rice yields of farms in three categories of power sources were also not statistically different from each other's: human labor (4.3 t/ha), animal (4.6 t/ha) and tractor farms (4.6 t/ha). However, the labor input per ha in land preparation for rice crop on farms using tractor farms (187 h) was significantly smaller than the labor input on both the animal farms (256 h) and human labor only (426 h).

According to operational agricultural machinery and equipment under custom hiring was reported by Hutabaean et al. (2005) from Sulawesi Centre and Yogatama et al. (2002) from Jogjakarta. They revealed that the business of small tractor hire services did not make profit due to low annual use and service rate. Financial analysis in both locations indicated that capacity of hand tractor to about 15 ha per season in Center Sulawesi and 30.8 ha per annum in Jogjakarta were not economically feasible.

Findings of some of the research studies on the impact of small farm machinery use have been summarized above. As evidence, these studies have dealt with some specific aspects only and thus are unable to form the bases for major policy decisions. The possible role of different levels of mechanization in the development process is yet to be comprehensively evaluated. This study attempts to highlight mechanization of small-scale rice farming and small farm machinery operations in Riau Province, Indonesia.

CHAPTER III
RESEARCH METHODOLOGY

3. 1. Method and Study Area

The study was carried out using the survey method in Riau Province, one of the 33 provinces in Indonesia, with the provincial capital and largest city is Pekanbaru. The province has ten regencies (Bengkalis, Indragiri Hilir, Indragiri Hulu, Kampar, Kuantan Sengingi, Rokan Hilir, Rokan Hulu, Pelalawan, Siak, and Kepulauan Meranti) and two cities (Pekanbaru and Dumai). There are 163 sub-districts and 1,759 villages available in the Province. Regency is predominantly an agricultural sector and city is industrial and service sector in its economy.

The study area was limited to four regencies from the province, including Kuantan Sengingi, Rokan Hulu, Siak, and Kampar (Fig. 3.1). The regencies are about 175 km west, 183 km north, 120 km south, and 51 km west of Pekanbaru, respectively, the provincial capital of Riau Province. The locations were purposively selected to represent an average condition of the most intensive farming system of rice production and the highest level of mechanization adopted in the province. At least one village each regency, which are the importance of rice production and large number of farm machines, were selected.

The climate of the study areas is tropical with two season; wet season and dry seasons. During the wet season (September – February) which is the main cropping season, the growing of rice on 90 to 100% area is possible and profitable, while during the dry season (March –August), rice on 60% to 70%, *palawija* crops (seasonal crops) on 25% to 30%, and vegetables on 5% to 10% area are possible (Khan, 1996). The main *palawija* crops are maize, soybean, peanut, cassava, and mung bean.

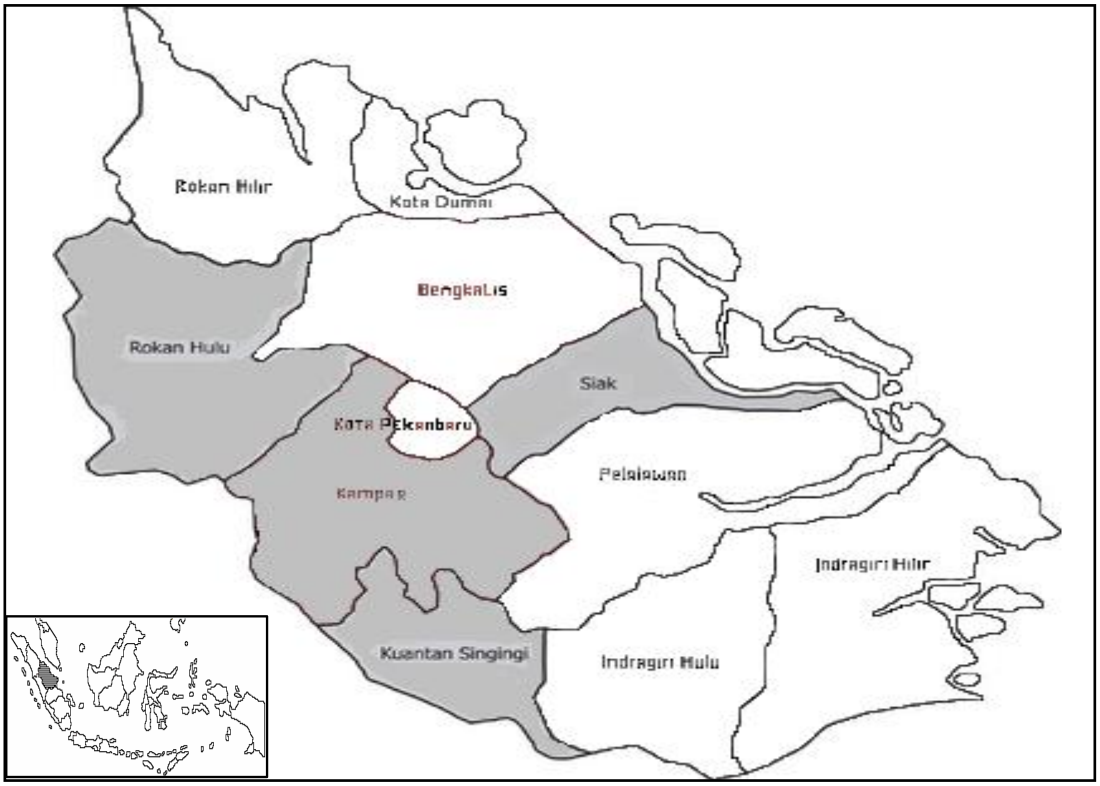


Figure 3.1. Map of Riau Province Showing Survey Area

3. 2. Sample Size

The samples selected were divided into three categories: farmers, hand tractrs, and hire service groups as presented in Table 3.1. In order to determine labor and time requirements and costs, a total of 120 farmers used farm machines from the four selected regencies (30 individuals in each) and 62 hand tractors from the regencies were randomly sampled. The rice farmers and the tractor owners (also operators) were interviewed by means of field visits to their houses or to their places of work by using structured questionnaires. The survey regencies included Kampar, Kuantan Sengingi, Rokan Hulu, and Siak in Riau Province. In addition, a total of 20 hire services groups located in seven districts, especially from Kampar regency was visited during the rainy season in 2012 to collect field data. The seven districts included Bangkinang Seberang, Kampar, Kampar Timur, Kampar Utara, Kuok, Salo, and Tambang. The selected groups were actively providing services to their respective group members.

Table 3.1. Number of selected samples in each survey area

Sample category	Regency				Total
	Kampar	Kuantan Sengingi	Rokan Hulu	Siak	
Farmer	30	30	30	30	120
Hand tractor	-	15	15	32	62
Machinery hire service group	20	-	-	-	20

3. 3. Data Collection

Data for the study consisted of primary and secondary data. The primary data were collected during the rainy cropping season in 2003 and 2008 which is the main season for rice growing in Riau Province. The primary data collected included farm size, machine and equipment types, purchase year, hectares of work (working hour), labor use and sources, labor wages, machinery and equipment rental charges, number and causes of breakdowns, the number and kind of replacement parts, place and repairer of tractor breakdowns, the length of repair, and detailed repair and maintenance expenses (parts, labour, maintenance, and transportation), income derived from hire service and rate of charged. In addition to this data, a number of problems facing individual farmers in making repairs, carrying out maintenance, and obtaining spare parts were also collected. Meanwhile, the secondary data were collected from government institutions and other legal sources, including land area of Riau Province, climatic conditions, harvested area of wetland paddy, rice production and productivity, number of farm machinery in Riau Province, and other required information.

3. 4. Analysis Method

The data were set and analyzed using simple descriptive, including percentages and means, and also quantitative approach using statistical techniques. Analysis procedures that are used in this study are explained as follows:

3.4.1. Mechanization Capacity and Farm Mechanization Degree

The mechanization capacity is the ratio of multiplying available machines with potential working capacity per year to the total operation expressed as a percentage.

$$M_c = \frac{N_m \, x \, W_c}{A_0} \quad \text{.......... (1)}$$

Where *Mc* is the mechanization capacity (%), *Nm* is the total number of available farm machines (unit), *Wc* is the average yearly working capacity for each machine (ha or ton), and *Ao* is the total operation (ha or ton).

Development stage of mechanization process is analyzed by using four criteria which are proposed by Herdt (1983):

1. Only a few tractors available for experimentation (introduction).
2. Early adoption with about 2.5 hand tractors/1000 ha.
3. Take-off with 20 hand tractors/1000 ha.
4. Full mechanization with 100 hand tractors/1000 ha and a variety of other equipment.

3.4.2. Costs Estimation

Tractor annual costs commonly are divided into two categories: fixed costs (ownership costs) and variable costs (operating costs). The fixed costs, which remain relatively constant per annum as the annual use of the machine increases (Butterworth and Nix, 1983), consist of depreciation, interest on capital, insurance, tax, and housing. The most realistic and simple method for estimating depreciation is the straight-line method (Butterworth and Nix, 1983; Kepner, Bainer, and Barger, 2005). Depreciation was figured as straight-line depreciation over 10 years of useful life. The remaining value of the tractors was assumed to be 10% of the initial purchase price (Kepner *et al*., 1978; Hafsah and Bernsten, 1983; Hunt, 1983; Jacobs *et al*., 1983). The most common equation to calculate the annual depreciation as used by Cicek (2011); Kamboj et al. (2012); Rahman et al. (2013) is expressed as:

$$D = \frac{P - S}{L} \qquad (2)$$

Where D is the annual depreciation, P is the initial price of machines, S is the salvage value, and L is useful life.

Furthermore, the annual interest on investment of power tillers is calculated as follow:

$$I = \frac{P - S}{2} x\, i \qquad (3)$$

Where: I is the interest on farm machines' investment and i is the annual interest rate (%). The interest rate was set to 8% as representing a current average rate for capital interest calculation in the survey.

The variable costs (*VC*) which consisted of repair and maintenance (*R*), labor wage (*W*), fuel (*F*), and oil and lubricants (*O*), can be obtained form the following equation:

$$VC = R + W + F + O \quad \text{(4)}$$

Thus, the total costs (*TC*) are given below:

$$TC = FC + VC \quad \text{(5)}$$

Dividing the fixed and variable costs by annual hectares of use is obtained the annual cost per hectare.

Revenue is the value received from service performed. Annual revenue (*R*) is calculated by multiplying the number of use (*u*) by service charge/custom rate (*C*).

$$R = uC \quad \text{(6)}$$

Profit (π) is the deference between revenue and total costs when revenue exceeds costs (Riggs *et al*., 1996). The cost-revenue-profit relationship can be written as follow:

$$\pi = R - TC \quad \text{(7)}$$

Because the variable costs increase per annum in proportion with use (Butterworth and Nix, 1983), *uVC,* so the profit model would be written:

$$\pi = u(C - VC) - FC \quad \text{(8)}$$

When the revenue and costs are equal ($\pi = 0$), it is at break-even, i.e., neither making profit nor losing money. Hence, the number of uses at the break-even point can be calculated by dividing the fixed costs per year by the difference between the service charge per ha and the variable costs per ha. Thus:

$$BEP = \frac{FC}{(C - AVC)} \quad \text{(9)}$$

Where: *BEP* is the break-even oint (BEP).

In this study, all costs, revenue, and profit are calculated into Indonesian Rupiah (Rp1000 is equivalent to US. $0.118 based on average of exchange rate in 2003).

3.4.3. Model Development

The estimation of the annual repair costs requires the specification of a functional form. The prediction model was established by the integration of the best model equation. Consistent with previous studies, the increase pattern of tractor repair costs annually is denoted by a function, f, that relates the annual repair costs, *RC*, to tractor age, *A*, number of annual uses, *U*, engine horsepower, *H*, and three binary variables of operator skill, S, ownership system, O, and manufacturers, M. The functional relationship is then written as follows:

$$RC = f(A, U, H, S, O, M) \quad (10)$$

In order to operationalize the model, it is necessary to choose an application model for our study. A tran-slog model of the multiplicative power function form, which is popularly called the Cobb-Douglas functional form, was chosen. The function has been widely used in agricultural studies (Cross and Terry, 1996; Ojo, 2004; Obi and Chisango, 2011; Mawa et al., 2014; Guesmi, 2015) because of its simplicity (Debertin, 2012). The model is also assumed to be consistent with the pattern of increasing repair costs that aren't at a constant rate. The model is expected to follow the behavior of increasing repair costs over the machine's life. Thus, we can apply ordinary least squares (*OLS*) techniques. By adding the stochastic disturbance term, ε, the economic specification of the tran-slog model is generally expressed in a linear relationship as follows (Leatham and Baker, 1981; Panin, 1994: Debertin, 2012):

$$\ln RC_t = \ln \alpha_0 + \sum_{i=1} \beta_i \ln X_{it} + \sum_{j=1} \gamma_j D_{jt} + \varepsilon_i \quad \text{...} (11)$$

Where $\alpha_0 = \ln \alpha$. X_{it} represents *A, U*, and *H* variables with the corresponding coefficient β_i. The repair costs are expected to increase with the *A, U*, and *H* increase. D_{jt} represents all dummy variables not transformed (*S*, *O*, and *M*) with the corresponding coefficient γ_i. The binary skill variable is 1 if skilled operator or 0 unskilled operators. The moving of tractor operators from unskilled to skilled is hypothesized to be lower repair costs. The tractor ownership system is 1 for the group ownership or 0 for the individual ownership. The manufacturer dummy variable is 1 if manufactured by Yanmar or 0 for other manufacturers. The β_i, and γ_i are unknown parameters yet to be estimated.

CHAPTER IV
RESULTS AND DISCUSSION

4.1. Description of the Study Area

4.1.1. Geographical Position

Riau Province has a very strategic position, which straddles between Malacca Straits, South China Sea and Berhala Straits (Fig. 4.1). The Province is located on the international trading route as it directly faces Malacca Straits and Singapore, one of the busiest shipping lanes in the world.

Figure 4.1. Map of Riau Province

Based on data from Representative Office of National Land of Riau Province, the area of Riau Province is approximately 8,867,267 sq-ha. The area stretching from the last slopes of Bukit Barisan up to the Malacca strait, laying between 01^{o}05'00’’ South Latitude to 02^{o}25'00'' North Latitude or between 100^{o}00'00 to 105^{o}05'00'' East Longitude of East Longitude.

The borders of Riau Province are as follow:

North side : North Sumatra Province, Malacca Straits

South side : Jambi Province

West side : West Sumatra Province

East side : Riau Archipelago

Province Riau with Pekanbaru as capital has eleven regencies, including Kuantan Singingi, Indragiri Hulu, Indragiri Hilir, Pelalawan, Siak, Kampar, Rokan Hulu, Bengkalis, Rokan Hilir, Bengkalis, and Kepulauan Meranti, and two cities, including Pekanbaru and Dumai.

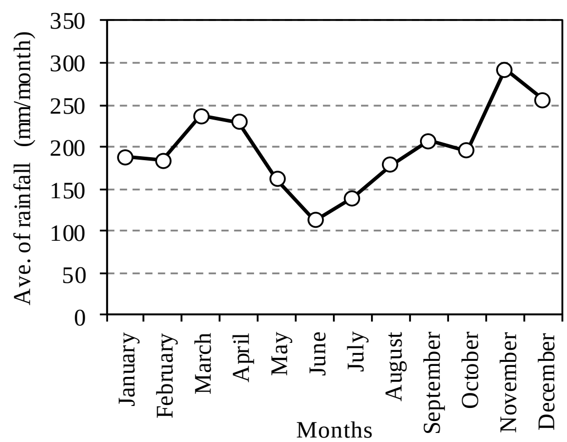


Figure 4.2. The average of rainfall in Riau Province in 2009-2013

4.1.2. Climatic Conditions

The climate of Riau Province is wet tropics and is classified into climate type "A" with relatively high rainfall, averaging from 139 on June to 292 mm/month on November influenced by the dry season and the rainy season (Fig. 4.2). Rainy season usually falls on September (sometimes

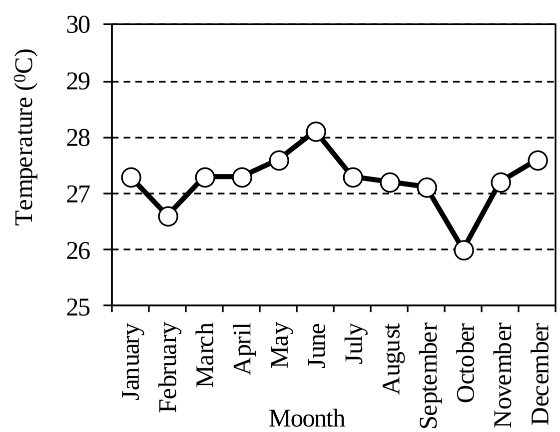


Figure 4.3. The average of temperature in Riau Province in 2009-2013

October) up to March, while dry season begins from April to August. The average temperature during 2012 was 26.0^0 Celsius, the maximum temperature was 35.1^0 Celsius and the minimum temperature was 21.8^0 Celsius (Fig. 4.3). The highest temperature occurred on July and the lowest temperature was October.

Most areas in Riau Province are lowland plain, including alluvial islands scattered along coastal line with average elevation less than 200 m above at the sea level. Archipelagic region of Riau, on the other hand, is formed from volcanic formation in the form of islands, big, and small. The territorial size of Riau Province is 329,867.16 km^2, consisting of land area 89,150.15 km^2 and water area 250,697.01 km^2.

In mainland region, there are four big rivers, i.e., Rokan River, Siak River, Kampar River and Indragiri River. These rivers spring from Bukit Barisan mountain, stretching along the border Riau Province and West Sumatra Province, and flowing down to Malacca Straits. The rivers play an important role as the means of transportation, sources of irrigation water, energy, and clean water as well as fishery resources.

4.1.3. Soil Type and Land Utilization

Riau Province has various types of soil. Based on data from Statistic Bureau of Riau Province (2014), the total area of the province reaches approximately 8,915,016 ha. *Histosols* soil type is the largest area to reach 3,865,360 ha (43.3%), followed by *Ultisols* of 2,950,849 ha (33.1%), *Inceptisols* 1,480,141 ha (16.6%), and *Oxisols* of 681,093 ha (7.64%). While both *Entisols* and *Mollisols* types are 234,552 ha (2.63%) and 23,157 (0.26%), respectively.

Land area in Riau Province is divided into various utilization purposes as presented in Table 4.1. The area can generally be divided into two utilization, i.e., rice cultivation

(10.08%) and non-rice cultivation (89.92%). The rice cultivation is dominated by highland paddy (84.44%), while non-rice cultivation is dominated by plantation (43.54%), consisting oil palm, rubber, coconut, sago palm, etc.

Table 4.1. Area of land by utilization in Riau Province in 2013 (ha)

Land utilization	Cropping intensity		Total	Percent
	Twice	Once		
A. Paddy				
1. Irrigation	6,764	12,120	18,884	2.10
2. Rainfed	6,437	56,461	62,898	7.00
3. Tidal	3,544	51,456	55,000	6.12
4. High land paddy	0	758,533	758,533	84.44
4. Other	0	3,034	3,034	0.34
Sub-Total	16,745 (1.86%)	881,604 (98.14)	898,349	10.08
C. Non Paddy				
1. House compound and surroundings			247,435	3.09
2. Bare land and garden			554,522	6.92
3. Dry land for seasonal crops and vegetables			204,011	2.54
4. Preliminary unused land			385,097	4.80
5. Steppe pasture			22,647	0.28
6. Community forest			553,243	6.90
7. National forest			1,132,278	14.12
8. Plantation			3,490,278	43.54
9. Swampy area			337,028	4.20
10. Fishpond			6,549	0.08
8. Others			1,083,579	13.52
Sub-total			8,016,667	89.92
Total			8,915,016	100,00

Source: Food Crops Service of Riau Province, 2014.

Wetland paddy consists of various categories based on water source. Rainfed paddy filed is the largest area to reach 7%, followed by tidal (6.12%) and irrigation (2.10%). Most of the wetland paddy (98.14) can only be planted rice once in a year (single cropping), while only 1.46% can be planted twice in a year (double cropping).

4.1.4. Social Economic Conditions

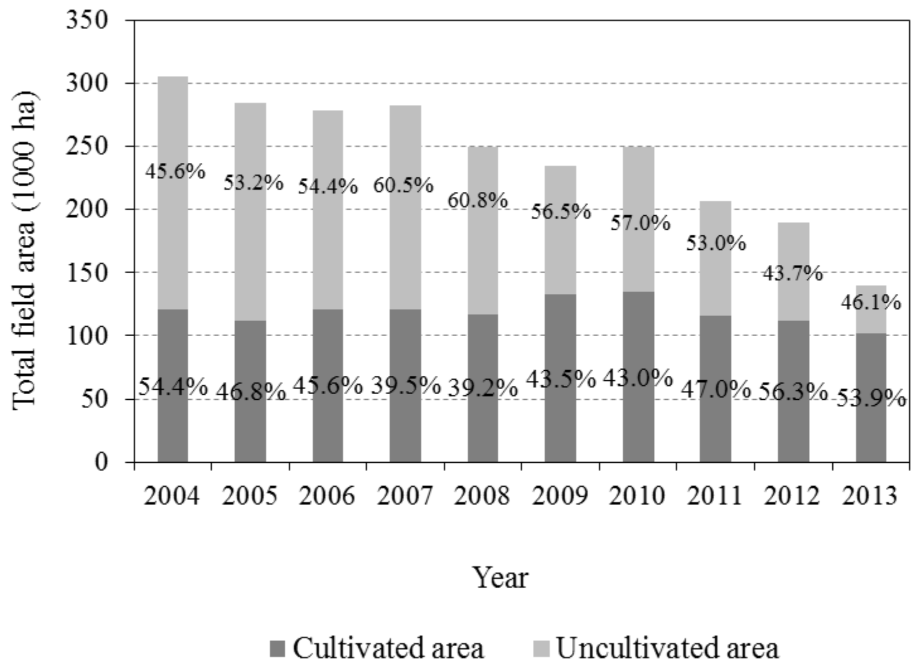
Based on Statistical Bureau of Riau Province (2014), the population of Riau Province was recorded as 6,125,283 persons, consisting of 3,162,525 male (51.6%) and 2,962,758 female (48.4%) with annual growth of about 3.37% on average during the last 5 years period. The number of households located in the province was recorded at 1,469,522 households with an average population of four persons per household. The population density was 68 per sq.km. Approximately 44.73% of the population engage in agricultural sector, including food, plantation, forestry, husbandry, and fishery. The second sector which has an important role in labor absorption in the province is trade, restaurants and hotels, accounting for 20.54%.

Riau province is one of the fastest growing parts of Indonesia in terms of economic and population. For example, the economic growth of Riau Province reached 6.01% in 2013 and higher than national growth of about 5.78% in the same year. Income per capita of Riau population in 2013 included oil and gas and based on current price averaged as IDR 100,691.46 thousand (US $ 8,055) or IDR 72,300.12 thousand (US $ 5,784) at constant price of 2010 (BPS, 2014). Riau Province occupies the central part of eastern region on Sumatra Island, which straddles between Malacca Straits, South China Sea and Berhala Straits. The Province is a strategic region as it directly faces Malacca Straits and Singapore, one of the busiest shipping lanes in the world.

Riau is the second number of the richest provinces after East Kalimantan in Indonesia. This province is rich with natural resources, particularly petroleum and natural gas, rubber, and oil palm. The majority of the province is heavily forested lowland; with palm oil plantations and logging being major industries and it is losing around 2,000 sq.km of forest per year. In 2005 the forest cover was down to 33% (or 27,000 sq.km) from 78% (or 64,000 sq.km) in 1982.

4.1.5. Rice Area and Production

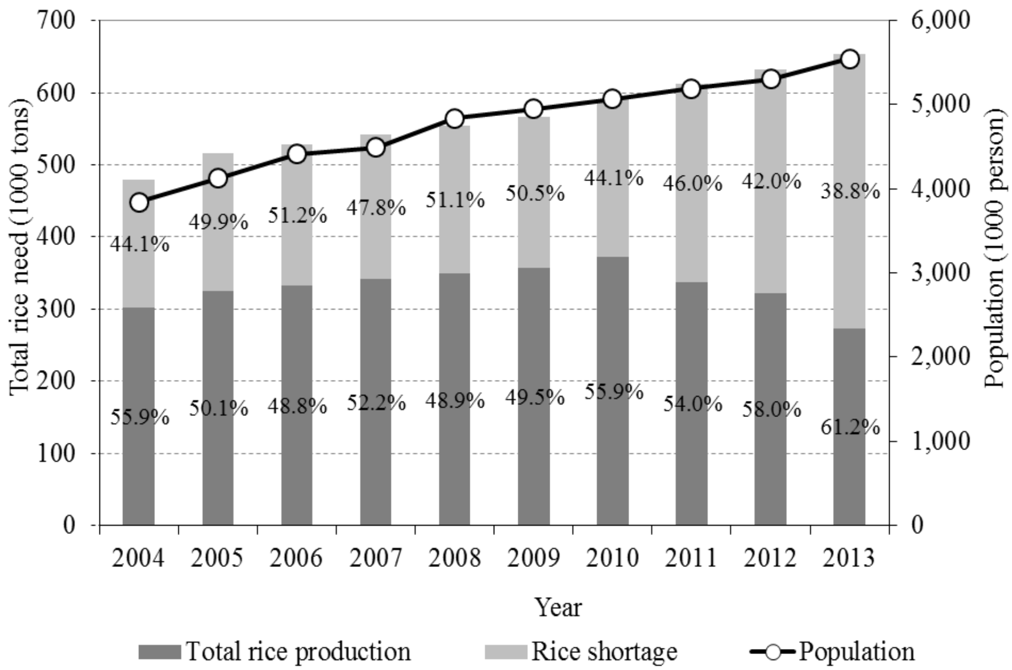
According to Subejo (2014), rice has become strategic commodity for a long time because it is not only as staple food for majority of Indonesian, but also an economic sector that provide directly million labor forces and related indirectly to the rice business. Rice farming in Riau which is dominated by small scale operation and subsistence level in production has been facing various problems. The limited cultivated area and low yields are on-going problems which have been encountered by most farmers over the years. The low yields of rice are attributed to primary untimely field operations, lack of irrigation (80% area under rain-fed conditions) and low technology application. Between 2004-2013, both cultivated and uncultivated area decreased to about -2.04% and -16.39% annually, respectively (Fig. 4.4).



Source: Food Crops Service of Riau Province, 2005-2014

Figure 4.4. Total area of paddy field in Riau Province during 2004-2013

According to Fig. 4.5, Riau Province has undergone a shortage of rice for about 46% annually on average. In other words, the rice yields could just fulfill annual rice need at around 54% on average that increased by 1.36% annually (about 643.06 thousand tons in 2013) as a result of increasing population. The rice shortage was usually supplied from neighboring provinces which produce a surplus production.



Source: Food Crops Service of Riau Province, 2005 - 2014

Figure 4.5. Total rice need and population in Riau Province during 2004-2013

4.2. Farm Machinery Development and Mechanical Power Availability in Riau Province

4.2.1. Farm Machinery Development

Currently, farm machinery plays a more important role in Riau agriculture that is showed by increasing number of major farm machines during the last ten years. In case of rice growing, the use of farm machines for tillage operations, pumping, threshing, drying, and milling was applied at the different levels. For example, land clearing, planting or seeding, transplanting, weeding, and harvesting, are generally performed by manual. For tillage works, small tractors has been the most popular to be used by rice farmers. When there is not possibility for mechanized land preparation by hand tractor, the farmers will do the land preparation manually or use draft-animal power. In case of labor shortage, a zero tillage system (also known in term of *TOT = tanpa olah tanah*) is be applied.

Table 4.2 shows a comparison of the development number of major farm machines from 2004 to 2013 in the Province. Power thresher and rice milling unit are the largest number, while large tractors and dryer are the smallest amount available. Most of the farm machines were direct government aid through farm mechanization schemes by provincial and regency governments.

Table 4.2. Population of major farm machinery in Riau Province during 2004 - 2013

Name of machine	Years										Growth (%/yr)
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Large tractor (25-50 hp)	28	30	37	47	49	47	31	35	24	29	2.88
Small tractor (<15 hp)	799	817	774	744	736	1296	1082	1978	1611	1721	13.63
Water pump	737	742	795	1628	1638	3378	3080	3080	4674	1431	21.44
Power thresher	1180	700	947	746	746	1100	799	1109	1281	2195	13.24
Dryer	100	89	164	59	59	64	45	50	51	12	-8.37
Rice Milling Unit	1078	1081	835	955	955	889	764	927	818	995	0.24

Source: Food Crop Service of Riau Province, 2004 - 2013.

According to Table 4.2, the farm machines grew at a different rate for each machine. The number of water s experienced the highest growth to reach 21.44% annually on average, followed by small tractors and power threshers to about 13.65 and 13.24% annually on average, respectively. While the number of dryers has experienced a negative growth of -8.37 annually on average during the same period. The type of the farm machines available on rice farms in Riau Province is depicted in Fig. 4.6.

Figure 4.6. Major farm machines on rice farms in Riau Province

4.2.2. Mechanical Power Availability

As outline above, the most common types of farm machines used on rice farms in Riau Province are four-wheeled tractors, hand tractors (including rotary tillers, moldboard tillers, hydro tillers, and cultivators), power threshers, water pumps, dryers, and rice milling units (RMUs). The increased availability of farm machinery has gradually contributed to raising farm power over the past 10 years to the point, whereas draught animals are no longer used for rice farming operations in Riau Province.

As shown in Table 4.3, the availability of mechanical power in terms of horsepower per hectare ranged from 0.25 to 0.38 hp/ha with an average of 0.31 hp/ha annually during 2001–2010. This power level is very low compared with that attained by the Philippines (1.36 hp/ha; Elepaño *et al*., 2009) and India (1.81 hp/ha; Singh *et al*., 2010).

The rate of mechanical power also showed rather slow progress, growing by approximately 0.75% annually, with cultivated area increasing at a rate of 3% per annum.

However, the simple regression analysis showed that the relationship between mechanical power and cultivated area had no statistically significance at the 95% confidence level.

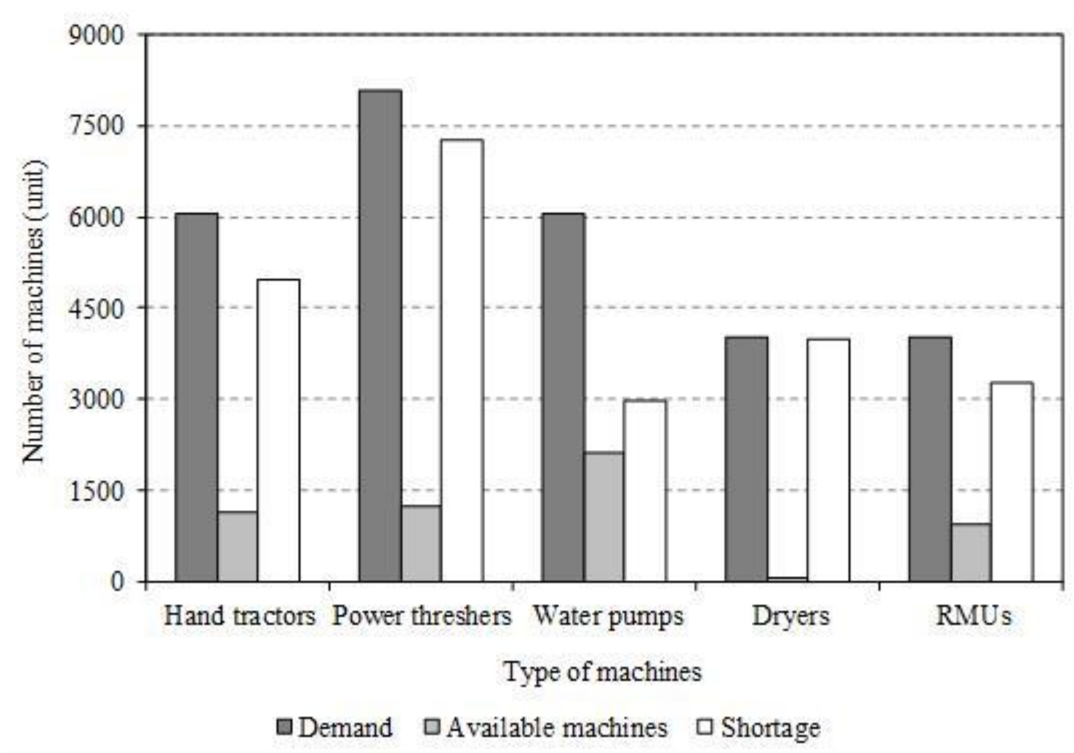
Table 4.3. Mechanical power, cultivated area, and the density of farm machines in Riau Province during 2004–2013

Year	Mech. power (hp/ha)	Cultivated area (1000 ha)	Density (Unit/1000 ha)					
			Four-wheel tractors	Hand tractors	Water pumps	Power threshers	Dryers	RMUs
2004	0.28	120.77	0.23	6.51	5.93	9.55	0.81	8.73
2005	0.29	111.68	0.32	7.18	6.51	7.99	1.44	9.48
2006	0.25	121.21	0.45	6.36	6.56	7.43	0.62	6.89
2007	0.28	121.37	0.39	6.13	13.41	6.15	0.49	7.87
2008	0.29	117.37	0.42	6.27	13.96	6.36	0.50	8.14
2009	0.38	132.37	0.36	9.79	25.52	8.31	0.48	6.72
2010	0.32	134.47	0.23	8.05	22.90	5.94	0.33	5.68
2011	0.48	115.57	0.30	17.12	26.65	9.60	0.43	8.02
2012	0.54	111.77	0.21	14.41	41.82	11.46	0.46	7.32
2013	0.52	102.41	0.28	16.80	13.97	21.43	0.12	9.72
Average	0.36	119.41	0.31	9.86	17.72	9.42	0.56	7.86
Annual growth (%)	8.76	-1.77	6.70	16.60	22.05	14.77	-7.95	3.47

Source: Food Crops Service of Riau Province, 2005-2014

Table 4.3 also shows the density of the available farm machines during 2001–2010 in Riau Province. According to Herdt (1983), the density of machines such as hand tractors can determine the stage of the mechanization process. During 2001–2010, the number of hand tractors ranged from 6.51 to 17.12 units/1000 ha with an average growth of 8.51% annually. This finding indicates that the mechanization process remains low in Riau Province, between the early stage (2.5 units/1000 ha) and take-off stage (20 units/1000 ha). Hence, rice farming operations, especially land preparation, are difficult to mechanize completely in Riau Province owing to the insufficient availability of the necessary farm machines.

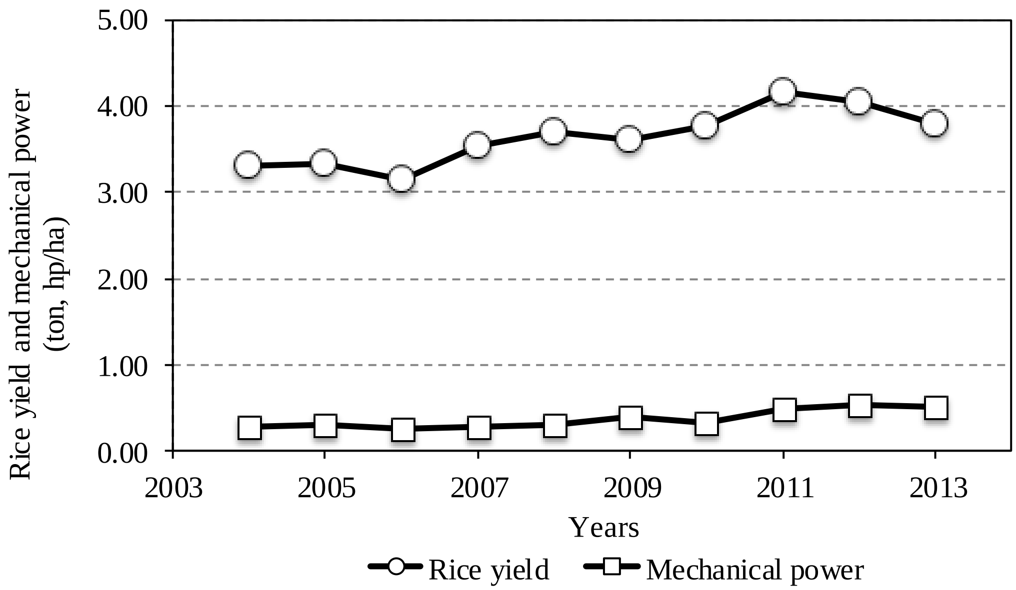
From 2004 to 2013, the density of hand tractors, four-wheeled tractors, water pumps, power threshers, and RMUs increased annually with water pumps was the highest growth (22.05%), whereas water pumps decreased at an annual average of -7.95%. Our interviews revealed that water pumps have become important for increasing the annual cropping rate from 100% (only on wet season) to 200% (on both wet and dry seasons). In other words, because the water pumps transport water from wells or rivers into paddy fields, which lack water during the dry season, so farmers can grow rice in both seasons.



Source: Food Crops Service of Riau Province, 2005-2014

Figure 4.7. Annual demand, availability, and shortage of farm machines on average in Riau Province during 2004-2013

Although farm machines have advanced slowly over the past 10 years, rice farmers have become increasingly dependent on mechanization to perform both tractive and stationary operations. Fig. 4.7 describes the annual demand and shortage for five types of farm machines on average in Riau Province. The greatest demand is for power threshers (8,072 units) and the least is for dryers and RMUs (4,036 units each). In addition, dryers suffered the largest shortage (98%) compared with water pumps (49%). These results reveal that the availability of all five types of farm machines is less than half the level of demand.



Source: Food Crops Service of Riau Province, 2005 - 2014

Figure 4.8. Rice yields and mechanical power availability in Riau Province during 2004-2014

The mechanical power available in Riau Province remains below that required to increase rice yields and achieve an efficient level of farm production. Fig. 4.8 illustrates that rice yields have increased lower the past 10 years in line with the slow development of mechanical power. During the period of 2004-2013, the rice yield increased at about

1.73% annually, while the increased mechanical power was 8.76% annually. This finding implies that the growth in rice yields has been influenced by factors other than the available mechanical power, such as improved seeds, fertilizer use, pest and disease control, and better irrigation.

4.3. Mechanization Capacity, Labor and Time Requirements of Rice Farming

4.3.1. Mechanization Capacity

Rice farming mechanization in Riau province varies widely from hand tools to power intensive machines such as hand tractor (power tiller), water pump, thresher, dryer and rice milling unit/huller. While animal-drawn implement was very rare to be used in rice farming system in the province primarily since farm machines have been extensively introduced to rice farmers in the 1990s. Currently, farm operations which require relatively little power are still performed completely by human being such as seeding, transplanting, weeding, harvesting, and drying. On the other hand, farm operations which require high power inputs are mostly performed by machines such as land preparation, threshing, and milling. In addition, rice farms which have very small in size (< 0.2 ha) are worked completely by human labor with manual tools except for threshing and milling operations.

By using Equation 1, the rice farming mechanization capacity was calculated and the results are presented in Table 4.4. Although increasing over the ten years period, the rice mechanization capacity remained very low except for milling and varied on each stage of operations. The mechanization capacity ranged from 17.2% for drying to 100% for milling with an average of 22.3% in 2006 and these figures were found to range from 5.9% to 100% for drying and milling, respectively, with an average of 27.8% in 2013.

Generally, the mechanization capacity has increased to about 20.6% during a period of 2006-2013. However, mechanization capacity for drying decreased from 17.2% in 2006 to 5.9% in 2013. Interview with farmers revealed that they preferred to dry paddy under sun (solar energy) than machine that requires high costs. Comparing nationally mechanization capacity (about 30% according to Handaka, 2005) to our results indicates that rice farming mechanization development in Riau has experienced a lower process. In addition, the average of rice mechanization capacity in the province in 2010 is slightly higher compared to the capacity found in Philippines at 21.7% in 2005 (Elepaño et al., 2009).

Table 4.4. Variation of mechanization capacity on rice farming operations in Riau Province (%)

Type of operations	2006		2013		Tools and machines used and capacity
	Hand-tool*	Mech. power	Hand-tool	Mech. power	
Land preparation	73.0	27.0	67.1	33.1	Using hand tractor with capacity = 40 $ha.yr^{-1}$
Seeding and trans-planting	100.0	0	100.0	0	Using traditional tools, such as hand pushed seeders and planting stick.
Weeding	100.0	0	100.0	0	Using traditional tools, such as hoe and weeding hoe
Pest control	100.0	0	100.0	0	Using hand sprayer
Irrigation	79.2	20.8	54.5	45.5	Using water pump with capacity = 30 $ha.yr^{-1}$
Harvesting	100.0	0	100.0	0	Using traditional tools, such as sickle and jagged sickle.
Threshing	75.2	24.8	73.5	26.5	Using power thresher with capacity = 30 $ha.yr^{-1}$
Drying	82.8	17.2	94.1	5.9	Using dryer with capacity = 120 $ton.yr^{-1}$
Milling	0	100.0	0	100.0	Huller and rice milling unit = 200 $ha.yr^{-1}$

According to Table 4.4, the low capacity of rice mechanization indicates that the number of farm machines available in Riau Province have not been sufficient for rice farming operations. The machinery application in rice farming operations is restricted to land preparation, irrigation, threshing, drying, and milling operations. The shortage of farm machines available in the province is a major factor causing such restrictive operations.

4.3.2. Time Requirement in Rice Operation Practices

Under condition of rice mechanization level in 2013, total time required for 1 ha of rice farm varied from 717 to 1,206 hours with an average of 851 hours as presented in Table 4.5. This finding is higher compared to the average working hours for rice cultivation under mechanized labor in South Sulawesi to about 588.8 hours in 1980, excluding drying and milling operations (Maamum et al., 1983). In addition, the average working hours in the Riau Province is much higher compared to the current national average of working hours for rice cultivation per hectare in Japan to only 350 hours under full mechanized system (Sasaki, 2002).

If working day is assumed by 7 hours according to the present survey, the total operation hours are equivalent to 122 working-days/ha (This result is obtained from dividing 851 hours by 7 hours per day). There was variation in total working time requirement among farmers as shown by coefficient of variation. The variation may be due to differences in farm size, level of mechanization, field conditions, etc.

Table 4.5. Average time required per hectare for various rice operations in Riau Province in 2013 (h/ha).

Type of operations	Human labor				Machine power	Total hours	*CV** (%)
	Family member		Hired labor				
	Man	Woman	Man	Woman			
Land preparation	0	0	0	0	26	26	29
Seedling	0	35	0	0	0	35	38
Transplanting	39	112	0	52	0	203	33
Weeding	38	98	0	18	0	154	39
Fertilizing	16	26	7	6	0	55	49
Pest control	29	8	0	0	0	37	41
Harvesting	55	64	7	53	0	179	48
Threshing	0	0	0	0	20	20	23
Cleaning	0	39	0	0	0	39	35
Transportation	44	0	0	0	0	44	62
Drying	24	25	0	0	0	49	48
Milling	0	0	0	0	10	10	21
Total	245	407	14	129	56	851	13
Percentage on total hours	28.8	47.8	1.7	15.2	6.6	100	-

*Note: * coefficient of variation*

From Table 4.5, the use of machine power for carrying out various rice operations created a little variation of operation hours between farmers as shown by smaller value of coefficient of variation compared to use manual tools. Farm operations by machine power such as land preparation (29%), threshing (23%) and milling (21%) had relatively smaller variation compared to other operations (ranging from 33% for transplanting to 62% for transportation) by human power. The results suggest that mechanized farming scheme should be applied to a wide range of operations not only for land preparation, threshing, and milling at present but also for transplanting, pest control, harvesting, and transportation. Thus, the level of rice mechanization can increase and farm operations can be done in timely and shorter time. Mechanization purposes such as improving timeliness for transplanting and harvesting and reducing human labor demands for peak farm operations can eventually be achieved.

Regression analysis was performed on the time requirement data and revealed a negative relationship between time requirement and farm rice cultivated area as described by following equation (Fig. 4.9).

$$Y = -97.25X + 931.70 \qquad \text{with } R^2 = 0.19$$

Where: Y is the time requirement (h/ha) and X is the farm rice cultivated area (ha).

The linear regression analysis results that it could explain only 19% of the observed variation in time requirement for hours per hectare. It means that farm cultivated area in hectare alone do not provide an adequate basis for explaining or predicting time requirement of farm operations. This suggests that other factors, not considered here, are important determinants of time requirement, namely operator skill, machine age, operation type and working conditions.

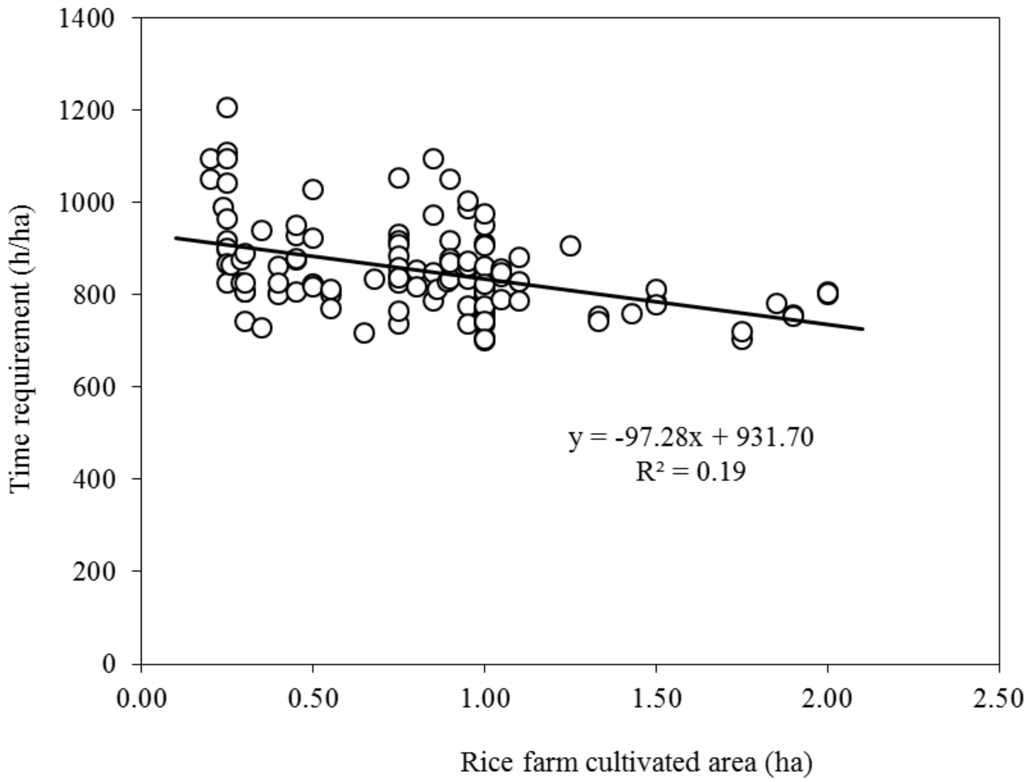


Figure 4.9. Relationship between farm size and time requirement

Most of the total hours (93.2%) came from human labor and the rest 7.8% was from machine power. It was observed that farm operations which involve farm machines included only land preparation, threshing, and milling, while other operations were employed entirely by human labor. The most human labor was required for transplanting, weeding, and harvesting operations that consumed about 63% of the total hours for rice production (Fig. 4.10).

According to Table 4.5, about 76.5% of the total hours of farm operations were carried out by family labor while the rest were carried out using hired labor. Farm operations which employed hired labor with manual tools were transplanting, weeding, fertilizing, and harvesting. It was also found that farmers who own farm size more than

0.5 ha frequently used hired labor. This result indicates a relatively low demand for hired labor using manual tools in the survey areas. Farmers confirmed that labor demand decreased gradually with increasing farm machines used in rice farming. Approximately 90% of the total hired labors of 195 hours were woman labor and the rest were man labor. This may be due to the woman labor was very dominant to perform rice farm operations in the survey areas, contributing about 63.5% compared to 36.5% of human labor for total. The hired labor was paid IDR 40,000 (US $ 4.4) and IDR 60,000 (US $6.7) per working day for woman and man, respectively.

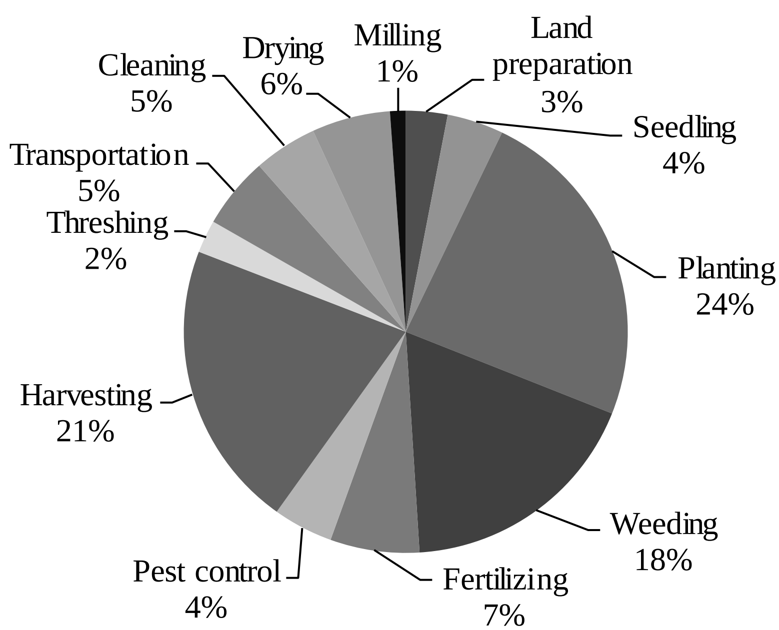


Figure 4.10. Contribution of relative operation time on total time requirements for rice farm operations

The result in Table 4.5 indicates that farm operations by mechanical power require shorter time than human and draught animal powers. For instance, land preparation, which is the most power intensive operation for rice farming required time to only 26 h/ha or about 6% of the total hours for rice production. Hand tractor equipped with single moldboard plow and circle puddler for plowing and puddling, respectively were the most common machines used by small farmers. Interview with farmers (according to farmers' experience before using hand tractor) revealed that the actual working time required for the same operation was about 588 h/ha by human or 82 h/ha by draught animal (Table 4.6). Besides shorter time, mechanized land preparation with hand tractor, for example, is also favored because its cost is considerable lower than animal and human powers; i.e., IDR 800 thousand/ha (US $89) compared to IDR 1,800 thousand/ha (US $200) and IDR 4,500 thousand/ha (US $500) for draught animal and human labor, respectively. It is important to be noted that the application of machine power in farm operations could relieve pressure on human labor at the critical time of high labor demand particularly during tillage period.

Table 4.6. Comparison of time requirements and cost for three methods of land preparation of rice farming in Riau province

Type of implements	Time requirements (h/ha)	Cost (IDR/ha)
Hand tools	588	4,500,000
Animal	82	1,800,000
Hand tractor	26	800,000

4.3.3. Labor Requirement and Cost in Rice Operations

The farm machines used by rice farmers in Riau Province are small power types (ranging from 5 to 23 hp) such as rotary tillers, moldboard plows, hydro tillers, power threshers, water pumps, and RMUs. In fact, the limited number of available farm machines on farm has restricted the operations that can be mechanically worked.

Currently, power-intensive operations such as land preparation, threshing, water pumping, and milling have just mechanized. While, other operations, such as seeding, planting, weeding, fertilizing, pest control, harvesting, cleaning, transportation, and drying, are still performed by human labor. According to Takeshima and Salau (2010), in the early stage of agricultural mechanization, the use of mechanical power is limited to power-intensive operations that require little control.

Table 4.7. Labor requirements and costs of rice farming operations

Type of operation	Man-days/ha	Machine-days/ha	Equivalent to hp/ha[a]	Equivalent to kW/ha	Cost/ha (IDR)	Cost/kW (IDR)
Land preparation	-	3.25	221.00	164.80	1,200,000	7,282
Seeding	3.50	-	2.80	2.10	210,000	100,000
Planting	21.25	-	17.00	12.75	1,275,000	100,000
Weeding	16.25	-	13.00	9.75	975,000	100,000
Fertilizing	4.75	-	3.80	2.85	285,000	100,000
Pest control	4.38	-	3.50	2.63	262,800	100,000
Harvesting	19.25	-	15.40	11.55	1,155,000	100,000
Threshing	-	2.50	110.00	82.00	793,430	9,676
Cleaning	3.88	-	3.10	2.33	232,800	100,000
Transportation	5.50	-	4.40	3.30	330,000	100,000
Drying	4.50	-	3.60	2.70	270,000	100,000
Milling	-	1.25	150.00	111.90	906,800	8,104
Total	83.26	7.00	547.60	408.66	7,895,830	-

Note: An adult man is assumed to be equivalent to 0.1 hp
One-day working equals 8 hours with IDR 60,000 the human labor wage
Average rice production was 4,534 kg/ha.

As shown in Table 4.7, labor requirements per hectare for mechanized operations are only 7 machine-days compared with 83.26 man-days for manual operations. These labor requirements were calculated from the ratio of the total hours required for certain operations relative to the average number of working hours per day (e.g., eight). This finding shows that rice farming operations still predominantly depend on human power using traditional hand tools.

However, labor requirements varied considerably according to the type and size of farming operations. Land preparation, the most labor-intensive and costly rice cultivation operation, is performed by machine power at the beginning of the growing season. Rotary and power tillers are the most popular machines for performing such activities, although some farmers use hydro tillers if the water supply is sufficient. As shown in Table 2, land preparation takes approximately 3.25 machine-days per hectare and costs IDR 1,200 thousand (US $133) based on local wage rates, representing approximately 15% of the total operation costs (Fig. 4.11).

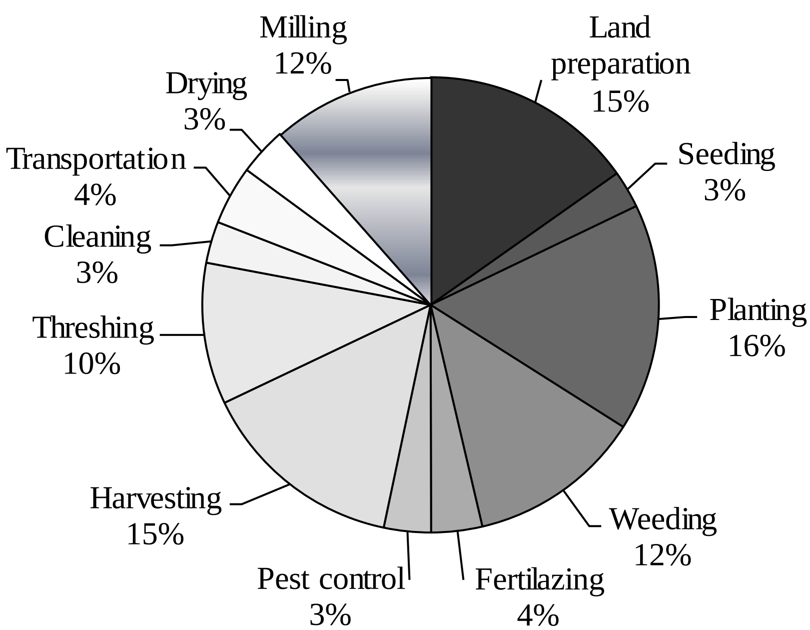


Figure 4.11. Contribution of relative cost components to the total cost of rice farming operations

Manual threshing and milling operations have been replaced by power threshers and RMUs, respectively. These activities now take 2.50 and 1.25 machine-days/ha for threshing and milling, respectively, and cost IDR 793 thousand (US $88) and IDR 907 thousand (US $101) per hectare, accounting for 10% and 12% of the total operation costs. These costs were calculated by multiplying total rice production per hectare by cost per kilogram (i.e., IDR 175 (US $0.019) for threshing and IDR 200 (US $0.022) for milling). Our discussions with farmers revealed that using mechanical power for these operations helps reduce labor and costs considerably, thereby minimizing yield losses, especially during threshing. Similarly, Sison *et al.* (1985) argued that the major effect of adopting machine power is the significant reduction in labor requirements for land preparation and mechanical threshers for postproduction operations.

Planting and harvesting are also highly labor-intensive rice farming activities. Srivastava *et al*. (2006) claimed that completing certain farming operations such as planting and harvesting in a timely manner increases yields and improves profitability. Delayed harvesting for one week after maturity, for instance, can lead to yield losses of 3.35–8.64% (Sunanto *et al*., 2011). Manual planting and harvesting is laborious and costly. Approximately 21.25 and 19.25 man-days/ha are required to plant seedlings and harvest rice by using a serrated sickle, respectively. Thus, planting incurs the largest cost per hectare (IDR 1,275 thousand or US $142) followed by harvesting (IDR 1,155 or US $128). These costs were computed by multiplying the number of man-days by the labor wage per day (IDR 60 thousand or US $6.67). Planting and harvesting costs thus account for 16% and 15% of the total operation costs, respectively (Fig. 4.11).

Seeding, weeding, fertilizing, pest control, cleaning, transportation, and drying are also still manual practices. There are no significant differences in labor requirements for each of these operations, except for weeding, which depends greatly on the weed-growing conditions and thus the frequency of weed control. Generally, the first weeding is carried out 10–12 days after plantation and subsequent weeding is performed every 10 days depending on the growing conditions. Approximately 16.25 man-days/ha are required to perform manual weeding, and this costs IDR 975 thousand (US $108) or approximately 12% of the total cost of rice operations. Overall, it was estimated that the total cost of rice farming operations is IDR 7,895.83 thousand (US $877), consisting of human labor (58%) and mechanical power (42%).

Further, the mechanical power can be estimated by multiplying the number of working hours by the average nominal horsepower of one machine, while human power was estimated by multiplying the number of working hours by average human power output. The result in Table 4.8 shows that the total power required to perform rice farming operations was 547.6 hp-h/ha, with farm machines accounting for 481 hp-h/ha (88%) of the total power required compared with human labor 66.6 hp-h/ha (12%).

According to Odigboh (1999) and Sahay (2004), an adult man can produce on average approximately 0.1 hp (0.075 kW) of power output. The total power requirement above is thus approximately 408.66 kWh/ha, consisting of 358.7 kWh/ha from machines and 49.96 kWh/ha from human labor. The results were calculated by multiplying total horsepower by a conversion factor of 0.75.

Table 4.8. Power requirements and cost for performing rice operations in Riau province.

Power Sources	Power requirements		Cost (IDR/kWh)
	hp-h/a	kWh/ha	
Human labor	66.6	49.96	100,000
Machine power	481.0	358.70	7,280
Total	547.6	408.66	-

The power requirement varies considerably depending on the power source used and type of operation performed. Mechanized farming operations are less time-consuming and incur a lower cost per kWh. By dividing the cost per hectare by the required energy, we can show that land preparation, for instance, costs only IDR 7.28 thousand (US $0.81) per kWh compared with IDR 100 thousand (US $11.11) per kWh for each manual operation. This result indicates that the use of farm machinery makes lower operation costs. Therefore, farmers should be encouraged to adopt mechanical power in order to shorten the time needed to perform farming activities, reduce cost, and thus increase operational efficiency.

4.4. Characteristics of the Sample Tractors

Of the 62 tractors surveyed, 55% were manufactured by Yanmar, 29% by Kubota, and the rest by other manufactures. The tractors averaged 4.7 years of age with a ranging from 1 to 12 years old. The engine power ranged from 7.5 (5.6 kW) to 10.5 hp (7.8 kW), with 8.5 hp (6.3 kW) being the most common type. The tractors were equipped with pairs of iron wheels, single moldboard plows, puddlers, and wetland circle puddler. The iron wheel was used to prevent tractors becoming stuck in deep mud. The moldboard plow is commonly used for primarily tillage (plowing) and the other implements are for secondary tillage (puddling) (Figure. 4.12).

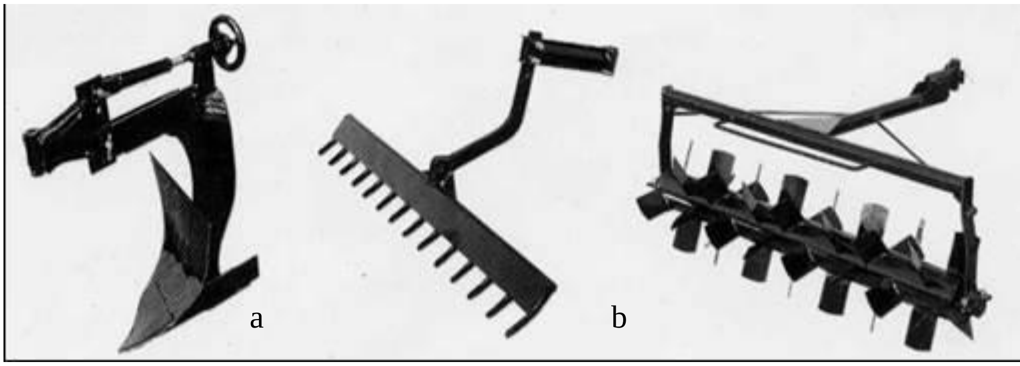


Figure 4.12. Domestically designed implements for hand tractors: (a) Single moldboard plow, (b) Harrow, and (c) Wetland circle puddler

All of the tractors and implements were produced by domestic manufacturers located in Java and distributed by their dealers to Pekanbaru (capital of Riau Province). The machines were purchased from the dealers, who offered farmers purchase discounts rather than guarantees.

Figure 4.13. Primarily tillage operation using single moulboard

4.5. Tractor Work and Use

Tractor work mostly concentrated on land preparation for growing rice. In survey areas, the rice is grown in widely diverse production environments, including wetland (irrigated lowland) and dry land (rain-fed lowland and upland). Tillage works for

Figure 4.14. Secondary tillage operation using puddler

wetland paddy are usually performed twice; primary tillage and secondary tillage. Secondary tillage is done about one week after primary tillage worked. Fig. 4.13 and 4.14 shows tillage operations by farmers in Riau Province.

The tractors that worked in irrigated areas (including tidal-affected land) were mostly used twice a year under double cropping systems, while those used only once in rain-fed paddy field areas under single cropping system. Based on these conditions, the average work of tractors was 52 days seasonally ranging from 20 to 56 days or less than 2 months. There was quite a variation of annually operation among tractors due to local climate conditions.

From Table 4.7, it is found that working hours of tractors were 7.5 h/day on average. There was a little variation across tractors as shown by coefficient of variation due mainly to different number of operators and local custom of the working hours. The working capacity was also found to slightly vary among tractors with an average of 22.5 h/ha for both operations. The required time was longer than the national average and similar operations in West Java at 14.5 h/ha (Singh and Siswasumarto, 1988) for a tractor of the same size. Field plot sizes and operator skills were possible main causes for the differences. The working capacity was found to differ between plowing and pulverizing operations. The pulverization operation required more time because this step needed to be repeated several times to complete the work. The length of working capacity for both operations also depended on supplying water into the field.

Table 4.9. Field measurement of tractor use

Items	Range	Average	CV* (%)	National range**
Working hours (h/day)	5 – 9	7.5	13	8
Working capacity (h/ha)	16 – 31	22.5	22	14 - 17
Ploughing	6 – 14	9.7	25	
Puddling	8 – 17	12.8	25	
Annual use in hectare	5 – 40	21.4	47	40 - 60
Own farm	0.25 – 4	1.2	78	
Hired service	4.5 - 37	19.9	49	
Wet Season	3 – 25	14.2	39	
Dry Season	0 – 20	7.2	101	
Annual use in hours	140 - 960	458	46	

*Note: * = Coefficient of variation*
*Source: ** =Central Bureau of Statistics, 2003.*

Most farmers did "custom hire" for neighboring farmers in addition to work on their own farms. The average annual use was 21.44 ha and this is equivalent to 458 h. About 95% of the annual work was from the custom service and the remaining 5% was from the farm alone. The annual use was found to differ between cropping seasons. Approximately 66% of the total annual use was done during the wet season and 34% during the dry season. The wet season, in which the total paddy field areas are usually planted with rice, is the most important season for growing rice (Khan, 1996).

Figure 4.15. Locally made wood trailer attaching on hand tractor

The results are clear that the amount of annual use depends mainly on the number of work orders from hiring farmers and rice cropping patterns. Discussions with farmers revealed that other factors, such as frequency of tractor breakdowns and repair times, shape and size of field plots, operator skill and experience, and the local climate conditions also affected the tractor annual use. For example, by using skilled and experienced operators, the annual use is expected to increase as a result of increasing the speed of tractors and decreasing the frequency of tractor breakdowns.

Although it is not common in the survey areas, about 11% of the tractors were used at least once for transportation activities in short distances. By attaching a trailer to the rear, the tractors were used to carry farm products, firewood, and shopping goods from local market centers during off-seasons (Fig. 4.15). The trailer was made from wood and used car tires by farmers themselves. The cost for making a trailer was estimated to about IDR 400 – 5000 thousand (U.S $47 – 59). The trailer uses concerned the farmers' household works themselves and required times from 8 to 65 h/yr. There is not trailer rental available in the survey areas.

4.6. Tractor Repair and Maintenance

4.6.1. Tractor Breakdowns and Repair Practices

According to the survey, about 95 % of the tractors experienced at least one field operation stoppage in a year due to breakdown problems. It is observed that one or more parts were found to be broken when a breakdown occurred. Most of the breakdowns occurred during puddling operation (68%) followed by plowing and transportation use as 26% and 4%, respectively. The remaining 2% occurred during travelling to and from the field due to poor farm roads. The high frequency of breakdowns occurred for puddling operation due to the operation required heavily stressed tillage work under wet conditions.

Table 4.10. Broken parts, frequency and causes of the breakdowns

Broken parts	Number of cases	Frequency (%)	Causes of breakdowns (%)				
			Operator fault*	Fuel & oil	Field conditions	Poor main-tenance	Other factors
Belts	27	21.6	14.8	-	37.0	29.6	18.5
Injection nozzle	19	15.2	-	52.6	-	-	47.4
Puddlers	15	12.0	-	-	66.7	-	33.3
Plunger	12	9.6	-	33.3	-	-	66.7
Piston ring	12	9.6	16.7	25.0	-	58.3	-
Piston	9	7.2	11.1	33,3	-	55.6	-
Wheel bearing	9	7.2	22.2	-	44.4	22.2	11.1
Wheel bolt/nut	6	4.8	-	-	50.0	33.3	16.7
Connecting rod	5	4.0	20.0	-	-	-	80.0
Oil seal	4	3.2	-	-	25.0	25.0	50.0
Metal	4	3.2	25	-	-	50.0	25.0
Mouldboard	3	2.4	-	-	100.0	-	-

Note: Operator's fault included improper or careless handling of tractor and accidents
Other factors consisted of overload, factory design, and normal wear

The number of broken parts, frequency, and causes of the breakdowns are presented in Table 4.10. According to the table, about 21.6% of the breakdowns resulted from broken belts followed by injection nozzle (15.2%), puddlers (12%), plunger and piston ring (9.6%). They contributed 68% of the total breakdowns and the remaining 32% were caused by pistons, wheel bearings, wheel bolt/nuts, connecting rods, oil seals, metal, and moldboard.

With regard to the causes of the breakdowns, field conditions were main causes of the broken moldboard, puddlers, wheel bearing and belts. Discussions with farmers revealed that the heavy weeds growing on field surfaces; and poor land cleaning that had left tree stumps in the field ground were major causes of the premature breakdowns of implements. Smearing with mud water primarily during puddling operation caused the belts to break faster. Most farmers stated that most belts got broken after operating two or three seasons on the muddy conditions. Furthermore, wheel bearings and wheel bolts/nuts suffered excessive wear due to operation under similar conditions.

Poor maintenance caused mostly piston ring, piston and metal got broken. Interviews with farmers revealed that failure to change oil at the correct times had caused the engine troubles. Survey showed that about 47% of farmers delayed to change engine oil due to follow unauthorized sources in the service schedules, such as past experience, manual test of oil viscosity, recommendation from other farmers etc. Meanwhile, most injection nozzles suffered damages due to fuel and oil. These also caused plunger, piston, and piston ring defects. Presumably, dirt and dust in both the fuel and oil would have caused excessive wear of the components. Jacobs *et al.* (1983) claimed that dirty oil, a lack of oil, or foreign objects can cause the scratches and scores on the pistons. Few farmers said that the use of inferior fuel and oil, resulting from adulteration had also caused frequent damages and major losses. It is because of the fuel and oil were commonly bought from unreliable local suppliers, while gas station that sell subsidized fuel and fine oil is not

Figure 4.16. Broken pudller during puddling operation

found around the village areas. Another consequently, the fuel price is always 20% higher than in the gas station.

Although it is not main causes, operators' fault contributed significantly to the tractor breakdowns. Improper or careless handling of the tractors and rough tractor handling were dominant factors in causing the breakdowns. In addition, besides normal wear, other factors causing the frequent breakdowns were factory design, intense usage, and poor farm roads. According to the experience of some farmers, the pivot of the puddlers broke frequently due to being too small in design. The intense usage of the tractor during peak seasons also contributed to broken parts. It was found that tractors used more than 30 ha annually required engine overhaul after three or four years. The poor road on farm level caused few accidents during travelling to and from the field.

Table 4.11 shows that most parts needed to be replaced after suffering damage and only implements required any repairs. It is because the implements frequently had broken on teeth and the pivot of the puddlers and got fractures on the moldboard blade. These could be repaired easily at any local welding workshop. Nevertheless, few farmers took them out of the area to acquire superior weld quality.

Table 4.11. Broken parts, service need and level, and repairer of tractors

Broken parts	No. of cases	Service need	Service level (%)	Repairer of tractors (%)		
				Farmers (operators) themselves	Local repair shops*	Other repair shops**
Belts	27	Change	81	100	0	0
Injection nozzle	19	Change	26	32	63	5
Puddler	15	Repair	-	0	60	30
Plunger	12	Change	17	8	42	50
Piston ring	12	Change	42	0	16	84
Piston	9	Change	0	0	11	89
Wheel bearing	9	Change	33	0	78	22
Wheel bolt/nut	6	Change	83	100	0	0
Connecting rod	5	Change	0	0	20	80
Seal	4	Change	25	25	25	50
Metal	4	Change	0	25	25	50
Mouldboard	3	Repair	-	0	67	33

*Note: * Repair shops available in or around village area*
*** Repair shops in the regency capital or dealer in province capital*

The results in Table 4.11 also indicate that there were insufficient shops to supply spare parts in the survey areas as shown by low service level. Consequently, many farmers were frustrated when their tractors broke down due to lack of spare parts in village areas. The higher service levels were found for wheel bolt/nut and belts to about 83% and 81%, respectively. An 83% service level means that 17% of the parts demanded were not available. The higher service levels of these parts were, belts for example, contributed mostly by farmers stocks rather than by local suppliers. Similar cases were found only for injection nozzles, plungers, piston rings, wheel bearings and seals. On the other hand, the broken down tractors that resulted from piston, connection rod, and metal damages were subject to delay. Survey showed that a few broken tractors remained idle for a season due to difficulties in getting the spare parts. They had to be procured by order from local (repair) shops or purchased directly from dealers when the spare parts were locally unavailable. It caused procurement of spare parts frequently became costly and was, in some cases, even more expensive than the actual cost of repair.

Moreover, farmers or local repair shops had difficulties in accessing spare part suppliers located out of the village area, so it took longer to find or wait on spare part orders. It has since been discovered that the time required waiting on spare parts ranged from 4 – 30 days with an average of 16 days. It is important that the farmers should keep a stock primarily of readily broken parts to prevent the delayed repair. Nevertheless, the best way to overcome the problems is to establish spare part depots in village areas. It could, for example, help farmers shorten the waiting time to even one day or further still, cut down on transportation costs.

According to Table 4.11, there weren't any suitable workshops to carry-out tractor repairs in the survey area, particularly for the major repair category. Farmers performed minor repairs in a small number of the breakdown cases. There were only 15% of farmers who had the skills to make the repairs and they were trained and experienced operators. Local repair shops that were actually set up to repair local cars and trucks mostly did the minor repairs. Local blacksmiths, for example, welded the broken implements.

In cases of serious breakdowns, such as engine overhauls, most tractors were sent to other repair shops out of the village area and needed 10 – 30 days to repair (Table 4.12). The repair, however, required a high level of skill and sophisticated tools; whereas the local repair shops had inadequate tools and a shortage of mechanics to do the repairs. Consequently, the repair included an extra cost to transport broken tractors long distances.

These results stress the need for adequate repair shops and qualified mechanics in village areas. Discussions with farmers revealed that there was not a local investor interested in establishing a complete tractor repair shop because it would not be economical under the conditions of only a small number of tractors. In addition, farmers had very limited access to expert advice from dealers or to the machinery section of the province's agricultural food service. Also, the agricultural extension officers had no knowledge on how to advise farmers in overcoming tractor problems.

The time required for tractor repair is given in Table 4.12. Repairs which were done by either local repair shops or the farmers themselves required 2.8 h to make a minor repair and 10.9 h for a major repair on average. It is clear that local repair shops in a short time could do the minor and major repairs if spare parts were available locally.

Table 4.12. Actual time required for repairing tractor breakdowns

Repair Categories	Farmers or local repair shops (hour)		Repair shop out of the area (day)	
	Time range	Average time	Time range	Average time
Minor repair	1 – 5	2.8	-	-
Major repair	5 – 21	10.9	10 - 30	17

4.6.2. Technical Skill of Operators

The results listed in Table 4.13 indicate that most operators can perform only the easiest levels of service and repairs. For instance, about 93% of the operators can perform minor services or adjustments on belts and clutch components. However, it was found that about 90% of the tractor operators have received no training or supervised experience in operating and maintaining tractors. Operators commonly learn mostly from other operators (farmers) or are taught by family members. Most of the operators also have little experience (less than 5 years) in tractor operation and little education (illiterate and elementary school level). Illiteracy and the completion of fewer educational levels limit the ability of operators to study the operator's manual and to understand all the instructions.

Table 4.13. Skill ability of operators to service and repair tractors

Service and repair items	No. of operators	Percent	Service and repair items	No. of operators	Percent
Belts	109	93	Injection nozzle	28	24
Air cleaner	74	64	Plunger	17	15
Fuel filter	74	64	Piston ring	6	5
Oil filter	62	54	Piston	6	5
Changing engine & transmission oils	86	75	Connecting rod	6	5
			Metal	6	5
Clutch	109	93	Oil seal	12	10
Wheel bearing	25	22	Implements	17	15

Due to lack of technical skill and training, few operators have the skill to perform major repairs such as repairing a piston ring, piston, connecting rod, and metal. These operators are commonly the ones who are most experienced; in a few cases, these experienced operators can perform major tractor repairs. Discussion with owners revealed that operators with five years or more work experience can perform major repairs or overhauls. Additionally, approximately 10% of operators have received government-sponsored short training courses. Service and repair needs that lie beyond the ability of tractor operators are performed by local mechanics; however, these mechanics have insufficient knowledge and skills to repair tractors. Qualified service technicians are generally clustered at tractor workshops and dealers in the city. In most major repair cases, therefore, the best current solution is to drive the tractor over long distances to the regency capital and to dealers in the province capital, Pekanbaru, for repair.

It is clear that the poor technical knowledge and skills of the operators and local mechanics are due mainly to an inadequate training program conducted by the provincial government. There is no institution provided by the government and other organizations for training tractor operators and mechanics in the Province. The existing training program is performed outside of the Riau Province and is attended by few farmers. Additionally, dealers and their agents do not provide adequate training related to tractor repair and handling at the time of sale.

4.6.3. Maintenance and Repair Facilities

Maintenance and repair facilities are not yet well developed in Riau province. Table 4.14 shows that very few repair and welding shops are available in each regency. Existing shops are divided into government and private repair shops, which receive financial support from the food crops service of the province. While tractors commonly operate in the village area, most of the facilities are located in the remote regency capital. In Siak regency, one of the areas surveyed, workshops are available 26 km from the village. In Rokan Hulu regency, the nearest repair shops are more than 20 km away. Therefore, serious breakdowns occurred are frustrating for most farmers due to inadequate repair facilities available in their village areas.

There are in fact some private repair shops, specifically for truck and car repairs and scattered throughout the village area, that offer a wide range of services. However, most of them lack appropriate tools and suitably skilled mechanics and do not stock sufficient parts, especially for repairing tractors. Therefore, disabled tractors frequently must be hauled by truck and trader cars to repair shops in the city and even to dealers in the province capital for repair. It was observed that most of the repair shops in the city apply inadequate tools and poorly skilled mechanics to repairs that require specialized tools and a high skill level. These conditions increase repair cost and time. Sometimes transportation is not possible, which limits repair options and also increases cost. In order to reduce transportation, distance, and costs, repair shops should ideally be located close to the village area.

Figure 4.17. Local workshop made repairs of breakdown tractors

Table 4. 14. Availability and distribution of repair shops in Riau Province

Regencies	Type and number of workshops		Total
	Repair shops	Welding shops	
Kampar	2	0	2
Indragiri Hulu	0	2	2
Indragiri Hilir	1	0	1
Rokan Hilir	4	1	5
Siak	1	0	1
Rokan Hulu	1	0	1
Kuantan Sengingi	0	0	0
Bengkalis	1	0	1
Pelalawan	0	3	3
Dumai	0	0	0
All Riau Province	11	5	16

Source: Food Crop Services of Riau Province, 2014

Apart from inadequate repair shops, there are hardly any shops selling spare parts in the village or district area. Most spare parts are available at the shops in regency capital or at dealers in the province capital (Table 4.15). Interviews with shop owners revealed that they only stock the best-selling spare parts. Many farmers have no access to the dealers, where are commonly located in the province capital, to procure spare parts. Spare parts not available at the shops can be ordered, but there is no guarantee when these orders will be delivered. The shop owners also stated that spare parts are sometimes difficult to find, particularly for some types and models.

Table 4.15. Place of purchase and price of tractor spare parts

Type of parts	Purchase place					
	Dealer in province capital		Shops in regency capital		Local shops near or within village area	
	Percentage	Price* (IDR1000)	Percentage	Price (IDR 1000)	Percentage	Price (IDR 1000)
Belts	19	40	44	45(13)	37	50(25)
Nozzle	86	195	16	225(15)	-	-
Plunger	86	275	16	315(15)	-	-
Metal	75	63	25	75(19)	-	-
Piston (plus ring)	100	294	-	-	-	-
Bearing	22	96	50	105(20)	33	120(25)

Note: Values in parentheses are percentage increase in price of parts compared to dealers
Rp1000 is equivalent to about U.S. $0.118 according to an average of exchange rate in 2004.
*Sources: *) Based on list price of spare parts in dealer*

Table 4.15 also compares the price of spare parts at the shops in the village area and in the regency capital compared to dealers in the province capital, Pekanbaru. As a consequence, farmers had to purchase spare parts, which were more expensive at a range from 13% to 20% at the shop in regency capital than at dealers, while the price was 25% higher at shops in the village area. The long distance and poor road infrastructure limited access to the city centers and consequently resulted in high transportation and spare parts costs in the village areas.

In addition, the limited availability of gas stations in the vicinity of villages led to increase fuel price. Most farmers purchase fuel from suppliers in the village area at a higher price of IDR 2200/l than prices of IDR 1650/l at the gas stations. Meanwhile, the suppliers obtain diesel fuel from gas stations 25-40 km away. The government subsidizes the diesel fuel sold at the gas station, so the price is cheaper than at fuel suppliers who purchase at the same place. Farmers commonly have no container to stock large amounts of fuel and buy only 5 to 10 liters at one time as a result.

Table 4.16. Repair process of the tractor breakdown at farm level

Repair category	Repair process (%)		
	According to schedule	Delay	
		Inadequate repair and maintenance facilities*	Financial difficulty
Minor repair	84.2	10.5	5.3
Major repair	6.7	60.0	33.3

*Note: * = Spare parts, workshops, and mechanics.*

Of the 125 breakdown cases, approximately 76% required minor repair, and the remaining 24% was in the major repair category. Table 4.16 shows that most minor repairs could be performed on schedule; only 11% of them were delayed due to inadequate repair and maintenance facilities. Meanwhile, about 5% of them were delayed due to financial difficulty of the farmers. On the other hand, about 60% of the major repairs were delayed because of the lack of spare parts, workshops and mechanics in the village areas, while about 33% were due to financial difficulty of the farmers. Only about 7% of the major repairs could be performed according to schedule. Accordingly, some severely damaged tractors remained unserviceable for at least one crop season due to both the lack of spare parts and financial difficulty.

4.6.4. Daily Checks and Service Schedules

Tractor operators are largely responsible for the daily checks and service of tractors. Service and maintenance practiced by the operators were investigated on the subject of daily checks and engine oil changes. Table 4.17 shows that only a minority of farmers perform maintenance on a regular basis. Hose leaks were maintained the most frequently by the farmers, while air cleaners were maintained the least frequently. Other maintenance targets, such as oil levels, belt tension, fuel sediment bowls, and lubrication were only occasionally checked. Maintenance before failure is a key part of safe, efficient operation in the field (Butterworth and Nix, 1983). For example, low oil levels reduce the degree of lubrication and thus cause rapid wear (Jain and Rai, 1980). However, most farmers are accustomed to sending a tractor to a repair shop for service only after it has limited functionality or has stopped operating completely.

Table 4.17. Daily maintenance checks which performed by the farmers

Maintenance checks	Number of tractors	Percentage
Air cleaner	15	24
Cooling water	18	29
Bolts and nuts	20	32
Loose or damaged parts	22	35
Leaks	25	40

Not all records of the servicing periods of the tractors could be known, so some service schedules were recalled from memory in cases where the farmers did not maintain records at all. Typical intervals between engine oil changes are presented in Table 4.16. Most farmers (90%) do not rely on the operator's manual for service interval schedules and only 10% of them follow the manual's instructions thoroughly. Additionally, farmers often use unauthorized sources for service interval schedules. They generally depend on past experience, manual test of oil viscosity, and recommendations from other farmers. A survey conducted by Wertz et al. (1990) in Lancaster County, Nebraska, documented that 42% of the farmers ignored the advice given in the manuals. The different distribution of maintenance practice between the two sets of operators may reflect differences in skill and education.

Referring to Table 4.18, it is seen that forty-three percent of farmers scheduled service more frequently than recommended, while 47% of farmers waited longer than the scheduled interval between service events. However, the appropriate service interval time can be reduced by one-half where tractors are operated in extremely dusty or dirty conditions (Jacobs and Harrell, 1983). More frequent service is, of course, more costly, but the additional cost is expected to correspond to reduced engine trouble. The results imply that the operator attitude toward good maintenance practices is very poor.

Table 4.18. Farmers' schedule of oil service interval in equivalent hour

Service schedule	Equivalent hour		Number of tractors	Percentage
	Range	Average		
According to operator's manual	-	100	6	10
Less than operator's manual	50 - 90	60	27	43
Longer than operator's manual	105 - 280	170	29	47

Oil prices differ between brands, with imported oils being more expensive. The most popular brands used by the farmers are Pennzoil (20% of samples), Mesran (35%), Power plus (40%) and others (5%). Farmers were found to choose oil brands based on oil quality (25%), availability (35%), and price (40%). Farmers commonly use SAE-40 for tractor engines with an average oil consumption of 0.04 l/h. For transmission oil, farmers commonly use Rored with SAE-90 with an average consumption of 0,01 lt/h.

4.6.5. Tractor Cleaning and Storing

The farmers generally clean the tractor engine at the end of the working day and the body and the implement at the end of the working season. In other words, tractors are cleaned thoroughly (engine, body, and implement) generally only twice per year, which allows rusting of the body, iron wheels, and nuts and bolts. Most farmers do not periodically lubricate high-friction parts during field operations, usually greasing them at the beginning of the working season only.

Safety and distance from the house to the field are important considerations of farmers' decisions to shelter their tractors. About 47% of the farmers left their tractors in the field covered with plastic or under a tree, 40% bring back only the tractor engine, and the remaining 13% brought the tractors home after each working season. During off-season, Table 4.19 shows that most farmers (40%) stored the tractors in a shed; other farmers put them on the porch (32%) or left them outdoors (27%). Unavailability of the shed was the primarily reason for tractors being stored outdoors.

Table 4.19. Way of storing tractors during off-season

Storing place	Number of tractors	Percentage
Shed	25	40.3
Porch	20	32.3
Outdoor	17	27.4

Results show that the lack of attention of some farmers towards tractor care and maintenance is, in fact, caused not only by poor skill and knowledge, but also financial problems. Discussions with farmers revealed that most of their farms operated at a subsistence level of production and did not make a profit. Low farm incomes make it difficult for farmers to shelter their tractors. Consequently, some farmers must left their tractors outdoors even when they know the consequences of such action.

4.6.6. Annual Costs of Tractors

The annual costs of the tractor operations were calculated to be IDR 6,99 million (U.S. $823) in average with a range from IDR 1,43 million (U.S. $169) to IDR 8,90 million (U.S. $1,047). The variable costs jointly account for about 62% of the total costs and the remaining 38% is fixed costs. The relative importance of the annual cost items is presented in Table 4.18. Labor is the largest (38%) single costs of the total costs, followed by depreciation (27%) and fuel cost (13%). Repair costs which are frequently the largest costs in other developing countries (Henderson and Fanash, 1984; Bukhari et al., 1988) were found to only about 9% of the total costs. The smaller repair costs are found here because the most tractors (63%) had been operating for less than 6 years, in which not many serious breakdowns were occurred. Interviews with the tractor owners revealed that they commonly did not use the aged tractor for hire operation due to lower power and high rate of breakdowns. The cost of fuel was accounted for about 14% of the total costs. This cost can be vary depending on the place of purchasing of the fuel at which the price is cheaper at the gas station than fuel supplier within villages and the increase of the following the world's oil price. The results also indicate that the largest variation (86%) occurs in the repair costs as shown by the value for the coefficient of variation (*cv*). It may be due to differences in tractor age, annual use, operator skill, maintenance management, and field conditions.

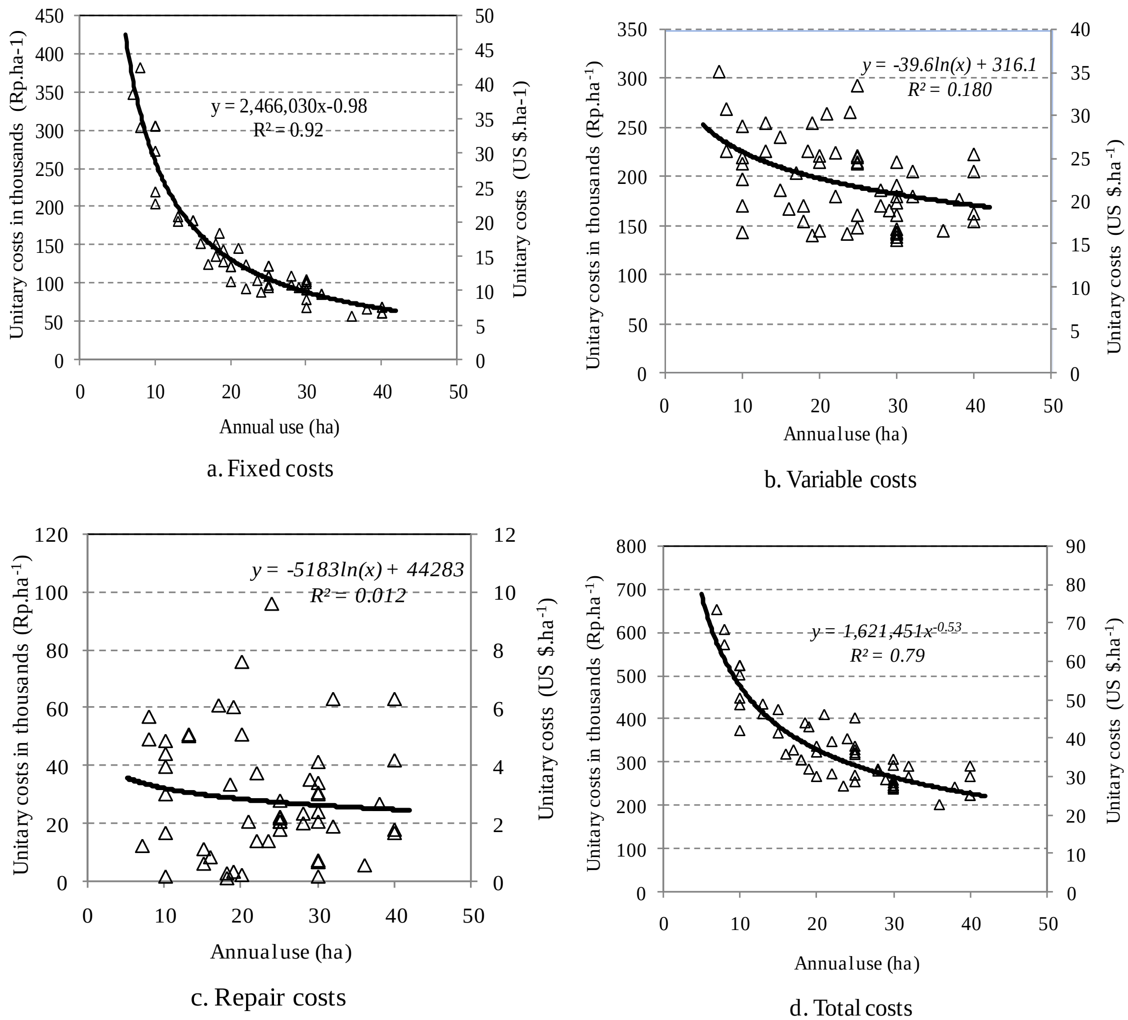


Figure 4.18. The relationship between four cost components per hectare and annual use of tractors

The repair, variable, fixed and total costs of the different annual use rates are depicted in Fig. 4.20. The curves describe in terms of data points which related to the above cost items per hectare to annual hectares of use. The curves show the same trend and negatively correlated. It is clear that as tractor annual use increases, the repair and variable costs per hectare tend to slightly decrease. This finding is in agreement with Butterworth and Nix (1983) who state that repair costs per hectare might fall to some extent with increased annual use. As a result, it is a relatively cheap operation of the tractors since the high rate of use means lower operating costs. The fixed and total costs per hectare show a quick decline with an increase of annual use. This result suggests that there is a great potential to reduce fixed and also total costs by increasing annual hectare of use. It is because the costs spread over the number of hectares and later cost per hectare would be smaller.

Table 4.20. The importance of annual costs item of tractor operations.

Item	Annual cost (IDR)	C.V* (%)	% of fixed or variable costs	% of total costs
Fixed costs	2,631,436 (U.S.$310)		100,00	-
Depreciation	1,891,607 (U.S. $223)	13	71.88	27.04
Interest	739,829 (U.S. $87)	13	28.12	10.58
Variable costs	4,363,086 (U.S. $513)		100,00	-
Repair	640,913 (U.S. $75)	86	14.68	9.16
Labor (operator)	2,633,433 (U.S. $310)	38	60.36	37.65
Diesel fuel	956,731 (U.S. $113)	51	21.93	13.68
Oil and lubricants	132,009 (U.S. $16)	32	3.03	1.89
Total costs	6,994,522 (U.S. $823)	-	-	100,00

*Note: * Coefficient of Variation*

In order to derive function for each cost item above, least squares regression method were used to determine the best fit function. The repair, variable, fixed, and total costs are taken as dependent variable (y) and annual use rates as independent variable (x). Simple functional relationships, such as linear, polynomial, exponential and power equations has tried. The derived functions which gave the best result are presented in Table 4.21.

Table 4. 21. Annual cost functions derived from study data

Cost items	Form	Equation	r^2
Fixed costs	Power	$y = (2.47x^{-0.98})10^6$	0.92
Total costs	Power	$y = (1.62x^{-0.53})10^6$	0.79

The variation of the curves is visible. A power function gave as good a result as any, accounting for 92% and 79% of the observed variations in fixed and total costs per hectare, respectively. These mean that there is a significant contribution of annual use on decreasing fixed and total costs. A logarithmic function could explain only 1% and 18% of the observed variation in repair and variable costs per hectare, respectively (Figure 4.18b and 4.18c). The very low r^2 value suggests that annual use of a tractor is not a major determinant for both repair and variable costs per hectare.

4.6.7. Repair Costs of Tractors

Table 4.22 highlights component costs resulting from repair process. The lack of spare parts and higher prices in the survey area caused a high cost of replacement parts. Of the IDR 685 thousand average annual repair cost, approximately 71% was replacement parts. This is because most spare parts were bought outside the village area, namely from either shops in the regency capital or dealers. Farmers sometimes had to purchase spare parts which were more expensive in the local and regency capital shops than at the dealers.

Table 4.22. Component costs for repairing tractors

Component costs	Value range (IDR 1000)	Average (IDR 1000)	Percentage
Replacement parts	23.75 – 1,965.50	550.05	71
Labor charge	2.50 – 530.00	110.00	14
Maintenance	18.25 – 94.50	37.47	5
Transportation	15.00 – 400.00	75.19	10
Total	20.00 – 2,871.00	685498	100

Note: Rp1000 is equivalent to about U.S.$0.118 according with an average of exchange rate in 2003.

Survey showed the price differences ranged from 38% to 47% and 15% to 33% for local and regency capital shops, respectively. These different prices resulted primarily from long distances between farm areas and shops. In the village of Bunga Raya (surveyed in the Siak Regency) for example, the distance is 26 km to the regency capital and 120 km to the province capital, where complete spare parts can just be purchased. In addition, the spare parts are frequently susceptible to price fluctuations, which arise from the varying exchange rate of the Indonesian Rupiah to the US dollar. Also, the relatively high annual inflation causes spare parts to become increasingly more expensive.

The long distance to centrally located workshops and service facilities increased the difficulty in obtaining spare parts and the high costs of transport are passed on to the customers. It contributed 10% of the total repair costs and about 14% and 5% of the costs were labor and maintenance costs, respectively. The maintenance costs here included greasing for moving parts, cleaning, and protecting tractors during field operations. The low maintenance costs may reflect poor maintenance done by farmers in survey areas.

Survey shows that the lack of attention of some farmers toward maintenance and occasionally delay repairs also attributed to their economic status. Financial problems resulting from low farm incomes created difficulties for farmers wishing to pay workshop costs, purchasing replacement parts, and providing protectors for tractors. In a number of cases, replacement of broken parts was sometimes postponed due to insufficient funds. Farmers are accustomed to sell rice production after harvesting and spend all their money on temporary needs. Consequently, they often have a financial difficulty when the money is needed primarily for repairing and maintenance of tractors. It suggests that a system needs to be arranged for farmers to finance tractor repairs and replacement parts.

4.6.8. Service Charge, Revenue, and Profitability

Economic pressures are encouraging farmers to pay more attention to managing their machinery for maintaining profitability and reducing cost operations. Since tractors are not possible to be utilized to their full capacity on a single small-scale farm, small farmers look for a collective use of the tractors such as custom hire service which has been widely practiced in Riau Province.

In farm practice for custom hire services, the tractor owners mostly received job contract from neighbor farmers. The contractual work between tractor owner and hiring farmer is made directly and agreed on in advance (at the beginning of the season). Tractor service rate was calculated on a hectare basis as a common standard practiced by most farmers in the survey areas. The rate took into account the conditions of the field being worked, distance and size of field plots, weed growth on the field, and prevailing rate of local wages. The level of competition among tractor owners may affect the rate of service charge. These conditions made the service charge relatively vary among owners.

The charge rates for service ranged from IDR 300 thousand (U.S. $35) to IDR 450 thousand (U.S. $53) with an average of IDR 348 thousand (U.S. $41) for both plowing and puddling works. The charges are lower than the government's recommended charge rate of IDR 500 thousand (U.S. $59) per hectare due primarily to low economic ability of hiring farmers and competition among owners. The charge for the service is usually paid in two stages (50 percent for each stage payment), before starting work and after completion of the work. The first payment is intended to be used to buy fuel, oil and other cash costs by the tractor owners. In some cases, the hiring farmers failed to pay off the payment at the second stage (50 percent) after completion of the work and the payment could just be paid off after harvest. Nevertheless, there is not an additional charge for that late payment.

Table 4.23. Average amount of revenue and profitability of tractor operation

Item	Value (IDR.year^{-1})	C.V, %	% of Revenue
Revenue (gross income)	7,920,089 (U.S. $932)	39	
Total costs	6,994,522 (U.S. $823)	25	88.31
Return on labor	3,559,000 (U.S. $419)	73	44.94
Return over variable costs	3,557,003 (U.S. $418)	49	44.91
Profit (net income)	925,567 (U.S. $109)	186	11.69
Break-even area (ha)	17.23		
Payback period (yr)	6.50		
Rate of return on investment (%)	10.02		

Revenue, which was estimated by multiplying the number of annual use (service work and own farm) and the service charge is presented in Table 4.23. In this analysis assumed that rate of service charge for own farm is the same for custom hire service. The annual revenue were derived from the operation averages IDR 7.92 million (U.S. $932) or ranges from IDR 3 million (U.S. $353) to IDR 14 million (U.S. $1647). The variations are caused primarily by difference in the number of job contracts and service charges between owners.

Profit, which is estimated from the differences between revenue and total costs (Riggs et al., 1996), averages IDR 926 thousand (U.S. $109) annually or about 12% of the revenue. The variation in the profit is extreme high as indicated by the value for coefficient of variation (*cv*). According to the survey, about 34% of tractor samples did not make profit because of either lower annual use or higher costs. This suggests the owners to increase the annual use by travelling to other villages to find new customers and eventually will receive more profit. Nevertheless, the owners who operate the tractor themselves got more return from labor wage. According to Table 4.21, the return received by the owners is an average of IDR 3.56 million (U.S. $419) or about 45% of the revenue. This result implies that the owners should operate tractor by themselves to receive more return from the operation. Furthermore, another alternative that can be received by tractor owners from the operation is return over variable costs, accounting for IDR 3.55 million (U.S. $418).

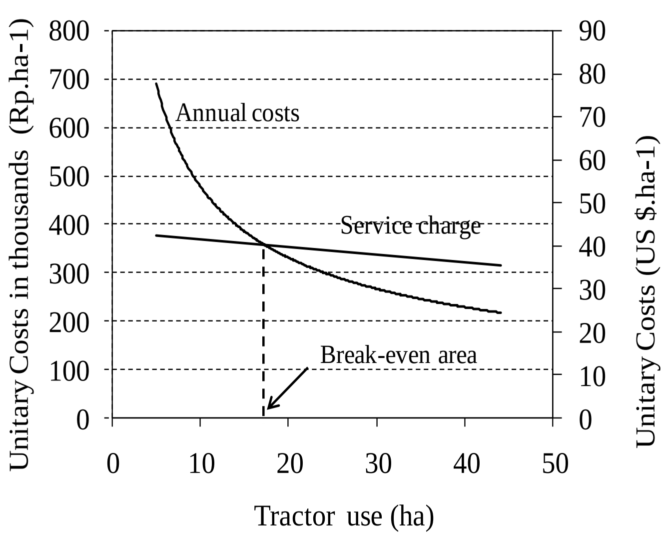


Figure 4.19. Break-even analysis using annual cost and service charge per hectare

The annual tractor use required for economic viability was evaluated using break-even point analysis and the result is illustrated in Fig. 4.19. According to Butterworth and Nix (1983), the break-even area was calculated by dividing the fixed costs per annum by differences between the service charge and the variable costs. The analysis result indicates that the break-even area was found to be 17.23 $ha.year^{-1}$, while the actual average annual used in this study was 23.13 ha. After this point, one additional hectare of use that has made would produce a profit. It is reasonable to conclude that tractors used for custom service, on average, make profit from their operations. The result suggests that the tractor annual use should be more than the figure to economically justify operating a tractor under Riau conditions.

This finding is lower than that derived by Duff (1986) who stated that the annual use should be 25.12 $ha.year^{-1}$ and 62.8 $ha.year^{-1}$ to justify owning for similar tractor type under west Java and South Sulawesi conditions, respectively. He was also found that the small tractor would achieve economic level to about 33 ha in Philippine, 5.8 ha in Thailand. These differences may be caused by the differences in maintenance management of tractor and field conditions among farm sites.

The breakeven area may be affected by changing a number of assumptions made in the analysis, such as costs and service charge. One of the most important assumptions which may be controlled by the tractor owners is the rate of depreciation. We assume that the tractors would last ten years (two years is longer than assumption was made in previous analysis), the annual fixed costs would reduce from IDR 2.63 million (U.S. $310) to IDR 2.25 million (U.S. $265) and the break-even area would then be 14.75 $ha.year^{-1}$. This result suggests tractor owners to prolong economic life of the tractors by taking good care of them and maintenance practices in order to shorten break-even area and also reduce costs.

Furthermore, this break-even analysis can also give a consideration for farmers to decide whether buying a tractor or hiring a tractor contractor service. The result implies that a farmer is more economical to purchase the machine if the annual use is above the area; conversely the contractor service is the less expensive for below the area.

Table 4.23 also presents the average payback period, i.e. the number of years that an investment takes to pay for itself (Butterworth and Nix, 1983). The payback period was analyzed to be 6.5 years of the tractor operation. It means that the tractor investment would pay for itself after that payback period. The rate of return on tractor investment was also found to about 10%. It is relatively good tractor investment for use in hire operation because the payback period is shorter than the expectation of most farmers for tractor economic life of 8 years.

4.7. Factors Affecting Repair Costs

Of the total repair costs, about 95% was spent on repair, while 5% was spent on maintenance. An expensive repair item was to purchase replacement parts (81%) and labor charge to make repairs was 14%. The high price of spare parts and materials contributed to the high cost of replacement parts. The amount spent on repair costs based on tractor age and usage ranges is presented in Table 4.24.

It is clear that the annual repair costs increased as tractors became older and added more hectares of use. The results are in agreement with other sources (Fairbanks et al., 1971; Henderson & Fanash, 1984; Ward et al., 1985; Al-Suhaibani & Wahby, 1999). In addition, the results indicate that there are not large variations occurring in the annual repair costs from one machine to another at the same age, as shown by the low value for the coefficient of variation (*cv*).

Table 4.24. Annual repair costs with different age and annual usage

Age range (years)	Number of tractors	Repair costs (IDR 1000)	Coefficient of variation (CV)	Usage range (ha)	Number of tractors	Repair costs (Rp000)
1	4	41	61	0 – 4	-	-
2	9	358	62	5 - 8	9	174
3	7	485	54	9 – 12	6	304
4	13	421	87	13- 16	5	346
5	5	458	59	17 – 20	9	727
6	8	454	71	21 – 24	5	716
7	6	684	59	25 – 28	9	562
8	5	614	46	29 – 32	13	751
9	2	1,619	79	33 – 36	1	190
10 and above	3	2,099	12	37 - 40	5	1,653
Total	62				62	

Note: Rp1000 is equivalent to about U.S.$0.118 according with an average of exchange rate in 2003

4.7.1. Estimation Results

Estimation results are summarized in Table 4.25. Parameters were estimated by Equation (2) in natural logarithms form using *OLS* method. The coefficient determination (Adjusted R^2 = 61) is moderately high. Simultaneously, all independent variables have a statistically significant at 99.9% confident level. Partially, all estimated coefficients except two of the dummy variables were significant at a range from 95% to 99.9% confidence levels. The signs of the estimated parameters are consistent with our expectations. The positive signs of β_1 *and* β_2 indicate that as the age and usage increase, the annual repair costs increase. Similar signs of coefficient regression were found for horsepower variable which means that the annual repair costs increase with larger engine horsepower. The dummy variable of the operator skill showed highly significant. This result implies that the annual repair costs of tractors have a significantly difference between skilled and unskilled operators.

The ownership and manufacturer dummy variables are not significant. It means that there is no significant difference in the annul repair costs between the two ownership system or among manufacturers. No significance of ownership system is proven by the fact that general maintenance procedure practiced between group and individual owners was almost indifferent. They also rarely received advice from agricultural extension officers or dealer experts. A detailed printout of statistical results is available from the authors.

Table 4.25. Results of the estimated parameters for the regression model

Variable	Parameter	Coefficient	Standard Error	*t*-Statistic
Intercept	α	5.763**	1.894	3.041
Age	β_1	0.946***	0.161	5.859
Usage	β_2	0.657***	0.173	3.804
Horsepower	β_3	1.786*	0.872	2.048
Operator skill (Dummy)	γ_1	-0.753**	0.221	-3.414
Ownership (Dummy)	γ_2	0.045	0.217	0.208
Manufacturer (Dummy)	γ_3	0.033	0.199	0.165
R^2 R^2-Ajusdted F-Statistic Number of sample		0.649 0.611 16.960*** 62		

**** Denotes statistical significance at the 99.9% confidence level*
*** Denotes statistical significance at the 99% confidence level*
** Denotes statistical significance at the 95% confidence level*

4.7.2. Application Model

In order to make a reasonable prediction, insignificant variables are excluded from the model through variable selection using stepwise forward method. The reduced form model of the annual repair costs function in logarithmic linear form is as follows:

$$\ln RC_t = 5.669 + 0.955 \ln A_t + 0.671 \ln U + 1.820 \ln H - 0.744 S \qquad \text{with } \overline{R^2} = 0.624$$
$$(6.151) \qquad (4.179) \qquad (2.221) \qquad (-3.484)$$

and *t*-statistic is in parenthesis.

Here RC_t is the estimated annual repair costs in a year t; A_t is the year of age of the tractor in year t; *U* is the average hectare of use per year; *H* is the engine horsepower; and S is the dummy variable for operator skill.

To facilitate an application in this study, reduced form model of the annual repair costs is formulated into exponential form:

$$RC_t = 290(A_t)^{0.96}(U)^{0.67}(H)^{1.82}e^{-0.74S}$$

As an example application of the use of model, we set up 21 ha of annual use (according to average use in data set), 8.5 hp (the most tractor samples available), tractor was operated by skilled operators, the estimated result during a period of 12 years (according to the oldest tractor in this study) is shown by base estimates in Fig. 4. 20. The results show that the annual repair costs increase each additional year of the machine's life.

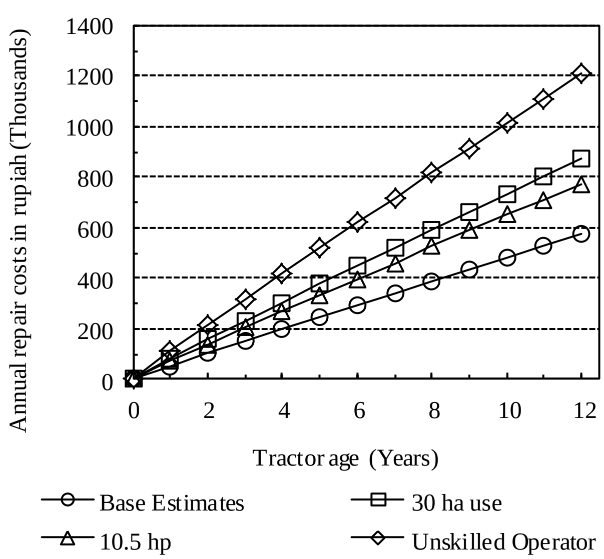


Figure 4.20. Repair cost estimates with changes in hectare of use, horsepower, and operator Skill

With regard to the curve of the base estimates, the annual repair costs increase from IDR 53 thousand in the first year to IDR 576 thousand at the end of the 12^{th} year. This means that the costs increased tenfold during a period of 12 years with an additional increase of IDR 48 thousand annually on averages.

Fig. 4.20 also illustrates the estimated annual repair costs as effect of usage, engine horsepower, and operator skill during the expected life of the tractor. When all other variables held constant, an increase in hectares of use from 21 to 40 per year (according to the highest annual use in this study) leads to higher repair costs over time. The average increase of the annual repair costs is IDR 73 thousand per year and the cost will be IDR 875 thousand or 52% higher than the base scenario at the end of 12^{th} year. The result suggests that the repair costs are suspected to increase more rapidly for heavier-used machines. By using 10.5 hp tractors, the annual increase would be IDR 65 thousand on averages, so the estimated annual repair cost reaches IDR 774 thousand at the same year or 34% higher than the base estimates.

As outlined above, the operator skill is a dummy variable that is statistically significant. The estimate shows that moving from skilled to unskilled operators increases the annual repair costs from IDR 111 thousand in the first year to IDR 1.21 million in the 12^{th} year. This increase is more than two times compared to the base scenario with the average annual increase being IDR 101 thousand per year during the period. The result implies that the annual repair costs increase at the highest rates when using unskilled operators. The result reflects that human factor may be a major cause of tractor breakdowns. It is important to emphasis the training of the tractor operator in order to achieve substantial saving in repair costs.

Based on the estimated annual repair costs, cumulative repair costs throughout the expected life of the tractor can then be predicted. By using similar scenarios, the estimated results, which are expressed as a percentage of the purchase price (%P), are illustrated in Fig. 4.21. The tractor purchase price is assumed to be about IDR 15.5 million (U.S.$1,824) for 8.5 hp tractors. Beginning with lower rates during the first few years, all estimates increase rapidly in later years. The cumulative repair costs would be about 25% of the purchase price at the end of the 12th year for base estimates with an annual increase of about 2.1% per year on average. The increasing rates are about 3.1% and 2.6% on average with the high level of use and larger horsepower, respectively. Consequently, the cumulative repair costs (%P) would be about 37% for 40 ha of annual use and about 31% for 10.5 horsepower at the end of the 12th year. When unskilled operator is assumed, the cumulative repair costs would reach about 52% of the purchase price in the same year with an annual increase of 4.3% on average. Compared to base estimates, this rate is about 27% higher at the end of the 12th year.

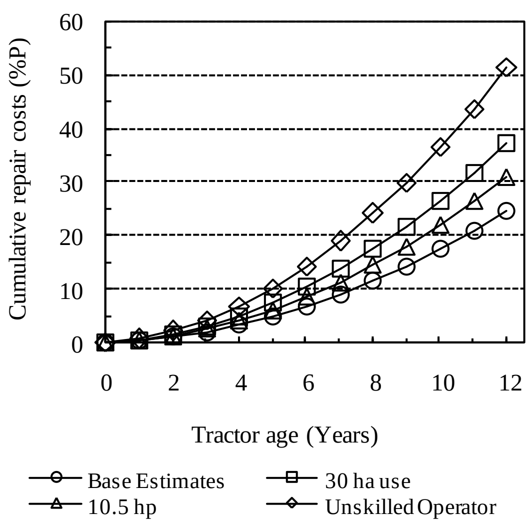


Figure 4.21. Cumulative repair cost estimates in percentage of the tractor purchase price (%p) with changes in hectares of use, horsepower, and operator skill

The lower rates of cumulative repair costs during the first few years of life are due to the tractors only requiring minor repairs and replacement of simple parts. The repair and part replacement thereafter is required more frequently; therefore the repair costs had also substantially increased. Interviews with farmers revealed that tractors firstly required engine overhaul after 3 or 4 years. Bukhari et al. (1988) reported that the repair costs as percentages of the total costs was more than double in the age group of 2 to 4 year old tractors and again it was double when the age of the tractor was 10 years.

The reasonable function proposed in this study provides a useful model to predict the annual repair costs for small tractors. An attempt to use the model for estimation purposes, a person must be aware that the function may be more applicative for the same type of tractors and similar conditions. It is important to note that there are other factors that aren't considered here, but may have substantially influence on the rates of the repair costs and eventually make different results. They are climatic and soil factors, operation type and working conditions, maintenance regime, operating practices and inherent machine defects, and availability of replacement parts.

4.8. Managing Farm Machinery by Custom Hire Services

Custom hire service is a farm machinery business that is managed by either a group or an individual. The purpose of these groups is to provide farm machinery hire services to farmers who are members of the group. Hire services groups owned one or more farm machines of various manufacturers and types. The machines consisted of rotary tillers, moldboard plows, hydro tillers, cultivators, water pumps, power threshers, and rice milling units (RMUs). All the machines were obtained through government aid via a mechanization development program that was funded by the regency, provincial, or national annual budgets.

Based on survey of 20 hire services groups located in seven districts of Kampar Regency, Riau Province and interviews with group managers and custom operators of the groups were obtained results as follow. The number of the machines per group was limited ranging from 1–14 units. They were distributed unequally among the groups of hire services as presented in Table 4.26. The Pulau Lestari group owned the highest number of machines, including two rotary tillers, four hydro tillers, two moldboard plows, two cultivators, one water pump, two power threshers, and one rice milling unit with the total of 14 machines.

Table 4.26. Machinery ownership by hire services groups and average age for various machine types

Machine type	Number of groups	Percentage*	Number of machines	Percentage	Average machine age
Rotary tiller	16	80.0	22	22.4	3.2
Moldboard plow	8	40.0	11	11.2	3.7
Hydro tiller	13	65.0	27	27.6	2.8
Cultivator	6	30.0	7	7.1	2.5
Water pump	7	40.0	10	10.2	3.7
Power thresher	10	50.0	13	13.3	3.2
Rice milling unit	8	40.0	8	8.2	3.1
Total			98	100.00	

*Note: * percentage of the total of 20 hire services groups owning this type of machine.*

The limited number and type of machines was a major obstacle in offering full-fledged services to the group members. Accordingly, the operational services that could be offered to farmers included only tillage, pumping, threshing, and rice milling operations. Since the priority was to serve group members, non-members could not be offered any services except milling. Although there are a few farmers in the survey area who own tillage machines and provide the same service, the number of such machines is also limited. Consequently, the availability of such machines had no effect on the demand for farm machines owned by hire services groups.

Tillage operations are labor-intensive and, therefore, majority of the farmers are heavily dependent on farm machines to perform these operations. Understandably, majority of the farm machines owned by hire services groups were tillage machines (Table 4.26). Of the 98 machines managed by the 20 hire services groups surveyed, about 68% were tillage machines and the rest were stationary machines. Most of the tillage machines were hydro tillers (27.6%), followed by rotary tillers (22.4%), moldboard plows (11.2%), and cultivators (7.1%). Given the local field conditions, both hydro and rotary tillers were suitable for tillage operations. Primary and secondary tillage can be done simultaneously using machines, while tillage using a moldboard plow is done in stages. As compared to the other tillage machines, the working capacity of hydro and rotary tillers was higher at about 0.053 ha/h and 0.048 ha/h, respectively (Table 4.27). Moreover, hydro tillers (also called floating/turtle power tillers) that work even in waterlogged fields were the most economical tillers in Philippines (Villaruz, 1985). The stationary machines largely comprised power threshers (13.3%), followed by RMUs (8.2%) and water pumps (10.2%). They were owned by ten (50%), eight (40%), and seven (40%) groups, respectively.

Table 4.27. Machine-wise seasonal working time, working capacity, and volume of seasonal work

Machine type	Working days per season	Working hours per day	Working capacity		Volume of seasonal work	
			Ha/h	Kg/h	Ha	Mg*
Rotary tiller	22.82	7.50	0.048	-	10.14	-
Moldboard plow	20.45	7.55	0.043	-	8.32	-
Hydro tiller	19.67	7.59	0.053	-	8.15	-
Cultivator	20.00	7.86	0.027	-	1.86	-
Water pump	20.20	7.80	0.040	-	5.50	-
Power thresher	16.70	7.10	-	542	16.22	64.88
RMU	All days	3.62	-	550	5.56	22.25

*Note: * Metric Ton*

Fig. 4.22 illustrates that the number of farm machines per 100 ha varied across the hire services groups. In the case of tillage machines, Karya Indah topped the list at about 8 tillers/100 ha, while Tani Bersama at 0.4 tillers/100 ha came at the bottom. The average for the sample was 2.8 tillers/100 ha. According to Herdt (1983), this indicated that the region has not reached the level of complete mechanization at about 10 tillers/100 ha. All the groups were below this level and about 45% of them were at less than 2 tillers/100 ha. This level, in our view, corresponds to the take-off stage. For other machines such as water pumps, power threshers, and RMUs, the threshold levels have yet not been reached. These results suggest that additions to farm machinery need to be made based on the demand from group members.

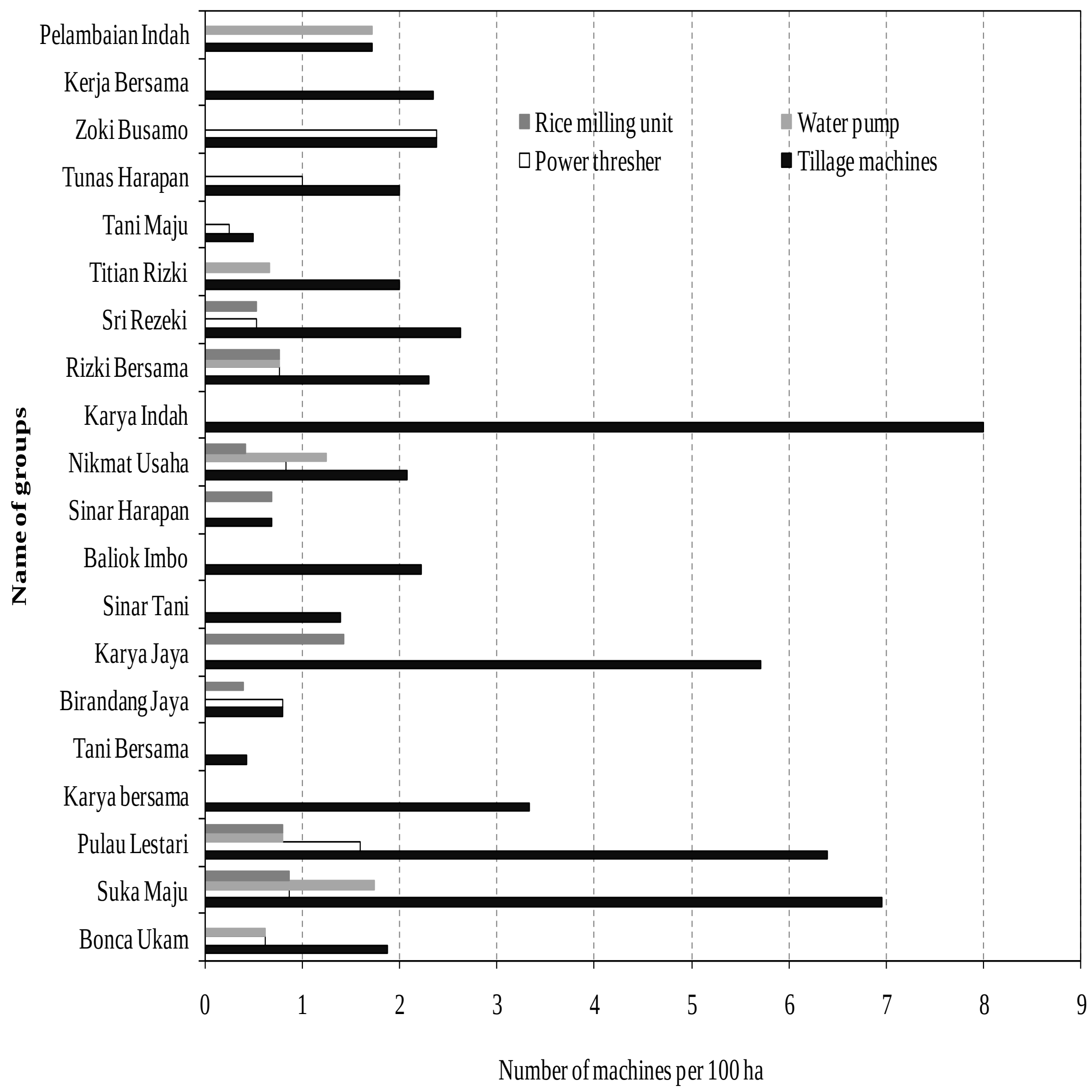


Figure 4.22. Estimated number of farm machines per 100 ha of group coverage area

Most paddy fields in the survey area are rain-fed and, therefore, suffer from water shortage during the dry season. The few irrigated paddy fields also face the same problem during the dry season due to poor irrigation facilities. Consequently, the rainy season has become the main season for rice cultivation because of the relatively sufficient supply of water. It is possible that cultivation levels in the rice planting areas may be close to 100% during the rainy season. Thus, most farm machines are required during the main growing season from September to February and, hence, the demand for machinery hire services is higher during the rainy season.

The volume of seasonal work done by the various types of machines managed by hire services groups is presented in Table 4.25. The size of the working area varied across machines during the season. Rotary tillers topped the list at 10.14 ha, followed by moldboard plows (8.32 ha), and hydro tillers (8.15 ha). The sizes of these working areas were lower than the national range of 20–30 ha. The working areas for cultivators and water pumps during the season were about 1.86 ha and 5.5 ha, respectively. There was low demand for cultivators that are specifically used to plow dry land for vegetable cultivation because only about 20% of group members owned dry land for vegetable crops. Further, the working area for power threshers during the season was 16.22 ha (equivalent to 64.88 Mg), which is lower than the national average of 33 ha with 25 working days per season. The seasonal working area (owned by group members) for RMUs was 5.56 ha (equivalent to 22.25 Mg). A complete record of the area worked on for non-members was not available.

According to Fig. 4.23, the coverage area of each group worked by tillage machines varied from 6% for Tani Bersama to 100% for Karya Indah; the average for the sample was 39%. The coverage area worked by other machines such as water pumps, power threshers, and RMUs was much smaller, as illustrated in Figures 4.24, 4.25, and 4.26. In the case of tillage machines, the small working area was a result of short working days per season, limited number of machines owned by the group, small size of the paddy fields, and low working capacity. The working days for the farm machines ranged from 15–25 days per season, except in the case of RMUs. Although the RMUs were available throughout the season, their utilization remained low at 3.63 h/day. The average seasonal working days and daily working hours of the various machine types are presented in Table 4.25. The seasonal working days of the group machines were lower than the national working days per season at 50–60 days for two-wheel tractors, 50 days for water pumps, and 25 days for power threshers. One of the important reasons for the short working days was the delay in the rice growing season. The late rain fall (a result of climate change) caused many farmers to frequently postpone the growing season.

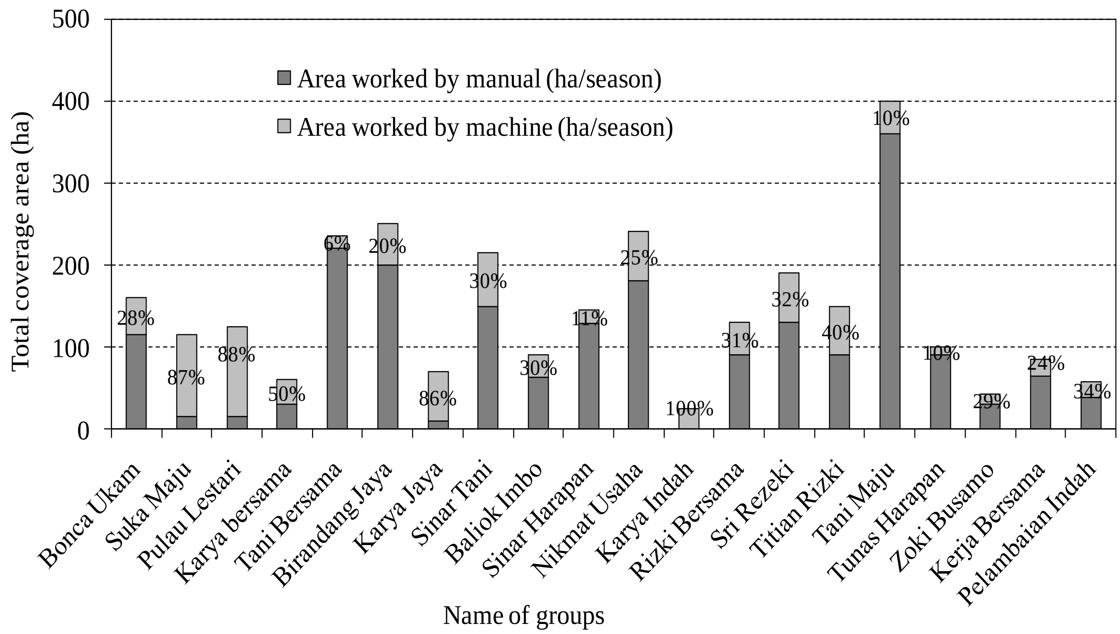


Figure 4.23. Group-wise coverage area worked by tillage machines

Water pumps were used by operators when the supply of water from the irrigation canals was not sufficient for tillage operations. Tillage operations require adequate soil water to facilitate tillage. Therefore, a pump will not be required if the water supply is sufficient. As per Figure 4.24, the coverage area worked by the available water pumps was low, ranging from 2% for Titian Rizki to 21% for Pelambaian Indah; the average for the sample was about 8%. Discussions with operators revealed that the demand for water pump hire services was low during the rainy season.

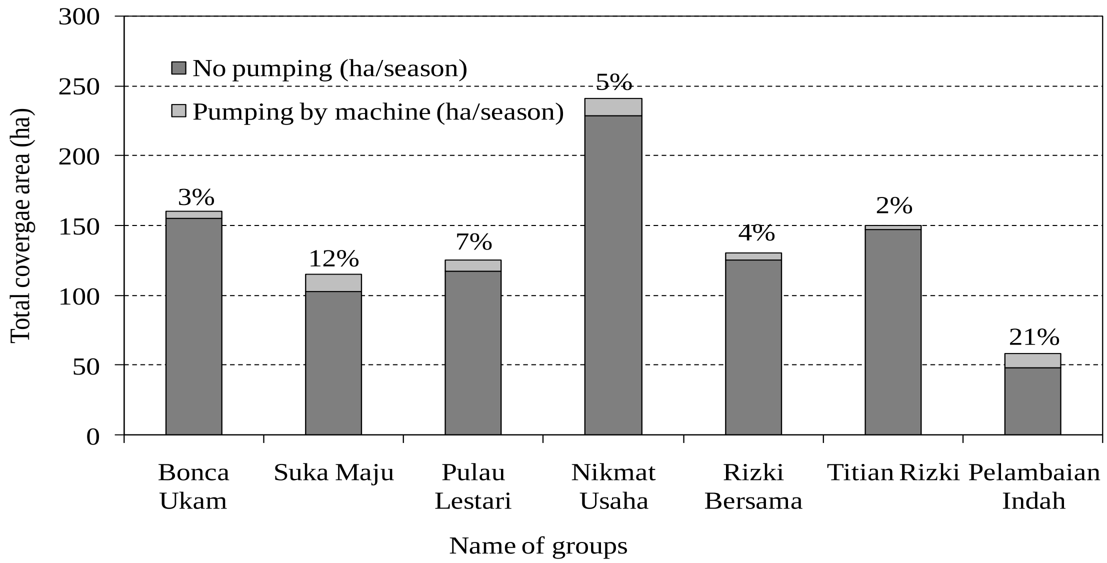


Figure 4.24. Group-wise coverage area pumped by water pumps

The power thresher has become more important than the pedal thresher for the farmers in the survey area. The number of power threshers in the group was not adequate enough to thresh the entire coverage area of the group members. As per Fig. 4.25, the working area worked by available power threshers varied from 3% for Tani Maju to 38% for Zoki Busamo and is based on the assumption of local rice yield of 4 Mg/ha. Around 16% of the coverage area was worked by power threshers and the remaining 84% was worked by pedal threshers or other manual tools. Besides the limited number of machines owned, the use of pedal threshers and traditional methods by farmers was also the reason for the low coverage area. Although pedal threshers and traditional methods (e.g., beating a bunch of panicles against a wooden board) are becoming increasingly unpopular among farmers, many farmers still own such equipment and use it for threshing rice. Even though it was considered impractical to use such equipment due to their high energy consumption, the farmers deemed them the most economical.

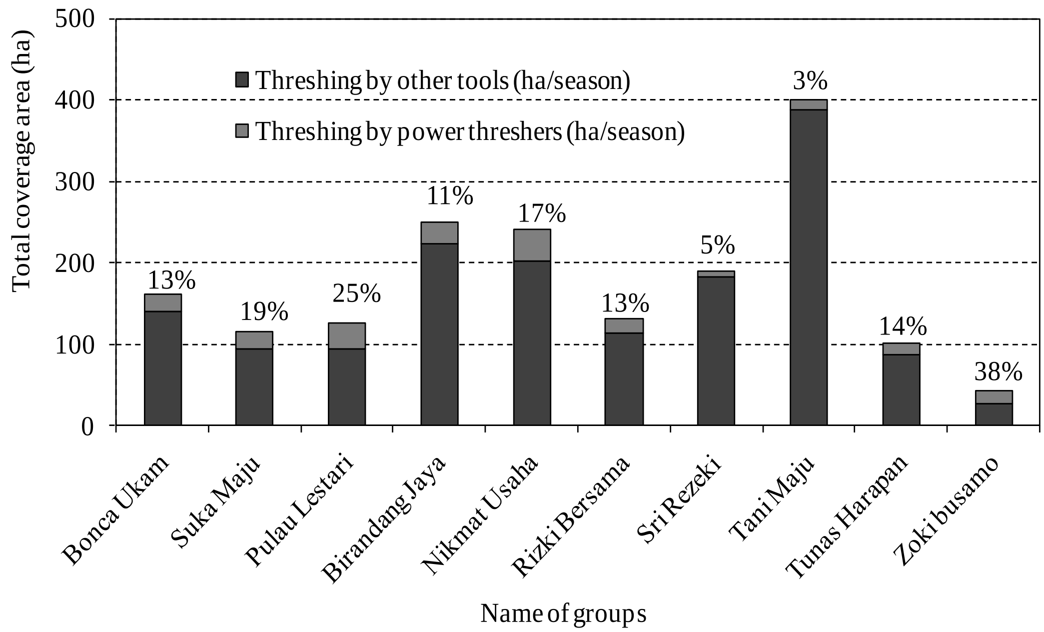


Figure 4.25. Group-wise coverage area worked by power threshers

The number of RMUs managed by hire services groups was very limited, with only one machine per group. The machines were small (less than 25 hp), with capacity of 550 kg/h on average (Table 4.25). Yet, most of the machines remained under-utilized (less than the machine capacity). Based on the earlier assumption for rice yield, the coverage area worked by RMUs ranged from 2% for Sri Rezeki and Nikmat Usaha to 21% for Karya Jaya. Thus, the coverage area remained low even though the machines were available for making services throughout the season (Fig. 4.26). Only about 4% (5.56 ha) of the coverage area of the group was worked by owned machines and the remaining 96% (133.44 ha) was worked by other individual machine hire services. The reason for this is that it is traditional to stock paddy and mill it for immediate consumption. In addition, the presence of some private RMUs/hullers that offered the same service in the area influenced the demand for milling services from the hire services groups.

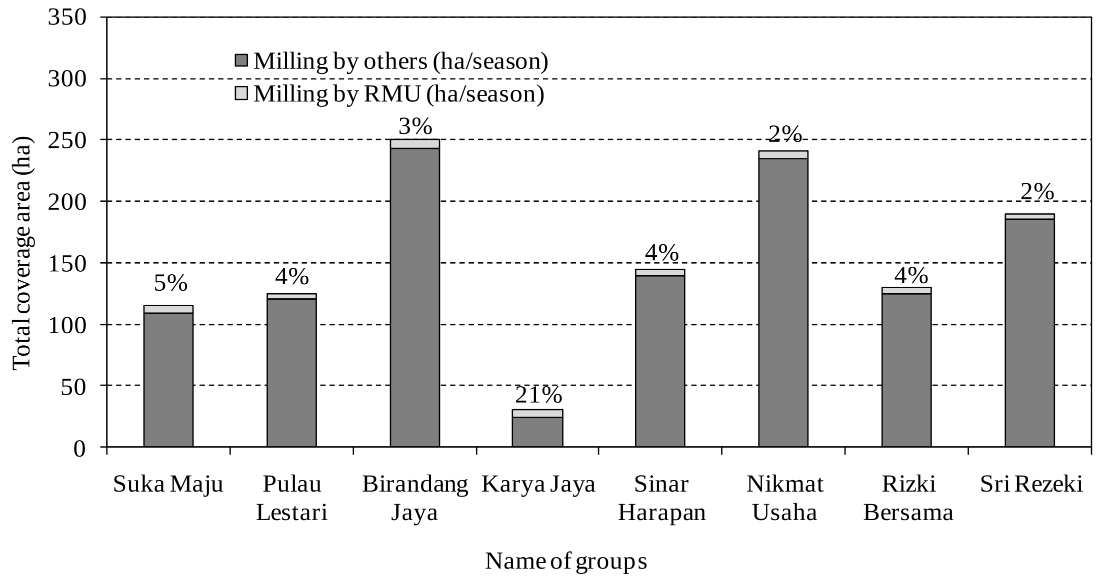


Figure 4.26. Group-wise coverage area worked by RMUs

4.9. Working Performance and Economic Comparison of Three Power Tiller Types Used by Hire Service Groups.

4.9.1. Working Performance

The amount of time available to perform land preparation in the survey area is roughly one month per season. The limited land preparation time is due to the delayed start of the growing season as farmers wait for rainfall. It is important to note that climate change has made it increasingly difficult to accurately predict the beginning of the rainy season. However, it was found that the seasonal working days of power tillers amounted to less than one month on average and varied slightly among tillers. The most common power tillers used by farmers for land preparation of paddy field are rotary tillers, moldboard plow, and hydro tillers. Table 4.28 shows that the longest average number of working day per season among the different tillers was 22.82 days for rotary tillers, and the shortest was 19.67 day for hydro tillers.

Table 4.28 indicates that the hydro tiller performs best in terms of working hours per hectare (18.86 h/ha), hectares per working day (0.40 ha/day) and working days per hectare (2.49 days/ha). The rotary tiller is the second-best performer in terms of working hours per hectare (20.96 h/ha), hectares per working day (0.36 ha/day), and working days per hectare (2.77 days/ha). The lowest performer is the moldboard plow, with 23.26 working hours per hectare, 0.32 hectares per working day, and 3.13 working days per hectare. For all three types of tiller, the working hours per hectare were under the maximum capacity, i.e., 8 h/ha for the rotary tiller, 16 h/ha for the moldboard plow, and 14 h/ha for the hydro tiller. The ANOVA results indicate that both working days per season and working hours per hectare did not significantly differ across power tillers ($p > 0.05$). In addition to field conditions and inherent machine features, the working performance of a power tiller may depend on the operator (Binisam et al., 2007).

Table 4.28. Working performance of three types of power tillers

Items	Rotary tiller	Moldboard plow	Hydro tiller
Working days per season (day/season)	22.82	20.45	19.67
Working hours per hectare (h//ha)*	20.95(8)	23.26(16)	18.86(14)
Hectares per working day (ha/day)	0.36	0.32	0.40
Working days per hectare (day/ha)	2.77	3.13	2.49
Working area per season (ha/season)	10.14	8.32	8.63

**Note: Values in parentheses show maximum performance achieved by each machine*

Furthermore, rotary tillers had the largest seasonal working area, covering an average of 10.14 ha, followed by hydro tillers (8.63 ha), and moldboard plows (8.32 ha). In addition to being affected by these variations in tiller performance, seasonal working areas were also influenced by the number of work contracts, available time of custom operators, machinery breakdowns, and paddy field conditions. Interviews with custom operators revealed that paddy field conditions, such as water supply and weed growth, greatly affected not only seasonal working areas, but also the types of power tillers that could be used. However, seasonal working areas did not significantly differ across power tillers ($p > 0.05$).

4.9.2. Power Tiller Operation Costs

Both fixed and variable costs were determined on a per-hectare basis. To determine the fixed cost per hectare, the fixed costs were divided by the number of hectares in which one machine can be operated during a season. The estimated average fixed costs per hectare were found to vary across power tillers.

Table 4.29. Cost, revenue, profit, and break-even point for three types of power tillers

Item	Rotary tiller		Moldboard plow		Hydro tiller	
	IDR (Thousands)	%	IDR (Thousands)	%	IDR (Thousands)	%
Costs*	839.46	75	858.97	78	701.26	67
Fixed costs	433.28		446.33		220.19	
Var. costs*	406.18		412.64		481.07	
Revenue	1,122.73		1,104.55		1,050.00	
Profit	283.27	25	245.58	22	348.74	33
BEP (ha)	5.14		4.29		3.07	

As shown in Table 4.29, the highest fixed costs was found to be IDR 446.33 thousand/ha (US $40.58/ha) for moldboard plows, followed by IDR 433.28 thousand/ha

(US $39.39/ha) for rotary tillers, and IDR 220.19 thousand/ha (US $20.02/ha) for hydro tillers. The lower fixed costs for hydro tillers were due to their lower purchase prices.

Variation also occurred in average variable costs. Hydro tiller operation had the highest variable costs, at IDR 481.07 thousand/ha (US $43.73/ha), followed by moldboard plows, at IDR 412.64 thousand/ha (US $37.51/ha), and rotary tillers, at IDR 406.18 thousand/ha (US $36.93). In general, fixed costs decrease as the seasonal or annual use of machines increases, and conversely, variable costs increase in proportion to seasonal or annual use (Butterworth and Nix, 1983).

The average total costs varied across power tillers, as did their percentage of total revenue, which ranged from 67% for hydro tillers to 78% for moldboard plows. The highest average total costs were for moldboard plows, at IDR 858.97 thousand/ha (US

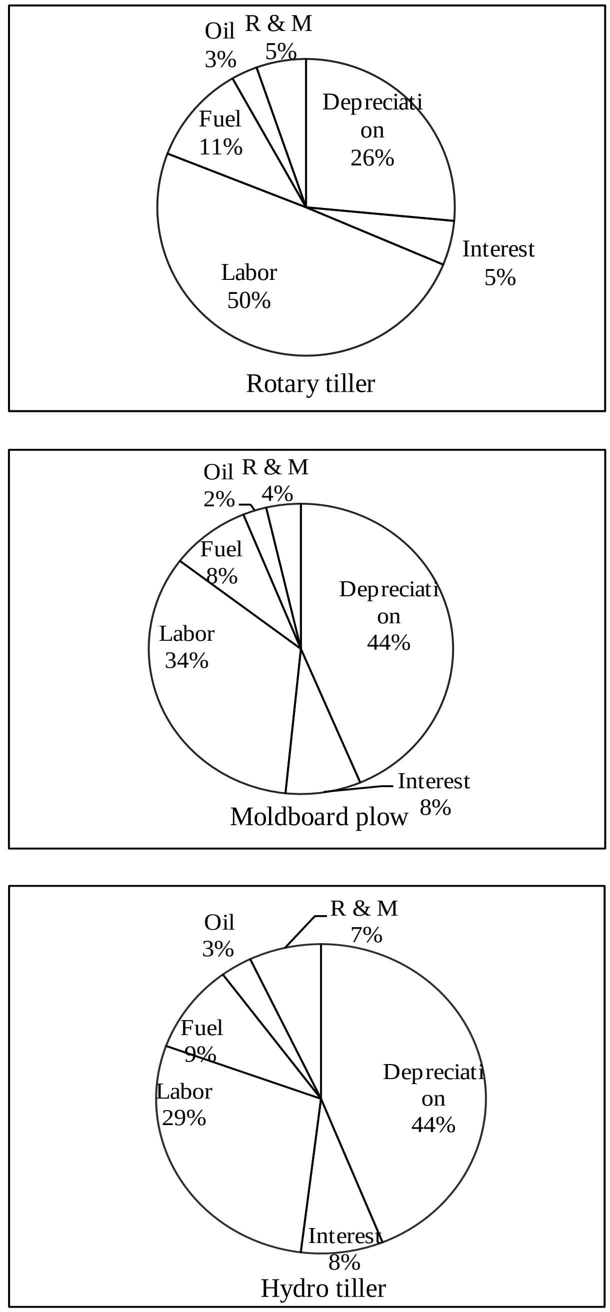


Figure 4.27. Relative importance of all cost items for three types of power tillers

$78.09/ha), followed by rotary tillers, at IDR 839.46 thousand/ha (US $76.31/ha), and hydro tillers, at IDR 701.26 thousand/ha (US $63.75/ha) on average. The ANOVA that there was no significant difference in the average fixed costs per hectare across power tillers, but there was a significant difference in the average variable and total costs per hectare ($p \leq 0.05$).

The relative importance of items contributing to the overall costs of the three types of power tillers are depicted in Fig. 4.27 The greatest single cost contributor for the three types of power tillers was generally operator wage (ranging from 29% for moldboard plows to 50% for hydro tillers), followed by depreciation (ranging from 26% for hydro tillers to 44% for both rotary tillers and moldboard plows), and fuel (ranging from 8% for rotary tillers to 11% for hydro tillers). Overall, repair and maintenance costs were relatively low (ranging from 4% for rotary tillers to 7% for moldboard plows). These results reflect the low repair and maintenance costs resulting from greater machine control. The relative newness of the studied machines also contributed to the lower costs, as serious breakdowns occurred.

4.9. 3. Revenue and Profit

The average revenue was found to vary slightly across power tillers of the same type. This is because the custom rate was largely determined by field conditions, such as weed growth, water supply, and distance between farmland and machinery centers. According to Table 4.29, the highest average revenue was found to be from rotary tillers at IDR 1,122.73 thousand/ha (US $102.07/ha), followed by moldboard tillers, at IDR 1,104.55 thousand/ha (US $100.41/ha), and hydro tillers, at IDR 1,050.00 thousand/ha (US $95.45/ha). The ANOVA confirmed that the average total revenue per hectare did not significantly differ across power tillers ($p > 0.05$).

Based on Table 4.29, the average profit was found to be IDR 283.27 thousand/ha (US $25.75/ha) for rotary tillers, IDR 245.58 thousand/ha (US $22.32/ha) for moldboard plows, and IDR 348.74 thousand/ha (US $31.70/ha) for hydro tillers, which represented averages of 25%, 22%, and 33% of total revenue, respectively. The average seasonal profit per hectare varied across power tillers, and hydro tillers were the most profitable. The ANOVA results indicated that the average profit per hectare varied significantly across power tillers ($p \leq 0.05$).

Larger seasonal working areas can be more profitable because of their lower cost per hectare. Increasing number of hectares covered per season is an easy way to increase profit without changing the custom rates. However, the profit

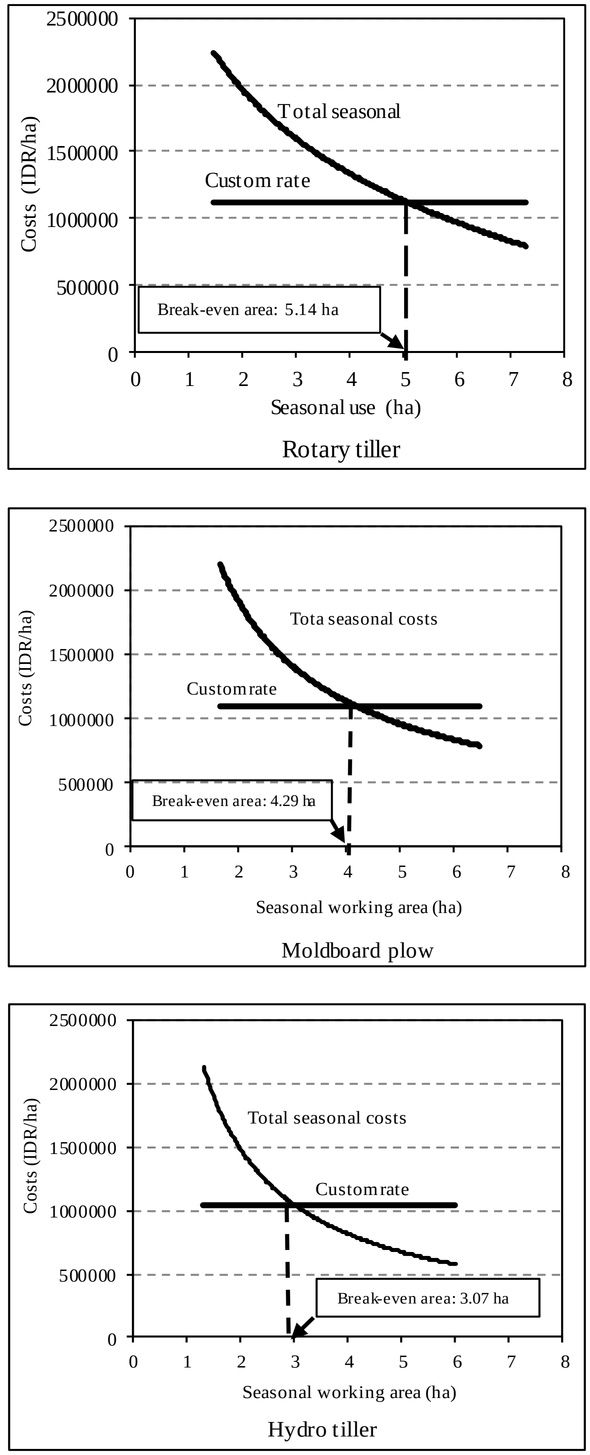


Figure 4.28. Break-even analysis for three types of power tillers

differences across power tillers more likely reflect the different levels of operation efficiency, as indicated by the lower cost per hectare for hydro tillers.

4.9.4. Break-Even Point

The break-even point (BEP) determines how much a machine needs to work per season to economically justify its possession. According to Table 4.29, hydro tillers reach the BEP most quickly, with a seasonal area of 3.07 ha. Both rotary tillers and moldboard plows required larger seasonal areas, of 5.14 ha and 4.29 ha, respectively, to reach the BEP. These figures mean that to justify owning a hydro tiller, rotary tiller, or moldboard plow in Riau, the owner must farm an area at least 3.07, 5.14, and 4.29 ha, respectively. There was a highly significant difference in the break-even area across power tillers ($p \leq 0.001$).

The above comparison can be generated using break-even analysis, as illustrated in Fig. 4.28. The break-even area depends on estimated seasonal costs and custom rates. For example, the break-even area will decrease with an increasing custom rate. The same effect is also brought about the low seasonal costs. Thus it can be argued that the cus tom rate and costs are important factors in determining the BEP.

CHAPTER V
CONCLUSIONS AND RECOMENDATIONS

5.1. Conclusions

The following conclusions can be drawn from this study:

1. The average mechanical power available to rice farmers is very low (0.31 hp/ha) and it only increased by 0.75% annually during 2004–2013.
2. The average mechanization capacity increased from 21.1% in 2006 to 24.7% in 2013, although the pace is relatively low, contributed by land preparation, irrigation, threshing, drying and milling.
3. The labor required to complete rice farming operations is 83.26 man-days/ha (equivalent to 49.96 kWh/ha), whereas the mechanical power necessary is only approximately 7 machine-days/ha (equivalent to 358.7 kWh/ha).
4. The total time required for rice farm operations was about 851 h/ha on average, contributed mostly by transplanting, weeding, and harvesting which still use hand tools.
5. The total cost of rice farming operations was IDR 7,895.83 thousand (US $877). This overall cost is relatively high because of the larger cost of human power (IDR 100,000/kWh; US $11.1) compared with IDR 8,354/kWh (US $0.93) on average for mechanical power.
6. The tractor breakdowns were resulted from operators' mistakes, using inferior fuel and oil, poor field conditions, poor maintenance, inadequate factory design, intense usage, and poor farm roads.

7. Inadequate repair shops, lack of spare parts, and a shortage of local mechanics were found to cause the repair to take longer and required high costs especially for replacement parts and transportation.
8. Unavailability of complete spare depots in the village areas and difficulty to access the spare parts center (dealers) caused low service level and high prices of spare parts.
9. The technical skill of the operators to service and repair tractors is very poor due to insufficient training, specific education, and work experience. Only 10% of the operators have received training in the proper operation, repair, and maintenance of tractors.
10. There is no institution providing training for farmers, operators, or mechanics in Riau Province. In the survey areas, it was found inadequate repair and maintenance facilities. About 60% of major repairs and 11% of minor ones cannot be performed on schedule due to the lack of spare parts, repair shops, and mechanics.
11. Farmers do not keep accurate service records and most of them pay little attention to daily checks, routine engine oil changes, and the need for periodic servicing. It is evident that about 90% of the farmers schedule engine oil changes without following the manufacturer’s recommendation.
12. The annual repair costs were statistically affected by age, hectare of use, horsepower and skill of operator. Ownership and manufacture variables were not significant explanatory variables in the model. A reasonable model was proposed to predict the annual repair costs.
13. Majority of the tractor hire operation is profitable under operating in wetland paddy field. Tractor owners receive profit in average of IDR 926 thousand (U.S. $109) per

annum under annual use of 23.13 ha and service charge of IDR 348 thousand (U.S. $41).

14. The annual use needs about 17.23 ha to justify economically ownership of the small tractor under Riau conditions.
15. The available machines could not cater to the entire coverage area owned by the group members. The average coverage area worked by tillage machines was about 38%, by water pumps was 8%, by power threshers was 16%, and by RMUs was 6%.
16. The overall seasonal work of the machines appears to be low due to short working days per season, limited number of machines, low working capacities, and small size of paddy fields.
17. Hydro tillers were found to have the best working performance in terms of working hours per hectare (18.86 h/ha), hectares per working day (0.40 ha/day), and working days per hectare (2.49 days/ha), although these performance parameters did not significantly differ the studied power tillers.
18. Hydro tillers had the lowest costs per hectare and were the most profitable, with average total costs of IDR 701,26 thousand/ha (US $63.75/ha) and average profits of IDR 348.74 thousand/ha (US $31.70/ha).
19. Hydro tillers must cover 3.07 ha to reach the BEP, whereas rotary tillers and moldboard plows must cover 5.14 and 4.29 ha, respectively and highly significant differences in break-even areas were found across the three power tillers.

5.2. Recommendations

The recommendations made are summarized as follow:

1. The mechanized farming scheme should be expanded to a wide range of operations to increase capacity of rice mechanization as well as complete farm works in timely and short time.
2. There is a need to increase the mechanical power available by providing more farm machines to local rice farmers.
3. Machine operators must be well-trained to improve the technical knowledge and skills that are required for correctly operating, prevent engine troubles and accidents, and maintaining the machines.
4. Farmers should always keep stock of spare parts, but the establishing of spare parts depot is the best way to ensure regular supplies and low price of necessary parts.
5. Government should provide training programs for all operators and mechanical extension officer to advice farmers in preventing tractor breakdowns.
6. A credit system should be made available for farmers to finance tractor repairs and replacement parts.
7. Repair and maintenance facilities, such as repair shops, spare parts shops, and local mechanics, should be established in the village areas to guarantee timely repair in case of breakdown along with spare parts available at low price.
8. Farmers should be encouraged to perform good care and maintenance by cleaning, greasing, protecting, and storing tractors during the working season and off-season.
9. The government should provide financial support to farmers who can not afford tractor repairs and maintenance requirements.

10. The use of tractor for custom hire service should be encouraged because of being a source of farmers' income and one of the methods to develop tractor ownership in the province.
11. More machines are required for machinery hire service groups in order to work the entire paddy field area owned by the group members.
12. Farmers would benefit most from using hydro tillers to perform tillage operations because the machine offers better working performance, provides economic benefits (lower cost and purchase price), and allows owners to quickly break even under flooded conditions.

REFERENCES

Adekoya, L, O., and P. A . Otono. 1990. Repair and Maintenance Costs of Agricultural Tractors in Nigeria. Tropical Agriculture, 67(2): 119-122.

Afsharnia, F., M. A. Asoodar, A. Abdeshahi, and A. Marzban. 2013. Failure Rate Analysis of Four Tractor Models in Southern Iran. Agricultural Engineering International: the CIGR Journal, 15(4): 160-170.

Ahmad, B. 1982. Implication of Farm Mechanization for Employment, Productivity, and Income. Agricultural Mechanization in Asia, Africa and Latin America, 14(2): 65-68.

Ahmed, M. H., A. B. Saeed, A. A. H. Ahmed, and I. Haffar. 1999. Tractor Repair and Maintenance Costs in Sudan-I; Development of a Standard Model. Agricultural Mechanization in Asia, Africa and Latin America, 30(2): 15-18.

Ahmed, M. H., A. B. Saeed, A. A. H. Ahmed, and I. Haffar. 1999. Tractor Repair and Maintenance Costs in Sudan-II; A Comparative Study among Major Agricultural Schemes. Agricultural Mechanization in Asia, Africa and Latin America, 30(2): 19-22.

Ajav, E. A. 2000. Animal Traction as A Source of Power for Agricultural Development in Nigeria. Kaumbutho P G, Pearson R A and Simalenga T E (eds), Empowering Farmers with Animal Traction. *In* Proceedings of the Workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA), 20-24 September 1999, Mpumalanga, South Africa.

Alabadan, B. A. and Y. Yusuf. 2013. Tractor Hiring Schemes in Nigeria: A Case Study of Federal Capital Territory (FCT). African Journal of Agricultural Research. 8(47): 5962-5966.

Al-Suhaibani. S. A. and M. F. Wahby. 1999. Tractor Repair and Maintenance in Saudi Arabia. Applied Engineering in Agriculture, 15(6): 591-596.

Anderson, A. W. 1988. Factors Affecting Machinery Costs in Grain Production. ASAE Paper No. 88-1057. ASAE, St. Joseph, Michigan, USA.

Andrade, P., and B. M. Jenkins. 2003. Identification of Patterns of Farm Equipment Utilization in Two Agricultural Regions of Central and Northern México.

Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, 5: 12.

Aneke, D. O. 1994. A Survey of Farm Power Problem in Nigeria. Applied Engineering in Agriculture, 10(5): 623-626.

Anguilar, A. M., E. C. Camacho, A. C. Generalla, P. B. Moran, J. F. Sison, Y. Tan, and J. A. Wicks. 1983. Consequences of Small Rice Farm Mechanization in the Philippines: A Summary of Preliminary Analyses. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 151 – 164.

Ariningsih, E. and H. Tarigan. 2005. Variety of Farm Machinery Hire Service (UPJA) in West Java: Case Study in Indramayu Regency (in Indonesia Language). ICASEPS Working Paper, No. 79, Indonesia Center for Agricultural Social Economic and Policy Studies, Bureau of Agricultural Research and Development, Agricultural Department, Jakarta. 22 p.

ASAE. 2006. Engine & Tractor Power. Fourth Edition, St. Joseph, Michigan, USA.

Audsley, E. and J. Wheeler. 1978. The Annual Cost of Machinery Calculated Using Actual Cash Flows. Journal of Agricultural Engineering Research. 23: 189 – 201.

Babatunde, O. O. 1996. An Appraisal of the Problem of Wheeled Tractors Used in Nigerian Agriculture. Agricultural Mechanization in Asia, Africa and Latin America, 27(3): 23-26.

Bagheri, N. and S. A. Moazzen. 2009. Optimum Strategy for Agricultural Mechanization Development in Iran. Journal of Agricultural Technology, 6(1): 225-237

Bakht, G. K., H. Ahmadi, A. Akram and M. Karimi. 2008. Determination of Optimum Life (Economic Life) for Mf285 Tractor: A Case Study in Center Region of Iran. American-Eurasian Journal Agricultural & Environment Science, 4(1): 81-85.

Balasankari, P. K., and V. M. Salokhe. 1999. A Case Study of Tractor Utilization by Farmers. Coimbatore District India. Agricultural Mechanization in Asia, Africa and Latin America, 30(3): 14 – 18.

Bani, R. J. and S. Y. Dorvlo. 2013. Agricultural Mechanization Strategy and Japan-Ghana Co-operation. Agricultural Mechanization in Asia, Africa, and Latin America, 44(4): 11-13.

Bappler, D. C and M. A. Hummaida. 1985. Maintaining and Repairing Ag. Equipment in Developing Nations. Agricultural Engineering, 66(12): 11-13.

Bardaie, M, Z. 1986. Agricultural Engineering. The Incorporated Society of Planters, Kuala Lumpur, Malaysia.

Beaton, A. J., K. C. Dhuyvetter, and T. L. Kastens. 2003. Custom Rates and the Total Cost to Own and Operate Farm Machinery in Kansas, Kansas State University, USA. 12 p.

Bell, M. A. and P. Cedilla. 1999. Mechanization in Asia: Statistics and Principles for Success. Agricultural Mechanization in Asia, Africa and Latin America, 30(4): 70 - 75.

Bell, R. D. and I. M. Johnson. 1986. Establishing Priorities for Research and Development of Agricultural Machinery in Developing Countries. *In* Small Farm Equipment for Developing Countries. Proceeding of International Conference on Small Farm Equipment for Developing Countries: Pas Experiences and Future Priorities; 2 – 6 September 19985. International Rice Research Institute, Manila. pp 455 -461.

Beppler, D. G., and M. A. Hummeida. 1985. Maintaining and Repairing Ag. Equipment in Developing Countries. Agriculture International, 66(12): 11 – 13.

Binisam, R. Manian, K. Kathirvel, T. Senthikumar. 2007. Energy cost of riding and walking type power tillers. Agricultural Mechanization in Asia, Africa, and Latin America, 38(1), 55-60.

Binswanger, H. P. 1978. The Economics of Tractors in South Asia. Agricultural Development Council, New York.

Binswanger, H. P. 1986. Agricultural Mechanization: A Comparative Historical Perspective. The World Bank Research Observer, 1(1): 27-56.

Bishop, C. 1997. A Guide to Preparing an Agricultural Mechanization Strategy. Food and Agriculture Organization of the United Nations, Rome. 32 p.

Bloome, P. D., T. R. Nelson, and C. E. Roush. 1975. Engineering Economics in Continuing Education – Cash Flow and Present Value Analyses of Farm Investment. Transaction of the ASAE, 18(4): 770 – 776.

Bond, L. K. and R. Beard. 1997. The Cost of Owning and Operating Farm Machinery. Utah State University Extension, Utah. 8 p.

Bowers, W. 1994. Machinery Replacement Strategies. Deere & Company, Moline, USA.

Bowers, W. and Hunt, D. R. 1970. Application of Mathematical Formulas to Repair Cost Data. Transaction of the ASAE, 13(6): 806-809.

Bukhari, S. B. 1982. Evaluation of Farmer's Competence to Maintain Farm Tractors. Agricultural Mechanization in Asia, Africa, and Latin America, Winter Issue, 45 – 47.

Bukhari, S. B., J. M. Baloch, and S. H. Naqvi. 1988. Cost of Operating Tractor on Quetta Farms, Pakistan. Agricultural Mechanization in Asia, Africa and Latin America, 19(1): 14 – 20.

Bukhari, S. B., M. S. Soomro, A. G. Rajper, and J. G. Sewar. 1984. Status of Farm Mechanization Facilities in Khairpur, Pakistan. Agricultural Mechanization in Asia, Africa, and Latin America, 15(1): 37 – 42.

Butterworth, B. and J. Nix. 1983. Farm Mechanization for Profit. Granada. London, England.

Calcante, A., L. Fontanini, and F. Mazzetto. 2013. Repair and Maintenance Costs of 4WD Tractors in Northern Italy. Transactions of the ASABE, 56(2): 355-362.

Campbell, J. K. 1986. Design and Development of Small Farm Equipment to Simplify Fabrication, Operation, and Maintenance in Developing Countries. *In* Small Farm Equipment for Developing Countries, Proceedings of the International Conference on Small Farm Equipment for Developing Countries; Past Experiences and Future Priorities, 2-6 September 1985, The International Rice Research Institute, Manila, Philippines, pp. 506-513.

Central Bureau of Statistics. 1994. Agricultural Census 1993. Jakarta

Central Bureau of Statistics. 2004. Agricultural Census 2003. Jakarta

Cervinka, V. and W. J. Chancellor. 1975. Regional Economic Implication of Various Intensities of Use of Crop Production Equipment. Transactions of the ASAE, 18(3): 453 - 458.

Chamsing, A. and G. Singh. 2000. Rice Mechanization and Processing in Thailand. Agricultural Mechanization in Asia, Africa, and Latin America, 31(4): 21 – 27.

Chancellor, W. J. 1971. Mechanization of Small Farms in Thailand and Malaysia by Tractor Hire Services, Transactions of the ASAE, 14(6): 847- 854, 859.

Chancellor, W. J. 1986. Improving Access to and Use of Appropriate Agricultural Machinery by Small Scale Farmers. *In* Small Farm Equipment for Developing Countries, Proceedings of the International Conference on Small Farm Equipment for Developing Countries; Past Experiences and Future Priorities, 2-6 September 1985, The International Rice Research Institute, Manila, Philippines, pp. 526-542.

Cicek, G., 2011. Determination of Harvesting Costs and Cost Analysis for Different Olive Harvesting Methods. Journal of Food, Agriculture and Environment, 9 (3&4): 201-204.

Clarke, L. J. 2000. Strategies for Agricultural Mechanization Development; the Roles of the Private Sector and the Government. Food and Agriculture Organization of the United Nations, Rome. 15 p.

Clarke, L. J. 2000. Strategies for Agricultural Mechanization Development: The Role of the Private Sector and the Government. Agricultural Engineering International, the CIGR Ejournal, 2: 1-15.

Crew, M. A. and P. R. Kleindorfer. 1992. Economic Depreciation and the Regulated Firm under Competition and Technological Change. Journal of Regulatory Economics, 4: 51 – 61.

Cross, T., B. Bowling, and K. Wilbert. 1998. Machinery Cost Calculator: Version 1.0. Agricultural Extension Service, The University of Tennessee Institute of Agriculture. 39 p.

Cross, T. L., and G. M. Terry. 1995. Depreciation Patterns for Agricultural Machinery. American Journal of Agricultural Economics, 77: 194 – 204.

Cross, T. L., and G. M. Terry. 1996. Remaining Value Function for Farm Equipment. Applied Engineering in Agriculture, 12(5): 547 – 553.

Cruzt, G. W., R. F. Combs, and S. D. Parsons. 1980. Equipment Analysis with Farm Management Models. Transaction of the ASAE, 23(1): 25 – 28.

Crossley, C. B. 1979. Theoretical Design of Small Tractors. Agricultural Mechanization in Asia. 10(2): 49 – 54.

Debertin, D. L. 2012. Agricultural Production Economics. Second Edition, Macmillan Publishing Company, Kentucky.

Depeng, K., L. Tongsen, and X. Guangqin. 1983. Small Tractors in China. Agricultural Mechanization in Asia, Africa, and Latin America, 14(1): 44 – 48.

Devendra, C. and D. Thomas. 2002. Small Farming System in Asia. Agricultural Systems, 71: 17 – 25.

Djojomartono, M. and S. Pertiwi. 1998. Present Status of Information Technology Utilization in Indonesia Agriculture. The Asian Federation for Information Technology in Agriculture. pp 9 – 12.

Dodson, B. 1994. Determining the Optimum Schedule for Preventive Maintenance. Quality Engineering, 6(4): 667-679.

Donovan, G., G. Binswanger, and P. Pingali. 1986. Farm Mechanization Issues and Policies. *In* Small Farm Equipment for Developing Countries, Proceedings of the International Conference on Small Farm Equipment for Developing Countries; Past Experiences and Future Priorities, 2-6 September 1985, The International Rice Research Institute, Manila, Philippines, pp. 23 - 33.

Duff, B. 1986. Some Consequences of Agricultural Mechanization in the Philippines, Thailand, and Indonesia. *In* Small Farm Equipment for Developing Countries, Proceedings of the International Conference on Small Farm Equipment for Developing Countries; Past Experiences and Future Priorities, 2-6 September 1985, The International Rice Research Institute, Manila, Philippines, pp. 59-94.

Dumler, T. J., R. O. Burten, Jr, and T. L. Kastens. 1998. Implications of Alternative Farm Tractor Depreciation Method. Selected Paper at the Annual Meeting of the American Agricultural Economics Association, August 2 – 5, Utah, USA.

Dunford, W. J. and R. C. Rickard. 1961**.** The Timing of Farm Machinery Replacement. Journal of Agricultural Economics, 14(3): 348 – 358.

Edwards, W. M. 2009. Acquiring Farm Machinery Services. Iowa State University of Science and Technology, Ames, Iowa.

Edwards, W. M. 2001. Estimating Farm Machinery Costs. Machinery Management; Iowa State University of Science and Technology, Ames, Iowa.

Elepaño, A. R., A. N. Resurreccion, D. C. Suministrado, V. A. Rodulfo, Jr., and M. V. L. Larona. 2009**.** Agricultural Mechanization Development in the Philippines: Country Report. UNAPCAEM 5th Technical Committee Session and Expert Group Meeting on Application of Agricultural Machinery for Sustainable Agriculture in the Asia-Pacific Region, Philippines.

Fairbanks, G. E., Larson, G. H. and Chung, D. S. 1971. Costs of Using Farm Machinery. Transaction of the ASAE, 14 (1): 98-101.

FAO. 1976. Workshop on the Effective Use of Marketing for the Development of Small Farms in Asia. 3 – 7 Mei, Bangkok, Thailand.

FAO. 1990. Agricultural Engineering in Development: Guidelines for Mechanization System and Machinery Rehabilitation Program. Agricultural Services Bulletin 85, Rome. 63 p.

FAO. 1992. Agricultural Engineering in Development: Guidelines for Rebuilding Replacement Parts and Assemblies. Agricultural Services Bulletin 91, Rome. 106 p.

FAO. 2007. Addressing the Challenges Facing Agricultural Mechanization Input Supply and Farm Product Processing. Agriculture and Food Engineering Technical Report, Rome.

FAO. 2008. Agricultural Mechanization in Africa: Time for Action, Planning Investment for Enhanced Agricultural Productivity Report of an Expert Group Meeting, Rome. 25 p.

FAO/RAFE. 1978. FAO Regional Office for Asia and the Far East. Bangkok, Thailand. pp. 72–77.

Farrington, J. 1985. Mechanization policy and the Impact of Tractors in South Asia – A Review. *In* Small Farm Equipment for Developing Countries; Proceeding of the International Conference on Small Farm Equipment for Developing Countries: Past Experiences and Future priorities, 2 – 6 September 1985, Manila, Philippines. pp 85 – 123.

Finner, M. F., and Straub, R. J. 1985. Farm Machinery Fundamentals. American Publisher Co., Wisconsin, pp. 345 –347.

Food Crops Service of Riau Province. 2005. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2006. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2007. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2008. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2009. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2010. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2011. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2012. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province. 2013. Serial Data of Food Crops in Riau Province. Pekanbaru.

Food Crops Service of Riau Province, 2014. Serial Data of Food Crops in Riau Province. Pekanbaru.

Friyatno, S., H. P. Rachman, and Supryadi. 2003. Farm Machinery Institution (in Indonesia Language). Agricultural Economic and Social Research Centre, Bogor, Indonesia. 30 p.

Ghandiryanfar, M., A. Keyhani, A. Akram, and S. Rafiee. 2009. A Pattern for Power Distribution Based on Tractor Demand in Iran. Agricultural Engineering International: the CIGR Ejournal. July Issue, 11: 1 - 9.

Gego, A. 1986. Problem of Agricultural Mechanization in Developing Countries. Agricultural Mechanization in Asia, Africa and Latin America, 17(1): 11-21.

Gifford, R. C. 1992. Agricultural Engineering in Development; Mechanization Strategy Formulation, Concepts, and Principles. FAO, Agricultural Service Bulletin, Rome. 74 p.

Goense, D. 2005. The Economics of Autonomous Vehicles in Agriculture. ASAE Paper No. 051056. St. Joseph, Michigan.

Guesmia, B., T. Serrab, and A. Featherstonec. 2015. Technical Efficiency of Kansas Arable Crop Farms: a Local Maximum Likelihood Approach. Agricultural Economics, 46: 703–713.

Haeruman, K. M. 1998. Development of Agricultural Mechanization Utilization in West Java (Indonesia). In Proceedings of Agricultural Mechanization Use Perspective in Increasing Competitive Commodities. E. Syafa'at, N. Hendiarto and R.N. Suhaeti, (Eds.), Bogor, pp. 86-90.

Hafsah, J. and R. H. Bernsten. 1983. Economic, Technical, and Social Aspects of Tractor Operation and Use in South Sulawesi, Indonesia. *In* Consequences of Small Rice Farm Mechanization, International Rice Research Institute, Los Banos, Philippines. pp. 86 – 94.

Handaka. 2005. Agricultural Engineering R & D in Indonesia: Challenge and Prospect Toward Sustainable Agriculture and APCAEM Programme. Paper for APCAEM TC/GC Meeting in New Delhi, 21 – 24 November 2005, India.

Handaka. 2009. Towards Sustainable Agricultural Mechanization in Indonesia: A Conceptual Model of Innovation Technology. Technology Monitor. January – February 2009, Jakarta. pp. 38-43.

Hansen, L. and H. Lee. 1991. Estimating Farm Tractor Depreciation: Tax Implications. Canadian Journal of Agricultural Economics, 39: 463 – 479.

Hazell, P., C. Poulton, S. Wiggins, and A. Dorward. 2007. The Future of Small Farms for Poverty Reduction and Growth. International Food Policy Research Institute 2033 K Street, Washington DC 20006-1002, USA.

Heidhues, F. and M. Brüntrup. 2003. Subsistence Agriculture in Development: Its Role in Processes of Structural Change. *In* Subsistence Agriculture in Central and Eastern Europe: How to Break a Vicious Cycle?. S. Abele and K. Frohberg, eds. Studies on the Agricultural and Food Sector in Central and Eastern Europe, Vol. 22. Institute of Agricultural Development in Central and Eastern Europe (IAMO), Halle, Germany.

Heltberg, R. 1998. Rural Market Imperfections and the Farm Size-Productivity Relationship: Evidence from Pakistan. World Development, 26(10): 1807–1826.

Henderson, H. D. and Fanash, S. 1984. Tractors Costs and Use Data in Jordan. Transaction of the ASAE, 27(4): 1003- 1008.

Herdt, R. W. 1983. Mechanization of Rice Production in Developing Asian Countries: Perspective, Evidence, and Issues. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 1 – 13.

Hoering, U. 2008. Who Feeds the World?, The Future is in Small Scale Agriculture. Church Development Service. An Association of the Protestant Churches in Germany (EED) – Evangelischer Entwicklungsdienst E.V. – Ulrich-von-Hassell-Strasse 76, D-53123 Bonn, Germany. 52 p.

Huber, S. G. 1967. Depreciation and Repair Costs of Self-Propelled Combine. Transaction of the ASAE, 10(2): 270 - 271.

Hunt, D. 1971. Equipment Reliability: Indiana and Illinois Data. Transactions of the ASAE, 14(5): 742-746.

Hunt, D. and K. Fuji. 1976. Repair and Maintenance Costs by Machinery Categories. ASAE Paper No. 76-1507, ASAE, St. Joseph, Michigan, USA.

Hunt, D. 1983. Farm Power and Machinery Management. Eighth Addition, Iowa State University Press, Ames.

Hutabean, L, R. H. Anasiru and IGP. Sarasutha. 2005. Feasibility Analysis of Tractor Hire Service in Sulawesi Centre (in Indonesia Language). Jurnal Pengkajian dan Pengembangan Technology Pertanian, 8(1): 150 – 163.

Igbeka, J. C. 1984. Development in Rice Production Mechanization. Agricultural Mechanization in Asia, Africa, and Latin America, 15(1): 27 – 32.

Inns, F. M. 1978. Operational Aspect of Tractor Use in Developing Countries – A Case for the Small Tractor. The Agriculture Engineers, Summer Issue: 52-54.

Inns, F. M. 1995. Selection, Testing and Evaluation of Agricultural Machines and Equipment; Theory. FAO, Agricultural Service Bulletin, Rome. 68 p.

Jabbar, M. A., M. S. R. Bhuiyan, and A. K. M. Bari. 1983. Cause of Consequences of Power Tiller utilization in Two Area of Bangladesh. *In* Consequences of Small Rice Farm Mechanization, International Rice Research Institute, Los Banos, Philippines. pp. 71 – 83.

Jacobs, C. O. and W. R. Harrell. 1983. Agricultural Power and Machinery. McGraw-Hill, Inc. New York.

Jain, B. K. S. 1979. Tractors in Indian Agriculture - Their Place and problem. Agricultural Mechanization in Asia, Africa, and Latin America, Autumn Issue 1979, 31 – 34.

Jhang, J. P. and S. H. Sheu. 1999. Opportunity-Based Age Replacement Policy with Minimal Repair. Reliability Engineering and System Safety, 64: 339–344.

Kadlec, J. E. 1985. Farm Management Decision, Operation, Control. Prentice-Hall, Inc., Englewood Cliffs New Jersey, USA.

Kamboj, P., R. Khurana, and A. Dixit. 2012. Farm Machinery Services Provided by Selected Cooperative Societies, Agricultural Engineering International: CIGR Journal, 14(4): 123-133.

Kampe, D. F. 1971. Methods for Machine Cost Analysis, Agricultural Engineering. March Issue, pp.121-123.

Kaneko, S., R. Fujikura, and H. Imura. 2000. A Study on Experts' Judgment on the Future Perspective of a Country: a Case Study for China. Integrated Assessment 1: 87–104.

Karale, D. S., V. P. Khambalkar, S. M. Bhende, S. B. Amle, and P. S. Wankhede. 2008. Energy Economic of Small Farming Crop Production Operations. World Journal of Agricultural Sciences, 4(4): 476-482.

Karimi, M., S. Rafiee, A. Rajabi Pour, K. Khairalipour and S. Shahin. 2008. A Pattern to Distribute Tractor Power from the Viewpoint of Energy, Case Study: Isfahan Province in Central Region of Iran. American-Eurasian Journal of Agriculture. & Environment Science, 3(4): 526-531.

Kastens, T. 1997. Farm Machinery Operation Costs Calculations. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Kansas. 25 p.

Kay, R. D. and W. M. Edwards. 1994. Farm Management. 3rd Edition, McGraw-Hill, Inc. New York.

Kepner, R. A., Bainer, R. and Barger, E. L. 1980. Principle of Farm Machinery. Third Addition, AVI Publishing Company, Inc., Westport, pp. 35-42.

Khan, M. M. 1996. A Manual of Mood Crops Production in ISDP Locations. Trans-Intra Asia Co. in Association with Mott Mac Donald Limited, Indonesia.

Khatiwada, M. K., and B. C. Sharma. 1995. Agricultural Mechanization in Nepal: A Case Study in Two Selected Districts. Agricultural Mechanization in Asia, Africa, and Latin America, 26(1): 52 – 58.

Khodabakhshian, R and M. Shakeri. 2011. Prediction of Repair and Maintenance Costs of Farm Tractors by Using of Preventive Maintenance. International Journal of Agriculture Sciences, 3(1); 39 – 44.

Kic, P. and R. Zewdie. 2013. Assistance in Promotion of Agricultural Mechanization in Developing Countries. Agricultural Mechanization in Asia, Africa, and Latin America, 44(4): 31-33.

Kobayashi, T. 2003. How to Reduce Manufacturing and Management Costs of Tractors and Agricultural Equipment. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, 5: 1 - 7

Kolawale, M. I. 1972. Economic Aspects of Tractor Contracting Operations in Western Nigeria. Journal Agricultural Engineering Research, 17: 289 - 294.

Kolawale, M. I. 1974. Economic Aspects of Private Tractor Operations in the Savanna Zone of Nigeria. Journal Agricultural Engineering Research, 19: 401-410.

Krause, R., and I. R. G. J. Poesse. 1997. The Role of Agricultural Engineering in the Development Process; Some Basic Aspects to Contribute for Better North-South Understanding and Cooperation Planning. Agricultural Mechanization in Asia, Africa, and Latin America, 28(2): 48 – 52.

Kulakarni, S. D. 2009. Mechanization of Agriculture - Indian Scenario. Central Institute of Agricultural Engineering (CIAE), Bhopal, India. pp 1 - 19.

Kumar, A., and T. Ahmad. 1996. Maintenance Decision for Farm Tractors in Allahabad District. Agricultural Mechanization in Asia, Africa, and Latin America, 27(3): 15–17.

Kumar, R., and J. R. Gross. 1980. Total Combine Harvester Cost Optimization in Alfalfa Seed Harvesting. Transaction of the ASAE, 20(1): 39 – 42.

Kuyembeh, N.G. 1986. Mechanization of Small Farm in Tropical Africa. Agricultural Mechanization in Asia, Africa, and Latin America, 17(3): 41 – 48.

Langemeier, L. N and R. K. Taylor. 1998. A Look at Machinery Cost. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, USA. 28 p.

Larson, G. H., G. E. Fairbanks, and F. C. Fenton. 1960. What It Cost to Use Farm Machinery. Agricultural Experiment Station, Kansas State University of Agriculture and Applied Science, Bulletin No. 417, 48 p.

Lazarus, W. F. 2009. Machinery Cost Estimates. University of Minnesota. USA. pp 1 – 9.

Leatham, D. J. and T. G. Baker. 1981. Empirical of the Effect of Inflation on Salvage Value, Cost, and Optimal Replacement of Tractor and Combines. North Central Journal of Agricultural Economics, 3(2): 109 -117.

Leiva, F. R. and J. Morris. 2001. Mechanization and Sustainable in Arable Land in England. Journal of Agricultural Engineering Research, 79(1): 81 – 90.

Lesikar, B. J., C. L. O'Neill, J. Mechell, G. Loomis, D. Kalen, D. Gustafson, N. Deal, and D. Lindbo. 2006. Operation and Maintenance Service Provider Program. ASABE Paper Number: 068046, ASABE, St. Joseph, Michigan, USA.

Liang, T. and D. A. Link. 1970. Farm Machinery Maintenance – Scheduling Preventive Maintenance by Dynamic Programming Markove Chain Method. Transaction of the ASAE, 13(3): 398 – 405.

Lim, P. C. 1985. Effects of Agricultural Mechanization on Farm Income Patterns. Journal of Philippine Development, 12(1): 198 -210.

Lips, M. 2013. Repair and Maintenance Costs for Nine Agricultural Machine Types. Transactions of the ASABE, 56(4): 1299-1307.

Lokollo, E. M. 2002. Adoption and Productivity Impacts of Modern Rice Technology in Indonesia. Paper presented on the Workshop on Green Revolution in Asia and Its Transferability to Africa, December 7-10, Tokyo, Japan.

Lockwood, B., M. Munir, K. A. Hussain, and J. Gardezi. 1983. Farm Mechanization in Pakistan: Policy and Practice. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 15 – 30.

Lohan, S. K., M. K. Narang, G. S. Manes, and N. Grover. 2015. Farm Power Availability for Sustainable Agriculture Development in Punjab State of India. Agricultural Engineering International: CIGR Journal, 17(3): 196-207.

Maamun, M. Y., I. G. P. Sarasutha, J. Hafsah, R. Bersten, R. Sinaga, and J. Wicks. 1983. Consequences of Small Rice Farm Mechanization in South Sulawesi: A Summary of Preliminary Analyses. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 177 – 184.

Maamun, M. Y.. 1991. Financial Analysis of Tractor Purchase Decision in South Sulawesi Indonesia. Master Thesis of Department of Agricultural Economics, Michigan State University, USA. 120 p.

Maggu, A. 1982. Tractorization in India: Dispelling Some Myths. Vikalpa, 7(1): 45-52.

Mancebo, S. T. 1986. Social and Economic Aspects of Farm Mechanization in the Philippines. Medium, 8(4): 23-26.

Mawa, l. I., M. M. Kavoi, I. Baktenweck, and J. Poole. 2014. Profit Efficiency of Dairy Farmers in Kenya: An Application to Smallholder Farmers in Rift Valley and Central Province. Journal of Development and Agricultural Economics, 6(11): 455-465.

McCauley, J. F. 2003. Plowing A head: The Effects of Agricultural Mechanization on Land Tenure in Burkina Faso. Journal of Public and International Affairs, 14: 6 – 27.

McNeill, R. C. 1979. Depreciation of Farm Tractor in British Columbia. Canadian Journal of Agricultural Economics, 27: 53 – 58.

Mehta, C. R. and R. K. Pajnoo. 2013. Role of Japan in Promotion of Agricultural Mechanization in India. Agricultural Mechanization in Asia, Africa, and Latin America, 44(4): 15-17.

Meij, J. L. 1960. Mechanization in Agriculture. Quadrangle Books, Chicago, USA.

Mondal, P., V. K. Tewari, P. N. Rao, and N. Balasubramanian. 2008. Up-shift Spectrum Analysis of 29 Tractors Available in India. International Journal of Agricultural Research, 3(1):51-60.

Morris, J. 1988. Estimation of Tractor Repair and Maintenance Costs. Journal of Agricultural Engineering Research, 41:191-200.

Morris, J. 1988. Tractor Repair Costs. Farm Management. 6(12): 433 – 441.

Morris, R. A. 1975. The Potential Impact of Mechanical Land Preparation in Indonesia Small-holder Rice Producing Sector. IRRI/IPI LP3, Bogor, Indonesia.

Munack, A. and H. Speckmann. 2001. Communication Technology Is the Backbone of Precision Agriculture. Agricultural Engineering International: the CIGR Ejournal, 3: 1-12.

Nehta, P. 1982. Economic Efficiency of Tractors on Punjab Farms. Agricultural Mechanization in Asia, Africa, and Latin America, Winter Issue, 22 – 26.

Obi, A. and F. F. Chisango. 2011. Performance of Smallholder Agriculture under Limited Mechanization and the Fast Track Land Reform Program in Zimbabwe. International Food and Agribusiness Management Review, 14(4): 85-104.

Odigboh, E. U. 1999. Human-powered Tools and Machines. CIGR Handbook of Agricultural Engineering, B. A. Stout (ed), Volume III. USA: American Society of Agricultural Engineers.

Ojo, S. O. 2004. Improving Labor Productivity and Technical Efficiency in Food Crop Production: A Panacea for Poverty Reduction in Nigeria. Food, Agriculture & Environment, 2(2): 227-231.

Ong'wen, O and S. Wright 2007. Small Farmers and the Future of Sustainable Agriculture. *In* Ecofair Trade Dialogue, Heinrich Boll Foundation and Misereor, IHR Hilfswerk.

Olaoye, J. O. and A. O. Rotimi. 2010. Measurement of Agricultural Mechanization Index and Analysis of Agricultural Productivity of Some Farm Settlements in South West, Nigeria. Agricultural Engineering International: the CIGR Ejournal. January Issue, 12: 1 - 21.

Ozmerzi, A. 1998. Mechanization Level in Vegetable Production in Antalya Region and Turkey. Agricultural Mechanization in Asia, Africa, and Latin America, 29(1): 43 - 43.

Pakpahan, A. 1995. Increasing the Scale of Small-Farm Operations in Indonesia. Center for Agro-Socioeconomic Research, Agency for Agricultural Research and Development, Bogor, Indonesia. 15 p.

Palmer, R. J., D. Wild, and K. Runtz. 2003. Improving the Efficiency of Field Operations. Biosystems Engineering, 84(3): 283–288.

Paras Jr., F. O. and R. M. C. Amongo. 2005. Technology Transfer Strategies For Small Farm Mechanization Technologies in The Philippines Agricultural Machinery Division and Agricultural Mechanization Development Program, Institute of Agricultural Engineering College of Engineering and Agro-industrial Technology. University of the Philippines Los Baños (UPLB), Laguna, Philippines.

Panin, A. 1995. Empirical Evidence of Mechanization Effects on Small Crop Production System in Botwana. Agricultural System, 47: 199 – 210.

Panneerselvam, R. 2007. Engineering Economics. Prentice-Hall of India, New Delhi.

Pariyar, M. P. and G. Singh. 1995. Farm Mechanization in Nepal. Agricultural Mechanization in Asia, Africa, and Latin America, 26(2): 55 – 61.

Pariyar, M. P., K. B. Shrestha, and N. H. Dhakal. 2001. Baseline Study on Agricultural Mechanization Needs in Nepal. Paper for Rice-Wheat Consortium for the Indo-Gangetic Plains CG Block, National Agricultural Science Centre (NASC) Complex, DPS Marg, Pusa Campus, New Delhi, India. 72 p.

Pechon, R. R., N. Ito, K. Kito, and H. Jinyama. 2007. Effect of Hand Tractor Implements on Soil Physical Properties in Upland Conditions. Agricultural Engineering International: the CIGR Ejournal. 10: 1-13.

Perry, G. M. and C. J. Nizon. 1991. Optimal Tractor Replacement: What Matters?. Review of Agricultural Economics. 72: 317 – 325.

Perry, G. M,. A. Bayaner, and C. J. Nixon. 1990. The Effect of Usage and Size on Tractor Depreciation. American Journal of Agricultural economics, 72: 317 – 325.

Peterson, C. L. and J. H. Milligan. 1976. Economic Life Analysis for Machinery Replacement Decision. Transaction of the ASAE, 19(5): 819 – 826.

Pflueger, B. 2005. How To Calculate Machinery Ownership and Operating Costs South Dakota Cooperative Extension Service, South Dakota State University. Dakota.

Phothecrai, B. P. 1969. The Small Tractor in Developing Countries. World Crops, 21(3): 225 -226.

Pingali, P., Bigot, Y, and Biswanger, H. P. 1987. Agricultural Mechanization and the Evolution of Farming Systems in Sub-Sabaran Africa. Work Bank Publication, John Hopkins University Press, Baltimore, MD.

Patterson, P. E. and K. Painter. 2011. Custom Rates for Idaho Agricultural Operations 2010–2011. Bul. 729, University of Idaho Extension, Moscow, Idaho.

Priyanto, A. 1997. Application of Agricultural Mechanization (in Indonesia Language). Bulletin Keteknikan Pertanian, 11(1): 54-58.

Puzey, G. A. and Hunt, D. 1968. Field Machine Repair Cost Patterns. Agricultural Engineering, March Issue, pp.139-141.

Rachmat, M., and Hendiarto. 1999. Research Status of Agricultural Mechanization in Indonesia: Review of Research Results during Last 20 Years. *In* Proceedings of Agricultural Mechanization Use Perspective in Increasing Competitive Commodities, E. Syafa'at, N. Hendiarto and R.N. Suhaeti, (Eds.), Bogor. p. 13-25.

Rahman, A., Latifunnahar, M., and Alam, M.M., 2013. Financial Management for Custom Hire Service of Tractor in Bangladesh. International Journal of Agricultural and Biological Engineering, 6(3): 28-33.

Rahmoo, S. A., H. D. Henderson, and G. E. Thierstein. 1979. Costs of Owning and Operating Tractors in Tharparkar District of Sind, Pakistan. Agricultural Mechanization in Asia, Autumn Issue, 27 – 30.

Ramírez, A. A., A. Oida, H. Nakashima, J. Miyasaka, and K. Ohdoi. 2007. Mechanization Index and Machinery Energy Ratio Assessment by Means of an Artificial Neural Network: a Mexican Case Study. Agricultural Engineering International: the CIGR Journal, 9: 1 – 21.

Rasouli, F., H. Sadighi, and S. Minaei. 2009. Factors Affecting Agricultural Mechanization: A Case Study on Sunflower Seed Farms in Iran. Journal Agricultural Science Technology, 11: 39 – 48.

Reid, D. W. and G. L. Bradford. 1983. On Optimum Replacement of Farm Tractors. American Journal of Agricultural Economics. 65: 326 – 331.

Reid, D. W. and G. L. Bradford. 1987. A Farm Firm Model of Machinery Investment Decisions. American Journal f Agricultural Economics, 69(1): 64 – 77.

Reid, J. F., J. Schueller, and W.R. Norris. 2003. Reducing the Manufacturing and Management Costs of Tractors and Agricultural Equipment. Agricultural Engineering International: the CIGR E-journal, 5: 1-12.

Riggs, J. L., Bedworth, D. D., and Randhara, S. V. 1998. Engineering Economics. Fourth Edition, McGraw-Hill Company, Inc., New York, USA.

Rijk, A. G. 1986. The Role of Farm Mechanization in Developing Counties: Experience in Asian Countries. *In* Small Farm Equipment for Developing Countries, Proceedings of the International Conference on Small Farm Equipment for Developing Countries; Past Experiences and Future Priorities, 2-6 September 1985, The International Rice Research Institute, Manila, Philippines, pp. 2 - 21.

Rijk, A. G. 1989. Agricultural Mechanization Policy and Strategy. Asian Productivity Organization, Tokyo.

Rizaldi, T. 2008. Tractor Development and Management for Land Preparation in Indonesia Development. District (in Indonesia Language). USU Repository, Medan. 14 p.

Rodulfo, V. A., RM. C. Amongo, and LV. L. Larona. 1998. Status of Philippines Agricultural Mechanization and Its Implication to Global Competitiveness. Philippine Agricultural Mechanization Bulletin, 5(1): 3 – 13.

Rotz, A., and W. Bower. 1991. Repair and Maintenance Costs Data for Agricultural Equipment. ASAE Paper No. 91-1531. St. Joseph, Michigan.

Ruiyin, H., Y. Wenging, Z. Yadong, and G. N. J. Van Somsbeek.1999. Improving Management System of Agricultural Machinery in Jiangsu. *In* Proceeding of 99 International Conferences on Agricultural Engineering, December 1999, Beijing. pp I-42 – I-43.

Saefudin, Y., H. Siswosumarto, R. Bernsten, A. Sri Bagyo, J. Lingar, and J. Wicks. 1983. Consequences of Small Rice Farm Mechanization in West Java: A Summary of Preliminary Analyses. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 165 – 175.

Saegusa, K. 1975. Text Book on Mechanization on Rice Farming. Indo-Japanese Agri. Training Center, Mandya, India.

Sahay, J. 2004. Element of Agricultural Engineering. Fourth Edition, Lomous Offset Press, Delhi, India.

Sahay, J. 2005. Elements of Agricultural Engineering. A. K. Jain (Prop), New Delhi.

Sakai, J. 1999. Two-wheel Tractor Engineering for Asian Wet Land Farming. Shin-Norisha Co., Ltd, Tokyo.

Sakai, J., T. Kishimoto, and S. Phongsupasamit. 1986. Studies on Evolutional Steps for Plowing and Tractorization in Japan; the Unique Mechanization Promotion in Small Scale Farming. Agricultural Mechanization in Asia, Africa and Latin America, 17(4): 11 – 19.

Sakai, J. 2013. National Modernization cannot be Realized without the Development and Diffusion of Agricultural Mechanization. Agricultural Mechanization in Asia, Africa and Latin America, 44(4): 43-44.

Saker, R. I, and D. Barton. 2006. The Impact of Power Tiller on Small Farm Productivity and Employment in Bangladesh. Agricultural Mechanization in Asia, Africa and Latin America, 37(1): 36 – 45.

Saker, R. I. and N. N. Sarker. 1979. Agricultural Mechanization Strategies in Bangladesh. Agricultural Mechanization in Asia. 10(2): 20 – 28.

Salokhe, V. M., and A. Hendriadi. 1995. Power Tiller Industry in Indonesia. Agricultural Mechanization in Asia, Africa, and Latin America, 26(4): 29 – 32.

Salokhe, V. M., and N. Ramalingan. 1998. Agricultural Mechanization in the South and South-East Asia. Paper Presented at the Plenary Session of the International Conference of the Philippines Society of Agricultural Engineers, 21 – 24 April 1998, Las Banos, Philippines, 23 p.

Salokhe, V. M., and A. Oida. 2003. Development of Appropriate Agricultural Machinery for Southeast Asian Countries. Laboratory of Agricultural Systems Engineering. Retrieved 16 April 2005 www.fsao.kais.kyoto-u.ac.jp/guest_prof/-Salokhe_report.pdf.

Sarker, R. I., and D. Dorton. 1006. The Impact of Power Tillers on Small farm Productivity and Employment in Bangladesh. Agricultural Mechanization in Asia, Africa, and Latin America, 37(1): 38– 45.

Sasaki, Y. 2002. Mechanization of Japanese Agricultural and Robotization Technology. Farming Japan, 36(2); 10-12.

Self, S. and R. Grabowski. 2007. Economic Development and the Role of Agricultural Technology. Agricultural Economics, 36: 395 – 404.

Setiawan, B., A. Tambunan, W. Hermawan, Desrial and Gardjito. 2006. Agricultural Engineering Education in Indonesia. Agricultural Engineering International: the CIGR Ejournal. Invited Overview, January Issue, 8(1):1 – 12.

Sharabiani, V. R and I. Ranjbar. 2008. Determination of the Degree, Level and Capacity Indices for Agricultural Mechanization in Sarab Region. Journal of Agricultural Science and Technology, 10: 215-223.

Sidik, M. 2004. Indonesia Rice Policy in View of Trade Liberalization. A Paper Presented at FAO Rice Conference, 12-13 February 2004 Rome, Italy. 11 p.

Sihombing, D. A., Soedjatmiko, and Handaka. 1984. Status of Agricultural Mechanization in Indonesia. *In* Development of the Agricultural Machinery Industry in Development Countries. Proceeding of the 2nd International Conference Amsterdam, 23 – 26 January 1984. pp 93 – 98.

Simatupang, P., A. Purwoto; B. Santoso, Hendiarto, Supriyati, S.H. Susilowati, V. Siagian, B. Prasetyo, E. Ariningsih, E.E. Ananto, and J. Simatupang. 1995. Development Patterns of Agricultural Mechanization in Indonesia. Agricultural Economic and Social Research Centre, Bogor, Indonesia. 16 p.

Sims, B. G., and J. Kienzle. 2006. Farm Power and Mechanization for Small Farms in Sub-Saharan Africa. Food and Agricultural Organization of the United Nation, Rome.

Sims, B. G., A. Rottger, and S. Mkomwa. 2011. Hire Services by Farmers for Farmers. Food and Agriculture Organization of the United Nations, Rome. 83 p.

Sinding, M. K., P. Defp, S. P. Reinhardt, and R. Rhoda. 1985. Promoting the Manufacture and use of Small Scale Agricultural Machinery in Indonesia. Paper No. AA.052. U. S. Agency for International Development (AID). 109 p.

Singh, G. 1984. Agricultural Mechanization in Selected Southeast Asian Countries. Agricultural Mechanization in Asia, Africa, and Latin America, 18(3): 33 – 39, 44.

Singh, G. 1996. Agricultural Mechanization in Bhutan. Agricultural Mechanization in Asia, Africa, and Latin America, 27(2): 51– 57.

Singh, G., 2006. Estimation of a Mechanisation Index and Its Impact on Production and Economic Factors-a; Case Study in India. Biosystems Engineering, 93(1): 99-106.

Singh, G. and H. Siswasumarto. 1988. Farm Mechanization in West Java, Indonesia. Agricultural Mechanization in Asia, Africa and Latin America, 19(1): 9-13.

Singh, G. and G. S. Yadao. 1979. Field Study of Agricultural Mechanization in Central Mindanao Philippines. Agricultural Mechanization in Asia, Winter Issue, 13 – 15.

Singh, G. and D. De. 1999. Quantification of a Mechanization Indicator for Indian Agriculture. Applied Engineering in Agriculture, 15(3): 197-204.

Singh, S. P., H. B. Singh, and H. N. Verna. 2001. Tractor Utilization for Various Agricultural and Developmental Operations: A Case Study. Agricultural Mechanization in Asia, Africa and Latin America, 32(1): 43 – 47.

Singh, S., J. P. Mittal, and S. R. Varma, 1997. Energy Requirement for Production of Major Crops in India. Agricultural Mechanization in Asia, Africa and Latin America, 28(4): 13-17.

Sison, J. F., R. W. Herdt, and B. Duff. 1985. The Effects of Small Farm Mechanization on Employment and Output in Selected Rice-Growing Areas in Nueva Ecija Philippines. Journal of Philippines Development, 12(1): 29 – 82.

Speedman B. 1992. Changes in Agriculture; Challenges for Education in Agricultural Engineering. *In* Proceedings of Agricultural Engineering and Rural Development Conference 2, 12–14 October, Beijing, China.

Spoor, G., R. Carillon, L. Bournas, and E. H. Brown, 1983. The Impact of Mechanization. M. G. Wolman and F. G. A. Fournier (Eds.), Land Transformation in Agriculture, John Wiley & Sons Ltd., pp 113 – 152.

Srivastava, A. K., C. E. Goering, R. P. Rohrbach, and D. R. Buckmaster. 2006. Engineering Principles of Agricultural Machines. 2nd Edition. American Society of Agricultural and Biological Engineers (ASABE), Michigan.

Srivastava, A. K., C. E. Goering, R. P. Rohrbach, and R. B. Buckmaster. 2006. Agricultural Mechanization and Some Methods of Study. St. Joseph, ASABE, Michigan, USA.

Statistics Bureau of Riau Province. 2014. Riau in Figure, Pekanbaru.

Statistics Bureau of Riau Province. 2014. Gross Regional Domestic Product 2010-2014, Pekanbaru.

Steenwinkel, W. A. 1979. Rural Development and External Assistance to That Sector. ILACQ Symposium Arnhem, Netherlands, pp. 77–94.

Subejo. 2014. Rice and Food National Problem. *In* Economy of Indonesian Rice. PERHEPI. Jakarta, pp. 1-39.

Sukharomana, S. Domestic Resource Cost of Agricultural Mechanization in Thailand: A Case Study of Small Rice Farms in Supanburi. In Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp 61 – 67.

Sunanto, Nasruddin Razak, and Nasrullah. 2011. Rice Harvest Handling to Reduce Yield Losses in South Sulawesi. Journal Sosial Ekonomi Pertanian, 8(1):55-62.

Sutter, D. 1974. Modifying and Applying Machinery for Small Farms: A Philippines Case Study. Experience in Farm Mechanization in Southeast Asia, ADC, New York.

Takeshima, H and S. Salau. 2010. Agricultural Mechanization and the Smallholder Farmers in Nigeria. International Food Policy Research Institute (IFPRI), Nigeria. 5 p.

Tewari, V. K., K. N. Dewangan, and S. Karmakar. 2004. Operator's Fatigue in Field Operation of Hand Tractor. Biosystems Engineering, 89(1): 1 – 11.

Toro, A. de. and P. A. Hansson. 2004. Machinery Co-operative – A Case Study in Sweden. Biosystems Engineering, 87(1): 13 - 23.

Tsorakidis, N., S. Papadoulos, M. Zerres, and C. Zerres. 2014. Break-even analysis. First Edition, Bookboon.com.

Tufts, R. A. 1985. Failure Frequency and Downtime Duration Effects on Equipment Availability. Transaction of the ASAE, 25(4): 999 -1002.

Vatsa, D. K. and D. C. Saraswat. 2008. Selection of Power Tiller and Matching Equipment using Computer Program for Mechanizing Hill Agriculture. Agricultural Engineering International: the CIGR E Journal, 10: 1-11.

Viegas, E. 2003. Agricultural Mechanization: Managing Technology Change. In Proceeding on ACIAR No. 113, Agriculture: New Directions for a New Nation, East Timor.

Wanjiku, J., J. U. Manyengo, W. Oluoch-Kosura, and J. T. Karug. 2007. Gender Differentiation in the Analysis of Alternative Farm Mechanization Choices on Small Farms in Kenya. UNU World Institute for Development Economics Research (UNU-WIDER), Helsinki. pp 1 - 23.

Wanjun, W. 1983. Profile of the Development of Agricultural Mechanization in China. Agricultural Mechanization in Asia, Africa, and Latin America, 14(3): 41 – 43.

Wapenham, W. A. 1979. The Big Problem of the Small Farmer. ILACO Symposium, Arnhem, Netherlands, pp. 29–51.

Ward, S. M. 1990. Tractor Ownership Costs. Agricultural Mechanization in Asia, Africa and Latin America, 21(1): 21 – 23.

Ward, S. M., Cunney, M. B and McNulty, P. B. 1985. Repair Costs and Reliability of Silage Mechanization System. Transaction of the ASAE, 28(3): 722 - 725.

Ward, S. M., McNulty, P. B. and Cunney, M. B. 1985, Repair Costs of 2 and 4 WD Tractors. Transaction of the ASAE, 28(4): 1074-1076.

Wattanutcharya, S. 1983. Economic Analysis of the Farm Machinery Industry and Tractor Contractor Business in Thailand. *In* Consequences of Small-Farm Mechanization; International Rice Research Institute and Agricultural Development Council, Los Banos, Philippines. pp. 39 – 49.

Watts, M. J. and G. A. Helmers. 1981. Machinery Cost and Inflation. Western Journal of Agricultural Economics, 6: 129 – 145.

Weersink, A. and S. Stauber. 1988. Optimal Replacement Interval and Depreciation Method for a Grain Combine. Western Journal of Agricultural Economics, 13(1): 18 – 28.

World Bank. 2003. Reaching the Rural Poor: A Renewed Strategy for Rural Development. Washington, D.C.

Wu, J., and G. M. Perry. 2004. Estimating Farm Equipment Depreciation: Which Functional Form Is Best?. American Journal of Agricultural Economics, 86(2): 483 – 491.

Xinan, D., L. Yuzhou., D. Suocheng and Y. Xiusheng, 2005. Impact of Resources and Technology on Farm Production in Northwestern China. Agricultural Systems, 84: 155-169.

Yogatama, M. R., S. Ciptohadijoyo, and R. E. Masithoh. 2002. Evaluation of Work Performance of Business of Agricultural Machinery and Equipment Services (UPJA) Contribution in Strategy of Agricultural Machinery and Equipment Development: Case Study of UPJA in DIJ (in Indonesia Language). Agritech, 2(4):

149 – 156.

Yohanna, J. K., A. U. Fulani, and W. Aka'ama. 2011. A Survey of Mechanization Problem of Small Scale (Peasant) Farmers in the Middle Belt of Nigeria. Journal of Agricultural Science, 3(2): 262 – 266.

Yuanjuan, S. and B. Chunjiang. 1999. Study on Economic Scale and Optimum Organization of Machinery Working Unit for Rice Production. *In* Proceeding of 99 International Conferences on Agricultural Engineering, December 1999, Beijing. pp. I-39 – I-41.

Zhou, X., R. Dong, S. Li, G. Peng, L. Zhang, J. Hou, J. Xiao, and B. Zhu. 2003. Agricultural Engineering in China. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, 5: 1 – 10.

APPENDIXES

Appendix 1. Capital, Land Area, and Height from Sea Level

Regency/City	Capital	Area (ha)	Percentage	Height from sea level (m)
Kuantan Sengingi	Teluk Kuantan	520,216.13	5.84	57
Indragiri Hulu	Rengat	767,626.66	8.61	4
Indragiri Hilir	Tembilahan	1,379,837.12	15.48	3
Pelalawan	Pangkalan Kerinci	1,240,413.93	13.9	5
Siak	Siak Sri Indrapura	823,357.00	9.24	5
Kampar	Bangkinang	1,092,819.71	12.26	30
Rokan Hulu	Pasir Pengarayan	722,977.68	8.11	91
Bengkalis	Bengkalis	843,720.00	9.46	2
Rokan Hilir	Bagan Siapi-api	891,142.93	10.05	5
Kep. Meranti	Selat Panjang	360,703.00	4.05	2
Pekanbaru	Prkanbaru	63,300.86	0.71	10
Dumai	Dumai	203,900.00	2.29	5
Riau Province	Pekanbaru	8,915,015.07	100.00	

Source: Statistical Bureu of Riau Province 2011.

Appendix 2. Number of Rainfall in Riau Province in 2013

Month	Regency/City											
	Kuantan Sengingi	Indragiri Hullu	Indragiri Hilir	Siak	Bengkalis	Rokan Hilir	Kampar	Rokan Hulu	Pelalawan	Pekanbaru	Dumai	Average
January	230	143	224	67	190	66	48	15	218	258	171	146
February	215	200	302	248	167	483	290	117	234	265	85	252
March	102	180	236	325	324	371	242	197	139	202	37	232
April	133	263	155	215	215	491	306	195	217	250	364	244
May	89	130	82	183	28	146	197	254	153	281	317	154
June	7	106	NA	141	NA	98	25	25	18	32	199	56
July	148	66	198	262	17	152	51	77	169	130	121	127
August	161	158	337	90	176	201	59	58	86	154	229	148
September	189	153	101	186	203	318	140	93	173	100	308	166
Oktober	281	167	152	229	156	691	297	236	287	280	120	278
Nopember	344	302	332	440	309	649	369	358	324	468	188	389
December	358	107	355	245	525	415	304	97	203	426	267	303
Aveage	188	165	225	219	210	340	194	144	185	237	2405	208

Source: Statistical Bureu of Riau Province 2014.

Appendix 3. Number of Paddy Field Area in Riau Province during 2004 – 2013

Regency	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Irrigation	12,011	27,390	24,036	24,487	20,612	18,985	16,449	15,096	22,934	18,884
Rain fed	131,521	149,195	147,872	136,242	136,712	123,833	140,965	121,297	99,071	62,898
Tidal	69,222	68,687	83,624	73,607	76,980	77,197	82,358	61,549	60,014	55,000
Low land	49,539	25,915	21,905	46,897	13,876	13,170	7,895	7,713	7,526	3,034
Others	43,366	12,577	1,239	1,271	1,409	1,755	1,922	760	-	-
Total	305,659	284,764	276,676	282,504	249,589	234,940	249,589	206,415	189,545	139,818

Source; Food Crop service of Riau Province, 2005 - 2014

Appendix 4. Number of Harvested Area of Paddy Field in each Regency in Riau Province during 2004 – 2013

Regency	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Rokan Hulu	3,331	3,283	3,206	3,992	4,539	4,270	5,189	5,162	6,073	4,377
Kuantan Sengingi	9,507	9,133	9,128	9,023	8,967	9,415	9,738	9,635	10,495	11,954
Pelalawan	7,341	8,644	8,284	8,803	9,823	10,282	11,341	10,536	11,532	11,126
Siak	6,721	5,446	5,537	5,921	6,921	7,529	8,324	6,460	7,781	8,359
Pekanbaru	NA	NA	NA	NA	NA	NA	3	10	12	9
Indragiri Hilir	35,531	31,280	30,035	31,707	29,272	29,562	30,813	30,662	29,972	31,475
Rokan Hilir	33,441	34,521	36,621	40,031	41,364	42,603	44,784	41,073	29,813	12,271
Bengkalis	15,159	12,061	9,545	9,339	9,314	9,436	7,207	6,657	6,305	6,284
Kampar	6,751	5,352	5,461	5,320	5,670	8,803	9,470	7,347	10,552	6,928
Indragiri Hulu	1,670	2,258	3,534	3,426	2,294	4,641	1,738	3,516	1,893	3,035
Dumai	3,992	2,050	3,142	2,890	2,685	981	688	213	1,184	244
Kepulauan Meranti	NA	NA	NA	NA	NA	NA	1,968	1,727	2,037	2,234
Total	123,3384	114,028	114,493	120,482	120,84	127,522	131,263	123,038	117,649	97,796

Source; Food Crop service of Riau Province, 2005 - 2014

Appendix 5. Number of Rice Production in each Regency in Riau Province during 2004 – 2013

Regency	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Rokan Hulu	10,876	10,404	10,322	14,159	16,114	15,430	20,565	19,812	22,929	17,507
Kuantan Sengingi	31,512	29,655	29,941	33,245	33,494	34,685	42,865	44,275	46,520	49,377
Pelalawan	23,448	27,945	27,256	30,814	34,129	36,301	39,130	37,475	41,722	47,280
Siak	22,158	17,385	18,89	20,848	24,627	31,577	32,857	27,032	31,810	36,978
Pekanbaru	NA	NA	NA	NA	NA	NA	10	32	45	34
Indragiri Hilir	120,353	106,744	102,404	117,942	110,266	115,571	119,221	121,681	125,619	124,801
Rokan Hilir	109,910	118,190	123,186	139,283	144,064	156,942	174,762	157,959	104,038	43,910
Bengkalis	49,482	39,022	31,213	32,296	32,689	31,395	25,229	24,626	22,318	21,438
Kampar	21,461	17,416	18,333	19,295	20,797	32,813	36,548	29,346	39,238	26,527
Indragiri Hulu	5,431	7,294	11,357	12,539	8,370	20,131	7,260	13,560	9,070	13,216
Dumai	12,845	6,320	9,933	10,116	9,305	3,498	2,308	694	3,891	771
Kepulauan Meranti	NA	NA	NA	NA	NA	NA	6,616	5,419	6,094	6,007
Total	407,516	380,335	382,034	430,577	433,855	478,343	507,370	481,911	453,294	387,849

Source; Food Crop service of Riau Province, 2005 - 2014

Appendix 6. Number of Productivity of Rice in each Regency in Riau Province during 2004 – 2013

Regency	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Rokan Hulu	3.265	3.169	3.220	3.557	3.550	3.614	3.963	3.838	3.776	4.000
Kuantan Sengingi	3.315	3.247	3,280	3.684	3.735	3.684	4.402	4.595	4.433	4.311
Pelalawan	3.194	3.233	3,290	3.500	3.474	3.531	3.450	3.557	3.618	4.250
Siak	3.303	3.192	3.267	3.521	3.558	4.194	3.947	4.185	4.088	4.424
Pekanbaru	NA	NA	NA	NA	NA	NA	3.333	3.200	3.750	3.778
Indragiri Hilir	3.397	3.413	3.409	3.720	3.767	3.909	3.869	3.968	4.191	3.965
Rokan Hilir	3.287	3.424	3.3364	3.479	3.483	3.684	3.902	3.846	3.490	3.578
Bengkalis	3.256	3.235	3.270	3.458	3.510	3.327	3.501	3.677	3.540	3,412
Kampar	3.179	3.254	3.357	3.627	3.668	3.727	3,859	3,994	3.719	3.829
Indragiri Hulu	3.252	3.213	4.214	3.628	3.649	4,338	4.177	3.857	4.791	4.356
Dumai	3.218	3.083	3.161	3.500	3.466	3.566	3.355	3.258	3.286	3.160
Kepulauan Meranti	NA	NA	NA	NA	NA	NA	3.361	3.138	2.992	2.689
Average	3.269	3.335	3.337	3.574	3.590	3.751	3.865	3.917	3.853	3.66

Source; Food Crop service of Riau Province, 2005 - 2014

Appendix 7. Number of Farm Machinery in each Regency in Riau Province in 2004

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	3	0	3	82	5	87	21	22	43	48	5	53	14	1	15	264	8	272
Kuantan Sengingi	2	0	2	63	31	94	11	1	12	84	14	98	15	5	20	145	19	164
Pelalawan	1	0	1	11	1	12	44	3	47	14	0	14	1	0	1	13	4	17
Siak	3	0	3	120	8	128	88	25	113	59	11	70	7	7	14	41	11	47
Pekanbaru	3	0	3	79	0	79	109	0	109	1	0	1	0	0	0	0	0	0
Indragiri Hilir	0	3	3	53	52	105	33	8	41	595	71	666	16	0	16	220	35	255
Rokan Hilir	0	0	0	124	16	140	47	4	56	157	39	196	15	0	15	158	13	169
Bengkalis	0	0	0	6	1	7	2	0	2	30	8	38	0	3	3	0	0	0
Kampar	1	0	1	79	0	79	145	15	160	24	0	24	7	0	7	109	13	122
Indragiri Hulu	8	0	8	51	4	55	15	4	19	11	5	16	9	0	9	23	5	29
Dumai	3	1	4	11	2	13	133	2	135	3	1	4	0	0	0	2	1	3
Total	24	4	28	679	120	799	648	84	737	1026	154	1180	84	16	100	975	109	1078
Persentage (%)	85.71	14.29	100.00	84.98	15.02	100.00	87.92	11.40	100.00	86.95	13.05	100.00	84.00	16.00	100.00	90.45	10.11	100.00

Source; Food Crop service of Riau Province, 2005

Appendix 8. Number of Farm Machinery in each Regency in Riau Province in 2005

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	3	0	3	82	5	87	21	22	43	48	5	53	14	1	15	264	8	272
Kuantan Sengingi	2	0	2	63	31	94	11	1	12	84	14	98	15	0	15	145	19	164
Pelalawan	1	0	1	11	1	12	44	3	47	14	0	14	1	0	1	13	4	17
Siak	3	0	2	120	8	128	88	25	107	59	11	69	7	1	8	41	11	52
Pekanbaru	3	0	3	79	0	79	109	9	118	14	0	14	0	0	0	0	0	0
Indragiri Hilir	0	3	3	53	52	105	33	8	41	66	71	137	16	0	16	220	35	255
Rokan Hilir	0	3	3	124	16	149	47	4	56	157	39	196	15	0	15	158	13	168
Bengkalis	0	0	0	6	1	7	2	0	2	30	8	38	0	3	3	0	0	0
Kampar	1	0	1	79	5	84	145	15	160	24	0	24	7	0	7	109	13	122
Indragiri Hulu	8	0	8	51	4	59	15	4	19	48	5	53	9	0	9	23	5	28
Dumai	3	1	4	11	2	13	133	2	137	3	1	4	0	0	0	2	1	3
Total	24	7	30	679	125	817	648	93	742	547	154	700	84	5	89	975	109	1081
Persentage (%)	80.00	23.33	100.00	83.11	15.30	100.00	87.33	12.53	100.00	78.14	22.00	100.00	94.38	5.62	100.00	90.19	10.08	100.00

Source; Food Crop service of Riau Province, 2006

Appendix 9. Number of Farm Machinery in each Regency in Riau Province in 2006

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	4	2	6	41	14	55	41	14	55	22	8	30	9	1	10	28	0	28
Kuantan Sengingi	2	0	2	11	1	12	11	1	12	84	14	98	15	5	20	145	19	164
Pelalawan	1	0	1	44	3	47	44	3	47	14	0	14	1	0	1	13	4	17
Siak	2	0	2	106	37	156	106	37	156	65	9	74	6	1	7	44	6	50
Pekanbaru	2	0	2	93	2	95	93	2	95	0	0	0	0	0	0	0	0	0
Indragiri Hilir	3	0	3	39	15	54	39	15	54	267	96	363	3	4	7	248	23	271
Rokan Hilir	0	0	0	58	11	61	58	11	61	223	44	267	88	9	97	158	13	169
Bengkalis	0	0	0	2	0	2	2	0	2	30	8	38	0	3	3	0	0	0
Kampar	7	2	9	109	11	120	109	11	120	24	1	25	8	1	9	85	9	94
Indragiri Hulu	8	0	8	27	7	34	41	14	55	22	8	30	8	2	10	28	0	28
Dumai	4	0	4	135	3	138	135	3	138	5	3	8	0	0	0	11	3	14
Total	33	4	37	665	104	774	679	111	795	756	191	947	138	26	164	760	77	835
Persentage (%)	89.19	10.81	100.00	85.92	13.44	100.00	85.41	13.96	100.00	79.83	20.17	100.00	84.15	15.85	100.00	91.02	9.22	100.00

Source; Food Crop service of Riau Province, 2007

Appendix 10. Number of Farm Machinery in each Regency in Riau Province in 2007

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	3	0	3	46	13	59	56	4	60	21	2	23	1	1	2	80	8	88
Kuantan Sengingi	8	0	8	49	6	55	27	7	34	22	8	30	8	2	10	28	0	28
Pelalawan	0	0	0	75	15	90	32	2	34	195	47	242	1	4	5	230	15	245
Siak	0	0	0	14	2	16	9	0	9	15	5	20	0	0	0	25	4	29
Pekanbaru	5	1	6	97	0	97	43	2	45	53	4	57	3	1	4	187	8	195
Indragiri Hilir	0	0	0	122	22	144	63	4	67	156	31	187	17	6	23	184	13	197
Rokan Hilir	9	6	15	64	23	87	14	2	16	32	7	39	4	8	12	91	5	96
Bengkalis	6	0	6	73	34	107	258	29	287	72	18	90	6	1	7	28	15	43
Kampar	4	0	4	16	5	21	135	3	138	5	3	8	0	0	0	11	3	14
Indragiri Hulu	4	1	5	19	7	26	175	573	748	0	0	0	0	0	0	0	0	0
Dumai	0	0	0	4	38	42	57	83	140	5	45	50	0	0	0	6	28	34
Total	39	8	47	579	165	744	869	709	1.578	576	170	746	40	23	63	870	99	969
Persentage (%)	**82.98**	**17.02**	**100**	**77.82**	**22.18**	**100**	**55.07**	**44.93**	**100**	**77.21**	**22.79**	**100**	**63.00**	**37.00**	**100,00**	**89.78**	**10.22**	**100**

Source; Food Crop service of Riau Province, 2008

Appendix 11. Number of Farm Machinery in each Regency in Riau Province in 2008

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	3	0	3	46	13	59	56	4	60	21	2	23	1	1	2	80	6	86
Kuantan Sengingi	8	0	8	49	6	55	27	7	34	22	8	30	8	2	10	28	0	28
Pelalawan	0	0	0	75	15	90	42	2	44	195	47	242	1	4	5	230	15	245
Siak	0	0	0	14	2	16	9	0	9	15	5	20	0	0	0	25	4	29
Pekanbaru	5	1	6	97	0	97	43	2	45	53	4	57	3	1	4	187	8	195
Indragiri Hilir	0	0	0	122	22	144	63	4	67	156	31	187	17	6	23	184	13	197
Rokan Hilir	9	6	15	64	23	87	14	2	16	32	7	39	4	8	12	91	5	96
Bengkalis	6	0	6	73	34	107	258	29	287	72	18	90	6	1	7	28	15	43
Kampar	4	0	4	16	5	21	135	3	138	5	3	8	0	0	0	11	3	14
Indragiri Hulu	4	1	5	19	7	26	185	573	758	0	0	0	0	0	0	0	0	0
Dumai	0	0	0	4	38	34	57	297	354	5	45	50	0	0	0	6	28	34
Total	39	8	47	579	165	736	889	923	1.812	576	170	746	40	23	63	870	97	967
Persentage (%)	82.98	17.02	100	78.67	22.42	100	49.06	50.94	100	77.21	22.79	100	63.00	37.00	100,00	89.97	10.03	100

Source; Food Crop service of Riau Province, 2009

Appendix 12. Number of Farm Machinery in each Regency in Riau Province in 2009

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	3	0	3	46	13	59	56	4	60	21	2	23	1	1	2	80	8	88
Kuantan Sengingi	8	0	8	49	6	55	27	7	34	22	8	30	8	2	10	28	0	28
Pelalawan	0	0	0	77	24	101	138	3	141	215	49	264	32	4	36	220	14	234
Siak	0	0	0	14	2	16	9	0	9	15	5	20	0	0	0	25	4	29
Pekanbaru	13	6	19	118	50	168	59	22	81	51	17	68	3	1	4	121	20	141
Indragiri Hilir	0	0	0	122	51	173	124	32	156	208	129	337	5	1	6	96	82	178
Rokan Hilir	2	2	4	95	48	143	24	2	26	45	8	53	3	1	4	49	11	60
Bengkalis	6	0	6	292	118	410	3.850	112	3.962	156	25	181	2	1	3	22	15	37
Kampar	5	0	5	24	6	30	41	15	56	18	2	20	0	0	0	16	4	20
Indragiri Hulu	0	0	0	23	0	23	1.318	14	1.332	1	0	1	0	0	0	0	0	0
Dumai	4	0	4	106	12	118	412	60	472	89	14	103	0	0	0	61	13	74
Total	41	8	49	966	330	1296	6.058	271	6.329	841	259	1100	54	11	65	718	171	889
Persentage (%)	83.67	16.33	100	74.54	25.46	100	95.72	4.28	100	76.45	23.55	100	83.00	17.00	100,00	80.76	19.24	100

Source: Food Crop service of Riau Province, 2010

Appendix 13. Number of Farm Machinery in each Regency in Riau Province in 2010

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	1	0	1	120	35	155	150	31	181	30	5	35	0	0	0	62	4	66
Kuantan Sengingi	0	0	0	26	0	26	12	0	12	20	0	20	0	0	0	4	0	4
Pelalawan	1	0	1	125	32	157	166	19	185	127	25	152	26	4	30	216	25	241
Siak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pekanbaru	14	6	20	126	52	178	56	17	73	62	20	82	4	0	4	128	29	157
Indragiri Hilir	0	0	0	48	24	72	49	24	73	181	71	252	5	0	5	159	11	170
Rokan Hilir	2	2	4	109	44	153	45	2	47	5	1	6	0	0	0	2	0	2
Bengkalis	4	0	4	249	0	249	1.945	49	1.994	127	25	152	4	1	5	39	4	43
Kampar	1	0	1	10	3	13	4	0	4	18	2	20	0	0	0	14	3	17
Indragiri Hulu	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0
Dumai	0	0	0	69	10	79	475	40	515	65	13	78	1	0	1	54	10	64
Total	23	8	31	882	200	1082	2.902	182	3.084	636	163	799	40	5	45	678	86	764
Persentage (%)	74.19	25.81	100	81.52	18.48	100	94.10	5.90	100	79.60	20.40	100	89.00	11.00	100,00	88.74	11.26	100

Source; Food Crop service of Riau Province, 2011

Appendix 14. Number of Farm Machinery in each Regency in Riau Province in 2011

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	16	6	22	141	55	196	70	18	88	55	22	77	NA	NA	NA	112	38	150
Kuantan Sengingi	1	0	1	124	83	187	23	8	31	57	19	76	NA	NA	NA	61	19	80
Pelalawan	4	0	4	164	20	184	185	34	219	79	13	92	2	1	3	64	11	75
Siak	4	0	4	430	73	503	1,750	49	1,799	133	22	155	4	1	5	32	4	36
Pekanbaru	NA	NA	NA	34	6	40	1,849	82	1,931	1	0	1	2	1	3	NA	NA	NA
Indragiri Hilir	NA	NA	NA	94	32	126	120	31	151	255	69	324	26	4	30	232	2	234
Rokan Hilir	NA	NA	NA	274	150	424	159	58	217	159	137	306	5	4	9	164	91	255
Bengkalis	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Kampar	NA	NA	NA	129	40	165	148	27	175	21	6	27	NA	NA	NA	51	4	56
Indragiri Hulu	2	01	83	84	24	106	31	3	34	23	8	31	NA	NA	NA	6	5	11
Dumai	1	0	1	27	12	39	24	5	29	18	2	20	NA	NA	NA	14	3	17
Kepulauan Meranti	NA	NA	NA	4	2	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	14	0	14
Total	28	7	35	1,505	477	1,976	4,359	315	4,674	811	298	1,109	39	11	50	750	177	927
Persentage (%)	8O.00	20.00	100.00	76.09	23.91	100.00	93.13	6.85	100.00	73.13	26.87	100.00	78.00	22.00	100.00	80.91	19.09	100.00

Source; Food Crop service of Riau Province, 2012

Appendix 15. Number of Farm Machinery in each Regency in Riau Province in 2012

Regency/City	Large tractor (<15-50 hp)			Hand tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	4	0	4	122	46	170	66	13	79	69	24	93	4	4	8	124	28	152
Kuantan Sengingi	NA	NA	NA	84	45	129	19	9	28	61	5	66	NA	NA	NA-	27	8	35
Pelalawan	2	0	2	96	13	109	184	12	196	84	8	92	2	1	3	66	5	71
Siak	5	0	5	193	72	265	314	78	392	112	44	156	NA	NA	NA-	34	4	38
Pekanbaru	3	6	9	46	22	68	197	75	272	NA	NA	NA-	2	1	3	NA	NA	NA-
Indragiri Hilir	NA	NA	NA	89	43	132	117	39	159	379	88	467	NA	NA	NA-	220	15	235
Rokan Hilir	NA	NA	NA	140	84	224	24	5	29	158	144	302	11	0	11	97	101	196
Bengkalis	NA	NA	NA	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-
Kampar	NA	NA	NA	131	34	165	157	33	190	30	7	37	NA	NA	NA-	58	3	61
Indragiri Hulu	2	1	3	48	10	58	49	6	55	31	1	32	18	5	23	7	3	10
Dumai	1	0	1	27	12	39	24	5	29	18	2	20	2	1	3	14	3	17
Kepulauan Meranti	NA	NA	NA	9	5	14	NA	NA	NA-	16	0	16	NA	NA	NA-	1	0	1
Total	17	7	24	1,223	388	1,611	1,156	275	1,431	958	323	1,281	39	12	51	648	170	818
Persentage (%)	70.83	29.17	100.00	75.92	24.08	100.00	80.78	19.22	100.00	75.97	24.03	100.00	76.47	23.53	100.00	79.22	20.78	100.00

Source; Food Crop service of Riau Province, 2013

Appendix 16. Number of Farm Machinery in each Regency in Riau Province in 2013

Regency	4-wheel tractor (<15-50 hp)			2-wheel tractor (< 15 hp)			Water Pump			Power Thresher			Dryer			RMU		
	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total	Good condition	Break-down	Total
Rokan Hulu	4	0	4	204	73	277	173	34	207	89	61	150	7	0	7	167	56	223
Kuantan Sengingi	NA	NA	NA	127	60	187	24	4	28	106	17	123	NA	NA	NA-	25	10	35
Pelalawan	2	0	2	122	12	134	122	7	129	80	7	87	NA	NA	NA-	69	4	737
Siak	2	0	2	289	28	317	802	32	834	152	13	165	NA	NA	NA-	40	4	44
Pekanbaru	8	1	29	75	11	86	919	126	1,045	4	0	4	NA	NA	NA-	2	0	2
Indragiri Hilir	35	4	7	116	33	149	89	40	129	443	101	544	3	1	4	310	23	333
Rokan Hilir	NA	NA	NA	168	96	264	76	41	117	204	186	390	1	0	1	104	85	189
Bengkalis	NA	NA	NA	NA	NA	NA	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-
Kampar	2	2	4	130	30	160	177	34	211	543	110	653	NA	NA	NA-	60	4	64
Indragiri Hulu	1	0	1	69	9	76	50	1	51	48	5	53	NA	NA	NA-	18	2	20
Dumai	NA	NA	NA	59	10	69	151	8	159	21	5	26	NA	NA	NA-	12	0	12
Kepulauan Meranti	NA	NA	NA	NA	NA	NA	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-	NA	NA	NA-
Total	22	7	29	1,359	362	1,721	2,583	327	2,910	1,690	505	2,195	11	1	12	807	188	995
Persentage (%)	75.86	24.14	100,00	78.62	21.38	100,00	88.76	11.24	100,00	76.99	23.01	100,00	91.67	8.33	100,00	81.11	18.89	100,00

Source; Food Crop service of Riau Province, 2014

Appendix 17. Level of Using Farm Machinery and Equipment on Rice Farming Operations in Indonesia (%).

No	Farm operations	Hand tools/ traditional	Mechanical power	Explanation
1	Land preparation/ tillage	62*	38	Using hand tractor with capacity = 40 ha/unit/yr
2	Planting or Seeding	100	0	Using traditional tools. such as hand pushed seeder and planting stick
3	Weeding	100	0	Using traditional tools. such as hoe and weeding hoe
4	Pest control	100	0	Using hand sprayer and power sprayer
5	Irrigation	50	50	Using water pump with capacity = 30 ha/unit/yr
6	Harvesting	100	0	Using traditional tools. such as sickle and finger-held knife.
7	Threshing	79	21	Using power thresher with capacity = 60 ha/unit/yr
8	Drying	85-90	10-15	Using dryer with capacity = 360 ton/unit/yr
9	Milling	0	100	Huller and rice milling unit

*Note: * = Including using animal power.*
Source: Diolah berdasarkan data jumlah mesin tahun 2004 dan survey pasca panen berbagai sumber.

Appendix 18. Characteristics of Tractor Samples

No. of sample	Maker	HP	Purchase		Location	Ownership system
			Year	Method		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Kubota	10.5	1994	cash	Siak	individual
2	Kubota	8.5	1992	cash	Siak	individual
3	Yanmar	7.5	2000	credit	Siak	group
4	Nandong	8.5	1998	cash	Siak	individual
5	Yanmar	10.5	1996	cash	Siak	individual
6	Kubota	8.5	2002	credit	Siak	individual
7	Kubota	8.5	2002	credit	Siak	group
8	Kubota	10.5	1994	cash	Siak	individual
9	Nandong	9.5	2001	credit	Siak	individual
10	Yanmar	10.0	2001	credit	Siak	group
11	Kubota	8.5	1995	cash	Siak	individual
12	Yanmar	10.5	1999	credit	Siak	individual
13	Nandong	9.5	1993	credit	Siak	individual
14	Yanmar	7.5	2000	credit	Siak	individual
15	Yanmar	8.5	2002	credit	Siak	group
16	Nandong	8.5	1996	cash	Siak	individual
17	Yanmar	8.5	2001	credit	Siak	group
18	Yanmar	8.5	2002	credit	Siak	group
19	Nandong	10.0	1996	cash	Siak	individual
20	Yanmar	8.5	2002	credit	Siak	individual
21	Yanmar	8.5	1993	credit	Siak	individual
22	Yanmar	10.5	1999	credit	Siak	group
23	Kubota	8.5	1996	cash	Siak	individual
24	Nandong	10.5	2001	credit	Siak	individual
25	Yanmar	10.5	1999	credit	Siak	individual
26	Yanmar	10.5	1999	credit	Siak	individual
27	Yanmar	10.5	1999	credit	Siak	individual
28	Nandong	9.5	1996	credit	Siak	individual
29	Yanmar	10.0	1999	credit	Siak	group
30	Yanmar	8.5	1995	cash	Siak	individual
31	Yanmar	8.5	1995	cash	Siak	individual
32	Nandong	10.5	2001	credit	Siak	individual
33	Yanmar	8.5	1995	cash	Siak	individual
34	Kubota	8.5	1997	cash	Siak	group
35	Kubota	8.5	1987	credit	Siak	individual
36	Nandong	10.5	2001	credit	Siak	individual
37	Yanmar	10.0	1999	credit	Siak	individual
38	kubota	8.5	1994	credit	Siak	individual
39	Yanmar	9.5	2000	cash	Siak	individual

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)
40	Yanmar	10.5	2000	aid	Rohul	group
41	Yamar	10.5	2000	aid	Rohul	group
42	Yanmar	8.5	1994	aid	Rohul	group
43	Yanmar	7.5	1998	aid	Rohul	group
44	Yanmar	8.5	2001	aid	Rohul	group
45	Yanmar	8.5	1998	aid	Rohul	group
46	Kubota	8.5	1995	aid	Rohul	group
47	Kubota	8.5	1996	cash	Rohul	individual
48	Nandong	10.0	1999	cash	Rohul	individual
49	Kubota	8.5	1998	aid	Kuansing	group
50	Yanmar	10.5	1995	aid	Kuansing	group
51	Kubota	8.5	1997	aid	Kuansing	gropu
52	Kubota	8.5	1998	aid	Kuansing	group
53	Yanmar	8.5	1999	aid	Kuansing	group
54	Yanmar	9.5	1999	aid	Kuansing	gropu
55	Kubota	8.5	1998	aid	Kuansing	group
56	Yanmar	8.5	1999	aid	Kuansing	group
57	Yanmar	8.5	1999	aid	Kuansing	group
58	Kubota	8.5	1997	aid	Kuansing	group
59	Kubota	8.5	1997	aid	Kuansing	group
60	Yanmar	8.5	2000	aid	Kuansing	group
61	Yanmar	10.0	2001	aid	Kuansing	group
62	Yanmar	10.5	1998	aid	Kuansing	group

Appendix 19. Profile of Tractor Operators

No.	Spl	Number of operators	Age (y)	Operator experience (Y)	Education level				Operator's skill obtained from					Duration (Y)
					Ne	Es	Yhs	Shs	Friend	Selt-study	Training	Father	Others	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	1	1	18	2			x		x					
2		2	20	2			x		x					
3	2	1	32	17			x		x					
4		2	34	2			x		x					
5	3	1	27	3		x			x					
6		2	33	4		x			x					
7	4	1	36	5			x		x					
8		2	40	9		x							x	
9	5	1	25	1		x			x					
10		2	40	6		x			x					
11	6	1	26	3		x			x					
12		2	50	10		x			x					
13	7	1	25	6			x		x					
14		2	26	5				x	x					
15	8	1	18	1			x		x					
16		2	25	6			x						x	
17	9	1	50	2		x				x				
18		2	17	2		x						x		
19	10	1	45	3		x			x					
20		2	18	1		x			x					
21	11	1	50	4	x				x					
22	12	1	30	3		x			x					
23		2	35	4		x			x					
24	13	1	22	6		x			x					
25		2	21	3		x			x					
26	14	1	25	5			x						x	
27		2	20	5			x						x	
28	15	1	27	2				x	x					
29		2	28	2			x						x	
30	16	1	47	7		x				x				
31	17	1	38	1						x				
32	18	1	52	10	x								x	
33		2	34	2			x						x	
34	19	1	50	8			x				x			6 months
35	20	1	49	4		x			x					
36		2	40	4		x			x					
37	21	1	45	6		x							x	
38		2	24	2				x					x	
39	22	1	39	9				x			x			6 moonts
40		2	45	10		x				x				

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
41	23	1	45	10		x			x					
42		2	17	1		x			x					
43	24	1	35	3		x			x					
44		2	35	4			x		x					
45	25	1	35	5		x			x					
46		2	28	3		x			x					
47	26	1	39	23		x			x					
48		2	18	3			x		x					
49	27	1	53	2	x				x					
50		2	25	1		x			x					
51	28	1	19	5			x		x					
52		2	18	4			x		x					
53	29	1	50	20		x			x					
54		2	35	18			x		x					
55	30	1	32	7				x	x					
56		2	35	7		x			x					
57	31	1	28	1				x			x			1 day
58		2	40	7		x					x			1 day
59	32	1	50	12			x		x					
60		2	21	7				x	x					
61	33	1	35	5		x			x					
62		2	40	7		x						x		
63	34	1	30	10		x			x					
64		2	28	1	x				x					
65	35	1	32	5		x			x					
66		2	28	1	x				x					
67	36	1	39	12		x			x					
68		2	27	3			x		x					
69	37	1	48	5		x			x					
70		2	32	5		x			x					
71	38	1	30	7		x			x					
72		2	40	8			x		x					
73	39	1	46	12			x			x				
74		2	40	2			x			x				
75	40	1	45	2		x			x					
76		2	43	4		x			x					
77	41	1	44	4		x				x				
78		2	35	3			x		x					
79	42	1	36	3			x		x					
80		2	51	7		x						x		
81	43	1	52	4		x						x		
82		2	34	4			x			x				
83	44	1	33	3			x		x					
84		2	42	6		x			x					
85	45	1	46	8		x			x					
86		2	26	3				x	x					

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
87	46	1	24	2				x	x					
88		2	33	5				x	x					
89	47	1	35	5				x			x			1 month
90		2	28	5			x		x					
91	48	1	35	8		x						x		
92		2	25	3				x	x					
93	49	1	57	6		x					x			2 days
94		2	35	1			x		x					
95	50	1	38	8			x						x	
96	51	1	50	12			x				x			1 weeks
97		2	40	10				x	x					
98	52	1	45	4	x				x					
99	53	1	47	2		x					x			1 weeks
100		2	20	6				x	x					
101	54	1	34	6			x						x	
102	55	1	32	5				x			x			1 day
103	56	1	35	5				x	x					
104		2	35	5				x	x					
105	57	1	34	3			x						x	
106		2	56	8		x							x	
107	58	1	36	5			x				x			1 week
108	59	1	34	3			x			x				
109		2	37	4			x				x			1 day
110	60	1	42	6			x		x					
111		2	44	4		x					x			1 day
112	61	1	35	3		x			x					
113		2	23	3				x	x					
114	62	1	30	5		x			x					
115		2	25	2			x		x					

Appendix 20. Operating Area of Tractors in Hectare Per Year

No. of Sample	Age (yr)	Operating area (ha/yr)				
		Farmer's own	Hired service	Wet season	Dry season	Total
(1)	(2)	(3)	(4)	(6)	(7)	(8)
1	9	4.0	36.0	20.0	20.0	40.0
2	11	4.0	18.0	11.0	11.0	22.0
3	3	0.0	30.0	15.0	15.0	30.0
4	5	4.0	36.0	20.0	20.0	40.0
5	7	4.0	21.0	10.0	15.0	25.0
6	1	4.0	14.0	15.0	3.0	18.0
7	1	0.0	19.0	10.0	9.0	19.0
8	9	4.0	26.0	15.0	15.0	30.0
9	2	4.0	6.0	4.0	6.0	10.0
10	2	0.0	30.0	15.0	15.0	30.0
11	7	4.0	26.0	15.0	15.0	30.0
12	4	8.0	22.0	15.0	15.0	30.0
13	10	2.0	15.0	10.0	7.0	17.0
14	3	4.0	21.0	15.0	10.0	25.0
15	1	0.0	20.0	10.0	10.0	20.0
16	7	4.0	16.0	10.0	10.0	20.0
17	2	0.0	30.0	15.0	15.0	30.0
18	1	0.0	10.0	5.0	5.0	10.0
19	7	4.0	6.0	7.0	3.0	10.0
20	1	4.0	14.0	12.0	6.0	18.0
21	10	4.0	15.0	12.0	7.0	19.0
22	4	0.0	10.0	0.0	10.0	10.0
23	7	4.0	36.0	25.0	15.0	40.0
24	2	4.0	19.5	8.0	15.5	23.5
25	4	2.0	28.0	15.0	15.0	30.0
26	4	8.0	22.0	15.0	15.0	30.0
27	4	4.0	24.0	16.0	12.0	28.0
28	6	4.0	26.0	15.0	15.0	30.0
29	4	0.0	38.0	19.0	19.0	38.0
30	8	4.0	20.0	17.0	7.0	24.0
31	8	0.0	40.0	20.0	20.0	40.0
32	2	2.0	34.0	19.0	17.0	36.0
33	8	9.0	11.0	10.0	10.0	20.0
34	6	0.0	32.0	17.0	15.0	32.0
35	15	4.0	24.0	15.0	13.0	28.0
36	2	4.0	18.0	10.0	12.0	22.0
37	4	0.0	30.0	15.0	15.0	30.0
38	9	4.0	25.0	15.0	14.0	29.0
39	3	2.0	30.0	16.0	16.0	32.0
40	3	0.0	8.0	4.0	4.0	8.0

Continuation

(1)	(2)	(3)	(4)	(6)	(7)	(8)
41	3	0.0	10.0	5.0	5.0	10.0
42	9	0.0	13.0	7.0	6.0	13.0
43	5	0.0	13.0	7.0	6.0	13.0
44	2	0.0	8.0	4.0	4.0	8.0
45	5	0.0	16.0	8.0	8.0	16.0
46	7	0.0	6.0	3.0	3.0	6.0
47	6	6.0	4.0	5.0	5.0	10.0
48	12	4.0	2.0	3.0	3.0	6.0
49	5	0.0	5.0	5.0	0.0	5.0
50	8	0.0	21.0	11.0	10.0	21.0
51	6	0.0	25.0	15.0	10.0	25.0
52	5	0.0	15.0	15.0	0.0	15.0
53	4	0.0	7.0	5.0	2.0	7.0
54	4	0.0	7.0	5.0	2.0	7.0
55	5	0.0	15.0	8.0	7.0	15.0
56	4	0.0	5.0	3.0	2.0	5.0
57	4	0.0	5.0	3.0	2.0	5.0
58	6	0.0	25.0	13.0	12.0	25.0
59	6	0.0	25.0	13.0	12.0	25.0
60	3	0.0	25.0	13.0	12.0	25.0
61	2	0.0	25.0	13.0	12.0	25.0
62	5	0.0	18.5	9.5	9.0	18.5
Average	5.19	2.05	19.39	11.38	10.06	21.44

Appendix 21. Operating Area of Tractors in Hour Per Year

No. of sample	Working hour (h/ha)	Operating area (h/yr)				
		Farmer's own	Hired servie	Wet season	Dry season	Total
(1)	(2)	(3)	(4)	(6)	(7)	(8)
1	24	96.0	864.0	480.0	480.0	960.0
2	23	92.0	414.0	253.0	253.0	506.0
3	25	0.0	750.0	375.0	375.0	750.0
4	16	64.0	576.0	320.0	320.0	640.0
5	16	64.0	336.0	160.0	240.0	400.0
6	31.5	126.0	441.0	472.5	94.5	567.0
7	24	0.0	456.0	240.0	216.0	456.0
8	18	72.0	468.0	270.0	270.0	540.0
9	25.5	102.0	153.0	102.0	153.0	255.0
10	25.5	0.0	765.0	382.5	382.5	765.0
11	24	96.0	624.0	360.0	360.0	720.0
12	16	128.0	352.0	240.0	240.0	480.0
13	18	36.0	270.0	180.0	126.0	306.0
14	27	108.0	567.0	405.0	270.0	675.0
15	18	0.0	360.0	180.0	180.0	360.0
16	30	120.0	480.0	300.0	300.0	600.0
17	21	0.0	630.0	315.0	315.0	630.0
18	27	0.0	270.0	135.0	135.0	270.0
19	25	100.0	150.0	175.0	75.0	250.0
20	18	72.0	252.0	216.0	108.0	324.0
21	27	108.0	405.0	324.0	189.0	513.0
22	28	0.0	280.0	0.0	280.0	280.0
23	22	88.0	792.0	550.0	330.0	880.0
24	16	64.0	312.0	128.0	248.0	376.0
25	18	36.0	504.0	270.0	270.0	540.0
26	17	136.0	374.0	255.0	255.0	510.0
27	24	96.0	576.0	384.0	288.0	672.0
28	16	64.0	416.0	240.0	240.0	480.0
29	16	0.0	608.0	304.0	304.0	608.0
30	25	100.0	500.0	425.0	175.0	600.0
31	24	0.0	960.0	480.0	480.0	960.0
32	16	32.0	544.0	304.0	272.0	576.0
33	16	144.0	176.0	160.0	160.0	320.0
34	16	0.0	512.0	272.0	240.0	512.0
35	16	64.0	384.0	240.0	208.0	448.0
36	17	68.0	306.0	170.0	204.0	374.0
37	17.5	0.0	525.0	262.5	262.5	525.0
38	16	64.0	400.0	240.0	224.0	464.0
39	16	32.0	480.0	256.0	256.0	512.0
40	18	0.0	144.0	72.0	72.0	144.0
41	18	0.0	180.0	90.0	90.0	180.0

Continuation

(1)	(2)	(3)	(4)	(6)	(7)	(8)
42	21	0.0	273.0	147.0	126.0	273.0
43	39	0.0	507.0	273.0	234.0	507.0
44	39	0.0	312.0	156.0	156.0	312.0
45	28	0.0	448.0	224.0	224.0	448.0
46	28	0.0	168.0	84.0	84.0	168.0
47	26	156.0	104.0	130.0	130.0	260.0
48	25	100.0	50.0	75.0	75.0	150.0
49	50	0.0	250.0	250.0	0.0	250.0
50	36	0.0	756.0	396.0	360.0	756.0
51	33	0.0	825.0	495.0	330.0	825.0
52	44	0.0	660.0	660.0	0.0	660.0
53	56	0.0	392.0	280.0	112.0	392.0
54	56	0.0	392.0	280.0	112.0	392.0
55	46	0.0	690.0	368.0	322.0	690.0
56	56	0.0	280.0	168.0	112.0	280.0
57	56	0.0	280.0	168.0	112.0	280.0
58	24	0.0	600.0	312.0	288.0	600.0
59	24	0.0	600.0	312.0	288.0	600.0
60	24	0.0	600.0	312.0	288.0	600.0
61	24	0.0	600.0	312.0	288.0	600.0
62	16	0.0	296.0	152.0	144.0	296.0
Average	25.85	42.39	445.79	266.80	221.38	488.18

Appendix 22. Breakdown Event and Replaced Spart Parts on Survey Year

No.of sample	Age (y)	Breakdown event					Replaced spare parts				
		Begin-ning	Middle	End	Off-season	Total	1	2	3	4	5
(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	9			x		1	belt	plunger	bearing	Axle	
2	11	x		x		2	bearing	piston	piston ring	nozzle	plunger
3	3		x			1	belt	chain	Axle	clutch	
4	5			x		1	machine overhaul	belt			
5	7		x			1	bearing	piston ring			
6	1					0					
7	1		x			1	blade	plunger			
8	9			x		1	blade	belt			
9	2			x		1	blade	belt			
10	2	x				1	oil pump	nozzle			
11	7			x		1	nozzle	oil pump	piston	metal	
12	4	x				1	piston ring	nozzle			
13	10		x			1	radiator	blade	nozzle		
14	3			x		1	radiator				
15	1		x			1	blade				
16	7			x		1	radiator	blade	radiator fun	nozzle	
17	2		x			1	blade				
18	1					0					
19	7			x		1	oil pump	nozzle	plunger		
20	1					0					
21	10		x	x		2	bearing	piston rod	piston	blade	
22	4			x		1	piston ring	piston	piston rod		
23	7	x				1	oil pump	nozzle	chain		
24	2			x		1	radiator	oil pump			
25	4			x	x	2	piston ring	wheel-trailer			
26	4	x				1	piston ring	metal			
27	4	x				1	nozzle	plunger			
28	6		x	x		2	piston	blade	plunger	nozzle	
29	4		x			1	belt	moldboard	blade		
30	8			x		1	piston	blade	piston rod		
31	8			x	x	2	piston	bearing	piston ring	Wheel-trailer	
32	2			x		1	moldboard	piston rod			
33	8		x	x		2	nozzle	plunger	bearing	piston	blade
34	6			x		1	nozzle	bearing	piston ring	piston	blade
35	15		x	x		2	piston	Piston ring	bearing	moldboard	

Continuation

(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
36	2	x	x			2	nozzle	piston rod			
37	4			x		1	plunger	metal	nozzle		
38	9			x		1	overhaul				
39	3			x		1	piston ring	nozzle			
40	3		x			1	piston	bearing			
41	3	x				1	piston ring				
42	9		x		x	2	belt	wheel-trailer	nozzle	Axle	
43	5		x			1	belt	seal	belt		
44	2			x		1	belt	battery	blade		
45	5		x			1	belt	blade			
46	7		x			1	belt	blade			
47	6			x		1	piston	chain	belt		
48	12			x		1	belt				
49	5			x		1	belt	nozzle			
50	8		x			1	blade	wheel			
51	6			x		1	wheel	belt	nozzle	seal	
52	5	x				1	piston ring	belt			
53	4			x		1	belt				
54	4	x				1	belt				
55	5		x			1	belt	plunger			
56	4			x		1	belt	bolt			
57	4		x			1	belt	bolt			
58	6			x		1	belt	bolt			
59	6	x				1	belt	bolt			
60	3		x			1	belt	bolt			
61	2	x				1	belt	bolt			
62	5			x		1	belt	nozzle			
Average	*5.2*	12	21	32	3	68					

Appendix 23. Interval Oil Change by Operators

No. of sample	Interval of oil change		Equivalent hour	Manufacture manual	Time (h)
	ha	hour			
(1)	(2)	(3)	(4)	(5)	(6)
1	7		168		168
2		50			50
3		50			50
4	10		250		250
5		80			80
6	5		158		158
7		50			50
8	10		180		180
9		60			60
10	6		153		153
11	6		144		144
12		70			70
13		60			60
14	7		189		189
15				100	100
16				100	100
17	3	63			63
18	10		270		270
19		50			50
20		90			90
21	5		135		135
22	5		140		140
23	10		220		220
24	8		128		128
25		70			70
26	10		170		170
27	5		120		120
28	8		128		128
29		80			80
30		50			50
31	5		120		120
32	7		112		112
33	8		128		128
34	10		160		160
35		64			64
36	8		136		136
37		88			88
38	10		160		160

Continuation

(1)	(2)	(3)	(4)	(5)	(6)
39		80			80
40		50			50
41		50			50
42	5		105		105
43	5	50			50
44	5	50			50
45	5	50			50
46	5	50			50
47	7				50
48			175		175
49		50			50
50			275		275
51			250		250
52	5		220		220
53		50			50
54			280		280
55		50			50
56		50			50
57		50			50
58				100	100
59				100	100
60				100	100
61				100	100
62		70			70
Average	6.67	59.82	166.78	100.00	115.02

Appendix 24. Working Time and Operator Wage. Fuel an Oil Use

No. of sample	Working time (hr/ha)			Operator wage/ha	Fuel		Oil	
	Tillage	Harrowing	Pulverizing		ltr/day	Price/ltr	ltr/ha	Price/ltr
(1)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	9		15	100000	5		0.5	
2	8		15	108000	10			
3	10		15	100000	10			
4	10		15	100000	10		0.25	7000
5	7		9	100000	5		0.5	
6	15.5		16	100000	6			
7	10		14		5	2000		
8	6		12					
9	8.5		17		6	2500		
10	8		17.5		5			
11	7		17	125000	5		0.42	7000
12	8		8	100000	6			7500
13	8		10		5			7500
14	12		15	80000	5			
15	8		10		5			
16	13.5		16.5		5			
17	7		14		5		0.93	
18	9		18	100000	5		0.3	
19	10		15		10			
20	6		12	125000	8			
21	9		18		10			
22	12		16					8000
23	6	6	6	100000	6	2250		7000
24	8		8	100000	5	2250		7500
25	8		18	100000	6	2250		7500
26	8		9	100000	5	2250		7500
27	7		7	100000	10	2250		6500
28	8		8	100000	6	2500		7500
29	8		8	100000	8	2250		7500
30	8		8	115000	6	2250		7000
31	7		7	115000	10	2500		7500
32	8		8	100000	8	2250		7500
33	8		8	100000	8	2250		7500
34	8		8	110000	7	2250		7500
35	8		8	115000	10	2250		7500
36	8		9	115000	10	2250		7000
37	7		10.5	100000	10	2200		6500
38	8		8	100000	6	2500		7000
39	8		8	110000	10	2500		7500
40	8		10	125000	10	2000		15000

Continuation

(1)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
41	8		10	125000	10	2000		15000
42	8		13	131250	5	2250		
43	18		21	131250	5	2250		
44	18		21	131250	5	2250		
45	14		14	131250	5	2250		
46	14		14	131250	5	2250		
47	13		13		5	2500		13000
48	20		15		9	2500		15000
49	20		40		5	2250		
50	30		40					
51	25		35	200000	10			10000
52	22		22					
53	22		44	231000	10			11000
54	22		44	231000	10			11000
55	28		28	264000				14000
56	28		28	264000				14000
57	28		28	264000				14000
58	6	13	17	140000	5			
59	6	13	17	140000	5			
60	6	13	17	140000	5			
61	6	13	17	140000	5			
62	6		9	140000	8	2200		14500
Average	11.43	11.6	15.78	129962	7.04	2280	0.48	9303

Note: Wage and price based on wage and price in 2004

Appendix 25. Operator Cost of Tractor Operations

No. of Sample	Operating area		Operator Cost		
	Ha/yr	Hr/yr	Rp/hr	Rp/ha	Rp/yr
(1)	(2)	(3)	(4)	(5)	(6)
1	40	960	4167	100000	4000000
2	22	506	4696	108000	2376000
3	30	750	4000	100000	3000000
4	24	600	4000	100000	2400000
5	25	400	6250	100000	2500000
6	18	567	3175	100000	1800000
7	19	456	4167	100000	1900000
8	30	540	5556	100000	3000000
9	10	255	3922	100000	1000000
10	30	765	3922	100000	3000000
11	30	720	5208	125000	3750000
12	30	480	6250	100000	3000000
13	17	306	5556	100000	1700000
14	25	675	3704	100000	2500000
15	20	360	5556	100000	2000000
16	20	600	3333	100000	2000000
17	30	630	4762	100000	3000000
18	10	270	3704	100000	1000000
19	10	250	4000	100000	1000000
20	18	324	6944	125000	2250000
21	19	513	4630	125000	2375000
22	10	280	4464	125000	1250000
23	40	880	4545	100000	4000000
24	24	376	6250	100000	2350000
25	30	540	5556	100000	3000000
26	30	510	5882	100000	3000000
27	28	672	4167	100000	2800000
28	30	480	6250	100000	3000000
29	38	608	6250	100000	3800000
30	40	640	7188	115000	4600000
31	40	960	4792	115000	4600000
32	36	576	6250	100000	3600000
33	20	320	6250	100000	2000000
34	32	512	6875	110000	3520000
35	28	448	7188	115000	3220000
36	22	374	6765	115000	2530000
37	30	525	5714	100000	3000000
38	29	464	6250	100000	2900000
39	32	512	6875	110000	3520000
40	8	144	6944	125000	1000000

Continuation

(1)	(2)	(3)	(4)	(5)	(6)
41	10	180	6944	125000	1250000
42	13	273	6250	131250	1706250
43	13	507	3365	131250	1706250
44	8	312	3365	131250	1050000
45	16	448	4688	131250	2100000
46	6	168	4688	131250	787500
47	10	260	5048	131250	1312500
48	6	150	5250	131250	787500
49	5	250	2800	140000	700000
50	21	1155	2545	140000	2940000
51	25	1250	3150	157500	3937500
52	15	660	3580	157500	2362500
53	7	392	2813	157500	1102500
54	7	392	2813	157500	1102500
55	15	690	3043	140000	2100000
56	5	280	2500	140000	700000
57	5	280	2500	140000	700000
58	25	600	6563	157500	3937500
59	25	600	6563	157500	3937500
60	25	600	6563	157500	3937500
61	25	600	6563	157500	3937500
62	18.5	296	9844	157500	2913750
Avearge	21.44	501	5055	118939	2455641

Note : Operator rate based on 2004.

Appendix 26. Repair Cost and Maintenance Costs of Tractor Operations

No. of sample	Age (yr)	Operating area		Repair costs (rp)			Maintenance cost (rp)		
		ha/yr	hr/y	(rp/yr)	(rp/ha)	(rp/hr)	(rp/yr)	(rp/ha)	(rp/hr)
(1)	(2)	(3)	(5)	(7)	(9)	(10)	(11)	(12)	(13)
1	9	40	960	2500000	62500	2604	40500	1013	42
2	11	22	506	780000	35455	1542	69600	3164	138
3	3	30	750	900000	30000	1200	43600	1453	58
4	5	24	600	2300000	95833	3833	35500	888	37
5	7	25	400	490000	19600	1225	77250	3090	193
6	1	18	567	0	0	0	44500	2472	78
7	1	19	456	30000	1579	66	62250	2490	156
8	9	30	540	700000	23333	1296	40500	2132	89
9	2	10	255	110000	11000	431	84600	8460	332
10	2	30	765	600000	20000	784	39600	1320	52
11	7	30	720	1170000	39000	1625	90500	3017	126
12	4	30	480	160000	5333	333	99500	3317	207
13	10	17	306	1000000	58824	3268	84600	2820	176
14	3	25	675	500000	20000	741	106500	4260	158
15	1	20	360	25000	1250	69	63250	3721	207
16	7	20	600	1000000	50000	1667	64500	3225	108
17	2	30	630	35000	1167	56	64500	2150	102
18	1	10	270	0	0	0	62250	3458	192
19	7	10	250	430000	43000	1720	32500	3250	130
20	1	18	324	0	0	0	100500	10050	359
21	10	19	513	1100000	57895	2144	94750	9475	338
22	4	10	280	250000	25000	893	95560	9556	341
23	7	40	600	700000	17500	1167	64250	1606	107
24	2	24	376	265000	11277	705	102750	2569	171
25	4	30	540	160000	5333	296	*95750*	3192	177
26	4	30	510	170000	5667	333	102500	3417	201
27	4	28	392	500000	17857	1276	79650	2845	203
28	6	30	480	1000000	33333	2083	34500	1150	64
29	4	38	768	1000000	26316	1302	35560	936	46
30	8	40	640	650000	16250	1016	30500	763	48
31	8	40	560	1629000	40725	2909	74560	1864	133
32	2	36	576	180000	5000	313	29560	1478	92
33	8	20	320	1455000	72750	4547	116560	5828	364
34	6	32	512	2000000	125000	7813	45500	2275	142
35	15	28	448	650000	23214	1451	39560	1413	88
36	2	22	374	300000	13636	802	29500	1341	79
37	4	30	525	900000	30000	1714	100500	3350	191

Continuation

(1)	(2)	(3)	(5)	(7)	(9)	(10)	(11)	(12)	(13)
38	9	29	464	1000000	34483	2155	103750	12969	720
39	3	32	512	555000	17344	1084	90500	3121	195
40	3	8	144	350000	43750	2431	129500	4047	253
41	3	10	180	350000	35000	1944	76500	9563	531
42	9	13	273	638550	49119	2339	107500	13438	345
43	5	13	507	638550	49119	1259	46500	5813	149
44	2	8	312	441000	55125	1413	99500	12438	319
45	5	16	168	109750	6859	653	108500	6781	646
46	7	6	168	109750	18292	653	*37500*	6250	223
47	6	10	260	397000	39700	1527	174500	34900	582
48	12	6	150	60000	10000	400	177500	29583	1183
49	5	5	300	90000	18000	300	46500	7750	310
50	8	21	1155	425000	20238	368	44250	2107	38
51	6	25	1500	650000	26000	433	135250	19321	345
52	5	15	660	120000	8000	182	133500	5340	89
53	4	7	392	60000	8571	153	54250	7750	138
54	4	7	392	60000	8571	153	50500	7214	129
55	5	15	280	80000	5333	286	32500	1300	54
56	4	5	280	80000	16000	286	36500	7300	130
57	4	5	280	80000	16000	286	49500	9900	177
58	6	25	600	500000	20000	833	*34500*	1380	58
59	6	25	600	500000	20000	833	38250	1530	64
60	3	25	600	500000	20000	833	50500	2356	105
61	2	25	600	425000	17000	708	33800	1352	56
62	5	19	296	555000	30000	1875	95000	5135	321
Average		21.44	482	555058	26405.37	1236	72009	5443	208

Appendix 27. Fuel Cost of Tractor Operations

No. of sample	Fuel Ltr/hari	Fuel				Cost		
		(ltr/hr)	(ltr/yr)	(ltr/ha)	Price/ltr	(rp/hr)	(rp/ha)	(rp/yr)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	10	1.11	1066.7	26.7	2100	2333	56000	2240000
2	10	1.43	722.9	32.9	2100	3000	69000	1518000
3	6	0.86	642.9	21.4	2100	1800	45000	1350000
4	10	1.25	750.0	31.3	2100	2625	65625	1575000
5	5	0.63	250.0	10.0	2100	1313	21000	525000
6	6	0.67	378.0	21.0	2250	1500	47250	850500
7	5	0.63	285.0	15.0	2000	1250	30000	570000
8	5	0.83	450.0	15.0	2250	1875	33750	1012500
9	6	0.71	180.0	18.0	2250	1588	40500	405000
10	5	0.59	285.0	9.5	2250	1324	21375	641250
11	5	0.83	600.0	20.0	2250	1875	45000	1350000
12	6	0.75	360.0	12.0	2250	1688	27000	810000
13	8	0.89	272.0	16.0	2250	2000	36000	612000
14	5	0.63	421.9	16.9	2000	1250	33750	843750
15	7	1.00	360.0	18.0	2000	2000	36000	720000
16	8	0.89	533.3	26.7	2250	2000	60000	1200000
17	5	0.71	450.0	15.0	2250	1607	33750	1012500
18	5	0.56	150.0	15.0	2250	1250	33750	337500
19	10	1.11	277.8	27.8	2250	2500	62500	625000
20	8	0.89	288.0	16.0	2250	2000	36000	648000
21	8	1.14	586.3	30.9	2000	2286	61714	1172571
22	5	0.59	164.7	16.5	2000	1176	32941	329412
23	6	1.00	600.0	15.0	2250	2250	33750	1350000
24	5	0.63	235.0	10.0	2250	1406	22500	528750
25	6	0.75	405.0	13.5	2250	1688	30375	911250
26	5	0.63	318.8	10.6	2250	1406	23906	717188
27	10	1.43	560.0	20.0	2250	3214	45000	1260000
28	8	1.00	480.0	16.0	2250	2250	36000	1080000
29	8	1.00	768.0	20.2	2250	2250	45474	1728000
30	6	0.75	480.0	12.0	2250	1688	27000	1080000
31	10	1.43	800.0	20.0	2250	3214	45000	1800000
32	8	1.00	576.0	16.0	2250	2250	36000	1296000
33	8	1.00	320.0	16.0	2100	2100	33600	672000
34	7	0.88	448.0	14.0	2100	1838	29400	940800
35	10	1.25	560.0	20.0	2100	2625	42000	1176000
36	10	1.25	467.5	21.3	2250	2813	47813	1051875
37	10	1.43	750.0	25.0	2200	3143	55000	1650000

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
38	6	0.75	348.0	12.0	2250	1688	27000	783000
39	10	1.25	640.0	20.0	2250	2813	45000	1440000
40	8	1.00	144.0	18.0	2000	2000	36000	288000
41	10	1.25	225.0	22.5	2000	2500	45000	450000
42	5	0.71	195.0	15.0	2250	1607	33750	438750
43	5	0.71	362.1	27.9	2250	1607	62679	814821
44	5	0.71	222.9	27.9	2250	1607	62679	501429
45	5	0.71	120.0	7.5	2250	1607	16875	270000
46	5	0.71	120.0	20.0	2250	1607	45000	270000
47	8	0.94	244.7	24.5	2250	2118	55059	550588
48	9	1.80	270.0	45.0	2250	4050	101250	607500
49	5	0.77	230.8	46.2	2250	1731	103846	519231
50	4	0.62	904.6	43.1	2200	1354	94769	1990154
51	6	0.75	1125.0	45.0	2200	1650	99000	2475000
52	5	0.63	412.5	27.5	2250	1406	61875	928125
53	6	0.92	400.6	57.2	2250	2077	128769	901385
54	4	0.62	267.1	38.2	2250	1385	85846	600923
55	5	0.77	215.4	14.4	2250	1731	32308	484615
56	5	0.77	215.4	43.1	2200	1692	94769	473846
57	5	0.77	215.4	43.1	2200	1692	94769	473846
58	3	0.50	287.5	11.5	2200	1100	25300	632500
59	4	0.67	383.3	15.3	2200	1467	33733	843333
60	4	0.67	383.3	15.3	2200	1467	33733	843333
61	4	0.67	383.3	15.3	2200	1467	33733	843333
62	5	0.83	231.3	12.5	2200	1833	27500	508750
Average	6.55	0.88	415.96	21.75	2194.35	1929.48	47757.51	911650.14

Note: Fuel Price Based on Price 2004.

Appendix 28. Oil Cost of Tractor Operations

No.of sample	Engine oil consumption				Price	Costs			
	(ltr/hr)	(ltr/ha)	(Ltr/yr-ha)	(ltr/yr-hr)	(rp/ltr)	(rp/hr)	(rp/ha)	(rp/yr-ha)	(rp/yr-hr)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	0.05	0.36	14.29	48.0	7500	375	2679	107142.9	360000
2	0.04	0.44	9.68	22.3	7500	330	3300	72600	166980
3	0.04	0.30	9.00	27.0	7500	270	2250	67500	202500
4	0.04	0.22	5.28	26.4	7000	308	1540	36960	184800
5	0.04	0.50	12.50	16.7	7000	291.67	3500	87500	116666.67
6	0.05	0.50	9.00	28.4	7500	375	3750	67500	212625
7	0.05	0.31	9.38	22.8	7500	375	2344	70312.5	171000
8	0.05	0.25	7.50	27.0	7500	375	1875	56250	202500
9	0.04	0.44	4.40	9.4	7500	275	3300	33000	70125
10	0.05	0.50	9.50	24.2	7000	350	3500	66500	169575
11	0.05	0.42	12.50	36.0	7000	350	2917	87500	252000
12	0.04	0.31	9.38	17.1	7500	267.86	2344	70312.5	128571.43
13	0.04	0.42	7.08	12.8	7500	312.5	3125	53125	95625
14	0.03	0.26	6.43	20.3	7000	210	1800	45000	141750
15	0.02	0.44	8.80	7.9	7000	154	3080	61600	55440
16	0.03	0.50	10.00	15.0	7000	175	3500	70000	105000
17	0.05	0.93	28.00	29.4	7500	350	7000	210000	220500
18	0.04	0.22	2.20	9.9	7500	275	1650	16500	74250
19	0.06	0.50	5.00	15.0	7500	450	3750	37500	112500
20	0.05	0.56	10.08	15.1	7500	350	4200	75600	113400
21	0.06	0.56	10.64	28.7	7000	392	3920	74480	201096
22	0.05	0.56	5.60	13.1	8000	373.33	4480	44800	104533.33
23	0.03	0.20	8.00	17.1	7000	200	1400	56000	120000
24	0.04	0.31	7.34	13.4	7500	267.86	2344	55078.13	100714.29
25	0.04	0.25	7.50	19.3	7500	267.86	1875	56250	144642.86
26	0.04	0.25	7.50	21.3	7500	312.5	1875	56250	159375
27	0.05	0.56	15.68	18.3	6500	303.33	3640	101920	118906.67
28	0.05	0.31	9.38	24.0	7500	375	2344	70312.5	180000
29	0.03	0.42	15.83	24.0	7500	234.38	3125	118750	180000
30	0.04	0.37	14.67	28.2	7000	308	2567	102666.7	197120
31	0.04	0.44	17.60	24.6	7500	330	3300	132000	184800
32	0.05	0.36	12.86	28.8	7500	375	2679	96428.57	216000
33	0.05	0.31	6.25	16.0	7500	375	2344	46875	120000
34	0.04	0.22	7.04	22.5	7500	330	1650	52800	168960
35	0.04	0.55	15.40	19.7	7500	330	4125	115500	147840
36	0.05	0.31	6.88	18.7	7000	350	2188	48125	130900
37	0.06	0.56	16.80	29.4	6500	364	3640	109200	191100

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
38	0.04	0.20	5.80	18.6	7000	280	1400	40600	129920
39	0.04	0.44	14.08	22.5	7500	330	3300	105600	168960
40	0.06	0.47	3.73	8.1	13000	728	6067	48533.33	104832
41	0.06	0.47	4.67	10.1	10000	560	4667	46666.67	100800
42	0.06	0.56	7.28	15.3	13000	728	7280	94640	198744
43	0.06	0.56	7.28	28.4	13000	728	7280	94640	369096
44	0.06	0.56	4.48	17.5	13000	728	7280	58240	227136
45	0.06	0.56	8.96	9.4	10000	560	5600	89600	94080
46	0.06	0.56	3.36	9.4	13000	728	7280	43680	122304
47	0.04	0.31	3.14	11.4	13000	572	4086	40857	148720
48	0.04	0.33	2.00	6.0	10000	400	3333	20000	60000
49	0.04	0.31	1.57	13.2	14000	616	4400	22000	184800
50	0.04	0.37	7.70	64.7	14000	616	5133	107800	905520
51	0.06	0.56	14.00	84.0	10000	560	5600	140000	840000
52	0.05	0.50	7.50	33.0	11000	550	5500	82500	363000
53	0.04	0.44	3.08	19.1	11000	484	4840	33880	210056
54	0.04	0.37	2.57	19.1	11000	484	4033	28233.33	210056
55	0.04	0.44	6.60	12.3	14000	616	6160	92400	172480
56	0.04	0.37	1.83	12.3	14000	616	5133	25666.67	172480
57	0.04	0.44	2.20	12.3	14000	616	6160	30800	172480
58	0.02	0.44	11.00	12.7	14000	308	6160	154000	177100
59	0.02	0.37	9.17	12.7	14000	308	5133	128333.3	177100
60	0.02	0.37	9.17	12.7	14000	308	5133	128333.3	177100
61	0.02	0.31	7.86	12.7	14000	308	4400	110000	177100
62	0.04	0.40	7.40	11.1	14500	580	5800	107300	160950
Average	0.04	0.41	8.57	20.74	9298.39	403.54	3871.87	74260.36	187848.55

Note: Oil Price Based on Price in 2004

Apendix 29. Revenue of Tractor Operations

No. of sample	Operating Area (ha/y)	Hired Operator (Rp/ha)	Income Rp/y/mc
(1)	(2)	(3)	(4)
1	40.0	330000	13200000
2	22.0	325000	7150000
3	30.0	350000	10500000
4	24.0	300000	7200000
5	25.0	300000	7500000
6	18.0	300000	5400000
7	19.0	330000	6270000
8	30.0	300000	9000000
9	10.0	330000	3300000
10	30.0	330000	9900000
11	30.0	350000	10500000
12	30.0	300000	9000000
13	17.0	300000	5100000
14	25.0	300000	7500000
15	20.0	350000	7000000
16	20.0	300000	6000000
17	30.0	300000	9000000
18	10.0	300000	3000000
19	10.0	300000	3000000
20	18.0	350000	6300000
21	19.0	300000	5700000
22	10.0	300000	3000000
23	40.0	350000	14000000
24	23.5	300000	7050000
25	30.0	300000	9000000
26	30.0	300000	9000000
27	28.0	330000	9240000
28	30.0	300000	9000000
29	38.0	300000	11400000
30	40.0	350000	14000000
31	40.0	350000	14000000
32	36.0	300000	10800000
33	20.0	300000	6000000
34	32.0	330000	10560000
35	28.0	350000	9800000
36	22.0	330000	7260000

Continuation

(1)	(2)	(3)	(4)
37	30.0	330000	9900000
38	29.0	330000	9570000
39	32.0	300000	9600000
40	8.0	400000	3200000
41	10.0	400000	4000000
42	13.0	375000	4875000
43	13.0	375000	4875000
44	8.0	375000	3000000
45	16.0	375000	6000000
46	6.0	375000	2250000
47	10.0	400000	4000000
48	6.0	400000	2400000
49	5.0	400000	2000000
50	21.0	400000	8400000
51	25.0	450000	11250000
52	15.0	450000	6750000
53	7.0	450000	3150000
54	7.0	450000	3150000
55	15.0	400000	6000000
56	5.0	400000	2000000
57	5.0	400000	2000000
58	25.0	450000	11250000
59	25.0	450000	11250000
60	25.0	450000	11250000
61	25.0	450000	11250000
62	18.5	450000	8325000
Avearge	21.44	353548.39	7376209.68

Appendix 30. Storage of Tractor During Off-season and Working Season

No. of sample	Storage during off-season	Storage during Working season
(1)	(2)	(3)
1	Porch	Field
2	Outside	Field
3	Outside	Home
4	Porch	Field
5	Shed	Field
6	Porch	Field
7	Shed	Field
8	Porch	Field
9	Shed	Field
10	Porch	Field
11	Shed	Field
12	Shed	Field
13	Shed	Field
14	Shed	Field
15	Outside	Field
16	Outside	Field
17	Porch	Field
18	Porch	Field
19	Porch	Field
20	Shed	Field
21	Shed	Field
22	Shed	Field
23	Porch	Home
24	Shed	Home
25	Shed	Home
26	Shed	Home
27	Shed	Field
28	Porch	Home
29	Porch	Home
30	Outside	Home
31	Shed	Home
32	Porch	Home
33	Shed	Home
34	Outside	Home
35	Porch	Home
36	Porch	Field
37	Porch	Home
38	Porch	Home
39	Shed	Home
40	Shed	Home

Continuation

(1)	(2)	(3)
41	Shed	Home
42	Outside	Home
43	Outside	Home
44	Outside	Home
45	Outside	Home
46	Outside	Home
47	Shed	Home
48	Shed	Home
49	Porch	Home
50	Porch	Home
51	Shed	Home
52	Shed	Home
53	Porch	Home
54	Porch	Home
55	Outside	Home
56	Outside	Home
57	Outside	Home
58	Outside	Home
59	Outside	Home
60	Outside	Home
61	Outside	Home
62	Shed	Home

Appendix 31. Time Requirement for Rice Farming Operation in Riau Province

No Spl	Time requirements (h/ha)												Total hour
	Land preparation	Seedling	Transplanting	Weeding	Fertilizing	Pest control	Harvesting	Threshing	Cleaning	Transportation	Drying	Milling	
1	24	66	249	220	68	40	80	28	56	16	46	12	824
2	23	35	310	92	40	20	368	14	48	12	42	11	863
3	25	60	188	128	40	36	124	12	16	14	36	12	707
4	16	34	240	184	66	34	108	16	16	8	38	11	755
5	16	52	264	275	42	48	102	18	40	8	34	12	896
6	32	37	198	192	56	30	201	25	48	12	72	13	877
7	24	42	252	283	40	40	74	16	48	8	30	12	827
8	18	46	236	132	40	32	84	14	40	12	32	13	764
9	26	45	142	104	48	24	288	15	48	12	52	12	930
10	26	58	218	236	90	48	80	19	48	30	60	12	847
11	24	58	192	158	100	60	110	21	32	21	90	10	933
12	16	38	134	96	34	20	132	14	40	16	24	11	737
13	18	44	184	120	84	28	104	15	40	16	50	9	708
14	27	49	301	142	32	26	116	20	32	10	26	11	717
15	18	37	294	90	72	54	78	16	40	10	40	12	701
16	30	45	159	237	40	20	68	16	56	12	32	9	812
17	21	49	259	172	68	80	112	28	32	28	40	12	875
18	27	52	196	88	46	20	96	16	48	24	36	10	707
19	25	45	280	112	82	36	92	16	32	20	34	11	701
20	18	40	255	96	42	40	98	18	32	44	28	12	720
21	27	45	184	112	66	16	72	15	56	16	26	11	718
22	28	42	262	155	40	16	367	16	24	20	24	12	942
23	22	60	210	120	54	34	160	28	32	22	28	12	827
24	16	21	302	176	68	32	144	16	48	48	48	13	889
25	18	45	334	220	46	16	208	28	32	12	44	10	855

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
26	17	21	158	104	52	16	80	14	48	16	22	11	703
27	24	21	210	176	48	22	112	26	64	18	38	9	742
28	35	45	233	78	48	48	96	20	24	16	56	11	879
29	16	42	402	96	80	48	96	20	40	32	70	12	712
30	25	26	204	130	64	48	80	28	56	48	44	10	835
31	24	23	256	138	86	31	102	30	24	62	96	9	777
32	31	44	216	132	26	24	68	20	25	20	72	8	738
33	16	21	326	202	50	20	84	28	44	46	102	10	873
34	32	18	205	112	38	26	128	26	17	44	66	10	705
35	16	26	150	136	36	20	88	24	23	52	116	12	701
36	17	35	168	120	38	40	367	20	38	44	76	11	950
37	18	21	256	82	72	40	140	20	24	92	112	8	797
38	16	38	196	100	40	24	92	20	45	42	74	13	841
39	21	21	160	116	76	32	84	15	58	40	112	13	708
40	18	18	226	275	40	22	84	20	15	24	60	6	734
41	18	35	226	124	36	32	132	16	30	48	64	8	711
42	21	40	276	175	38	25	80	17	46	44	66	10	714
43	39	20	249	119	40	58	216	17	24	42	32	12	873
44	39	18	296	78	48	46	208	21	30	49	48	12	749
45	28	16	195	168	56	46	128	28	26	35	48	13	912
46	28	18	296	168	32	51	176	22	35	56	24	13	767
47	26	18	150	140	72	25	152	25	56	56	32	7	753
48	25	22	136	189	80	46	152	17	14	42	40	13	816
49	35	36	128	140	112	31	124	30	42	49	40	7	806
50	36	25	110	168	104	25	184	19	56	35	48	8	1052
51	33	22	214	203	98	46	120	30	35	42	72	10	863

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
52	42	20	154	210	80	51	128	21	42	35	84	12	977
53	16	24	186	224	40	41	144	22	35	56	84	12	818
54	35	32	176	210	88	37	152	22	49	70	80	5	1000
55	42	26	402	119	64	33	252	16	35	42	24	10	807
56	35	22	314	84	72	58	160	30	35	35	56	10	743
57	35	18	204	212	24	51	168	16	42	42	16	10	738
58	30	34	175	91	64	60	136	26	21	56	72	9	824
59	24	38	202	228	88	33	152	29	21	35	16	9	777
60	30	28	247	98	72	33	128	17	28	56	72	10	702
61	24	20	176	119	80	31	144	17	28	49	48	8	880
62	16	26	250	140	72	34	136	21	49	70	48	10	742
63	34	26	108	138	56	56	276	22	21	28	72	10	907
64	40	40	305	112	56	56	84	15	27	42	80	11	703
65	29	46	174	92	40	40	66	17	42	63	48	10	791
66	35	20	210	170	32	32	276	17	28	49	40	8	857
67	28	16	250	138	24	20	290	28	42	70	56	5	955
68	34	20	197	238	24	20	190	21	56	49	56	9	881
69	18	40	174	138	28	27	367	28	21	42	40	9	968
70	34	20	156	184	32	32	184	22	35	49	64	10	830
71	28	34	152	92	32	32	413	19	49	21	72	8	1088
72	34	28	268	184	28	28	276	25	21	20	80	8	882
73	42	28	250	76	40	40	275	17	49	18	38	8	826
74	23	28	188	92	56	92	458	30	14	21	35	9	1172
75	23	20	252	192	40	56	184	17	63	28	30	7	870
76	46	34	144	184	56	66	276	18	14	26	32	7	1055
77	34	34	168	138	66	40	184	15	63	34	28	9	849

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
78	18	40	337	80	80	20	358	16	42	16	38	7	855
79	34	28	120	338	40	32	295	15	42	28	26	8	1082
80	35	16	202	138	28	28	197	18	63	26	28	8	835
81	34	28	154	238	28	32	376	10	42	28	46	9	1021
82	35	28	152	138	28	40	276	21	35	36	40	7	934
83	28	20	320	94	56	28	275	22	49	34	52	8	863
84	18	16	144	138	24	16	284	22	49	36	21	9	804
85	34	20	176	338	24	20	184	26	35	34	44	8	917
86	34	28	244	92	32	32	230	14	63	30	22	9	744
87	38	34	152	183	56	56	80	26	72	22	35	9	771
88	18	20	252	283	58	72	276	28	70	32	28	8	1095
89	34	28	120	92	16	28	276	21	42	30	35	8	760
90	35	34	144	230	58	72	322	21	70	18	30	8	1108
91	34	34	146	183	72	72	275	18	35	20	21	9	909
92	40	34	104	275	56	48	184	30	42	22	18	7	906
93	26	48	225	196	44	46	268	18	40	96	20	7	917
94	18	68	104	76	70	58	192	21	64	102	68	8	1050
95	18	14	130	183	14	30	76	14	28	14	18	7	818
96	28	43	120	88	172	66	172	17	48	86	86	8	988
97	20	51	168	212	106	40	176	19	64	52	102	7	1005
98	26	38	140	132	128	51	184	17	40	66	66	9	885
99	21	43	298	84	44	28	209	17	48	106	44	9	829
100	28	52	150	172	28	34	208	20	40	88	55	7	842
101	28	48	164	96	46	25	192	17	56	84	46	7	859
102	18	57	210	88	106	33	128	22	40	88	116	8	878
103	17	42	164	196	42	58	200	15	40	96	42	10	870

Continuation

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
104	18	42	188	96	42	46	196	16	48	103	42	12	767
105	27	53	150	212	106	30	120	19	24	45	52	13	859
106	18	58	150	128	30	66	180	24	24	77	60	11	808
107	35	58	140	91	38	40	124	23	28	77	58	11	901
108	18	48	158	184	48	32	162	22	30	88	28	12	864
109	21	32	150	216	36	51	182	21	50	84	30	12	951
110	16	60	152	76	50	28	214	23	20	92	50	13	842
111	30	20	168	122	30	34	182	16	34	48	18	12	772
112	18	34	212	180	34	34	135	23	44	84	34	13	767
113	30	46	171	90	50	46	204	27	26	112	46	6	837
114	28	52	150	80	52	33	242	27	51	104	26	9	1030
115	21	66	196	102	100	22	258	19	66	98	50	10	1196
116	37	18	160	188	152	18	198	22	18	40	18	9	923
117	27	25	144	204	12	20	105	20	38	84	38	6	765
118	28	52	160	104	38	22	190	20	52	108	52	8	824
119	19	28	120	256	52	23	211	19	28	58	28	8	940
120	17	36	188	206	30	25	316	19	34	84	36	8	1007
Average	26	35	203	154	55	37	179	20	39	44	49	10	851
STDEVA	29	38	33	39	49	41	48	23	35	62	48	21	13