EFFICIENCY OF LATEX PRODUCTION AND LABOUR PRODUCTIVITY IN RUBBER PLANTATIONS IN EDO AND DELTA STATES, NIGERIA

BY

GIROH, YUNIYUS DENGLE
Ph.D/AE/07/0050

JULY, 2012

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A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY, YOLA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D) IN AGRICULTURAL ECONOMICS

JULY, 2012

DECLARATION

I hereby declare that this thesis entitled **"Efficiency of Latex Production and Labour Productivity in Rubber Plantations in Edo and Delta States, Nigeria"** was written by me and it is a record of my own research work. It has not been presented before in any previous application for a higher degree. All references cited have been duly acknowledged.

……………………………………… Date ……………………

GIROH, YUNIYUS DENGLE

DEDICATION

This project is dedicated to God Almighty for His constant protection and unlimited intervention in all aspects of my life and to the entire family of Tayirah Dengle Kpasham, who assisted me in the study.

APPROVAL PAGE

This thesis entitled **"Efficiency of Latex Production and Labour Productivity in Rubber Plantations in Edo and Delta States, Nigeria"** meets the regulations governing the award of Doctor of Philosophy of the Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

The study analyzed efficiency of latex production and labour productivity in rubber plantations in Edo and Delta States, Nigeria. The specific objectives were to examine the influence of rubber farmers'socio- economic characteristics on their technical efficiency; examine labour availability and productivity; determine the profitability of latex production; determine the allocative, technical and economic efficiency of factors employed in latex production; determine an optimal tappable trees/ task that will *satisfice* a set of multiple objectives of plantation owners and examine factors or constraints affecting rubber farmers and tappers in latex production. Primary data on 2009 and 2010 production were collected from 300 rubber farmers and 120 rubber tappers using a multi stage, purposive and random sampling techniques. Data collected were analyzed using descriptive statistics, Likert scale, budgetary technique, stochastic frontier production function and weighted goal programming models. Analyses of the result revealed that respondents were literate, majority were married (76%) with a mean family size of 7 people, had mean farming experience of 19 years. Labour productivity analysis revealed latex yield of 826,434.31 kg dry rubber per year and monetary value of ₦81,949,226.18 per year as gross revenue with output per man day of 22.58 kg. The gross margin analysis showed that average variable cost/ha was ₦55, 700.94 with total revenue (TR) and Gross margin (GM) per hectare of ₦163,594.17 and ₦107,893.23 respectively. The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production function of rubber farmers revealed that number of trees/ task, labour; farm size and age of plantation, clone, wage and depreciation on fixed cost items were significantly related with rubber output. The mean technical efficiency (TE) of rubber farmers was 0.84 with the scope of improving their efficiency by 16%. Education, extension contact and experience were the significant factors that increase the technical efficiency of rubber farmers. The estimates of the parameters of stochastic cost frontier analysis showed that safety kits, cost of labour and output were significantly related with cost of production with mean allocative efficiency (AE) of 0.77 while the minimum and maximum allocative index were 0.27 and 0.99. Age, extension contact and farm distance enhance the allocative efficiency of rubber farmers. The economic efficiency index ranged from 0. 20 to 0.93 with the mean of 0.65 indicating wide differentials between the least and efficient farmer with the scope of improving economic efficiency among rubber farmers by 35% in the short-run. Goal programming analysis revealed that tappable rubber trees and latex production were achieved out of the five goals. The major significant constraints of rubber farmers included shortage and high cost of labour and poor rubber prices while wage casualization and irregular payment of wages and salaries were among the problems of tappers. The resuscitation of extension activities of ADPs in the rubber belt of the country through adequate funding by government to improve the efficiencies of farmers, replanting of old plantations using improved clones and the formation of cooperative societies by farmers to enable them access production credit amongst others were recommended in the study.

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CHAPTER ONE

INTRODUCTION

1.3 Background of the Study

Commercially, natural rubber is obtained almost exclusively from *Hevea brasiliensis* (genus *Hevea*, family *Euphorbiaceae*), a tall softwood tree indigenous to Brazil. The world rubber industry began to develop in the 1800s, with the invention of the masticator and the vulcanization process. Demand for rubber grew rapidly with the invention of the solid and later the pneumatic rubber tyre and the demand for rubber insulation by the electrical industry which made *Hevea brasiliensis* Muell Arg as the major source of natural rubber because of its superior latex yield over other species of *Hevea*. A notable fact in the early 1900s was also the emergence of production by smallholders, which produced rubber as one amongst several crops. Despite its original commercial development as a plantation crop, by the mid-1930s natural rubber production was evenly splitted between estates and smallholdings (Uraih *et al.*, 2006).

Natural rubber was introduced into Nigeria in 1895 from the Wickham collection of 1876. Transition period between 1876 and 1895 was the era of planting at Kew Botanical Gardens in England and Asia (Aigbekaen *et al.*, 2000). The earliest plantation in Nigeria was planted in 1903 and by 1925 single estates of about 1000 hectares was planted. The early plantations were raised from unselected seeds with latex yield of 300 – 400 kg/ha/yr. Genetic improvement of *Hevea brasiliensis* commenced in Nigeria in 1960s following the establishment of Rubber Research Station (RRS) in 1961 and became the Rubber Research Institute of Nigeria in 1973 with the mandate of genetic improvement of natural rubber and other latex producing plants of economic importance (Uraih *et al.*, 2006). Germplasm collection for the purpose of genetic improvement started in 1960s with the importation of primary and improved hybrid clones from Malaysia and Sri - Lanka. Among the collections are the RRIM series, RRIC series, PB series, GT1 and so on. Some clones of Indonesian origin such as PR and Tjir series and IAN series of Brazil were part of the collection from Malaysia and Sri- Lanka. To date, twenty-four high latex yielding clones have been developed in Nigeria. These clones have latex yield of 2000 – 3500 kg/ha/yr (Omokhafe and Nasiru, 2004).

Natural rubber was ranked as the fourth most valuable agricultural export commodity in Nigeria after cocoa, groundnut and palm kernel, with 92 percent of natural rubber production exported, making rubber essentially a foreign exchange earner for the national economy(Abolagba *et al.*,2003). Natural rubber is a dependable source of raw material for local industries; it also provides employment opportunities for farmers, tappers, manufacturers and other personnel in marketing. Natural rubber has diversity of uses. Latex and coagula are important in automobile industries for the manufacture of tyres and tubes. Latex is useful in the manufacture of surgical gloves while the rubber seeds are processed into rubber seed oil, rubber seed cake for feeding of livestock and alkyd resins for industrial uses. Furthermore, rubber is environmentally friendly and helps to protect the soil from soil erosion (Abolagba and Giroh, 2006). Nigeria has 247,100 hectares of land under rubber cultivation and majority of these hectares are owned by small-scale farmers (Aigbekaen et *al.,* 2000; Delabarre and Serier, 2000).

It is important to emphasize that despite the potential benefits of the natural rubber, its over all productivity remains low due lack of exploitation and is most clearly evidenced by much lower standards of living in the rural areas compared to urban areas, thus the largest concentration of absolute poverty, illiteracy and infant mortality in the rural areas (Abolagba *et al.,* 2003). There is considerable agreement with the notion that an effective economic development strategy depends critically on promoting productivity and output growth in the agricultural sector, particularly among small scale producers. Empirical evidence suggests that small farms are desirable not only because they provide source of reducing unemployment , but also because they provide a more equitable distribution of income as well as an effective demand structure for other sectors of the economy(Bravo- Ureta and Evenson, 1994).

Consequently, many researchers and policy makers have focused their attention on the impact that the adoption of new technologies can have on increasing farm productivity and income. However, during the last decade, major technological gain stemming from the green revolution seems to have been largely exhausted across the country. This suggests that attention to productivity gains arising from a more efficient use of existing technology is justified. An important policy implication stemming from significant levels of inefficiency is that it might be more cost effective to achieve short-

run increased in farm output, and thus income, by concentrating on improving efficiency rather than the introduction of new technologies (Bravo - Ureta and Pinheiro, 1997).
The presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, then empirical measures of efficiency are necessary in order to determine the magnitude of gains that could be obtained by improving performance in agricultural production with a given technology (Belbase and Grabowski, 1985).

Efficiency is a very important factor of productivity growth especially in developing agrarian economies, where resources are meager and opportunities for developing and adopting better technologies are dwindling. Such economies can benefit from efficiency studies which show that it is possible to raise productivity by improving efficiency without increasing the resource base or developing new technologies. Raising productivity and output of small farmers would not only increase their incomes and food security, but also stimulate the rest of the economy (Ajibefun and Daramola, 2003; Adeyemo *et al.,* 2010). A study on the exploitation of rubber latex is necessary and to give direction in resources use and allocation in order to increase output from natural rubber.

1.4 Problem Statement

Agriculture is the dominant occupation in Nigeria with a population of over 70% rural farmers. Natural rubber is one of Nigeria's most important industrial and export crop which provides employment opportunity and serves as foreign exchange earning for the country. Products from tapping of natural rubber are useful in the automobile industries for the manufacture of tyres and tubes; surgical gloves used in medical fields and the protection of buildings in earthquake prone areas of the world are obtained from latex (AbMalek and Basir 2002; Abolagba *et al.,* 2003).

The Nigerian civil war (1967-1970) and oil boom era (1973-1978) which changed the agricultural priorities of both the government and the people of Nigeria marked the major decline in natural rubber production. Many rubber farms were abandoned and some land areas under rubber cultivation were recovered from rubber and given to arable food crop production and other non-timber industries (Abolagba and Giroh, 2006).

In reaction to the worrisome performance of the rubber industry, the Federal Government of Nigeria had introduced many policies and programmes which include the Agricultural Research Institute Decree in 1973, the abolition of Commodity Board in 1986, National Accelerated Industrial Crops Production Programme ; NAICPP in 1994 and the Presidential Initiative on Natural Rubber (PIR) in 2006 to promote rubber production and to diversify the hitherto mono commodity or monolithic economy with oil as the major source of revenue (RRIN, 1995; Giroh *et al.,* 2008). Government efforts in funding research for the improvement of rubber resulted to the breeding of high yielding clones of natural rubber by Rubber Research Institute of Nigeria, having advanced from 200 to 300 kg per hectare per year of local groves to 3500 kg per hectare per year (Omokhafe and Nasiru, 2004). The minimal impact of these polices and programmes might be attributed to poor quality data for agricultural sector planning.

With all these policies and programmes, it is expected that the establishment of more rubber plantations should be on the increase, but empirical evidence revealed only an increase in demand for rubber produce while supply lags behind (Spore, 2004). This may be attributable to a number of constraints associated with estate and smallholder development activities, seedlings production and uptake, processing and alternative uses and local marketing and export. About 80% of the current population of the estate and smallholder plantations are over 30 years and have passed their economic life span of 25 years and most plantations are planted with unselected planting materials. Inadequate information, poor marketing facilities, lack of credit facilities and high cost of credit, low yield and under exploitation due to the inability and unaffordability of vital production inputs and decreased earnings from rubber business are problems of rubber production (Abolagba *et al.,* 2003; Agwu, 2006). Thus, efforts to increase rubber production will largely depend on proper understanding of factors influencing farmers to continue to remain in rubber production. Efficiency of their production may be influenced by farm specific characteristics, use of improved seedlings and production practices. Understanding rubber farmers' production efficiencies is important. Gain in efficiency will lead to increased output (Giroh and Adebayo, 2007).

Considerable researches have been conducted on the natural rubber in the areas of crop improvement and other production innovations in Nigeria (Alika, 1982;

Aigbekaen and Alika, 1984; Esekhade *et al.*, 1996; Omokhafe and Nasiru, 2004; Umar *et al.*, 2008; Mesike *et al.*, 2010). However, Giroh and Adebayo (2007) carried out studies on the technical efficiency of rubber tapping in the Rubber Research Institute of Nigeria, Edo State but have not examined the allocative and economic efficiencies of rubber production by farmers in Edo and Delta States of Nigeria. A study of this nature is required to bridge the gap in order to examine the efficient allocation of resources by rubber farmers in production. This research was therefore conducted to answer the following questions:

i. What are the influences of the socio-economic characteristics of rubber farmers on their efficiency of production?
ii. What is the source of labour and its productivity in rubber production?
iii. What are costs and returns in latex production?
iv. How efficient are the rubber farmers in the use of resources?
v. Do the rubber plantation owners operate at a level of technical, allocative and economic efficiency sufficient to justify future survival of the industry?
vi. What is the optimal tappable trees/ task that will *satisfice* a set of multiple objectives of plantation owners?
vii. What are the constraints of rubber farmers and tappers in latex production?

1.3 Objectives of the Study

The main objective of this work is to study the efficiency of latex production and labour productivity in rubber plantations in Edo and Delta States, Nigeria.

The specific objectives are to:

i. examine the influence of rubber farmers' socio- economic characteristics on their technical efficiency;
ii. examine labour availability and productivity;
iii. determine profitability of rubber production ;
iv. determine the allocative , technical and economic efficiencies of factors employed in latex production;

v. determine an optimal tappable trees/ task that would *satisfice* a set of multiple objectives of plantation owners and;

vi. examine factors or constraints affecting rubber farmers and tappers in latex production

1.4 Research Hypothesis

The hypotheses of this study stated in the null forms are that:

Ho_1 : $\beta_j = 0$. The parameter estimates of explanatory variables were not significantly different from zero.

Ho_2 : $\gamma = 0$. There is no technical inefficiency in rubber tapping.

1.5 Justification of the Study

Natural rubber (*Hevea brasiliensis*) takes a gestation of 5 to 7 years from planting to exploitation or tapping. In response to the growing demand of the rapidly expanding automobile industry, *Hevea brasiliensis* (Muell Arg) was found to be the best source of rubber planting material because of its singular ability to renew its bark and thus ensure sustained harvest. It is an economic tree cultivated for its latex which is of economic importance. Latex is important in automobile industries for the manufacture of tyres and tubes. Latex is useful in the manufacture of surgical gloves while the rubber seeds are processed into rubber seed oil and alkyd resins for industrial uses. Furthermore, rubber is environmentally friendly and helps to protect the soil from soil erosion. It also provides foreign exchange earning for the country and generates employment opportunity to a sizeable segment of Nigeria's rural populace (Abolagba *et al.*, 2003; Abolagba and Giroh, 2006).

Considering these enormous benefits from the rubber tree and its long economic life span calls for careful and efficient exploitation as the bark of the rubber tree is the farm capital or economic reserve of the farmer as its quality conditions the quantity of latex regenerated after successive tapping that determines the financial returns of the rubber plantations. The survival of the Nigerian Rubber industry depends on the skills of the tappers. It is imperative that efficient exploitation of rubber will lead to more output to meet domestic and foreign consumption and consequently uplifting the socio-economic status of the farmers and foreign exchange earning for the country. The study will help to determine the level of resource allocation and factors that are associated with rubber production in Edo and Delta States. Thus, the various individuals and organizations growing rubber in the States would be able to improve on the factors that enhance production and also modify other negative factors affecting them. This will be of immense benefit to all as it would increase the aggregate production level in the States. The result of the study will be useful to farmers who wish to venture into rubber production. It will also provide information to researchers, planners and policy makers to enhance policy formulation for the production of natural rubber. Result will also be useful to students for further studies on the natural rubber industry. It will also serve as a guide to enhance rubber production in Nigeria.

CHAPTER TWO

LITERATURE REVIEW

2.1 Production of Natural Rubber in Nigeria

Natural rubber (*Hevea brasiliensis* Muell Arg) was found to be the best source of rubber planting material to supply the demand of a rapidly expanding automobile industry because of its singular ability to renew its bark and thus ensure sustained harvest. It is a perennial crop that is capable of being exploited for 35 years. The plant thrives in rain forest regions of the lowland tropics with temperature between 23 - 45^{0}C and a well-distributed rainfall of 2000 mm /year or more, a well drained soils with pH of 4.5 to 6.00 have been found suitable. Natural rubber tree originated from the area which extends from the Amazon basin southwards towards the Matto Grosso region of Brazil and Northwards into the upper part of Orinoco basin in Latin America. It takes 5-7 years for the tree to get to maturity and it is usually replanted after 25-35 years, when yields fall to an uneconomical level. It was introduced into Nigeria from England around 1895 with the first rubber plantation was established by the Division of Agriculture in Sapele in 1906 in the then Bendel State . The second by Pamol at Ikot- Mbo (Cross- River State) the then eastern region in 1912. The first major Nigerian owned plantation was established at Sapele, between 1909 and 1917, 2000 hectares were established in the then Midwestern region (Bendel State) area alone(Anschel, 1965; Elabor- Idemudia, 1984). Of the over 250,000 hectares of rubber production in the country, about 35% were established in then Bendel State (Edo and Delta States) (Anschel, 1965; Elabor-Idemudia, 1984, Aigbekaen *et al.*, 2000).

Rubber is grown in Edo, Delta, Ondo, Ogun, Abia, Anambra, Akwa-Ibom, Cross River, Imo, Ebonyi, Bayelsa, Rivers, Southern Kaduna, Taraba and Adamawa States (Aigbekaen *et al*., 2000; Giroh *et al.*, 2008). The rubber growing belts of Nigeria are classified as traditional and marginal areas (Fig.1).

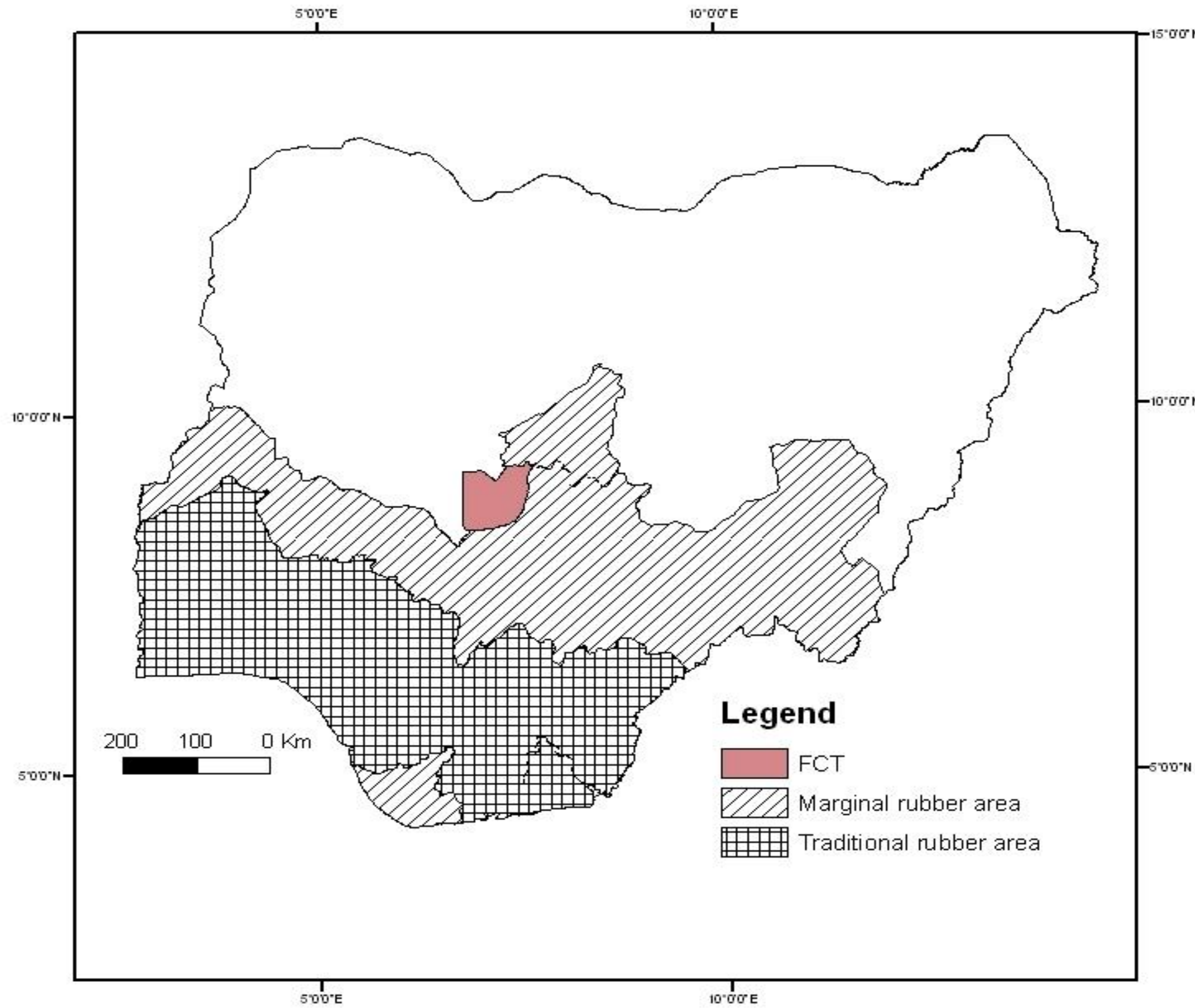

Fig 1: Map of Nigeria showing Traditional and Marginal rubber growing areas (Source: Orimoloye, 2011)

The Nigerian rubber industry has enormous potential (favourable ecology and improved planting materials) for its sustainable growth and development. Breeding programme by Rubber Research Institute of Nigeria has made impact on Nigerian rubber yield having advanced from 200- 300 kg per hectare per year of local grove to 3500 kg per hectare per year of RRIN developed clones which are higher than the adapted clones introduced to Nigeria (Omokhafe and Nasiru, 2004). Rubber is either grown through the planting of seedlings or vegetative propagation which is preferred in both estate and smallholdings.

The common agronomic practices in rubber production include land preparation, field planting, weeding, pruning and fertilization. Land preparation includes various operations such as land clearing, lining and holing. The nature and extent of clearing required will depend on the previous land use. The clearing operations for jungle lands are more elaborate. Large trees of good timber value are removed first, followed by removal of smaller ones; the undergrowth is slashed and left in the field for about one month for drying before burning. Large stumps that interfere with planting lines in terraces have to be removed. The procedure for lining depends on the planting system and spacing to be adopted. To provide favourable condition for the early establishment and growth of the young plant, a hole is dug at the planting point and refilled with fertile topsoil, referred to as holing. The standard depth of the hole is 45 cm. Planting is done during favourable weather, (April – July) in Nigeria. The actual method of planting depends on the materials used for planting. For seedling and budded stumps, planting is done as early as possible after pulling them out from the nursery.

Rubber plantation both immature and mature phase are infested by various weed species and calls for weed control which could be by manual or chemical. A combination of manual and chemical weed control methods and cover crop establishment can be integrated for optimizing weed management. Proper manuring is highly essential at the immature phase to accelerate growth and reduce unproductive phase in rubber. During the first four years, rock phosphate fertilizer is applied to provide good soil conditions for development of the root system of the young plant. Fertilizer recommendation from the fifth year and successive years till the plant become ready for tapping (NPK 12-12-12 mixture) the rubber under tapping; the recommended dose of NPK (30-30-30 mixture). The time of application depends mainly on the moisture status of the soil. There should be sufficient moisture in the soil at the time of application of fertilizer. The first application should be made at the onset of rain in April - May while the second application is made between September before the onset of dry season (Delabarre and Serrier, 2000).

Natural rubber is an economic tree crop in Nigeria and has diversity of uses which include provision of raw materials for agro-based industries, foreign exchange earning and offers employment to a sizeable segment of the Nigerian farming rural population

(Abolagba *et al*., 2003). The usage of rubber is related to its property. The predominant property of solid rubber is its elastic behaviour or deformation by compression or tension. The tyre industry is the major consumer of natural rubber. It is well suited for the manufacture of tyre especially radial, heavy duty and high-speed tyres because of its dynamic qualities such as good tear strength and low heat build up. Beyond the use of rubber for manufacture of tyres, rubber is used for the manufacture of specific products such as flexible oil resistance pipelines for offshore oil fields, inner tubes of tyres, footwear, bridge pad and building foundation in Earthquake prone areas. The latex concentrate is used for the production of carpet underlay, adhesives, foam, balloons, condoms, and medical accessories such as gloves and catheters. The rubber seed is also used in the manufacture of rubber seed oil, putty and alkyds resins, which find application in the paint, leather industry, soap, skin cream and hair shampoo industries. Furthermore, rubber seed cake extracted from rubber seeds is valuable in livestock feeds while the rubber wood is used for furniture, particleboards and fuel (Fasina, 1998; Giroh *et al.*, 2007a).

Natural rubber takes five to seven years before the commencement of tapping and the spacing of 6.7 m x 3.34 m, which gives about 450 plants/hectare. The introduction of intercropping with arable crops before canopy closure ensures effective utilization of the avenues and labour for maintenance. It has been observed that the multiple cropping in the vast inter row of young rubber plantation holds key to attracting small holders to rubber farming. It has been found to be economically feasible where the farmer obtains revenue from the sales of the crops while waiting for the maturity of the trees before the commencement of tapping. Integrated farming (mini livestock, Honey bee production, snailery) and production of shade tolerant crops such as cocoyam and edible mushroom can be practiced under matured phase of rubber. Small- scale farmers in particular, practice inter-cropping for deriving short-term income. Inter-cropping when properly done has been found to enhance the growth of rubber. However, it is important to plant the inter-crops sufficiently away from rubber to minimize competition (Esekhade *et al*., 1996). The planting of rubber with food crops has also been reported to be compatible in Indonesia and Brazilian Amazon forests (Schroth *et al*., 2004).

Table 2.1: Rubber Production (export and local consumption) in Nigeria in tonnes

Year	Total production	Export	Local consumption
1970	56,250	49,000	7,008
1971	61,750	50,000	11,750
1972	57,199	46,230	10,790
1973	66,250	46,250	20,000
1974	78,000	50,000	28,000
1975	67,500	42,750	25,000
1976	52,500	26,500	26,000
1977	59,250	32,250	27,000
1978	57,500	29,500	28,000
1979	56,250	27,200	29,000
1980	44,500	14,575	29,925
1981	33,200	23,007	10,193
1982	36,298	24,005	12,293
1983	38,950	26,316	12,634
1984	39,206	28,636	10,570
1985	43,571	31,643	11,928
1986	36,761	26,035	10,775
1987	45,286	33,658	11,628
1988	80,500	65,800	14,700
1989	118,400	101,300	17,100
1990	152,000	121,000	19,800
1991	155,000	139,000	16,700
1992	129,000	110,000	19,000
1993	97,700	79,700	18,000
1994	68,600	49,600	19,000
1995	116,200	99,200	17,000
1996	63,800	48,800	15,000
1997	65,000	53,000	12,000
1998	80,000	65,000	15,000
1999	265,000	38,000	227,000
2000	275,000	36,000	239,000
2001	279,000	30,000	249,000
2002	285,000	24,000	261,000
2003	290,000	17,200	272,800
2004	45,000	28,000	17,000
2005	142,000	24,000	118,000
2006	142,500	32,000	110,500
2007	143,000	34,635	108,365
2008	143,500	35,500	108,500

Source: Abolagba *et al.*, (2003); Mesike (2005), CBN Statistical Bulletin various issues

Despite remarkable improvements in the breeding of high yielding clones of rubber by the Rubber Research Institute of Nigeria and favourable ecologies, the Nigerian rubber output continue to decline. Natural rubber production shows a gradual downward trend till 1988 (Table 2.1). The introduction of Structural Adjustment Programme (SAP) in1986 resulted to the increase in production of natural rubber in 1989 which peaked in 1991. The increase in output was not as a result of increase in hectarage cultivated, but it was because farmers returned to the tapping of abandoned plantations because of the high prices of rubber. Thereafter, the trend has been warping and this could be traced to a number of factors such as unstable government policies as well as crash in world prices of rubber which affects producers (Abolagba *et al.*, 2003; Schroth *et al.*, 2004).

2.2 Tapping of Natural Rubber

Rubber trees are usually tapped for latex by making a spiral cut through the bark of the tree on alternate days. The milky sap or latex which oozes out when the tree is wounded (tapped) can be processed into solid rubber or liquid rubber (known as latex concentrate). Rubber tapping is one of the major employers of labour in many rubber-producing countries of the world. Once begun, tapping is normally continued for 10 – 20 years, depending on how quickly the accessible bark is consumed. A task is normally 500 – 600 trees which takes 3 – 4 hours to tap by a tapper. Younger trees are simpler to tap. The same person then returns to collect the still - liquid latex cups emptying it into a bigger container. There is then a residual flow of latex which coagulates on the cut and in the cup; this is secured at the next tapping as scrap and cup lump (International Rubber Research and Development Board, IRRDB, 2006). For profit maximization, it is advisable that the plantation be opened for tapping when 70 to 75 percent of the trees in the plantation have reached tappable girth of 50 cm. The conventional system of tapping expresses the frequency of tapping as a fraction of daily tapping on a full circumference; alternate daily tapping denoted by $^{1}/_{2}$ S d_2 . This means that half the circumference of the tree is cut during tapping and is done on alternate days and ideal for older plantation while d3 was suitable for younger plantation.

Vijayakumar *et al.* (2009) reported a change in tapping notation for latex harvesting as the interval between tapping in days expressed by the letter d followed by Arabic numeral (Table 2.2).

Table 2.2: Tapping Notation

Old		New
d/1	= Daily tapping	d1
d/2	= Alternate daily tapping (once in 2 days)	d2
d/3	= Third daily tapping (once in 3 days)	d3
d/4	= Fourth daily tapping (once in 4 days)	d4
d/5	= Fifth daily tapping (once in 5 days)	d5
d/6	= Sixth daily tapping (once in 6 days)	d6
d/0.5	= Twice a day tapping	d0.5

Source: Vijayakumar *et al.*, (*2009*).

Schroth *et al.* (2004) agreed that the system improves the general health of the trees as compared to tapping all around the trunk, reduces bark consumption and liberate time to tap perhaps 50 percent more trees without any reduction in per-tree yields.

Empirical evidence suggests that yields derivable from the *Hevea* tree is controlled by several factors such as the tappers skill, level of field maintenance, clonal characteristics, climate, degrees of exploitation, tapping efficiency and socio-economic factors (Williams *et al.*, 2001; Giroh *et al.*, 2006a). Bark consumption and depth of cut is another factor affecting yield/tree. Tapping cut should penetrate deep enough very near to the cambium layer but should not touch the cambium. If the cambium is damaged, it will result to irregular bark regeneration and frequently lead to bark bursting; hence the need for efficient exploitation as the bark of the rubber tree is the economic reserve of the farmer. Removal of 1 to 1.5 mm is ideal (Delabarre and Serier, 2000).

Samat and Ehika (2005) reported that an ideal tapping system is expected to maximize yield, minimize costs, give satisfactory growth, ensure good bark regeneration and reduce incidence of disease attack especially bark burst. However, for quality control the plantation must be slashed regularly to the ground level. Wind broken trunks and branches should be removed as soon as they occur. This is done to create airy and less humid environment. Tapping knives, latex cups, buckets must be cleaned before use. Tapping panels should also be cleaned, pieces of barks, leaves should not be allowed into the latex as these introduce impurities with consequences such as poor pricing of output and production of inferior automobile products (Uraih *et al.,* 2006).

2.3 Determination of Dry Rubber Content from Natural Rubber Latex

Hevea latex (natural rubber latex, NRL) is a biological product of complex compound. The basic component of freshly tapped natural rubber latex is made up of water, carbohydrates and dry rubber content amongst others. Rubber latex contains hydrocarbon of which the structural unit is the isoprene molecule (Khalid, 1982). Table 2.3 gives the constituents of natural rubber latex.

Table 2.3: Constituents of Latex

Constituents	Percentage composition
Rubber particles (Cis-1 poly isoprene)	30 – 40
Protein	2-3
Water	55- 65
Steril glycosides	0.1 -0.5
Resins	1.5 -3.5
Ash	0.5 – 1.0
Sugars	1- 2

Source: Jayanthy and Sankaranarayanan (2005).

Transactions with tappers in many rubber producing countries of the world depend on the dry rubber content (DRC) of latex and the true DRC of the latex must be determined to ensure a fairer price. DRC is the percentage of rubber available in any known or given volume of natural rubber. It is the total dry weight (Jayanthy and Sankaranarayanan 2005; IRRDB, 2006). Jayanthy and Sankaranarayanan (2005) reported that many methods of determination for DRC of field latex have been developed and included standard laboratory method, Chee method and hydrometric method respectively. The standard laboratory method is based on Malaysian Standard MS3: 35 – used in research and quality laboratory and is not suitable for field because of high capital outlay. The chee method is the simplified version of the standard laboratory.

However, in Nigeria, of all methods of determining DRC, only the hydrometric method which uses the principle of measurement of specific gravity of latex that is commonly used because of its speed and operational simplicity (Osaretin, 1987, Giroh *et al.*, 2006a). This method involves mixing one part of field latex with two parts of water and reading the specific gravity of the resulting mixture in terms of DRC using a latex hydrometer called metrolac. The whole operation which takes about five minutes is conducted in the presence of the tapper and needs no skilled operator. The method requires the use of latex hydrometer, a latex jar, latex pan and latex cups for delivering and mixing the latex with water. The apparatus are portable, cheap and easily obtained from local supplies.

In the procedure, the two parts of water and one part of latex is thoroughly stirred and all the foam on the surface removed, allow the metrolac to rest without touching the base and sides of the jar. Take the reading on the stem at the base of the meniscus of the latex. The latex hydrometer was previously calibrated in the imperial system of pounds of dry rubber per gallon of latex had been used. For example, the scale reading is 1 on latex hydrometer calibrated in the imperial system of pounds of dry rubber per gallon of latex. This means that the dry rubber present in one gallon of diluted latex is one pound. In practice, it is generally accepted that one gallon of diluted latex weighs 10 pounds. The DRC of diluted latex is therefore 10 percent. Taking into account a 1:2 dilution of the latex, the DRC of the original undiluted latex is 30 percent.

However, the use of latex hydrometer calibrated in metric unit is similar to that calibrated in the imperial system. When a field latex of 30% DRC is diluted at the ratio of 1:2 with water and its DRC is estimated using the hydrometer method in the imperial unit will give a scale reading of 1 pound of dry rubber per gallon of latex, whereas the latex hydrometer calibrated in metric unit will read 100g of dry rubber per litre of latex which weighs 1000g. So a DRC of 10% is estimated for diluted latex in both cases (Table 2.4).

Table 2.4: Scale reading on a Latex Hydrometer

Scale reading (of dry rubber per litre of latex)	Dry rubber of Diluted Latex (1:2 Dilution)	Dry Rubber % of original un diluted latex
50	5.0	15.0
55	5.5	16.0
60	6.0	18.0
65	6.5	19.5
70	7.0	21.0
75	7.5	22.5
80	8.0	24.0
85	8.5	25.5
90	9.0	27.0
95	9.5	28.5
100	10.0	30.0
105	10.5	31.5
110	11.0	33.0
115	11.5	34.5
120	12.0	36.0
125	12.5	37.5
130	13.0	39.0
135	13.5	40.5
140	14.0	42.0
145	14.5	43.5
150	15.0	45.0
155	15.5	46.5
160	16.0	48.0

Source: Osaretin (1987); Rubber Research Institute of Malaysia Planters' Bulletin No. 169, 1982 p 162.

2. 4 Labour in Natural Rubber Production

The field production of natural rubber (NR) is a labour-intensive sector involving millions of farmers (mostly women). Tapping and latex collection are normally carried out by paid labourers (estates) or household work (smallholdings). If land values were omitted, labour would constitute the largest single cost per kilogramme in the field production of natural rubber. Although this cost varies considerably among countries (owing to differentials in wages and yields), it tends to be prominent in all contexts. According to data drawn from private records of production and marketing enterprises, management and labour represented over half total direct expenditure on estates and smallholdings in many rubber producing countries of the world (IRRDB, 2006). Labour constitutes the total endeavour or effort, which human beings expend in the course of conceptualizing and producing goods and services to meet societal needs and objectives. Labour is productive economic effort (Yusuf (2000). In many countries of West Africa, labour productivity holds key to the development of agricultural economies (Chianu *et al.*, 2001).

The agricultural sub sector of the Nigerian economy has been reported to be constrained by a number of factors that affect many workers employed in the sector. These factors are classified into internal and external factors. The internal factors include wages - the amount, time and method of payment, lack of incentives, and dislike of job while external factors are those of transport, poor housing, schooling facilities and poor health (Johnson, 1990). Chianu *et al*. (2001) reported that labour is a limiting factor of production in the vast majority of West African farming systems technologies and labour productivity holds the key to the development of agricultural economies.

The Nigerian rubber belt corresponds with the oil-producing belt and competes with scarce labour with the oil sector characterized by shortage and high cost of labour where tree exploitation for latex was reported to be below 40 percent (RRIN, 1983). Aigbekaen and Alika (1984) reported that the cost of labour to the overall cost of production of natural rubber in Nigeria is estimated at 63 percent. This implies that even if other costs of inputs are held constant, the overall production cost will be significantly affected as the labour cost continues to rise. As a result of this, majority of small holders have abandoned their holdings due to low availability of labour as the reason for low level of exploitation. A highly significant and negative correlation was obtained between labour wage and rubber production in Nigeria (Aigbekaen and Alika, 1984). The authors further reported that the productivity of tappers is the daily output of rubber in kilogramme or litres per day and a tapping task of 450 to 500 trees/day. Their studies also revealed an increase in wages paid to tappers from 75 kobo/day in 1973 to ₦4.81 in 1981. The high cost of labour has forced many farmers and estate owners to embark on a share – tappers arrangement that resulted to slaughter tapping in order to make more money.

Chew (2001) conducted a study on share contracts in Malaysian rubber smallholdings. The study identified that rubber harvesting (tapping) were carried out by different parties under share tapping, contract tapping, wage tapping and fixed rent in order to overcome high cost of labour in rubber harvesting. According to this study, a share tapping refers to a process where a share tapper is a tenant contracted the right to tap the trees for a certain percentage; example the tapper may get 40 percent of the dry rubber content (d.r.c.) yield with the owner retaining the remaining 60 percent. A contract tapping is an arrangement where the contract tapper is a tenant with the right to tap the trees for certain remuneration per unit yield where a tapper may get 30 cents for 0.6048 kg. Wage tapping is where the tapper is a tenant employed on a monthly basis by the owner to tap the trees for a fixed daily wage irrespective of the amount of rubber produced.

Suyanto *et al*. (2001) in a study on land demand and land management efficiency in smallholder rubber production in customary land areas of Sumatra found out that rubber trees are over exploited under renting arrangement due partly to short term nature of land tenancy contracts and partly to the difficulty land owners face in supervising tapping activities of tenants in spatially dispersed rubber fields. Schroth *et al*. (2004) reported that the consequence of share tapping arrangement is that the trees are damaged. Spore (2004) attributed low availability and high cost of labour as well as the wider use of synthetic rubber products that put natural rubber to the danger of extinction.

Giroh *et al.* (2006a*)* conducted a study on the productivity of rubber tappers in the rubber belt of Nigeria and found out that tappers productivity is affected by lack of infrastructures in rubber plantation like living quarters, pipe - borne water, electricity, health facilities and roads. Giroh and Adebayo (2007) identified poor wages, delay in payment, job insecurity, and inadequate management of rubber plantations as factors affecting the productivity of rubber tappers. Umar *et al.* (2008) in another study on factors affecting rubber tappers identified poor welfare package, low wage rate and incidences of stings and bites by insects and reptiles in many rubber plantations in Nigeria. The authors further asserted that poor management of the plantations was a predisposing factor to snake bite and other insects.

2.5 Review of Production function and Efficiency Studies

The production function stipulates the technical relationship between inputs and outputs used in the production process. This function is assumed to be continuous and differentiable in mathematical terms. Economists used it to determine rates of return to the various factors of production. The concept of efficiency is concerned with the relative performance of the processes used in transferring given input into output. The computation of this important productivity statistics can be achieved from the analysis of production functions. Such productivity statistics include the average product (AP), marginal product (MP), marginal rate of substitution (MRS), elasticity of production (EP) and returns to scale (RTS). This analysis has made the delineation of three economic stages of production function that enables us to know the point of efficient utilization of resources in the production process possible (Upton, 1997).

The study of productive efficiency started with the pioneering works of Michael Farrell 1957 as cited by Ojo and Imoudu (2000). Three types of efficiency were identified, these are: technical, allocative and economic efficiencies. Technical Efficiency (TE) is the achievement of the maximum potential output from a given quantity of inputs under a given technology. It is the attainment of production goal without wastage (Jondrow *et al.*, 1982; Amaza and Olayemi, 1999). Abdourahmane *et al*.(2001) considered economic efficiency as the ability to produce a given level of output using a cost minimizing input ratios. Technical efficiency is defined as the ability to achieve a high level of output given similar level of production inputs while allocative efficiency has to do with the extent to which farmers make efficient decision by using inputs up to the level at which their marginal contribution value is equal to the factor cost. Economic efficiency combines both technical and allocative efficiency. It occurs when a firm chooses resources and enterprises in such a way as to attain economic optimum (Olayide and Heady, 1982; Russell and Young, 1983; Adesina and Djato, 1997; Bravo – Ureta and Pinheiro 1997, Ajibefun, 1998). Russell and Young (1983) stated that technical inefficiency arises when less than maximum output is obtained from a given bundle of factors and allocative inefficiency arises when factors are used in proportions that do not lead to profit maximization. The authors further reported two measures of technical efficiency; these are Timmer measure of technical efficiency as the ratio of actual output to potential output given the level of input use on the farm and Kopp measures of technical efficiency compares the actual level of input use to the level which could be used if a farm is located on the frontier given the actual output of farm i and given the same ratio of input usage. Both measures yield substantially similar results.

The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or certain level of output at least cost. The analysis of efficiency has fallen into two categories: Parametric and non-parametric. The parametric approach relies on a parametric specification of the production function, while the non-parametric approach has the advantage of imposing non- *apriori* parametric restriction to the underlying technology (Adewuyi and Okunmadewa, 2001).

Ogunjobi (1999) outlined the importance of efficiency measurement to include: success indicator and performance measure by which production units are evaluated, the exploring of hypothesis concerning the sources of efficiency differential can only be possible by measuring efficiency and separating its effects from the effects of the production environment and identification of sources of inefficiency is important to the institution of public and private policies designed to improve performance. There are two types of frontier models; these are deterministic and stochastic models respectively. The term deterministic is used to describe that group of methods that assumed a parametric form of production frontier along with a strict one sided error term (Coelli, 1995a) and example of such work are the works of Aigner and Chu (1968), Afriat (1972) and Schmidt (1976). Coelli (1995a) observed that the deterministic frontier takes no account of the possible influence of measurement errors and other noise upon the shape and position of the estimated frontier, since all observed deviations from the frontier are assumed to be the result of technical inefficiency. Aigner and Chu (1968) and Meeusen and van den Broeck (1977) considered estimation of a parametric frontier production in input/ output space and specified a Cobb- Douglas production in logarithm for a sample of N firms depicted as:

$\ln(y_i) = F(x_i; \beta) - U_i$ ……………………………………………………………………(2.1)

Where: $i = 1,2 \ldots N$

Aigner *et al.,* (1977) and Meeusen and van den Broeck (1977) independently proposed the stochastic frontier production function, where noise is accounted for by adding a symmetric error term Vi to the non-negative error of the deterministic model (Tran *et al*., 1993; Coelli, 1995b). The parameters of this model are estimated by the maximum likelihood estimate (MLE) and corrected ordinary least squares (COLS). The COLS approach was widely preferred and used for samples smaller than 400 but the development of and availability of automated maximum likelihood makes the ML estimator more preferred to the COLS estimator (Tran *et al*., 1993; Coelli, 1992). The stochastic model specification not only address the noise problem associated with earlier deterministic frontiers, but also permitted the estimation of standard errors and tests of hypotheses which were not possible with the early deterministic models because of the violation of maximum likelihood conditions. The main criticism of stochastic frontier is that there is no *apriori* justification for the selection of any particular distributional form for Ui.

The use of the stochastic frontier production function has some conceptual advantage in that it allows for the decomposition of the error term into random error and inefficiency effects rather than attributing all errors to random effects (Xu and Jeffrey, 1998, Ojo, 2008).

It is specified as:

$Y_a = f(X_a : \beta) + (V_- U)$ (Battese, *et al.*, 1993). …………………………………….....(2.2)

Where:

Y_a = Production of the ith firm

X_a = Vector of input quantities of the ith firm

β = Vectors of unknown parameters

V = Assumed to account for random factors such as weather, risk and measurement error. It has zero mean, constant variance, normally distributed and independent of U. It covers random effects on production outside the control of the decision unit.

U = is non negative error term having zero mean, and constant variance (Xu and Jeffrey,1998). It measures the technical inefficiency effects that fall within (because the errors could be controlled with effective and adequate managerial control of the firm), the control of the decision unit (Apezteguia and Garate, 1997). The production technology of the farms was assumed to be specified by the Cobb- Douglas functional form. Bravo-Ureta and Pinheiro (1997) and Ojo (2008) reported that the stochastic frontier models are better estimated using the Cobb- Douglas functional form because of its simplicity and wider use in farm efficiency analyses in both developing and developed countries.

The Stochastic Frontier Cost Function is specified as:

$$\text{Ln } C_a = f(P_a, Y_a: \beta) + (V_+ U) \quad \text{...(2.3)}$$

Where:

C_a = total cost of production of the ith firm

P_a = input prices

Y_a = Output of the ith firm

β = parameters to be estimated

V = systematic component which represents random disturbance cost due to factors outside the scope of the firm.

U = one sided disturbance term used to represent cost inefficiency and is independent of V. The cost efficiency of an individual firm is defined in terms of the ratio of observed cost (b) to the corresponding minimum cost ($c^{\mathbf{min}}$) under a given technology.

$$CE = \frac{(c^b)}{(c^{min})} = \frac{f(P_a, Y_a: \beta) + (V_+ U)}{f(P_a, Y_a: \beta) + (V)} = \exp(U) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

Where:

CE = Cost efficiency,

C^b = the observed cost and represents the actual total production cost;

C^{min} = the minimum cost and represents the frontier total production cost or least total production.

Applying Shephard's Lemma, the system of minimum cost input demand equation can be obtained by differentiating the cost frontier with respect to each input price (Bravo-Ureta and Pinheiro, 1997):

$$\frac{\partial C}{\partial P_i} = X_i (P_a, Y_a: \beta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

Substituting a farm's input prices and quantity of output in equation (2.5) yields the economically efficient input vector X_e. With observed levels of output given, the corresponding technically and economically efficient costs of production will be equal to (X_{it}.P) and (X_{ie}.P) . The cost of farm's actual operating input combination is given by X_i.P. The three cost measures can then be used to compute the technical (TE), economic (EE) and allocative efficiency (AE) indices as follows:

$$TE = X_{it}.P / X_i.P \quad \ldots\ldots (2.6)$$

$$EE = X_{ie}'.P / X_i.P \quad \ldots\ldots (2.7)$$

$$AE = EE / TE = Xi_e.P / X_i.P \quad \ldots\ldots (2.8)$$

Wider application of stochastic frontier production function have been reported in both developed and the developing countries of the world. In Nigeria for instance, Ogundari (2009) conducted study on a Meta analysis of technical efficiency in Nigerian agriculture from 1999- 2008 and reported that out of the 64 studies, 63% were on food crops, 14% cash crops while livestock related studies accounted for 23%. A drop was witnessed in the cash crop sector especially permanent crops such as cocoa, rubber and oil palm which were further corroborated by Central Bank of Nigeria, CBN (2006).

2.5.1 Technical and Allocative Efficiency

Tran *et al*. (1993) examined the TE of state rubber farms in Vietnam. They estimate a time varying stochastic frontier production function for 33 farms and obtained a mean TE of 0.59 for the farms. Their results further showed that 21 percent of the farms have high TE (above 0.80) while 40 percent attained TE of more than the average but less than 0.80. The remaining farms (39 percent) have low TE below the mean value. The reasons advanced for the variations were that of management and different field husbandry methods adopted in the farms.

Bravo-Ureta and Evenson (1994) used stochastic efficiency decomposition methodology to derive technical, allocative and economic efficiency measures separately for cotton and cassava for 148 eastern Paraguay peasant farms. The Cobb-Douglas functional form was used to fit separate stochastic production frontiers for both crops using maximum likelihood procedures. They applied Shephard's Lemma to the cost frontier which yields the minimum cost factor demand equations which in turn were used to obtain the economically efficient input vector and thereby compute technical efficiency (TE) and economic efficiency (EE) indices. The mean economic (EE), technical (TE) and allocative (AE) efficiency indices computed for 87 cotton producers were 40.7, 58.2 and 70.1 per cent, respectively. The corresponding indices for the 101 cassava producers were 52.3, 58.7 and 88.9 per cent. It was concluded that EE and AE were significantly higher in cassava production as compared to cotton production, while no difference was found across two crops for technical efficiency (TE).

Bravo-Ureta and Pinheiro (1997) used stochastic efficiency decomposition methodology to derive technical, allocative and economic efficiency measures in peasant farms in the Dominican Republic. The Cobb-Douglas functional form was used to fit separate stochastic production frontiers using maximum likelihood procedures and applied Shephard's Lemma to the cost frontier which yields the minimum cost factor demand equations which in turn were used to obtain the economically efficient input vector and thereby compute technical efficiency (TE) and economic efficiency (EE) indices. The mean economic (EE), technical (TE) and allocative (AE) efficiency indices computed were 31, 70 and 44 per cent, respectively.

Tadesse and Krishnamoorthy (1997) estimated TE in paddy farms in Tamil Nadu using stochastic frontier model. The study shows that 90 percent of the variation in output among paddy farms is due to difference in TE. Land, animal power and fertilizer have significant influence on the technical efficiency levels of the farmers.

Ojo and Imoudu (2000) conducted a comparative study on productivity and technical efficiency of oil palm farms in Ondo State of Nigeria and found out that training of farm settlers increase their technical efficiency than those not trained and concluded that technical efficiency positively correlates with training.

In another study conducted by Amaza *et al*. (2001) on the factors that influence technical efficiency of cotton farmers in Nigeria, the status of cotton farmers, credit and education had significant effect on the technical efficiency of the farmers.

Maurice (2004) examined the resource use productivity in cereal crop production among fadama farmers in Adamawa State. The result indicates that the TE among the sampled farmers ranged from 0.29 to 0.97 with mean TE of 0.80. Maurice *et al.* (2005) analyzed the technical inefficiency in rice based cropping patterns among dry season fadama farmers in Adamawa State. The result of the inefficiency model indicated that farming experience and level of education increased the technical efficiency of farmers.

Idumah (2005) used the stochastic frontier approach in a study on land productivity differentials and resource use efficiency by food crop farmers in the Niger Delta Area of Nigeria. The estimated coefficients were positive for age, sex, family size and year of schooling implying that these socio-economic factors affected the food production efficiency negatively.

Okoye *et al.* (2006) employed a stochastic frontier cost and production function to measure the allocative efficiency and its determinants in smallholder cocoyam farmers in Anambra State, Nigeria. The result of the analysis showed that the mean allocative efficiency of the farmers was 65% with farm size, fertilizer and credit access significant and directly related to allocative efficiency.

Awotide and Adejobi (2006) studied technical efficiency and costs of production among plantation farmers in Oyo State using stochastic frontier production function. The results indicated that the farmers were fairly efficient in the use of resources and greater reduction in cost can be achieved through efficiency improvement.

Adebayo (2006) conducted a study on resource – use efficiency and multiple objectives of dairy pastoralists in Adamawa State using the stochastic frontier production function. The result shows that labour, potential milking cows, veterinary inputs and feed supplement have significant influence on output. The result also indicated that pastoralists had mean TE of 0.87 with possibility of increasing milk output by 13 percent. More over, the inefficiency analysis revealed that age; experience has positive impact on pastoralists' efficiency while household size had no significant relationship with efficiency.

Esobhawan (2006) studied the efficiency of Artisanal fishery production in Edo State using profitability analysis and stochastic frontier production function. The result of the profitability analysis showed that Artisanal fishery business was profitable venture.

The efficiency analysis showed that 45.30 percent of the variation in fish output was due to technical inefficiency. The technical efficiency (TE) indices of respondents were varied and ranged between 33 to 99 percent with a mean TE of 88 percent. The study also found out that education contributed positively to TE. Examination of allocative efficiency showed that the given optimization condition was never achieved.

Umoh (2006) conducted a study on resource use efficiency in urban farming in Uyo Akwa Ibom State using stochastic frontier production function. The study found out that urban farmers were 70 percent technology efficient with maximum technical efficiency of 0.91 while minimum TE in urban farming was 0.43.

Shehu and Mshelia (2007) investigated the productivity and technical efficiency of small-scale rice farmers in Adamawa State using stochastic frontier production function. The empirical results indicated that the farmers were operating in the irrational stage of production (stage1) as depicted by RTS of 1.06. The predicted TEs for farmers ranged from 74 percent to 98.9 percent with a mean of 95.7 percent. Farmers' literacy level had significant effect on TE.

Shehu *et al.* (2007) analyzed the TE of small scale Rain fed upland rice farmers in the North West Agricultural Zone of Adamawa State, Nigeria and modeled the stochastic frontier production function. Results showed that 88 percent of the farmers were more than 80 percent technically efficient. Age was found to increase technical inefficiency.

Giroh and Adebayo (2007) conducted a study to analyze the technical efficiency of rubber tapping in Nigeria by subjecting their data to stochastic frontier production function. The study found out that tappers operated 0.72 below the stochastic frontier production function with the least and best tapper operating 0.38 and 0.99 respectively.

Giroh *et al.* (2007b) examined resource use efficiency in natural rubber tapping in the rubber belt of Nigeria using production function analysis. Empirical results show that tapping resources (man days of labour, wage, durable asset and level of technology use) were used within the rational zone but not at optimal level except man-days of labour.

Ojo (2008) conducted a study on the effects of land acquisition for large scale farming on the performance of small scale oil palm in Nigeria using the stochastic frontier production function analysis. Empirical results of the study showed that farmers in group B farms were efficient in the allocation of resources and technically efficient than those of group A farms (small-scale farmers).

Giroh and Adebayo (2009) conducted a study to analyze the causes of technical inefficiency of rubber tapping in Rubber Research Institute of Nigeria by subjecting their data to stochastic frontier production function and found out that education enhances the technical efficiency of tappers thereby increasing tree productivity.

2.6 Constraints to Latex Production

Constraints in latex production in many rubber producing countries of the world may have been influenced by a number of factors including government policy towards rubber replanting, rehabilitation, the prices of rubber, alternative crop opportunities, age composition and yields of the trees, weather and technology levels. Several factors affecting latex production have been reported in many rubber growing countries of the world (le Roux *et al.,* 2000).

Aigbekaen et *al.* (2000) conducted a study on the adoption of some recommended agronomic practices of natural rubber in Nigeria and found out that the adoption of inappropriate tapping technique by smallholder rubber farmers' affected latex production with attendant consequences of tree dryness, low yield and income. Abolagba *et al.,* (2003) investigated the farm gate marketing of natural rubber in the South East zone of Nigeria and identified poor prices for rubber as one of the factors affecting small scale rubber farmers or planters. Abolagba and Giroh (2004), identified lack of credit facilities and old age of rubber trees with declining yields as constraints of the rubber farmers. Abolagba *et al.* (2005) identified inadequate extension contact and poor linkage between Rubber Research Institute of Nigeria and the rubber farmers as a factor affecting technology transfer and the adoption of improved farm practices.

Giroh et *al.* (2006a) reported the dearth of skillful labour force in many rubber plantations in Nigeria. Giroh and Adebayo (2007) reported that bush burning, inadequate credit facilities, high cost of credit and unaffordability of vital production inputs also affect rubber farmers. They further stated that high labour wage has forced many plantation owners adopting share tapping with willing unskillful tappers leading to destructive tapping characterized by poor bark regeneration, bark bursting, declining productivity and eventual death of the trees.

Giroh *et al.* (2008) in the evaluation of the impact of the presidential initiative on natural rubber noted that many plantations are planted with unselected planting materials due to the farmers' unawareness of improved planting materials.

Shokpeka and Nwaokocha (2009) examined British economic policy in Nigeria with emphasis on Benin province observed that the long gestation period of natural rubber affected production in the province. Ajokporise and Akpere (2010) conducted a study on the constraints to rubber production in Sapele Local Government Area of Delta State and found out that destruction of rubber trees for fuel wood, fire disasters, pests and diseases adversely affected rubber production in the study area.

In another study conducted on the on - station evaluation of the production of *Hevea* planting material by Giroh *et al.* (2010b), it was discovered that smallholder rubber farmers used wildings or unselected seedlings which have the consequences of low yield hence low income, undesirable secondary characteristics such as poor bark regeneration and poor girth.

2.7 Gross Margin and Profitability of Rubber Latex Production

Gross margin analysis involves evaluating the efficiency of an individual enterprise or farm plan so that comparison can be made between enterprises or different farm plans. It is useful planning tool in situations where fixed capital is a negligible portion of the farming enterprise as is the case with subsistence agriculture. It is easy to compute, a guide to the selection of enterprises by comparing their margins and helps manager to critically examine the variable cost components (Olukosi and Erhabor, 1988). Gross margin gives difference between the gross income and the total variable cost of production (Adegeye and Dittoh, 1985).

Studies have indicated that several factors affect the net return from the tapping of natural rubber in Nigeria. Suyanto *et al.* (2001) in a study to identify the impacts of land tenure institutions on the efficiency of farm management based in customary land areas of Sumatra. The study identified age and ownership systems as determinants of gross revenue and residual profit. Age of rubber trees is a major factor affecting profit, which peak at 32 and 34 years. They further stated that profits are also higher under borrowing and renting through share tenancy, counter to the familiar argument that share tenancy is inefficient because tenants shirk from their tasks. Since both borrowing and renting tend to be short-term arrangements in the study area, temporary operations may seek to squeeze much output from rubber trees as possible in the short run. This over tapping can have detrimental effects on profitability over time, since tapping intensity is negatively related to future latex production. High cost of production of natural rubber in many rubber producing countries have continued to be on the increase over the years, with low productivity of the tappers. Rubber Research Institute of Sri – Lanka, RRIS (2002) reported a tapper's daily productivity of 7.6 kg, which is low and was attributed to intermittent wet weather, which also affected tapping days.

Abolagba *et al*. (2003) studied farm gate marketing of natural rubber in the south east of Nigeria and discovered a positive correlation between world market prices and local prices of rubber in Nigeria, which affects income derivable from rubber by estate owners. Okoruwa *et al.* (2003) observed that increase in export prices of most agricultural commodities stimulated production. Schroth *et al*. (2004) also found out that increased in the world prices of natural rubber propelled Brazilian rubber tappers to tap for more salary. Rubber Asia (2006) identified price volatility and unseasonable rains disrupting tapping as factors that affect profit.

Uraih *et al.*(2006) in a study on rubber farmers awareness on quality standard of rubber produce identified poor field hygiene and deliberate adulteration of rubber latex with sand, barks of tree to increase weight of the coagula as major factors that affect pricing of natural rubber at local and international markets.

Giroh *et al. (*2006a) conducted a study on casual tappers productivity using labour productivity model. The result shows that tappers output/ man-day was 11.93 kg of dry rubber with a mean wage of ₦3,049 and a net labour productivity of ₦399.58 after adjusting for the tapper's wage. Sajen (2006) attributed the increase in rubber prices to global economic recovery and resultant higher demand for rubber, especially from China.

Abolagba *et al.* (2010) examined the determinants of agricultural exports and discovered that increase in producer price led to increase in rubber export as the farmers were encouraged to maintain their rubber farms leading to increased output.

2.8 Review of Linear Programming Studies in Agricultural Production

Linear programming techniques have been widely used in farm planning as mainly a procedure for providing answers to problems which are so formulated. The techniques involve the optimization of a linear function subject to linear inequalities. Linear programming constitutes the major tool – a broad field of empirical method known as activity analysis (Romero and Rehman, 1985; Adebayo, 2006). It generally refers to the computational method used in prescribing production patterns which maximize profit of firms, minimize costs of producing a specific commodity or related type of aggregate analysis.

The linear programming paradigm used in farm planning is stated as:

Maximize $Z = f(x) = CX$ ……………………………………………………….(2.10)

Subject to $AX \leq b$

and

$X \geq 0$

Where: Z is the criterion function, it is a scalar of C and X. X is a vector of decision variables such as acres of wheat, tapping tasks and C is the vector giving corresponding constituents of these variables to the criterion factors. The vector b represents the physical, institutional and personal which choices are made and A defines the technical relationship between variables and the restraints (Okoruwa, 1994).

There are some basic assumptions on which the traditional linear programming is based and are stated as follows (Olayemi and Onyewanku, 1999; Adebayo, 2006):

Linearity - The assumption implies that input- output coefficients are constant and independent of the scale of operation; also the coefficients of the objective function are also constant irrespective of the volume of the output.

Independence or additivity - This implies that the total quantity of inputs (resources) used in different activities are equal to the sum of the quantities of different inputs used in each activity and that the size of any activity is independent of the size of other activity. This implies the absence of any interactions effects among resources and activities.

Divisibility- This means that inputs and outputs are infinitely divisible. Thus, a linear programme can specify inputs and outputs in fractional units.

Finiteness - It is assumed that there is a limit to the number of alternatives and to the resource restrictions, which need to be programmed.

Non – negativity of decision variables - This implies that we cannot use negative quantities of resources or produce negative outputs.

Certainty- This assumption implies that prices of inputs and outputs, the input- output coefficients and the levels of resources are known with certainty. Hence a linear programming model is deterministic.

Goal programming is one of the satisficing multiple- criteria decision making models which help the decision maker to minimize deviation from his/ her set of goal targets (Aromolaran, 1992). It was developed by Charnes and Coopers in 1961 and has been widely used in management sciences. Goal programming tries to optimize several simultaneous goals and this is accomplished by minimizing the deviations between goal target or aspiration levels and the actual levels through addition of positive and negative deviational variables operating either under utilization or over achievement of each goal.

In order to incorporate the goals into the model, each goal is expressed in the form of a goal constraint and generally takes the form:

$f(x) \leq t$ or $f(x) = t$……………………………………………………………………(2.11)

Where t is a parameter representing the aspiration level or target values. With goals, the right –hand is a target aspired to be achieved by the decision maker which may or may not be achieved. This can be considered as soft constraints, which could be violated without producing infeasible solutions. The amount of violation is measured by introducing positive and negative deviational variables into the model. For example if n and p are negative and positive deviational variables, a goal can be represented mathematically as $f(x)+n- p = t$. A goal cannot be both under and over achieved, hence at least one of the deviational variables for each goal would be zero. When a goal (Gi) matches its aspirational level exactly, then both ni and pi are zero. In lexicographic pre emptive goal programming, the minimization process is carried out by attaching pre emptive or absolute weights to the sets of goals situated in different priorities i. e fulfilment of a set of goals situated in a certain priority is immeasurably preferable to the achievement of any other situated in a lower priority (Piech and Rehman, 1993). A higher priority is not degraded by lower priority goal. What is derived from this is referred to as the achievement function, which replaces the objective function of the traditional paradigm.

Weighted goal programming considers all goals simultaneously in a composite objective function which minimizes the sum of all the deviations between the goals and their aspiration levels. The deviations are however weighted according to the relative importance of each goal to the decision maker. The deviations from the targets are always expressed as percentage in objective function to overcome the problem of differing units used to measure various goals. Goal programming has a lot of advantages over and above the traditional linear programming techniques (Adebayo, 2006).Whereas the linear programming is characterized by optimization of a single objective function or decision criterion and all constraints are rigid and flexible, the weighted goal programming model on the other hand is more practical in model building as well as in its application to real life situations. Goal programming involves multiple and possibly conflicting objectives. It automatically adjusts the level of certain resources to satisfy the goal of the decision maker. It also accommodates objective function with non homogeneous units of measurements. More over, it is possible to obtain feasible solution even with conflicting objectives.

It can be expressed as:

$$\text{Minimize } Z = a_1n_1x100 / K_1 + a_2n_2\, x100 / K_2 + a_3n_3x100 / K_3 \text{ etc} \qquad (2.12)$$

Where:

a_1 - a_3 are the weights that reflect the decision makers' preferences regarding the relative importance of each goal, K_1…………….. K_n are goal targets of the respondents.

Amir *et al.* (1986) evaluated the potential of integrating sheep and smallholder rubber producers in Sumatra and by subjecting their analysis to goal programming and found that there is economic viability in the combination to enhance the income of rubber farmers.

Nicholson *et al*. (1994) developed a deterministic, multi- period linear programming model of the dual-purpose cattle production system in the Surde Lago region of Venezuela. Their model application demonstrated that alternatives to traditional feeding practices are profitable and nutritionally feasible even though benefits of alternative nutritional management depend on labour availability.

Manyong (1995) in an attempt to find out the sustainability of the African smallholder farming system applied goal-programming model on data collected from 60 farms in Ijenda district of Burundi. The major objectives of the farmers were more to provide food for his/ her family throughout the year, to maintain soil fertility and to accumulate monetary income. He concluded that there were qualitative and quantitative imbalances in the farmers' essential objective.

San (1995) studied the dynamic decision making in agricultural households by integrating sheep and crops with smallholder rubber producers in Indonesia by subjecting the data to linear programming. Analysis revealed that integrating sheep production activity into rubber plantations increases net present value of future income by 20%, and integrating both sheep and soybeans into a rubber plantation can provide a 38% increase in net present income.

San and Deaton (1999) conducted a study on the feasibility of integrating sheep and crops with smallholder rubber production systems in Indonesia using linear programming model. Result of the study indicated that for a given level of resources, technology, and credit repayment policy, the optimal number of trees for a smallholder producer is 593.

Ndubuisi (1999) in his studies of the crop- livestock integration among pastoralists in the northern Guinea Savanna of Nigeria made use of goal programming techniques to develop strategies for optimum utilization of resources in the integrated crop –livestock system. The result suggested that respondents in the market driven areas of crop agriculture intensification should specialize along commodity lines while livestock farmers concentrate on livestock.

Shi *et al*.(2005) evaluated better access to new technologies and credit service, farmers land use decisions, and policy for poverty alleviation and rangeland conservation in agro- pastoral area of Inner Mongolia China using linear programming to describe the relationship between changes in policy and socio-economic circumstance and land degradation process. The findings indicated that the introduction of sedentary beef production increased income under all the three grazing restriction scenarios in both systems by 30 – 42 percent in the cropping system and 3 – 18 percent in the pastoral system. The study recommended the introduction of credit facilities to poor household with the introduction of credit facilities to poor household with the possibility of increasing their income by 51 percent. The study indicated that the major advantage of mathematical programming is that it may combine economic behaviour and biophysical process in an integrated framework. The disadvantage is that it generates a vast amount of results with what if analysis when some of the parameters of the model are not known with great accuracy.

Haruna (2005) studied optimum crop combination in the fadama areas of Bauchi State, Nigeria, using linear programming model. It was found out that cropped area under less remunerative and low labour demand crops like cabbage, lettuce and okra should be shifted towards the production of higher remunerative and high labour demanding crops like tomato, pepper and irrigated rice. Inadequate credit, high cost of farm inputs and inadequate marketing outlets were identified as constraints of fadama user groups in the study area.

Adebayo and Olayemi (2005) reported two widely used algorithms for solving goal programming problems; lexicographic pre-emptive goal programming (LGP) and weighted goal programming (WGP) methods. Despite the advantages, their application in general and rubber production (tapping) in particular is scanty.

Going through the review of relevant literatures, a lot of researches were conducted on other crops using various tools of analyses. Several studies conducted on natural rubber like the works of Alika (1982); Aigbekaen and Alika, (1984); Esekhade *et al.* (1996); Omokhafe and Nasiru, (2004); Umar *et al.(* 2008) and Mesike *et al.*(2010) extensively dealt on crop improvement and other production innovations in Nigeria. Giroh and Adebayo (2007) evaluated the technical efficiency of rubber tapping in the Rubber Research Institute of Nigeria, Edo State but have not examined the allocative and economic efficiencies of rubber production by farmers in Edo and Delta States of Nigeria. This knowledge gap was addressed in this study using the relevant tool of analyses (weighted goal programming, stochastic frontier production function).

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

The study was conducted in Edo and Delta States of Nigeria. Edo State lies between Latitudes 5^o 44´ and 7^o 34´ N of the equator and between Longitudes 5^o 04´ and 6 ^{o} 43´ E of the Greenwich Meridian. It shares boundary to the south by Delta State, in the West by Ondo State and in the East by Kogi and Anambra States (Emokaro and Erhabor, 2006a). The State covers a land area of about 17,902 km^2 with a population of 3,218,332. Edo State is divided into 18 Local Government Areas (NPC, 2006). The State is characterized by a tropical climate which ranges from humid to sub humid at different time of the year. Three distinct vegetation identified in the State are mangrove forest, fresh swamp and Savannah vegetations. The mean annual rainfall in the northern part is 1270 mm to 1520 mm while the southern part of the State receives about 2520 mm to 2540 mm rainfall respectively. Mean temperature in the State ranges from a minimum of 24 ^{0}C to a maximum of 33^0 C. The people of the State are mostly farmers growing a variety of crops such as cassava, rice, yam, plantain, pineapple and tree crops such as rubber, oil palm and cocoa. Other occupations of the State include small and medium scale businesses and jobs done by artisans and civil servants who engage in farming on part time basis (Emokaro and Erhabor, 2006a).

Delta State lies between latitude 5^0 00´ and 6^0 30´ N of the equator and longitude 5^0 00´ and 6^0 45´E of the Greenwich meridian. The State has a land area of 17,440 km^2; about one third of this is swampy and waterlogged (Delta State Diary, 2003). The State is bounded in the North by Edo State, in the East by Anambra and Rivers State and in the South by Bayelsa State. The Atlantic Ocean forms the Western boundary while the North West boundary is Ondo State. There are 25 Local Government Areas in the State with a population of 4,098,391 people (NPC, 2006) .The State has a tropical climate marked by dry and rainy seasons. The rainy season starts in April and ends in October. The dry season starts in November and ends in March. The rainfall ranges from 1905mm to 2660 mm monthly. The temperature ranges from 24 ^{0}C to 34^0 C with an average of 30^0 C (Delta State Ministry of Agriculture, 2000; Ike, 2010).

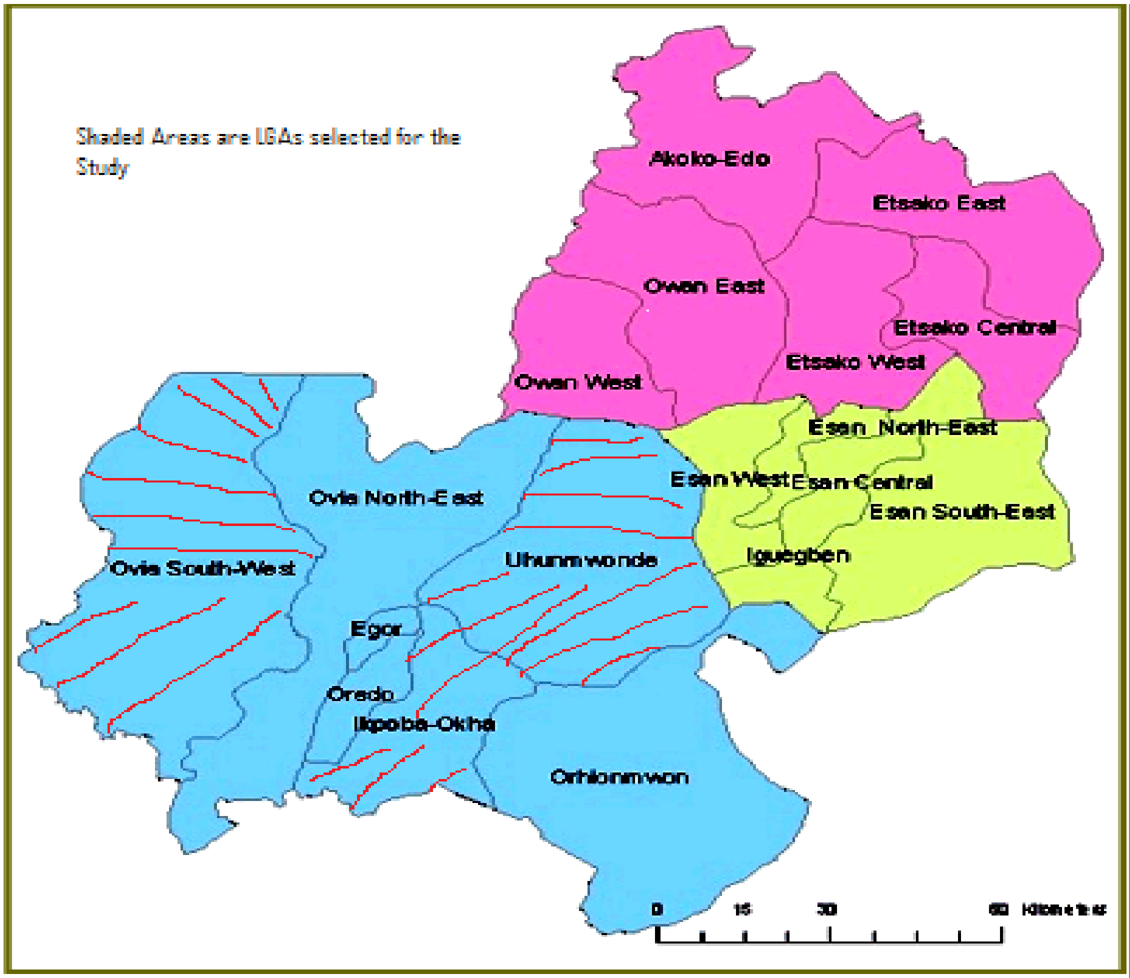

Figure 2: Map of Edo State showing Study Area

3.2 Sources of Data and Sampling Technique

Data for this study were obtained mainly from primary source. The data were mainly collected on the 2009 and 2010 production activities of the farmers using structured interview schedule in a multi-stage sampling technique. The first stage involved the purposive selection of Tapping Division of the Rubber Research Institute of Nigeria (Main station, Iyanomo, Ikpoba - Okha Local Government Area), Iguoriakhi Farm settlement, Odia Rubber Estates (Ovia South West and Uhunmwode Local Government Areas in Edo State) and Utagba – Uno, Mbiri Farm settlements and Mars Plantation in Ndokwa East, Ika North East and Ndokwa West Local Government Areas of Delta State respectively.

Figure 3: Map of Delta State showing Study Area

The second stage of the sampling was obtaining the list of 407 rubber farmers from the selected locations from Tree Crop Units and Ministry of Agriculture and Natural Resources in Edo and Delta States. Similarly, a list of 160 rubber tappers was obtained from Tapping Division of Rubber Research Institute of Nigeria, Mars Plantation and Odia Rubber Estates. The respondents were served with interview schedules.

Finally, a total of 300 rubber farmers and 120 tappers (Table 3.1 and Table 3.2) were randomly selected using proportionality factor adopted by Adebayo and Olayemi (2005):

S = p/P x Q/1……………………………………………………………………(3.1)

Where:

S =Total number of respondents sampled

p = Number of rubber farmers in each location

P = Total population of rubber farmers

Q = Total number of questionnaires administered.

Table 3.1: Proportionality of Rubber Farmers Selected in each State

State	LGA/ Locality	No of rubber farmers	No. of rubber farmers selected
Edo	A. Ovia south West		
’’	1. Iguoriakhi farm settlement	94	70
’’	2.Igueladidi	29	21
’’	3. Iguelaiho	15	11
’’	B. Ikpoba- Okha LGA		
’’	1. Imasabor	12	9
’’	2. ObagieNevbuosa	9	7
’’	3. Obayantor	6	4
’’	C. Uhunmwode LGA		
’’	1. Eguaholor	15	11
’’	2. Iguezomo	10	7
’’	3. Evbueneki	17	13
’’	**Total**	**207**	**153**
Delta	A. Ika North East LGA		
’’	1. Mbiri Farm settlement	115	85
’’	2.Emuhu	3	2
’’	3. Akumazi Umuocha	5	4
’’	B. Ndokwa East LGA		
’’	1. Utagba- Uno	25	18
’’	2. Umutu	10	7
’’	C. Ndokwa west LGA		
’’	1. Kwale	23	17
’’	2. Abraka	19	14
Total		**200**	**147**

Source: Field survey 2010

Total number of rubber farmers in Edo State = 207

Total number of Rubber Farmers in Delta State = 200

Grand total 407

Number of farmers selected:

Edo State = 153

Delta State =147

Grand total 300

Table 3.2: Proportionality of Rubber Tappers Selected in each Estate

Estate	**No. of Tappers**	**No. of Tappers selected**
Rubber Research Inst. of Nigeria , Benin City	108	81
Odia Rubber Estate Ugomoson	32	24
Mars Plantation Kwale	20	15
Total	**160**	**120**

Source: Field survey 2010

3.3 Methods of Data Analysis

The data collected were subjected to descriptive statistics, budgetary technique, labour productivity model, Likert scale, stochastic frontier production function (SFPF) and goal programming.

3.3.1 Descriptive statistics

Descriptive statistics was used to achieve objective (i) and (vi) of the study. The descriptive statistics were frequency and percentages which were used to describe variables and their occurrences among respondents. Mean, mode and standard deviation were used as a measure of central tendency.

3.3.2 The Empirical Gross margin analysis

Gross margin analysis was used to achieve objective (iii) of the study. The Gross Margin (GM) per hectare is expressed as

$GM = \Sigma Q_y P_y - \Sigma X_i P_{xi}$ ………………………. ………………………(3.2)

Where:

Q_y = Output of rubber (Kg/ha)

P_y = Unit price of the output (₦/Kg)

$Q_y P_y$ = Total revenue from rubber produced (₦/ha)

X_i = Quantity of the ith input used in Kg/ha

P_{xi} = Price per Kg of the ith input

$X_i P_{xi}$ = Total cost associated with the ith input per hectare

Σ = Summation sign

3.3. 3 Labour Productivity Analysis

Labour productivity model developed by Upton (1997) and used by Chianu *et al.*, (2001) was adopted to achieve objective (ii) of the study.

It is explicitly stated as:

APL = [TPP] / [Ψ] ……………………………………………………………….(3.3)

GLP (naira) = [q_c•p_c] / [Ψ] …………………………………………………………(3.4)

NLP (naira) = [(q_c• p_c) – (L_c)] / [Ψ]…………………………………………………. (3.5)

Where:

TPP = total physical product (kilogramme of dry rubber),

APL = average labour productivity,

GLP = gross labour productivity,

NLP = net labour productivity,

q_c = Output (kg of dry rubber) ,

p_c = unit price / kg of dry rubber content(d.r.c),

L_c = labour cost and

Ψ = number of man-days of labour in standard days.

3.3.4 Goal programming Model

Goal programming was used to address the resource allocation problem associated with rubber latex production in the study area. Weighted goal programming method was used to actualize objective five. The model is specified as:

Minimize $Z = (a_i n_i + a_{i.} p_i)$……………………………………………………….(3.6)

Subject to:

$\sum G_{ij} X_j - P_i + n_i = g_i$ for all i_s

$\sum ak_j X_j \leq bk$ for all k_s

$X_i, P_i n_i \geq 0$ for all i and j

Where: G_{ij} = coefficient of goal achievement, P_i = the amount of deviation or overachievement of goal g_i; n_i = the amount of negative deviation or underachievement of goal gi; a_{kj} = technical coefficients of xj subject to resource endowment of b_{ks} and X_j = matrix of $X_{ij.}$(Adebayo,2006).

3.3.5 Proposed Activities in the Model and Constraints

The activities consisted of tapping all tasks allocated and rubber latex production. Resource and subjective constraints were included in the model. The most important constraints are hired labour, cash income while the subjective are minimum tree density/ha or task, minimum gross margin. The costs incurred include variable and fixed cost of tapping inputs.

3.3.5.1 Labour resources constraints: Data was collected from hired labour and wage rate in the study area. Conversion rate for the aggregation of man, woman, child days suggested by Norman in 1973 and adopted for study by Adebayo (2006) was used (Table 3.3).

Table 3.3: Male Adult Equivalent of Man, Woman and Child days

Labour class	Age(years)	Male Adult Equivalent
Small Child	Less than 7	0.00
Big Child	7 – 14	0.50
Female Adult	15 – 60	0.75
Male Adult	15 – 60	1.00
Male and Female Adult	Above 60 years	0.00

Source: Norman 1973 as cited by Adebayo (2006).

The Goal Programming analysis was done using Quantitative Systems for Business plus Version 2(QSBPlus).

3.3.6 The Empirical Stochastic Frontier Production Model

The stochastic frontier production model used is specified as follows:

$LogY_1 = \beta_o + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6 + \beta_7 \log X_7 + V_i - U_i$……………………………………………………………………………(3.7)

Where:

Y_1 = Output (kg of dry rubber) of the ith farmer

X_1 = Number of trees/task (a task has 450 to 500 tappable trees)

X_2 = Wage (in naira)

X_3 = Labour use (in man days)

X_4 = Number of Hectares tapped

X_5 = Age of plantation (in years)

X_6 = Clone (1 exotic, otherwise zero)

X_7 = Depreciation on fixed cost items such as tapping knives, cup hangers, spouts, sharpening stones, buckets, bulking containers, coagulating pans, (in naira)

V and U as previously defined.

The technical efficiency of rubber tapping for the ith farmer or plantation , defined by the ratio of observed production to the corresponding frontier production associated with no technical inefficiency, is expressed by TE = exp ($-u_i$) so that $0 \leq$ TE $0 \leq 1$…………..(3.8)

Variance parameters are: $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / \sigma^2$……………………..(3.9) so that $0\leq \gamma \, 0\leq 1$.

The inefficiency model is defined by:

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6$ ……………………………………….(3.10)

Where:

U_i = Technical inefficiency effect

Z_1 = Age of rubber farmer (in years)

Z_2 = Literacy level (in years)

Z_3 = Farming experience (in years)

Z_4 = Extension contact (1 contacted, otherwise zero)

Z_5 = Family size (total number of persons in household)

Z_6 = Farm distance (kilometre)

3.3.7 The Empirical Stochastic Frontier Cost Production Model

The empirical stochastic frontier cost production model used is specified as follows:

$LogC_1 = \beta_o + \beta_1 \log P_1 + \beta_2 \log P_2 + \beta_3 \log P_3 + \beta_4 \log P_4 + \beta_5 \log Yi + V_i + U_i$………… (3.11)

Where:

C_1 = Total production cost (naira)

P_1 = Cost of safety kits (rain boot, raincoat and other protective device) (naira)

P_2 = Fuel and other operational cost (naira)

P_3 = Depreciation cost on fixed cost items such as tapping knives, cup hangers, spouts, sharpening stones, buckets, bulking containers, coagulating pans, (naira)

P_4 = Cost of labour (naira)

Y_1 = Output (kilogramme of dry rubber) of the ith plantation

The inefficiency model is defined by:

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7$ ……………………………………(3.12)

Where:

U_i = Cost inefficiency effect

Z_1 = Age of rubber farmer (in years)

Z_2 = Literacy level (in years)

Z_3 = Farming experience (in years)

Z_4 = Extension contact (1 contacted, otherwise zero)

Z_5 = Family size (total number of persons in household)

Z_6 = Farm distance (kilometre)

σ^2, δ, γ, βs are unknown parameters that were estimated. The Maximum Likelihood Estimates (MLE) for all the parameters of the stochastic frontier production and cost functions were obtained using the computer program FRONTIER version 4.1c (Coelli, 1996; Ogundari and Ojo, 2007). The model was used to achieve objective four of the study.

Likert scale (Osuala, 1993) was used to measure the production constraints inhibiting their production efficiency. The Likert scale was adopted with score of the items of constraints as very serious (3), serious (2) and not serious (1). The mean score, which formed the benchmark on which the constraints were judged, was observed by the formula:

$X = \sum Xi/N$ …………………………………………………………………………..(3.13)

Where:

i = 1, 2, 3; X assigned constraint (i.e. 3 very serious, 2 serious and 1 not serious);

N = number of occurrence.

$\sum$= summation sign.

The bench mark on which the significance of the constraints on production efficiency was judged was by summing up assigned values and dividing by the number of occurrence; 3 +2+1 = 6 and divided by 3 = 2. The decision score = 2 was considered significant constraint. This was used to achieve objective (vi) of the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of the study. It covered the socio- economic characteristics of the respondents, sources of labour and labour productivity, costs and returns to latex production, technical and cost efficiencies of production, goal programming analysis and constraints to latex production.

4.1 Socio- economic Characteristics of the Respondents

The socio-economic variables treated included age, marital status, gender, family size, land ownership, farm size and farming experience.

4.1.1 Age Distribution of Respondents

Table 4.1 shows the distribution of respondents based on their age groups. Majority of respondents (76 percent) are within the ages of 45 years and above. The mean age of the farmers was 51 years with a standard deviation of 20.16 years. This shows that the farmers are relatively old. The preponderance of older farmers in rubber production portends serious danger to the rubber industry with declining productivity and likely reduction in hectares of rubber production.

This result is in accord with the previous studies that rubber production in Nigeria are by older farmers as the result of mass exodus of the youth to the city centres for white collar jobs leaving rubber production to elderly population(Abolagba and Giroh 2006; Otene *et al.,* 2011). The rubber belt of Nigeria is in the oil belt of the country with oil companies offering brighter job prospects than the rubber industry.

Rubber production is a male dominated activity. This result is a further confirmation of empirical evidences that suggested gender inequality in employment and agricultural production where men are more favoured than the women. Women are the primary labour force in Sub- Saharan Africa and their crucial roles in agricultural production have been widely reported in Nigeria (Fakoya and Oloruntoba, 2002). It is however regrettable those women farmers remained one of the most deprived groups in the country. Reij and Waters - Bayer (2002) and Giroh *et al.* (2010a) attributed the lack of self – esteem of women with respect to their farming activities to the traditional beliefs and attitudes regarding women's role in the society; the low level of formal education of women; poor access of women to external information, small size of plot allocation to women that does not attract the attention of extension workers, thus these women have limited access to extension activities.

Table 4.1: Distribution of Respondents by Age

Age (years)	Frequency	Percentage
≤ 34	29	9.67
35- 44	43	14.33
45- 54	128	42.66
55- 64	29	9.67
>65	71	23.67
Total	**300**	**100**
Mean 51		
Minimum 25		
Maximum 62		
Mode 41		
STD 20.16		

Source: Field survey, 2010.

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Overcoming these socio- cultural barriers affecting women will lead to more participation of women in rubber production thereby creating an opportunity for Women in Agriculture (WIA) extension component for the mobilization of women for rubber technology adoption to tap their technical and managerial efficiencies.

4.1.2 Marital status of Respondents

Based on their marital status as indicated in Table 4.2, majority of respondents are married (about 76 percent), single (19 percent) while only about 5 percent are widowers. The above result shows that married people are more into rubber production than those who are single. This is because married people have more family responsibilities such as feeding and educating the children that require means of livelihood of which rubber production provided for them. However, single farmers may face fewer responsibilities as compared to the married respondents.

Table 4.2: Distribution of Respondents by Marital status

Marital status	Frequency	Percentage
Married	229	76.33
Single	57	19.00
Widower	14	4.67
Total	300	100

Source: Field survey, 2010.

4.1.3 Family size of Respondents

Family sizes of farmers provide sources of labour for production especially in African agriculture that is not mechanized. As shown in Table 4.3, majority of respondents about (76 percent) had between 1 and 10 family members with the minimum and maximum family sizes of 1 and 12 respectively. The mean family size was 7 people with a standard deviation of 2.47 which is a reflection of the fact that many of the farmers were married. Large family size of respondents could be used as a vital source of labour for rubber production and other productive activities. Large family size can put pressures on family heads in devising means of obtaining income to meet family needs.

Table 4.3: Distribution of Respondents by Family size

Family size(number)	Frequency	Percentage
1-5	143	47.67
6-10	86	28.67
11 and above	71	23.66
Total	**300**	**100**
Mean 7		
Minimum 1		
Maximum 12		
Mode 5		
STD 2.47		

Source: Field survey, 2010.

4.1.4 Educational attainment of Respondents

Education has been found to be a catalyst and vital component in technology adoption in agriculture. Distribution based on educational levels of respondents (Table 4.4) revealed that all the respondents are educated and had one form of formal education or the other. The mean years of formal schooling was 10.09 years with a standard deviation of 8.26 years showing that the farmers were educated. One can infer from this that with the preponderance of educated rubber farmers, the adoption of improved techniques of production may not be difficult as they are more likely to learn with ease and disseminate new innovations. Education has been found to increase the production efficiency of farmers (Meskel, 2000). Ogundari (2009) reported that education provided a measure of managerial ability of the farmers through which the Nigerian agricultural productivity could experience a push into new direction of growth and development. Of course such reposition depends on the right policy measure that addresses human capital development of the farmers which can be achieved through education.

Table 4.4: Distribution of Respondents by Educational attainment

Educational level	Frequency	Percentage
Primary education	143	47.67
Secondary education	100	28.67
Tertiary education	57	19.00
Total	**300**	**100**
Mean 10.09		
Minimum 6*		
Maximum 14		
Mode 6		
STD 8.26		

Source: Field survey, 2010. * Years of formal schooling.

4.1.5 Farm size Distribution of Respondents

Distribution of respondents by farm size as indicated in Table 4.5 shows that ≤ 1.5 to 3.99 hectares had about 52.33 percent while about 47.67 percent had 4 and above hectares of farm land. The mean farm size was 1.7 hectares with a standard deviation of of 1.12 implies that farmers operated at different levels of farm sizes which tend to affect their production levels. This result indicates that majority of the farmers are small holders. The result is line with several studies conducted which showed that small scale farmers in Nigeria are major producers of food and cash crops (Delabarre and Serier,2000; Abolagba *et al.*, 2003 and Agumagu and Adesope, 2007) .

Table 4.5: Distribution of Respondents by Farm size in hectares

Farm size(hectares)	Frequency	Percentage
≤ 1.5	43	14.33
1.6 – 3.99	114	38.00
4 and above	143	47.67
Total	**300**	**100**
Mean 1.7		
Minimum 0.5		
Maximum 5.5		
Mode 0.5		
STD 1.12		

Source: Field survey, 2010.

4.1.6 Methods of Land acquisition of Respondents

Table 4.6 shows the distribution of respondents based on type of land acquisition. From the table, 33 percent of the farmers acquired their farmlands through inheritance while 24.33 percent got theirs through purchase. Government allocation formed the highest form of land acquisition which accounted for about 43 percent. This result shows that farmers may be able to make long-term commitment to the land by obtaining credit for rubber production. Adebayo *et al.* (2010) found that access to productive resources especially land served as a source of collateral security in the acquisition of credit for farmers in Africa.

Table 4.6: Distribution of Respondents based on type of Land acquisition

Type of land acquisition	Frequency	Percentage
Inheritance	99	33.00
Purchase	73	24.33
Government allocation	128	42.67
Total	**300**	**100**

Source: Field survey, 2010

4.1.7 Farming Experience of Respondents

Years of farming experience have been reported to provide a measure of managerial ability among farmers in Nigeria. Table 4.7 shows the distribution of respondents based on farming experience. Majority of the respondents about (86 percent) had more than 10 years experience in rubber production. The mean farming experience was 19 years with standard deviation of 9.65 years. This implies that the farming experience varied significantly among the farmers. The result showed that majority of the rubber farmers might have perfected their production of natural rubber with years of experience. The result is in line with the study of Otene *et al.* (2011) who reported the involvement of experienced farmers in rubber production.

Table 4.7: Distribution of Respondents based on rubber Farming experience

Farming experience(years)	Frequency	Percentage
≤ 10	43	14.33
11 – 20	171	57.00
21 and above	86	28.67
Total	**100**	
Mean 19		
Minimum 8		
Maximum 25		
Mode 17		
STD 9.65		

Source: Field survey, 2010

4.2 Sources of Labour and Labour Productivity

Result in Table 4.8 is based on mode of engagement of labour sources for rubber tapping by respondents in the study area. From the table, contract tapping accounted for 9 percent. A contract tapping is an arrangement where the contract tapper is a tenant with the right to tap the trees for certain remuneration per quantity tapped. From Table 4.8, wage tapping and share arrangement accounted for 43.33 percent and 36.33 percent respectively. This implied that about 43 percent of rubber farmers adopted wage tapping to tap the trees for a fixed wage irrespective of the yield of rubber produced. Giroh and Adebayo (2009) found out that both contract and wage tapping were adopted in Rubber Research Institute of Nigeria plantation where permanent and casual rubber tappers were engaged. The study however revealed that casual labour contracted to tap were paid on the basis of daily productivity (kg of dry rubber tapped) while the permanent tappers were paid irrespective of the quantity of dry rubber tapped.

Share arrangement (36.33 percent) was the second most dominant form of engagement and popular among small holder plantation owners in Edo and Delta States. This arrangement is a situation where a share tapper is a tenant contracted the right to tap the trees for a certain terms of agreement based either on percentage dry rubber content (d.r.c.) yield or the number trees based on the sharing formula with the owner. It was found from the study that majority of the farmers used a sharing ratio of 3:1 trees tapped and not based on kilogramme of dry rubber. This translates to owner of the plantation retaining 75 percent while the share tapper has 25 percent of the trees tapped.

Table 4.8: Distribution of Respondents based on mode of Tapping arrangement

Mode of engagement	Frequency	Percentage
Contract tapping	27	9.00
Wage tapping	130	43.33
Share arrangement	109	36.33
Owned and tapped by self	34	11.33
Total	300	100

Source: Field survey, 2010

The result is similar to that of Chew (2001) who conducted a study on share contracts in Malaysian rubber smallholdings. The study identified that rubber harvesting (tapping) were carried out by different parties under share tapping, contract tapping, wage tapping and fixed rent in order to overcome high cost of labour in rubber harvesting. Schroth *et al*. (2004) reported that the consequence of share tapping arrangement is that the trees are damaged. Respondents who owned and tapped plantation themselves accounted for 11.33 percent using family members as source of labour for latex exploitation.

Labour productivity model result is presented in Table 4.9. Labour productivity can be measured either in terms of total physical products (826,434.31 kg dry rubber) or monetary value (₦81,949,226.18) as gross revenue while output per man day of 22.58 kg was obtained from the study. Wage / man day was ₦377.78, while an average plantation owner reaps ₦1,860.56 after adjustments were made to wages and other variable cost of operation. It could be inferred from this study that there was an increase in labour productivity as compared to 11.93 kg and 17.09 kg of dry rubber for permanent and casual tappers reported by Giroh and Adebayo (2007) and 9.56 kg of dry rubber/ day as reported by Aigbekaen and Alika (1984). This increase in output per man day was as a result of improved or a response to contract tapping where a plantation owner engages a tapper to tap and payments subjected to the quantity tapped. The more the quantity tapped, the more the tapper is paid.

Table 4. 9: Result of Labour Productivity Model

Variable	Value
a. Total output	826,434.31 kg
b. APL (average productivity of labour)	22.58 kg(a/c)
c. Total labour (man days)	36,598.22
d. Gross revenue	₦81,949,226.18 (a x ₦99.16)
e. GLP (gross labour productivity)	₦ 2,239.16(d/c)
f. NLP (net labour productivity)	₦ 1,860.56(d- g x c/c)
g. Labour cost/ man day	₦ 377.78(c x g/c)

Source: Field survey, 2010

4.3 Gross Margin Analysis

The gross margin was used as profitability of latex production among farmers and is presented in Table 4.10**.** The average variable cost/hectare was ₦55,700.94 with labour cost accounting for about 50 percent of the total tapping cost. This result is in line with earlier studies conducted which showed that labour was scarce and costly in rubber production in Nigeria. This is as a result of the fact that the Nigerian rubber belt corresponds with the oil belt of Nigeria attracting able bodied youth to the industry leaving the older population as a source of labour for the natural rubber industry (Abolagba and Giroh, 2006). The attendant consequences may be declining productivity and plantation owners may resort to share tapping arrangement for latex production. It was also found out that this arrangement does not give the plantation owners firm grip of production. The willing tappers may slaughter tap, and this may result to detrimental effects such as destruction of cambium cells, retarding regenerative ability and eventual death of the trees. The total revenue (TR) and Gross margin (GM) per hectare were ₦163,594.17 and ₦107,893.23 respectively. This shows that rubber production is a profitable venture in the short- run in the study area because of the positive gross margin.

This result lends credence to Cena (2011) who observed that the huge industrial demand for natural rubber is expected to keep the price of rubber high for decades because of long period of productivity; environment sustainability; high value of rubber wood; and allows intercropping of food and cash crops for higher farm income.

Table 4.10: Average cost and return of rubber farmers per hectare

Cost item	Value	Percentage of cost
Safety kits	₦ 5,750.00	10.32
Tapping inputs	₦ 9,500.00	17.06
Transportation	₦ 12,850.00	23.07
Labour cost	₦27,600.94	49.55
Total variable cost	₦ 55,700.94	
Total output/Hectare	1,649.80 kg	
Price/ Kilogramme	₦ 99.16	
Total revenue	₦163,594.17	
GM(TR- TVC)	₦ 107,893.23	

Source: Field survey, 2010

4.4 Technical Efficiency of rubber production

The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production function of rubber farmers is shown in Table 4.11. The Table contained the estimates of the parameters for the frontier production function, the inefficiency model and the variance parameters of the model. The variance parameters of the stochastic frontier production function are represented by sigma squared (δ^2) and gamma (γ).

Table 4.11: Maximum Likelihood Estimate of parameters of Cobb- Douglas Stochastic Frontier Production function for Rubber farmers

Variable	Parameter	Coefficient	Standard error	t. value
Production factors				
Constant	β_o	0.181	0.388	0.46
No of trees/ task	β_1	0.646**	0.075	8.60
Wage(naira)	β_2	0.132***	0.025	5.12
Labour(SMD)	β_3	0.730*	0.386	1.89
Hectares	β_4	0.344***	0.042	8.13
Age of plantation	β_5	-0.339***	0.037	- 8.97
Clone	β_6	0.133***	0.031	4.21
Depreciation on fixed cost items	β_7	0.080***	0.019	4.04
Inefficiency model				
Constant	δ_0	0.309	0.209	1.47
Age	δ_1	0.025*	0.013	1.86
Education	δ_2	-0.834**	0.349	- 2.38
Farming experience	δ_3	-0.875**	0.355	- 2.46
Extension contact	δ_4	-0.375*	0.217	- 1.72
Family size	δ_5	-0.116	0.106	- 1.09
Farm distance	δ_6	0.283	0.239	1.18
Variance parameters				
Sigma squared	δ^2	0.822***	0.057	14.33
Gamma	Γ	0.923***	0.053	17.18
Log likelihood function	LLF	-0.702		

Source: Computer Print Out

*** Significant at 1 percent ** Significant at 5 Percent * Significant at 10 Percent

The sigma squared in Table 4.11 is 0.822 and significantly different from zero at one percent level. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma indicates that the systematic influences that are unexplained by the production function are the dominant sources of random error.

The gamma estimate which is 0.923 shows the amount of variation resulting from the technical inefficiencies of the rubber farmers. This means that 92.30 percent of the variation in farmers output is due to difference in technical efficiency. This implies that the ordinary least squares estimate (OLS) will not be adequate in explaining the inefficiencies on rubber latex production thereby justifying the specification of a stochastic frontier production.

Typical of the Cobb - Douglas production function, the estimated coefficients for the specified function can be explained as the elasticities of the explanatory variables. Except for age of plantation, the signs of the coefficients of the stochastic production frontier are positive. The returns to scale parameter was found to be 1.726, implying increasing return to scale for production among the farmers. This shows that rubber farmers were operating in stage 1 of the production surface. This suggests that a proportionate increase in all inputs would result to more than proportionate increase in output of the farmers. In this case, optimum efficiency of production or resource use has not been attained, but misallocated.

Number of trees/ task

The estimate of the parameters of the stochastic production frontier indicated that elasticity of output with respect to number of trees/ task is positive and approximately 0.646 and it is statistically significant at 1 percent level. This implies that number of trees/ task is a positive and significant factor that influences the output of rubber farmers. An increase of one percent in number of trees/task will result to an increase in output by 0.646 percent. The immediate recognition of an increase in latex output is the number of trees associated with that production. The higher the number of trees, the greater is expected volume of latex depending on the management of the rubber plantations. Schroth *et al.* (2004) established in their studies variability in yield levels ranging from low to high on stand structure of rubber trees in the Brazilian Amazon forest.

Wage

The coefficient for wage is 0.132 and this was statistically significant at one percent. This implies that wage is a positive and significant factor that influences the output of rubber farmers. An increase of one percent in wage will result to an increase in output by 0.132 *ceteris paribus*. This result is in line with earlier studies conducted which identified wage as a significant factor in natural rubber production in Nigeria (Abolagba and Giroh, 2006)**.** A lower wage structure normally experienced in the agricultural sector of the Nigerian economy made the rubber sector unattractive to skilled labour as compared to other sectors like the oil and gas industries in the rubber belt of Nigeria that offer fat and attractive salaries to workers. In order to overcome this challenge, farmers should not be left alone; government has to intervene by making the sector attractive to skilled labour by making the wages of plantation workers attractive to reflect the prices of rubber.

Labour

The coefficient of the variable associated with labour was 0.730 and statistically significant at ten percent. This means that a one percent increase in the coefficient of labour will lead to a 0.730 % increase in output. Natural rubber production is a labour – intensive activity and is constrained by skilled labour resource to tap rubber and poses a threat to many other rubber producing countries (Ke *et al.,* 2006; Sinam 2011). Mesike *et al.* (*2009*) reported that labour has been a critical factor in rubber production in Nigeria where production is done manually. Inconvenient working conditions (unattractive wages, inadequate medical and housing facilities) may be repulsive factors. The effect of this on the rubber industry are likely to manifest in the reduction of hectarage of rubber cultivation, plantations may not be tapped resulting to low yield and income to the farmers and a reduction in foreign exchange earning.

Farm size (Hectares)

The estimated coefficient for farm size was 0.344 and statistically significant at one percent level and a critical factor in rubber latex production. A unit increase in hectarage will lead to an increase of 0.344 kg of rubber production. Mustapha (2011) reported a significant relationship between cultivated area of rubber smallholdings in Malaysia and increase in the production of latex. Farm size has been found to be one of the most important factors of production and critical in the adoption of innovations in agriculture (Awotide and Adejobi, 2006; Ogundari and Ojo, 2007; Mesike *et al.*, 2009).

Age of plantation

The production elasticity of age of plantation is – 0.339 and statistically significant at one percent and inversely related with output. This shows that output from rubber trees is necessarily a function of age. Age is the single factor determining the yield of a rubber tree for a given clone. While a tree normally attains the required girth for tapping in the seventh year of planting, the yield, which increases from the fourth year, stabilizes in the 13th year of tapping. Though variations in the economic life span of rubber trees have been reported in many rubber producing countries of the world. Etherington (1977) found out that the optimal replacement period for natural rubber is in the 32nd year in Malaysia while Sajen (2006) reported an economic life span 29- 30 years in India.

Mesike *et al.* (2010) found out that output from rubber trees in Nigeria decline when the trees are beyond their economic life span of 35 years. The consequence of old age of rubber plantation was low yield with corresponding low income to the farmers (Abolagba and Giroh, 2006). In the absence of timely replanting by growers, prospects of tapping more rubber from the existing aged trees appears bleak, leading to production decline. Such trees need to be replaced by replanting programme using improved clones.

Clone

The production elasticity with respect to clone (0.133) is statistically significant at one percent and a critical factor in rubber latex production. The basic component of any crop production enterprise is the planting material. *Hevea* clones are improved planting materials with potentials for high yield, wind and disease resistance. This result is in line with earlier studies conducted in Pakistan by Battese *et al.*(1996) which shows that improved seeds has a significant effect on yield of wheat. Emokaro and Erhabor (2006b) also reported a significant relationship between improved planting materials and yield among cassava farmers in Edo State. Spore (2007) reported that rubber farmers need more productive varieties or clones of natural rubber that are adapted to community conditions. In Nigeria, Eze and Akpa (2010) also discovered increase in output of food crops farmers when improved seeds were used. Njukeng *et al.* (2011) reported higher yields from rubber plantations where improved clones were used as planting materials. Farmers who adopted the use of improved rubber clones are likely to have increased yields from their plantations leading to the earning of more income.

Depreciation on fixed cost items

The coefficient for depreciation on fixed cost items was 0.080 and was statistically significant at one percent probability level. Output of the farmers increases with increase in operational cost and agrees with the *apriori* that firms incur more cost in production as output increases. This implied that farmers spend more to produce more. The result lends credence to the works of Giroh *et al.* (2007b) and Amaefula *et al.* (2010).

The existence of technical inefficiency provides a good ground to find out the sources of inefficiencies among rubber farmers in the study area. Some variables were considered and estimated in the model and the result is presented in Table 4.11. The signs and coefficients in the inefficiency model are interpreted in the opposite way such that a negative sign means the variable increases efficiency while positive signs indicated that the variables decrease efficiency.

The result of the inefficiency model shows that the coefficients of the efficiency variables with the exception of age of the farmers and farm distance had the expected signs. Family size was estimated to be - 0.116, implying that it affected efficiency but not significantly. Similarly, the coefficient for farm distance variable is estimated to be positive (0.283) and statistically not significant. This implies that farm distance reduce farmers efficiency but not significant.

Age

The estimated coefficient for age of farmers (0.025) had a positive sign and is statistically significant at ten percent and contributed to the technical inefficiency of the farmers. This implies that as the farmer gets older, the productivity and efficiency declines. Many studies conducted on rubber production revealed that the elderly population dominates rubber production in Nigeria. This is similar to earlier studies conducted by Abolagba and Giroh (2006); Adeyemo *et al.* (2010) which reported that older people may not easily adopt improved technologies that enhanced efficiency.

Education

The coefficient for education was – 0.834 and statistically significant at five percent, a critical factor that increases the technical efficiency of the respondents. Educated farmers are innovative and the transformation processes by extension agents are likely to be easier. This result in agreement with the works of Awotide and Adejobi (2006) and Ogundari and Ojo (2007) who identified education as a catalyst in the improvement of technical efficiency of farmers in Nigeria. Education obviously will improve production efficiency as it will enable farmers to access improved technology and best practices available to them.

Farming experience

The estimated coefficient for farming experience (–0.875) is statistically significant at five percent. Farming experience increase the technical efficiency of the rubber farmers and this result is in conformity with the work of Ogundari (2009) who reported that out of the studies conducted on the technical efficiency of Nigerian agriculture over the years, 38% identified farming experience as a significant determinant of technical efficiency.

Extension contact

The coefficient for extension contact is –0.375 and statistically significant at ten percent. Extension contact will lead to increase in the efficiency of the farmers. The implication of this is that increasing the number of contact with extension agents through efficient extension delivery system can bridge the gap between the efficient and inefficient rubber farmers in the study area. Such approaches stimulate farmers' adoption of agricultural technologies which in the long run shifts the farmers' production frontier upward. The main function of extension agents is to disseminate the latest research results to the farmers. They provide farmers with information on planting and processing techniques, pests and disease control and prices of inputs and outputs. It must be emphasized that the effectiveness of extension agents does not only depend on the frequency of their visits but also on the rubber farmers' attitude and receptivity. Sepien (1979) found a positive correlation between extension visits and yield of rubber latex among smallholder rubber farmers in Malaysia. This result is consistent with the findings of Rahman (2003), Binam *et al.* (2004) and Feeder *et al.* (2004).

4.4.1 Distribution of Technical Efficiency of rubber farmers

Technical efficiency indices derived from the analysis of the stochastic frontier production function in respect of the respondents is presented in Table 4.12. From Table 4.13, 1.33 percent of the respondents fall to the range of ≤ 0.49, 2.34 percent were in the range of 0.50 - 0.59 followed by 2 percent (0.60 – 0.69), 13.33 percent were in the range of 0.70 – 0.79. Majority of the respondents (53 percent) had TE in the range of 0.80 – 0.89 while 28 percent attained TE from 0.90 – 1.00. Analysis further showed that 30.37 percent of the farmers have technical efficiency (TE) index below the mean figure of 0.84 while majority (69.67 percent) attained TE above the mean. This result shows an improvement in farmers' efficiency as compared to the mean TE of 0.59 and 0.72 for rubber tappers in Nigeria and Vietnamese rubber farms (Giroh and Adebayo, 2009). Mustapha (2011), who investigated the technical efficiency of smallholder rubber farmers in Malaysia, found out mean technical efficiency scores of 0.832(Cobb- Douglas) and 0.817 (Tran slog). His figures are lower as compared to the one obtained in this study. This result suggests that farmers are not utilizing their production resources efficiently, indicating that they are not obtaining maximal output from their given quantities of input. In other words, technical efficiency among the respondents can be increased by 16 percent (1- 0.84) through better use of available production resources, given the current state of technology. This would enable the farmers obtain maximum output from rubber production from the given quantum of inputs and hence increase their income level, improve their family needs, health and improvement in their quality of life. This study validates claim by Asogwa *et al.* (2011a) that Nigerian rural farmers are not obtaining maximum output from their given quantum of inputs.

Table 4.12: Frequency Distribution of Technical Efficiency of rubber farmers

Range of Technical Efficiency	Frequency	Percentage
≤ 0.49	4	1.33
0.50 – 0.59	7	2.34
0.60 – 0.69	6	2.00
0.70 – 0.79	40	13.33
0.80 – 0.89	159	53.00
0.90 – 1.00	84	28.00
Total	**300**	**100**
Mean 0.84		
Maximum 0.95		
Minimum 0.23		
Mode 0.79		

Source: Computer print out

4.5 Allocative Efficiency of Latex production

The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic cost frontier model of rubber farmers is presented in Table 4.13. The Table contained the estimates of the parameters for the frontier cost function, the inefficiency model and the variance parameters of the model. The diagnostic statistics of the variance parameters of the stochastic frontier cost function are represented by sigma squared (δ^2) and gamma (γ). The sigma squared in Table 4.13 is 0.059 and significantly different from zero at one percent level. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma indicates that the systematic influence that are unexplained by the cost function are the dominant sources of random error .The gamma estimate which is 0.95 shows the amount of variation resulting from the allocative inefficiencies of the rubber farmers. This means that 95 percent of the variation among the rubber farmers is due to differences in allocative efficiency. This implies that the ordinary least squares estimate (OLS) will not be adequate in explaining the allocative inefficiencies among rubber farmers thereby justifying the specification of a stochastic frontier cost function.

The estimates of the parameters of stochastic cost frontier model of the rubber farmers as contained in Table 4.13 were positive. This implies that the variables used in the regression analysis have direct relationship with total cost of latex production. The cost of tapping increases by the value of each coefficient as the quantity of each variable is increased by one. Also, the estimated coefficients for the specified function can be explained as the elasticities of the explanatory variables which is typical of the Cobb-Douglas production function. The return to scale (RTS) was found to be 1.429 (increasing return to scale) for production cost among the sample farmers. This suggests that a proportionate increase in all the inputs given their respective prices would result to more than proportionate increase in the production cost of the farmers. The coefficients for fuel and other operation cost and depreciation were positive and not statistically significant. This implies that they affect total cost of production but not significantly.

Cost of safety kits

The estimated coefficient for cost of safety kits was 0.108 and statistically significant at ten percent level. This implies that the variable is a positive and significant factor that influences cost of production of rubber farmers. An increase of one percent in the cost of safety kits will result to an increase in the total cost by 0.108 percent depending on the management of the rubber plantations.

Output

The coefficient of the variable associated with rubber output was 0.397 and is statistically significant at ten percent. The implication of this is that rubber farmers incur more cost as output or production of rubber latex increases. This result is in conformity with the works of Amaefula *et al.*(2010) who found out that farmers incur more cost when they produce more and consistent with *apriori* expectation.

The determinants of allocative inefficiency among rubber farmers are presented in Table 4.13. The variations in allocative inefficiency of the farmers may arise from managerial decisions, farmers' characteristics, existing technology and other factors. The result of the inefficiency model shows that the coefficients of the inefficiency variables with the exception of farming experience have the expected signs. The coefficients for family size and education were estimated to be – 0.017 and – 0.018 respectively, implying that they affect efficiency but not significantly.

Table 4.13: Maximum Likelihood Estimate of parameters of Cobb- Douglas Stochastic Frontier cost function for Rubber farmers

Variable	Parameter	Coefficient	Standard error	t. value
Cost factors				
Constant	β_o	0.561	0.567	0.99
Cost of safety kits	β_1	0.108*	0.060	1.80
Fuel and other operational cost	β_2	0.189	0.136	1.39
Depreciation	β_3	0.162	0.124	1.29
Cost of labour	β_4	0.573***	0.101	5.66
Output	β_5	0.397*	0.234	1.69
Inefficiency model				
Constant	δ_0	0.862**	0.292	2.95
Age	δ_1	- 0.016**	0.0073	- 2.29
Education	δ_2	- 0.018	0.0143	- 1.27
Farming experience	δ_3	0.082***	0.0125	6.55
Extension contact	δ_4	- 0.167*	0.0148	-11.30
Family size	δ_5	- 0.017	0.0142	- 1.19
Farm distance	δ_6	-0.053***	0.0145	- 3.71
Variance parameters				
Sigma squared	δ^2	0.059***	0.0153	3.86
Gamma	γ	0.95***	0.223	4.25
Log likelihood function	LLF	1.966		

Source: Computer Print Out *** Significant at 1 percent ** Significant at 5 Percent
* Significant at 10 Percent

Age

The estimated coefficient for age of farmers (-0.016) was negative to inefficiency and is statistically significant at five percent. This implies that as the farmers get older, they become efficient in the allocation of resources in rubber production activities. The result is in line with the works of Asogwa *et al.* (2011) who found out that older farmers exhibited allocative efficiency in agricultural production in Nigeria.

Farming experience

The coefficient for farming experience was estimated to be positive (0.082) and statistically significant at one percent level. The implication is that the more experienced the farmer is, the higher his level of allocative efficiency. This is consistent with the works of Bravo- Ureta and Evenson (1993) and Egwu *et al.* (2010) who found positive impacts of farm experience on the efficiency of farmers.

Extension contact

The computed value for extension contact was –0.167 and is statistically significant at one percent and a critical factor that increases farmers' allocative efficiency. Increasing the number of contact with extension agents can bridge the gap between the efficient and inefficient rubber farmers. Regularity in extension visits has been found to enhance farmers' adoption of agricultural technologies which in the long run shifts the farmers' production efficiency upward. This result is in agreement with the findings of Onyeweaku *et al.* (2005) who reported a considerable improvement in the efficiency of farmers when extension visit is regular.

Farm distance

The estimated coefficient for farm distance is negative to inefficiency and statistically significant at one percent probability level. This means that farm distance increases the allocative efficiency of the farmers. This is probably because the distance from the house to the plantation could affect the standard of management; requiring longer travelling time to the farm thereby adding to the cost of production. Sepien (1979) obtained a negative association between distance to rubber plantation and management practices.

4.5.1 Distribution of Allocative Efficiency of rubber farmers

Allocative efficiency among respondents varied widely ranging between 0.27 and 0.99, with a mean allocative efficiency of 0.77 (Table 4.14). In other words, 23 percent of the resources are inefficiently allocated relative to the best-practiced farms producing the same output and facing the same technology in the study area. This implies that the allocative efficiency among respondents could be increased by 23 percent through better utilization of resources in the optimal proportions given their respective prices and given the current technology. This would enable the farmers to equate the marginal revenue product (MRP) of input to the marginal cost of input thereby improving farm income.

From Table 4.14, majority of the rubber farmers fall to the range of 0.80 – 0.89 (32%) followed by those in the range of 0.70 – 0.79 (19.70%) and 0.90 –1.00(19.70%), respectively. Also, 70 percent of the rubber farmers have allocative efficiency (AE) index below the mean AE of 0.77 while 30.00 percent are those with AE above the mean.

This result indicates that rubber farmers in the study area are fairly allocatively efficient in producing a given level of output using cost minimizing input ratios indicative of their tendency to minimize resource wastage associated with rubber tapping process. The allocative efficiency found in the study is higher than those obtained by Bravo- Ureta and Pinheiro (1997) and Asogwa *et al.* (2011b).

Table 4.14: Frequency Distribution of Allocative Efficiency of rubber farmers

Range of Allocative Efficiency		**Frequency**	**Percentage**
≤ 0.49		17	5.70
0.50 – 0.59		27	9.00
0.60 – 0.69		42	14.00
0.70 – 0.79		59	19.70
0.80 – 0.89		96	32.00
0.90 – 1.00		59	19.70
Total		**300**	**100**
Mean	0.77		
Maximum	0.99		
Minimum	0.27		
Mode	0.69		

Source: Computer print out

4.6 Distribution of Economic Efficiency of Latex production

A substantial variation was observed among respondents' economic efficiency which ranged between 0.20 and 0.93, with a mean economic efficiency (EE) of 0.65. (Table 4.15). The frequency distribution of rubber farmers EE indices as presented in the table shows that the majority of the rubber farmers fall to the range of 0.70 – 0.79 (28.67%) followed by those in the range of 0.60 – 0.69 (23.33%), 0.50 – 0.59 and 0.80 – 0.89 represented by (14.67%) each respectively. Only 0.67 percent is those in the range of 0.90 and 1.00. Analysis further showed that 39.67% of the respondents fall below the mean EE of 0 .65 while 60.34 percent are those above the mean economic efficiency.

These figures indicate that if the average farmer in the sample were to reach the economic efficiency level of its most efficient counterpart, then the average farmer could experience a cost savings of 69.23 percent [i.e. 1-(.20/.65)]. The result suggests that the farmers in the study area are not able to minimize the cost of production as 35 percent of the production costs were wasted relative to the best practiced farms producing the same output facing the same technology in the study area. The implication is that the over all economic efficiency of the rubber farmers could be increased by 35 percent (i.e. 1.00-0.65) through the reduction in production costs that would occur if production were to occur at the allocatively and technically efficient point in the short – run under a given technology. This would enable the farmers to minimize production costs, hence maximizing income and profit. The result is in line with the findings of Amaza and Olayemi (2002), Maurice (2011), Asogwa *et al.* (2011b) who observed in their studies wide variations in farmer- specific efficiency level as a common feature in the developing countries agriculture.

Table 4.15: Frequency Distribution of Economic Efficiency of Rubber farmers

Range of Economic Efficiency	Frequency	Percentage
≤ 0.49	54	18.00
0.50 – 0.59	44	14.67
0.60 – 0.69	70	23.33
0.70 – 0.79	86	28.67
0.80 – 0.89	44	14.67
0.90 – 1.00	2	0.66
Total	**300**	**100**
Mean 0.65		
Maximum 0.93		
Minimum 0.20		
Mode 0.45		

Source: Computer print out

4.7 Hypothesis Testing

A value for the test statistic as contained in Table 4.16 is 161.34 while the critical value was obtained from Table 1 of Kodde and Palm (1986). The percent critical value for the mixed chi-square distribution with eight degree of freedom is smaller than the observed statistics. Alternative hypothesis is upheld while rejecting the null hypothesis at 5% level. Deviation from the production frontier are as a result of inefficiency thereby justifying the specification of the stochastic frontier production function and OLS estimate is not an adequate representation of the data.

Table 4.16: Tests of hypothesis that farmers are not fully Technically efficient.

Null hypothesis	LR	χ^2 value 0.95	Decision rule
Ho: $\gamma = \delta_{1} + \ldots\ldots + \delta_{6} = 0$	161.34	21.232	Reject

Source: Field survey, 2010.

4.8 Empirical Results of the Linear Goal Programming

The linear goal programming model consisted of five activities and two constraints. The activities are indicated in Table 4.17. The data were first subjected to the conventional Linear programming analysis to generate an optimum gross margin which was built into the goal programming model. The model produced an optimum gross margin of ₦3, 018,358.96.

The achievement function for the farm was expressed as:

Minimize : $a_1n_1x100 / 27787.98 + a_2n_2 x100/ 282 + a_3n_3x100/ 3018358.96 + a_4n_4 x 100 /24090.70 + a_5n_5x100/30760.50$.

The equivalent form of the objective function was obtained as follows:

$1.439a_1n_1+354.609a_2n_2+0.019a_3n_3+0.830a_4n_4+0.325a_5n_5$.

The result produced by LP model is presented in Tables 4.18 and 4.19. The optimal plan (Table 4.19) is that the average rubber farmer allocates his resources to tap 283 trees, produced 37, 345.98 litres of rubber latex, 25,523.23 kg of dry rubber and ₦3, 018,358.94.

Shadow prices are marginal returns to increments of available resources. In a maximization problem, shadow prices are income penalties. They indicate the amount by which farm income would be reduced if any of the excluded activities is forced into the programme. In a minimization problem, shadow prices are cost penalties. They indicate the amount by which the value of the programme will increase while keeping other parameters constant.

Table 4: 17 Tabular representation of the objective function of goal programming model for the average farm household

Goals of production	Achievement of Objective	Function Statement: to Minimize	Deviation variable in Objective Function	Priority Level	Pre-emptive weights
Increased Tappable Trees	Minimum tappable trees	Under achievement	N	2	10
Increased rubber production (kg)	Minimum production(kg dry) of rubber	Under achievement	N	1	4
Increased Income	Minimum gross margin	Under achievement	N	3	6
Increased Latex production in Litres	Minimum Latex	Under achievement	N	5	1
Reduced Cost of operation	Maximum cost of operation	Over achievement	P	4	2

Source: Field survey 2010. N= Negative deviational variable, P= Positive deviational variable.

Moreover, the included resources in the programme and their status of usage as indicated in Table 4.19 revealed that the fully utilized resource is land with a shadow price or marginal value of ₦550, the marginal value was ₦225 in Table 4.21. If land is forced into the programme, the cost of latex production would increase by ₦550 and ₦ 225, respectively. Labour according to this study was not fully utilized by the respondents and is consistent with earlier studies conducted by Tanko *et al.,* (2011) and Igwe *et al.,* (2011) who reported labour resource misallocation among farmers in Nigeria.

Table 4.18: Optimum production plan for LP model

Activities	Existing or production Level	Optimal Level
Gross margin	2,729,697.968	3,018,358.936
Tapped Trees	282.16	283.34
Latex production (litres)	30,760.5	37, 345.98
Rubber production(kg dry)	27787.98	25523.23

Source: Computer print out of LP model

The result in Table 4.20 shows that the average rubber farmer cannot fully achieve his production goals from the available resources at his disposal. The plan is able to achieve or satisfy completely two goals out of the five as both deviational variables were zero. These are tappable rubber trees and latex production in litres. The goals of rubber production in kilogramme dry rubber and income were underachieved by 2, 264.75 kg and ₦13, 797.70 respectively while production cost was overachieved by ₦274, 921.40, because it overshoot the desired level. The gross margin, dry rubber and cost of production goals did not reach their desired levels. The average rubber farmer cannot fully satisfy his multiple production goals.

Table 4.19 : LP result for average farm resource

Resource	Status of Use	Slack	Shadow Price
Land (ha)	Fully Utilized	-	550
Labour	Not fully utilized	14	

Source: Computer print out of LP model

The optimal tappable tree of 282 obtained in the study is low as compared to the optimum tappable trees of 593 reported in Malaysian smallholder farms (San and Deato 1999). Several factors have been reported to affect the population of tappable rubber trees in many rubber producing countries of the world. In Nigeria for instance, the damaging effects of the wind (stem and branch snapping, total uprooting), incidences of pest and diseases, fire outbreak and management practices are factors that can determine rubber tree population. These factors might have been responsible for the low optimum tappable trees found in the study.

Table 4.20: The LGP production and goal attainment results

Goals	Existing targets	Programme Value	Under achieved	Over achieved	Degree of attainment
Tappable Trees	282	282	0	0	Achieved
Rubber production Kg	27787.98	25523.23	2264.75	0	Not Achieved
Income	3018358.96	3004561.26	13797.70	0	Not Achieved
Latex production	30,760.5	30,760.5	0	0	Achieved
Cost	₦24090.7	₦299012.1	0	274921.4	Not Achieved

Source: Computer print Out of goal programming

4.9 Constraints to Latex Production

The constraints considered in this section relates to rubber farmers and tappers engaged as hired labour.

4.9. 1 Problems of plantation owners

Analysis of the result (Table 4.22) indicates that the major problems affecting plantation owners include poor rubber prices, pests and diseases, inadequate credit, shortage and high cost of labour, inadequate farm machineries, lack of market information, inadequate research/ extension support services, storage facilities problem, inaccessibility to cheap farm inputs and land tenure problem.

4.9.1.1 Shortage and high cost of labour

Shortage and high cost of labour ranked the first major problem (10.91 percent) experienced by farmers. This is as a result of the fact that the rubber growing belt is in the oil belt of Nigeria where active population are attracted leaving rubber cultivation to the older and aged population as reported by Abolagba and Giroh (2006). The attendant consequence may be reduction in hectarage under cultivation and declining productivity (Table 4.22).

4.9.1.2 Inadequate credit

Table 4.22 shows that inadequate credit affected all the farmers and was the second most important and significant constraint of rubber farmers. Rubber production is both labour and capital intensive and therefore requires a large capital outlay and inadequacy of credit would stifle expansion of rubber production. This result is consistent with the work of Banmeke and Omoregbee (2009) that identified inadequate credit as one of the major problems of rubber farmers in Edo and Delta States of Nigeria.

Table 4.21: LGP resource use and allocation pattern

Resource	Status of Use	Slack	Shadow Price (MVP)
Land (ha)	Fully Utilized	-	225
Labour	Not fully utilized	12	

Source: Computer print Out of goal programming

4.9.1.3 Poor rubber prices

Poor rubber prices were a significant factor and accounted for 10.91 percent and ranked the third most important problem of rubber farmers. Poor prices offered may be a disincentive to rubber farmers leading to decline in production. The result is in agreement with Abolagba *et al.*, (2003) who identified inaccurate pricing natural rubber that leads to low farm income and a disturbing problem of the rubber industry. This is due mainly to the activities of the middlemen who pass wrong price signals to the unsuspecting farmers.

4.9.1.4 Storage facilities problem

Storage facilities problem was the fourth most important significant problem faced by respondents and this accounted about 9.93 percent. Attractive prices for natural rubber have to do with storage facilities to avoid chances of produce adulteration. Studies conducted by Uraih *et al.*(2006) identified high cost associated with the use of cemented surface and other improved storage facilities as the problem faced by rubber farmers in the rubber belt of Nigeria.

4.9.1.5 Lack of market information

All respondents viewed lack of market information as the fifth most important problem facing them (Table 4.22). This shows that without information on product prices, farmers are likely to be cheated and some middlemen will capitalize on this short coming by offering less attractive prices, a disincentive towards boosting rubber production. Studies have indicated that adequate information sources available to farmers enable them to adopt technologies and improve their wellbeing. Studies in Malaysian rubber farms indicated that farmers overcome inadequate market information by the formation of rubber related associations for exchange of market information and other matters of mutual interest (Malaysian Rubber Board; MRB 2009). Nigerian rubber farmers can also form similar association to enhance their production activities.

Table 4.22: Constraints to Latex Production

Constraint	Total score	Frequency	Percentage	Mean score	Rank order*
Poor rubber prices	860	300	10.91	2.87	3
Pests/ diseases	681	259	9.42	2.63	6
Inadequate credit	879	300	10.91	2.93	2
Shortage and high cost of labour	891	300	10.91	2.97	1
Incidence of fire	612	250	9.09	2.45	9
Lack of market information	831	300	10.91	2.77	5
Storage facilities problem	764	273	9.93	2.80	4
Inadequate research/ extension support services	715	290	10.55	2.46	8
Inaccessibility to cheap farm inputs	729	286	10.40	2.54	7
Land tenure problem	340	191	6.95	1.78	10

Source: Field survey 2010.* Rank order based on mean values of constraints

4.9.2 Problems of rubber Tappers

Analysis of the result (Table 4.23) indicates constraints affecting tappers productivity and includes irregular payment of wages and salaries, long distance to task location, inadequate wages and salaries, bushy plantation, accommodation, lack of training, inadequacy of tapping equipment and wage casualization.

4.9.2.1 Wage casualization

Wage casualization ranked as the first most important problem experienced by the respondents. It was found to be very prominent in rubber estates owned by the Institute and not very common with small holder farmers. Giroh and Adebayo (2007) in their studies found out that tappers engaged as casuals were more productive than those engaged as permanent staff as their payment of wages depend on quantities of dry rubber tapped which propelled them to tap more and also, their chances of being permanent workers depends on their productivity and punctuality at work.

4.9.2.2 Irregular payment of wage and salary

Table 4.23 shows that 9.30 percent of rubber tappers are constrained by irregular payment of wages and salaries. This was ranked as the second problem experienced by the tappers.

4.9.2.3 Bushy plantation

Bushy plantation is associated with the management systems adopted by plantation owners. This constraint was significant and ranked the second most important problem of tappers as indicated by 11.63 percent (Table 4.23). Weedy task fields could impair their movement thereby reducing daily output and inability to tap all trees. Product adulteration may also be possible and tappers are at health risks as dangerous reptiles (snakes) might bite them as experienced by tappers in the many rubber producing countries of the world (Schroth *et al.*, 2004; Umar *et al.*, 2008; Umar *et al.*, 2011). Agwu (2006); Ajokporise and Akpere 2010) reported that bushy plantations are reflections of poor management and could predispose such plantations to diseases such as white root rot and other pests with the chances of fire outbreak.

4.9.2.4 Inadequacy of tapping equipment

Table 4.23 indicated that all the tappers identified inadequacy of tapping equipment as the fourth most important and significant constraint. Inadequacy of items such as safety kits, tapping kits, buckets, bulking containers for storage of latex might affect efficient exploitation of rubber plantation.

4.9.2.5 Accommodation

Inadequate housing near plantation accounted for 13.95 percent and the fifth major problem of rubber tappers employed especially in Rubber Research Institute of Nigeria.

Table 4.23: Distribution based on Constraints affecting tappers productivity in latex production

Constraint	Total score	Frequency	Percentage	Mean score	Rank order
Irregular payment of wages and salaries	190	80	9.30	2.38	2
Long distance to task location	112	70	8.14	1.60	9
Inadequate wages/ salaries	164	95	11.05	1.73	7
Bushy plantation	232	100	11.63	2.32	3
Transportation	240	115	13.37	2.00	6
Accommodation	264	120	13.95	2.20	5
Lack of training	192	90	10.47	1.60	8
Inadequacy of tapping equipment	276	120	13.95	2.30	4
Wage casualization	175	70	8.14	2.50	1

Source: Field survey, 2010. * Rank order based on mean values of constraints

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Major Findings

The objectives of the study were to examine the influence of rubber farmers' socio- economic characteristics on their technical efficiency; examine labour availability and productivity; determine costs and returns in latex production; determine allocative, technical and economic efficiency of factors employed in latex production; determine an optimal tappable trees/ task that would *satisfice* a set of multiple objectives of plantation owners and examine factors or constraints affecting rubber farmers and tappers in latex production. Primary data were collected from 300 rubber farmers and 120 rubber tappers using purposive and random sampling techniques. Data collected were analyzed using descriptive statistics, Likert scale, budgeting technique, stochastic frontier production function analysis and weighted goal programming model.

The result of the socio – economic characteristics of the respondents revealed that all were males and were literate and had one form of formal education or the other. The preponderance of older farmers (76%) in rubber production portends serious danger to the rubber industry with declining productivity. Majority of respondents were married (76.33 percent) with a mean family size of 7 people. Also, (85.67 percent) had 11 years and above of rubber farming experience and mostly smallholder farmers with a mean farm size of 1.67 hectares.

Labour productivity analysis revealed a yield of 826,434.31 kg dry rubber per year and gross income of ₦81, 949,226.18 per year while the output per man day was 22.58 kg. Wage / man day was ₦377.78, while an average plantation owner reaps ₦1, 860.56 after adjustments were made to wages and other costs of operation.

The gross margin analysis showed that average variable cost/hectare was ₦55, 700.94 with labour cost accounting for about 50 % of the total tapping cost. The total revenue (TR) and Gross margin (GM) per hectare were ₦163, 594.17 and ₦107, 893.23 respectively.

The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production function of rubber farmers revealed that the elasticity of the outputs with respect to inputs showed that number of trees/ task, labour, farm size, age of plantation, clone and depreciation on fixed cost items were all significant at one percent, while wage was significant at ten percent, respectively. The entire rubber farmers operated below the efficiency frontier with a mean technical efficiency (TE) of 0.84 (84 percent) suggesting that rubber farmers output can be improved by 16 percent through improved resource allocation. The minimum and maximum TE index was 0.23 and 0.99. Education, extension contact, experience were the significant factors that increase the technical efficiency of rubber farmers.

The estimates of the parameters of stochastic cost frontier model of the rubber farmers were positive and implied that the variables used in the regression analysis have direct relationship with total cost of latex production and revealed that cost of safety kits, cost of labour and output were significantly related with cost of production. The mean allocative efficiency of rubber farmers is 0.77 (77 percent) implying that the farmers are not fully efficient as the observed cost was 23 percent less than the frontier maximum cost suggesting that allocative efficiency of the farmers could be improved by 23 percent through improved resource allocation. Age, extension contact and farm distance increase the allocative efficiency of rubber farmers. The mean economic efficiency was 0.65 with a maximum and minimum economic efficiency of 0 .93 and 0.20 respectively.

Results of goal programming analysis also revealed that the average rubber farmer cannot fully achieve his production goals from the available resources at his disposal as the plan was able to achieve or satisfy completely two goals out of the five. These are tappable rubber trees and latex production in litres. The goals of rubber production in kilogramme dry rubber and income were underachieved by 2,264.75 kg and ₦13,797.70 respectively while production cost was overachieved by ₦274, 921.40, because it overshoot the desired level. The gross margin, kilogramme of dry rubber and cost of production goals did not reach their desired levels.

The major constraints of rubber farmers include poor rubber prices, pests and diseases, inadequate credit, shortage and high cost of labour, inadequate farm machineries , lack of market information, inadequate research/ extension support services storage facilities problem, inaccessibility to cheap farm inputs and land tenure problem

The problems identified to be associated with rubber tappers productivity also included bushy plantation, inadequate wages and salaries, delay in payment of wages and salaries, wage casualization, lack of training , long distances to task location and transportation constraints.

5.2 Conclusion

Based on the results of this study, the following major conclusions are drawn. Males dominated rubber production, all were literate and are older, experienced and mostly smallholder farmers with a mean farm size of 1.67 hectares.

Labour productivity analysis revealed a yield of 826,434.31 kg dry rubber per year with gross income of ₦81, 949,226.18 while output per man day was 22.58 kg. Rubber latex production was profitable as indicated by total revenue (TR) and Gross margin (GM) per hectare of ₦163, 594.17 and ₦ 107,893.23.

The Maximum Likelihood Estimate (MLE) of the parameters of the stochastic frontier production function of rubber farmers revealed that the elasticity of the outputs with respect to inputs showed that number of trees/ task, labour, farm size, and age of plantation, clone and depreciation on fixed cost items were all significantly related with output. The technical efficiency of the entire rubber farmers is less than one, indicating that the farmers were not operating on the efficiency frontier with the mean technical efficiency of 0.84. Education, extension contact and experience were the significant factors that increase the technical efficiency of rubber farmers.

The MLE of the parameters of the stochastic cost frontier also indicated that cost of safety kits, cost of labour and output were significantly related with cost of production. The mean allocative efficiency was 0.77. Age, extension contact and farm distance increase the allocative efficiency of rubber farmers. The mean economic efficiency of the farmers was less than one with a mean of 0.65

Goal programming analysis also revealed that the average rubber farmer cannot fully achieve his production goals from the available resources at his disposal. The plan was able to achieve or satisfy completely two out of the five goals.

The major constraints of rubber farmers include poor rubber prices, inadequate credit, shortage and high cost of labour, lack of market information and storage facilities.

Wage casualization, irregular payment of wages and salaries, bushy plantation, inadequate tapping equipment and accommodation were the major constraints of rubber tappers.

5.3 Recommendations

Based on the findings of the study, the following recommendations are made:

i. To improve the technical and allocative efficiency of the farmers, extension activities of the Rubber Research Institute of Nigeria and the ADPs in the rubber belt of the country should be re – strengthened through adequate funding so that farmers can be reached with improved production packages.

ii. The budgetary analysis indicated latex production is profitable, thus farmers should avoid produce adulteration to attract prices from buyers.

iii. Rubber plantations with trees that are too old should be replanted using improved clones. Private estates should also be involved in the production of improved clones in partnership with the Rubber Research Institute of Nigeria to promote rubber production.

iv. Farmers should form cooperative societies and associations to enable them access production credit from commercial and Nigerian Agricultural Cooperative and Rural Development Bank (NACRDB).This will enable the farmers to employ labour and pay for wages commensurate to output. Prompt and regular payment of such wages will spur tappers to increase output.

v. The preponderance of the older farmers in rubber production calls for government to encourage youth participation in rubber production through incentive programmes such as attractive wages and provision of infrastructural facilities in the rural areas.

vi. End users of research results on rubber, NGOs and the three tiers of government in the rubber producing belt should be encouraged to fund farmers' capacity building activities like famers field days, OFAR trials to enhance their efficiencies in production.

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APPENDIX 1: STUDY QUESTIONNAIRE ON EFFICIENCY OF LATEX PRODUCTION AND LABOUR PRODUCTIVITY IN RUBBER PLANTATIONS IN EDO AND DELTA STATES, NIGERIA

SECTION A: PERSONAL INFORMATION

(To be completed by rubber farmers)

1. Locality ………………………… (b)LGA/ State…….………………………….

2. Age………………..years 3. Gender: Male [ ] Female [ ]

4. Marital status a) Married [ ] b) Single [ ] c) Widow [ ]

d) Divorced [ ]

e) Others (please specify)………………………………………………………….

5. Number of children: a) Male [ ] b) Female [ ]

6. Total number of people in the household including you ………………………..

7. Level of education: a) No formal education [ ]b) Primary school cert [ ]

b)GCE/WASC O/L [ ] c) OND [ ] d)HND [ ] e) University [ ]

f) Others (please specify)…………………………….

SECTION B: RUBBER PRODUCTION INFORMATION

8. How long have you been in rubber farming?……………years.

9. How did you acquire your rubber farm land? (a) Inheritance [ ] (b) Rent [ ]

(c) Purchase [ ] (d) gift [ ] (e) Government allocation [ ]

(f) Others (specify)……………………………………

10. If purchased or rented state the amount you pay per hectare ₦………………………

11. What is the size of your rubber farm?……………………hectares.

b) Please indicate number of hectares currently tapped……………………………………

12. Age of plantation currently tapped (in years) …………………………………………

13. State the type of clone used……………………………………………………............

14. Do you tap your plantation yourself? Yes [ ] No [ ]

If Yes in Q14 indicate:

i. Tapping experience in years………………………………………………………………

ii. Were you trained as a rubber tapper? Yes [ ]No [ ]

iii. If yes in question ii above, state duration of training in days /weeks …………………

iv. How many trees do you tap in a day? ……………………………………………………

v. What is the distance of the collection centre from your task field?……………km

15. If no in Q14 fill the tables below:

16. Information on family labour used on latex production

Farm Operation	Adult Male			Adult Female			Children		
	No.	No. of days Worked	No. ofHrs worked/day	No.	No. of days Worked	No. of Hrs worked/day	No.	No. of days Worked	No. of Hrs worked
Tapping									
Others(specify)									

17. Information on Hired Labour on latex production

Farm Operation ↓	Adult Male					Adult Female					Children				
	No.	No. of days Worked	No. of Hrs worked/day	Wage rate/day Food Value (₦)	Money (₦)	No.	No. of days Worked	No. of Hrs worked/day	Wage rate/day Food Value (₦)	Money (₦)	No.	No. of days Worked	No. of Hrs worked/day	Wage rate/day Food Value (₦)	Money (₦)
Tapping															
Others(specify)															

18. Mode of engagement of tapper (tick as appropriate)

a) Wage tapping [ ] b) Share arrangement [ ] c) Contract tapping [ ]
d) Others(please specify)………………………………………………………………………..

19. Indicate amount paid as wages based on mode of engagement of tappers
i. Wage tapping ₦ …………./ day/ month
ii. Contract tapping ₦………./kg/ day
iii. Share arrangement (indicate sharing formula)……………………………………

20. Variable Cost Items

Items	Quantity(litres)	Unit cost/litre (₦)	Total Cost (₦)
Ammonia			
Ethrel(Ethephon)			
Formic acid			
Fuel			
Rain coat			
Rain boot			
Others(specify)			

21. Fixed capital Assets

Item	Year of Purchase	Condition of purchase (New or Old)	Quantity	Unit Cost (₦)	Life Span (Years)
Latex Cup					
Cup Hanger					
Tapping Knife					
Bucket					
Sharpening Stone					
Churn					
Coagulating pan					
Spout					
Latexometre					
Tractor					
Weighing balance					
Dip stick					
Stiring cup					
Others(specify)					

22. Information on rubber yield for 2008/2009 and 2009/2010 cropping seasons

	2008/2009	2009/2010
Total yield in kilogramme of dry rubber		
Total yield in litres of rubber latex		
Price / Kg dry (₦)		
Price / litre (₦)		
Total amount realized from latex sales (₦)		
Total amount realized from coagula sales (₦)		
Transportation cost:		
(a) Farm to house (₦)		
(b) House to market (₦)		
Others(specify)		

23. Do carry out latex preservation for 2009 and 2010 production years? Yes [ ] No [ ]

24. If yes, use the table below

Type of anticoagulant	Quantity(litres)	Unit cost/litre

25. If No in question 24, did you use coagulant for lump or coagula in 2009 and 2010? Yes [ ] No [ ]

26. If yes, indicate the type of coagulant used in the table below

Type of coagulant	Quantity(litres)	Unit cost/litre

If not, what did you use?

i. Autocoagulation [ ]

ii.Others(please specify)…………………………………………………………

27. Do you store your dry rubber before disposing them off? Yes [ ] No [ ]

28. If yes, where do you store them?

i. Local storage facility [ ]

ii. Cemented surface [ ]

iii. Raised platform [ ]

iv. Others (please specify)……………………………

29. Do you have ready market for rubber? Yes [ ] No [ ]

30. How do you dispose off your produce?

i. At the farm gate [ ]

ii. Dealers buy at home [ ]

iii. Market [ ]

iv. Through cooperative society [ ]

31. Do you have access to Extension services? Yes [ ] No [ ]

32. If yes, how often do Extension Agents visit you?

i. Regular [ ]

ii. Irregular [ ]

SECTION C: PRODUCTION OBJECTIVES AND CONSTRAINTS
(To be completed by plantation owners)
Production objectives

33. Please which of the following explains your preference for latex production? Select and rank those applicable according to how important they are to you starting from 1 for the most important, 5 for the least.

to increase gross margin [ ]

to tap all tasks allocated [ ]

maximum latex production in litres [ ]

to minimize costs of tapping [ ]

maximum rubber production in kg dry rubber [ ]

Constraints of Latex Production
34. Indicate whether the given option is a constraint or not and also indicate the degree of severity of the constraint on a 3-point scale by ticking the appropriate option(s).

S/No	Constraints	3	2	1
1	Low rubber prices			
2	Pests and diseases infestation			
3	Inadequate credit facilities			
4	Shortage of labour			
5	Incidence of fire			
6	Lack of market information			
7	Lack of good storage facilities			
8	Inadequate research and extension support			
9	Inaccessibility to cheap farm inputs			
10	Land tenure problems			
Others (specify)				

35. Suggest ways on how these problems could be solved
…………………………………………………………………………………………
…………………………………………………………………………………………
Thank you.

SECTION D: PERSONAL INFORMATION

(To be completed by rubber tappers)

36. Tapper No…………………………(b)Location……..………………

37. Age………………..years

38. Gender Male [ ] Female [ ]

39. Marital status a) Married [ ] b) Single [ ] c) Widow [ ]

d) Divorced [ ] e) Others (please specify)………………………………………

40. Number of children: a) Male [ ]b) Female [ ]

41. Total number of people in the household including you …………………………

42. Level of education: a) No formal education [ ]

b) Primary school cert [ ] c) GCE/WASC O/L [ ] d) OND [ ]

e)University [ ]e) Others (please specify)………………………………………………..

SECTION B: RUBBER TAPPING

43. Tapping experience in years……………………………………………

44. Status of tapping: Permanent a) [ ] b) Non permanent [ ]

45. If permanent, please indicate your salary grade level……………………

46. Were you trained as a rubber tapper? Yes [ ] No [ ]

47. If yes in question 11 state duration of training…………………………

48. How many trees do you tap in a day? ………………………………….

49. What is the distance of the collection centre from your task field?……………….km

SECTION E: CONSTRAINTS AFFECTING TAPPERS PRODUCTVITY IN RUBBER LATEX PRODUCTION

50. Indicate whether the given option is a constraint or not and also indicate the degree of severity of the constraint on a 3-point scale by ticking the appropriate option(s).

S/N	Constraints	3	2	1
1	Irregular payment of wages and salaries			
2	Long distance to task location			
3	Inadequate wages/ salaries			
4	Bushy plantation			
5	Transportation			
6	Accommodation			
7	Lack of training			
8	Inadequacy of tapping equipment			
9	Wage casualization			
	Others (specify)			

51. Suggest ways on how these problems could be solved

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Thank you.

APPENDIX 2: HYPOTHESIS TESTING

Null hypothesis tested is that the inefficiency effects are not present (H_o: $\gamma = \delta_1 + \ldots\ldots\ldots + \delta_6 = 0$) is tested against alternative(H_a: $\gamma>0$) using the log likelihood ratio (LR) test is as follows:

LR = -2[LnL(H_0) – LnL(H_1)] which has a mixed chi-square distribution with seven degrees of freedom under the null hypothesis because γ is non negative. The values of the likelihood function for the restricted and the unrestricted model are represented by L(H_0) and L(H_1). When there is no inefficiency effect (U= 0 for all i), then the production frontier is a simple mean response function using the Ordinary Least Squares (OLS) method. The log likelihood value from OLS estimate is - 81.37 and the log likelihood values from MLE of full frontier model is - 0.702.