

ENERGY REQUIREMENTS FOR OPTIMAL CASSAVA PRODUCTION IN KWARA
STATE, NIGERIA

BY

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Energy Requirements for Optimal Cassava Production in Kwara State, Nigeria

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Date

DEDICATION

This work is dedicated to the Almighty God, the Giver of life, strength and wisdom, whose mercy and grace sustained me throughout this work; to the memory of my late father Elder John Arogundade Adekanye and to my wife Oluwafunmike and my children Oluwasemilore, Oluwagbemiga, Oluwatodimu and Precious-Grace Ayomide.

DECLARATION

I hereby declare that this thesis is a record of my research work. It has neither been presented nor accepted in any previous application for a higher degree. Also all sources of information have been specifically acknowledged.

Signature:

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Adekanye, T. A.

Date

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ABSTRACT

Knowledge of energy in crop production is essential for enhancing food production for the rapidly increasing population. Adequate attention has not been given to the analysis of energy inputs in crop production in Nigeria. Consequently, it is difficult to determine viable energy inputs in the production processes and plan for conservation. Therefore, there is a need for evaluation of energy consumption in cassava production in Kwara State, Nigeria. The aim of this study was to determine energy requirement in cassava production in the State, and hence develop model equations for predicting yield under different farming practices. The specific objectives of the study were to: i) investigate energy inputs and output per hectare in cassava production; ii) determine energy use efficiency in cassava production; iii) investigate the effects of energy inputs on cassava productivity; and iv) investigate the relationship between cassava yield and different energy input sources.

Data from 175 farms were collected through site visits and physical measurements for 3 consecutive cropping seasons (2013 - 2016). The farms were classified into 3 groups based on size of farm and level of mechanization: small scale (1 to 5 ha), medium scale (6 to 15 ha) and large scale (16 to 50 ha). There were 92 farms in the small scale group while medium and large scale farms were 54 and 29 farms, respectively. Inputs used in cassava production (cassava setts, chemicals, diesel fuel, fertilizers, human labour and machinery) and output (cassava yield) were determined per hectare and then multiplied by the coefficient of energy equivalents. The data generated were statistically analyzed using R software. Cobb-Douglas production function and multiple linear regression analysis were applied to analyze the relationship between energy inputs and cassava yield to develop yield predictive models.

The findings of the study were that:

- i) cassava production consumed a total energy of 4904.87 MJ/ha, 36352.04 MJ/ha and 96 257.93 MJ/ha while average energy output were 107,632 MJ/ha, 604,800 MJ/ha and 2,016, 000 MJ/ha, respectively in small, medium and large scale farms respectively;
- ii) energy use efficiency for cassava production was 16.13, 16.69 and 20.94% for small, medium and large scale farms, respectively;
- iii) average values of net energy used and energy productivity were respectively 100, 959 MJ/ha and 2.88 for small scale farms, 568, 560 MJ/ha and 2.98 for medium scale farms, and 1, 919, 742 MJ/ha and 3.74 for large scale farms; and
- iv) indirect and non- renewable energies had higher impacts on cassava yield than direct and renewable energies in medium and large-scale farms. Reverse was the case in small scale farms;

The study concluded that input variables in cassava production are independent of each other. Three parametric models were developed in this study to predict cassava yield. Model I with the highest R^2 value and no autocorrelation at 5% significance level is recommended to scientists in order to boost cassava yield. Results of this study would be useful to cassava farmers in Kwara State and elsewhere with similar soil characteristics and operating conditions.

TABLE OF CONTENTS

TITLE PAGE	i
APPROVAL PAGE	ii
DEDICATION	iii
DECLARATION	iv
ACKNOWLEDGEMENTS	v
ABSTRACT	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	x
LIST OF FIGURES	xi
ACRONYMS	xii
NOTATIONS	xiii
CHAPTER ONE	
INTRODUCTION	1
1.1 Background of Study	1
1.2 Statement of the Problem	3
1.3 Aim and Objectives of Study	4
1.4 Justification of the Study	4
1.5 Scope of the Study	5
1.6 Conceptual Framework	6
CHAPTER TWO: LITERATURE REVIEW	
2.1 Economic Importance Cassava Crop	8
2.2 Energy in Agricultural Production	13
2.3 Agricultural Energy Input Sources	13

2.4 Energy Analysis in Agriculture	14
2.5 Energy Inputs in Cassava Cultivation	15
2.5.1 Direct energy input	15
2.5.2 Human labour	16
2.5.3 Mechanical power	16
2.6. Indirect energy input	17
2.6.1 Physical energy input	17
2.7 Chemical Energy Input	20
2.8 Seed Energy Input	20
2.9 Energy Requirement and Conversion Factor	21
2.10 Energy Input and Output Ratio	21
2.11 Modeling of Crop Yield	24
2.11.1 Crop simulation models	25
2.11.2 Application of statistical models in Agricultural Production	25
CHAPTER THREE: MATERIAL AND METHODS	28
3.1 The Study Area	28
3.2 Data Collection and Experimental Procedure	30
3.3 Energy Equivalents of Inputs and Output	34
3.4 Computation of Parameters	36
3.4.1 Manual Energy Input	36
3.4.2 Mechanical Energy Input	37
3.4.3 Pesticides and herbicides energy	38
3.5.4 Biological Energy Inputs	38

3.5. Evaluation of Energy Ratio	38
3.6 Experimental Design	39
3.6.1 Model development for cassava yield	39
3.6.2 Model assumptions	41
3.6.3 Justification for least square regression methods	41
3.7 Parameter Estimation and Hypothesis Testing	42
3.8 Analysis of Cassava Energy Input and Output	43
CHAPTER FOUR: RESULTS AND DISCUSSION	45
4.1. Management practices for cassava Farms	45
4.1.1. Socio – Economic Characteristics of Cassava farmers	45
4.2 Analysis of Energy Consumption in Cassava Production	49
4.3 Effects of Energy Inputs on Cassava Yield	56
4.3.1 Relationship between Cassava Yield and Different Energy Inputs	56
4.3.2 Effects of direct energy and indirect energy on cassava yield	59
4.3.2 Effects of renewable energy and non-renewable energy on cassava yield	60
CHAPTER FIVE: CONCLUSIONS, RECOMMENDATIONS AND CONTRIBUTIONS TO KNOWLEDGE	67
5.1 Conclusions	67
5.2 Recommendations	68
5.3 Contributions to Knowledge	69
REFERENCES	
APPENDICES	

LIST OF TABLES

TablePage

2.1	Average cassava yield/ha in Nigeria (2000-2016)	10
2.2	Energy coefficients (MJ/h) of some farm equipment	18
2.3	Energy coefficients for producing and repairing agricultural machines	19
2.4	Data to calculate energy sequestered and energy required in field operations	23
3.1	Kwara ADP Zones	32
3.2	Sample outlay for the study	33
3.3	Energy equivalents of inputs and output in cassava production	35
3.4	Energy equivalent values of some crops	35
4.1	Management practices of cassava farms in the study area	47
4.2	Socio – economic characteristics of cassava farmers	48
4.3	Average amount of input and output in the cassava farms	52
4.4	Average energy inputs and output in cassava production per hectare (MJ ha ⁻¹)	53
4.5	Energy input and output ratio in cassava production	55
4.6	The estimation results for Model I and their coefficients	62
4.7	Estimation for model II and their coefficients	63
4.8	Estimation for model III and their coefficients	63

LIST OF FIGURES

Figure	Page
1.1Conceptual framework of the research	7
2.1Top cassava producing countries	9
2.2A simplified cassava value chain	12
3.1Map of the study area	29
4.1Total energy inputs and outputs in cassava production	54
4.2Cassava yields in the study farms	54
4.3Trends of observed and predicted energy output in the small-scale farms	64
4.4Trends of observed and predicted energy output in medium-scale farms	65
4.5Trends of observed and predicted energy output in large-scale farms	66

ACRONYMS

CYSM = Crop Yield Simulation Models

CSI = Crop Stress Index

ADP = Agricultural Development Program

KWADP = Kwara State Agricultural Development Project

MOANR = Ministry of Agriculture and Natural Resources

LGAs = Local Government Areas

ADP = Agricultural Development Projects

FOS = Federal Office of Statistics

NOTATIONS

MJ ha^{-1} = Mega Joule per hectare

MJ/hour = Mega Joule per hour

L ha^{-1} = Liter per hectare

Y_i = Cassava yield

X_1 = Human labour energy input

X_2 = Machinery energy input

X_3 = Fuel energy input

X_4 = Chemicals energy input

X_5 = Fertilizer energy input

X_6 = Cassava stem energy input

e_i = error term

D = Amount of diesel fuel consumed, litres

$E_{\text{eqv.}}$ = Unit energy value, MJ

M_E = the machine energy input (MJ/ha),

W = the weight of the implement (kg),

T = the economic life of the implement (h), and

E_{FC} = the effective field capacity (ha/hr).

H_{ar} = Application rate (kg) of herbicide

H_{eqv} = Energy equivalent (MJ/kg) of herbicide applied

A = Application area (ha)

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Energy has been defined as the capacity to do work. It is very necessary for all human activities, including agricultural production. Different types of energy are important for the development of the human society (Pishgar-komleh *et al*, 2012). There exists a form of interdependence between agriculture and energy. Agriculture utilizes energy from the sun and also supplies bio-energy (Ozkan *et al.*, 2004a). Food production systems have been divided into several categories; cropping, livestock and fisheries, food processing, packaging and marketing (Wallgren and Höjer, 2009; Safa, 2011). Crop yields, food supply to families, and markets are directly related to energy input during crop production (USDA, 2008; Stout, 1990). Energy inputs in agricultural production are derived from chemicals, fertilizers, improved seed, irrigation and mechanization (Dhavan and Mittal, 1989; Moulik *et al.*, 1992; Kitani, 1999; Ebrahim, 2012). Also, energy is consumed indirectly in chemicals and fertilizers manufactured off the farm (Jekayinfa, 2001; Ozkan *et al.*, 2004a; Ozkan *et al.*, 2004b; Thankappan *et al.*, 2005).

Agricultural operations include all activities that occur after the land has been cleared and prepared for planting, such as tillage, planting, fertilizer application, pest and weed control, harvesting, post-harvesting, and transportation until the produce (harvested crops) leaves the farm gate. Energy is required for timely farm operations for increasing productivity and handling crops produced to reduce losses (Shrivastava, 2006; Mohamadi and Omid, 2010). Energy input in agricultural production is essential for enhancing crop production and processing of agricultural products. Its use in crop production is described by the level of development of

technology (mechanization) and the scale of production. Chemicals, electricity, fuel, fertilizer, machinery, and seed account for significant portion of the energy inputs in the modern day crop production systems. These factors have greatly enabled farmers to increase outputs (yields) and reduce drudgery in agricultural production (Esengun *et al.*, 2007). Hence, demand for energy input in crop production systems has increased considerably in response to demand for food by the teeming population and also to enhance status of farmers (Mohammadi *et al.*, 2008).

Crop production energy inputs are classified into four types. These are direct energy, indirect energy, renewable energy and non-renewable energy. Direct energy includes diesel, electricity and human power used in crop production. It is used to perform various tasks such as tillage, planting, weeding, irrigation, fertilizer application; harvesting, threshing and transportation of other inputs and farm labourers (Mandal *et al.*, 2002; Singh 2000; Singh *et al.*, 2004; Beheshsti *et al.*, 2010). Indirect energy refers to energy consumed in producing chemicals, fertilizers, farmyard manure, seed, and machinery used crop production. Non-renewable energy includes chemicals, diesel, fertilizers and machinery while renewable energy consists of human labour, seeds and manure (Beheshsti *et al.*, 2010; Farzad and Mohammed, 2012). It has been said that a larger part of energy expended in crop production can be classified as indirect (Ozkan *et al.*, 2004b; Farzad and Mohammed, 2012). Kizilaslan, (2009) and Handan *et al.* (2009) affirmed that proper application of energy is a fundamental requirement for improving agriculture because crop yield and food supply are directly connected to energy inputs during production.

Energy expenditure in the crop production is a factor of number of people involved in the agricultural processes, available cultivable land and technological level (mechanization) (Ozkan

et al., 2004b; Bayramoglu and Gundogmus, 2009). There are other factors such as machine and human factors, which have resultant effects on energy expended in the production.

In agriculture, several parameters, such as fuel, seed, pesticides, and fertilizers have direct effects on energy consumption. However, there are several other controlled and uncontrolled factors, such as annual rainfall, soil fertility, and farm conditions which may indirectly affect agricultural production and energy consumption.

1.2 Statement of the Problem

Knowledge of energy applied in crop production is essential for enhancing food production for the rapidly increasing population. Adequate attention has not been given to analysis of energy inputs in agriculture in Nigeria, hence, it is difficult to determine viable energy used in the crop production stages and consequently plan for preservation of crops (Abubakar and Ahmed, 2010; Ibrahim and Ibrahim, 2012). Therefore, there is a need to evaluate energy used in cassava farms in Kwara State. This is because efficient energy utilization in crop production will promote sustainability (Pervanchon, *et al.*, 2002).

Use of models for predicting crop yield have helped a lot of farmers in the developed countries in the areas of budgeting during successive farming season. However, these developed models are not applicable in Nigeria due to differences in soil, weather, management practices and operating conditions. Hence, there is a need to develop a simple model equation for predicting cassava production (yield) to promote cassava cultivation in Nigeria.

Prediction of crop production in agricultural production and other processing units is necessary in order to minimize costs, achieve more consistent product quality, and manage different processes, which can be carried out using energy efficiency analysis. Energy efficiency analysis

can predict energy consumption in cassava production under different conditions; using several crucial input variables, would help farmers, scientists, and decision makers compare energy efficiencies in different farming systems under different farming conditions.

1.3 Aim and Objectives of the Research

The aim of this study was to investigate energy requirements in cassava production in Kwara State, Nigeria, and hence develop model equations for predicting yield under different farming practices. The specific objectives were to:

- i. determine energy inputs and output per hectare in cassava production in three farm sizes and technologies;
- ii. estimate energy use efficiency (energy ratio) in cassava production;
- iii. determine effect of energy inputs on cassava productivity; and
- iv. establish the relationship between cassava yield and different energy input sources.

1.4 Justification of Research

Cassava crop contributes about 80% of calories used in developing nations (Safa, 2011). Other food sources are corn, cattle, millet, rice, sugar, sorghum and wheat. Cassava is one of the most important and popular staple crops grown in Kwara State, Nigeria. This research aims at improving cassava production by assessing efficiency of cassava production and developing models to predict yields. This is vital as it can help cassava growers and processors to formulate plans for optimal control of their production activities, help them to correct areas of waste and properly estimate energy expenditures in the production processes.

There is presently inadequate research information on the connection between energy input and crop yield in Nigeria (Abubakar and Ahmed, 2010). Ibrahim and Ibrahim (2012) concluded that there are few studies on energy consumption in Nigerian agriculture. However, such research work on crop energy analysis (crop energy budget) is a necessity to meet the increasing demand for food as the human population increases.

Modeling cassava production will promote investments in more cassava research; facilitate multidisciplinary collaborations and rational policymaking. This study intends to provide farmers with a decision model that makes crop yield maximization possible. The importance of this study lies in the fact that it will provide farmers with a formula that predicts cassava yields. With this study, cassava farmers will be able to plan properly. Predicting cassava yield can be extremely useful to farmers and processors. If farmers have an idea of the amount of cassava yield before harvest, it is possible to convince buyers for the product even before harvest.

1.5 Scope of the Study

Kwara State is one of the major States noted for intensive cassava production in Nigeria. Different forms of energy used in cassava production farms need to be identified and defined in order to promote sustainability of cassava production in the State and Nigeria as a whole. Hence, the study is concerned with the quantity of energy (Mega joule) expended to produce one kilogram (kg) of cassava with respect to farm size. Production and management of cassava also depend on many other important factors such as agronomic practices, size of farmlands, socioeconomic conditions of the farmers, transportation, and processing.

This study is mainly concerned with the determination of biological, chemical, and physical energy inputs (MJ/ha) consumed in cassava production and energy output (MJ/ha). This study will consider only energy inputs (expenditure) in cassava production from tillage operation to harvesting operation, without considering other types of energy like rain, radiation, wind, etc. This study would be limited to collection and analysis of energy inputs data in cassava production and development of models for predicting cassava yields relative to energy inputs. Chemicals, fuel, fertilizers, human labour, machinery, and cassava setts used in cassava production were considered as inputs in this study. However, energy used in processing cassava into different products and that used to transport farm materials to and from the farm is beyond the scope of this study.

1.6 Concept of Research

The concept of this research was effects of energy expenditure in cassava production based on field operations, energy sources and modeling of cassava yield. Comparison of energy inputs, output, energy productivity and specific energy of cassava production farms were determined with respect to the size of the farm by converting physical units used into respective energy equivalents. Figure 1 shows the concept of this research.

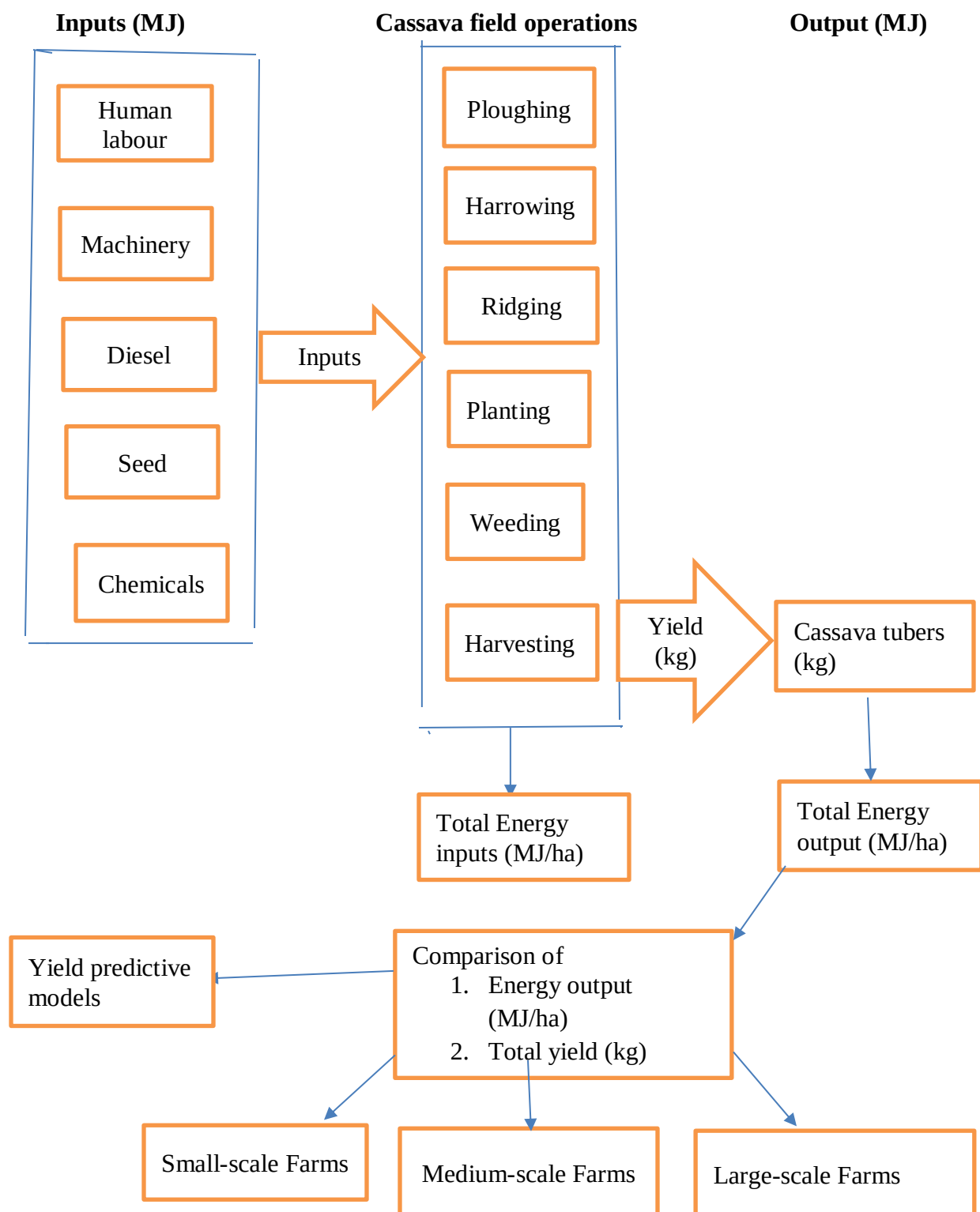


Figure 1.1: Concept of the research

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic Importance of Cassava Crop

Cassava (*Manihot esculenta*) is a tropical tuber crop that is well suited to conditions of low nutrient availability and can survive drought (Eke-Okoro *et al.*, 1999; Franklin and Kue, 2015). Cassava is a native of Brazil dispersed widely by the Portuguese to tropical and subtropical areas of Africa, Asia, and the Caribbean during the sixteenth and seventeenth centuries. It soon became a staple food crop in many of these places because of its tolerance to drought and poor soil conditions. It can be successfully grown on marginal soils where many other crops do not grow well. Also, cassava is rated as second, after maize, as the most important food staple in Africa (Oni and Oyelade, 2013; Adekanye *et. al*, 2013). More than 500 million inhabitants of Africa, Asia, and Latin America depend on cassava (Nweke *et al.*, 1988; FAO, 2002).

At the end of 2010, top four cassava producing countries were Nigeria (47,504,100 metric tons), Brazil (24,524,300 metric tons), Indonesia (23,918,199 metric tons) and Thailand (22,005,700 metric tons) (Oppong, 2013). Nigeria is still the highest producer of cassava among cassava producing nations in terms of volume of production as shown in Figure 2.1. Table 2.1 shows the average yield of cassava in Nigeria from 2000 to 2016. According to Odoemenem and Otanwa (2011) cassava is planted all yearround in all the States of Nigeria. However, Nigeria is ranked 8th position in terms of cassava yield (kg/ha) compared with other cassava producing nations like Brazil and Thailand. This may be as a result of farming practices adopted and type of cassava varieties planted by Nigeria cassava producers (FAO, 2004; Ohadike, 2007; Elemo, 2013).

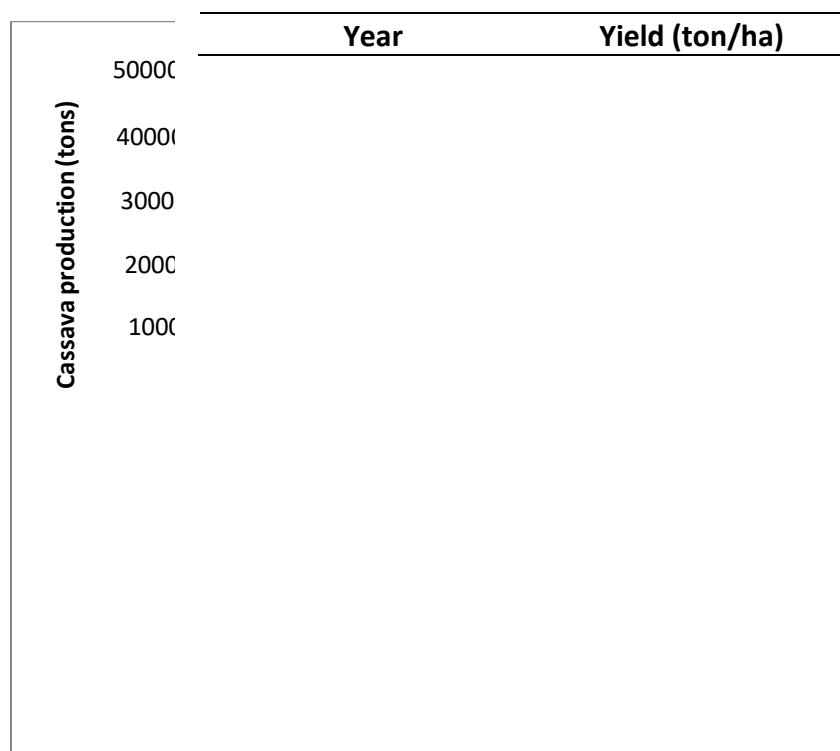


Figure 2.1:Top cassava producing countries

Table 2.1:Average cassava yield/ha in Nigeria (2000-2016)

2000	32, 010, 000
2001	32, 068, 000
2002	32, 120, 000
2003	36, 304, 000
2004	38, 845, 000
2005	41, 565, 000
2006	45, 721, 000
2007	43, 410, 000
2008	44, 582, 000
2009	36, 822, 000
2010	42, 533, 180
2011	46, 190, 248
2012	50, 950, 292
2013	47, 406, 770
2014	56, 328, 480
2015	57, 643, 271
2016	57, 134, 478

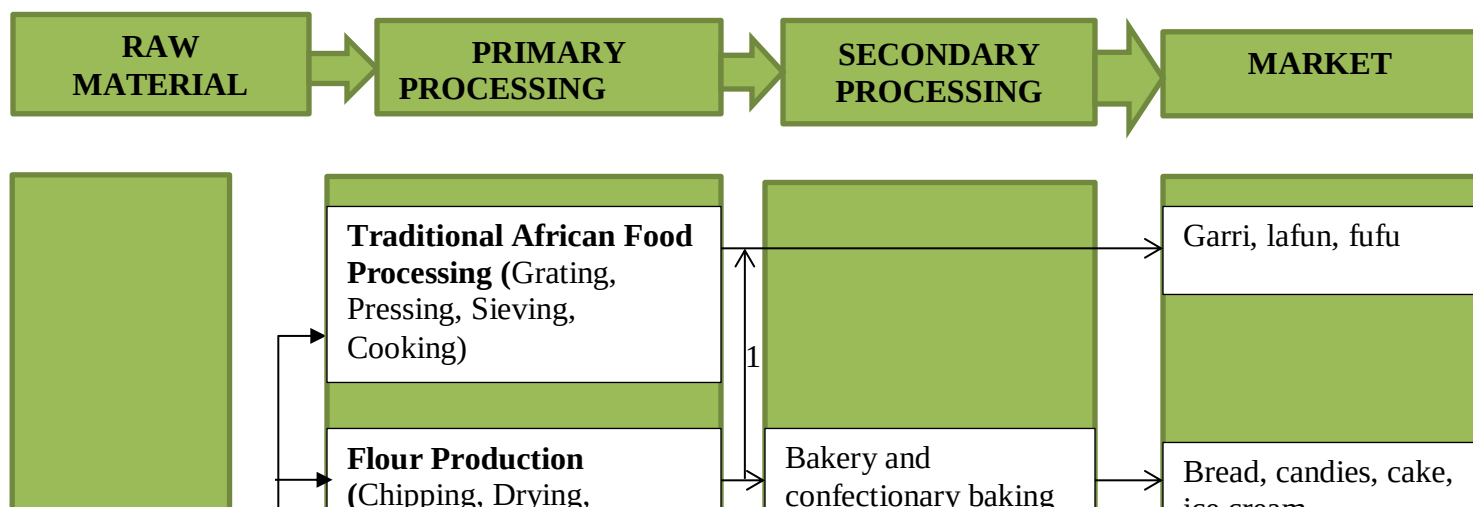
Source: www.factfish.com (2017)

Cassava tubers can be further processed into several other useful products like adhesives, chips, flour, ‘garri’, pellets, and also serves as an important raw material in alcohol/ethanol,

confectionery, food, textiles, wood, and soft drink industries livestock feed (Akinlosoye, 2009; Adekanye *et. al*, 2013; Franklin and Kue, 2015; Hahn *et al.*, 1987; Iheke, 2008). Figure 2.2 shows a simplified cassava value chain.

The growth period of cassava is generally from 9 to 24 months. This depends on variety, growing conditions and whether the roots are to be consumed fresh or processed into flour or starch (Akinlosoye, 2009). Cassava is rich in carbohydrate and has multiple end uses (Phillips *et al.*, 2004; IITA, 2006). Cassava is also available all year- round hence it is preferred to other seasonal crops and also serves as a cash crop generating cash income for many households (Akoroda and Teri, 2004).

Cassava crop is one of the major sources of dietary foods and a source of earning for the majority of Nigerian farmers therefore; its production and utilization must be given the required attention through research and policy initiatives in cassava production, and processing in order to maximally derive inherent potentials of cassava, most especially as a substitute for some foreign raw materials for industries.



2.2 Energy in Agricultural Production

There are some important variables that determine energy consumption in crop production. These factors include number of people engaged, size, available arable land and level of mechanization (technology) (Gezer *et al.*, 2003; Alam *et al.*, 2005). Energy inputs in crop production may be from animal power, chemical, electricity, fuels, fertilizers, human labour, seeds, machinery, and water for irrigation. These energy forms may be used on the farm directly or indirectly. Energy is also required for post-harvest operations such as drying, cooking, packaging, storage, and transportation (FAO, 2000). Intensive application of energy in crop production will promote sustainable agriculture (Uhlin, 1998).

2.3 Agricultural Energy Input Sources

From the mid-twentieth century until recent years, the consumption of fertilizers, pesticides, fossil fuels, and electricity in agriculture has increased by about 20 to 50% (Pimentel, 2009). These increased inputs were necessary to enhance agricultural production. However, the rate of input increase was significantly more than yield increases. The inputs in energy analysis in crop production include direct factors or operational energy consumption (field machinery, fuel, human labour, and irrigation pumps) and indirect energy sources (fertilizer, pesticides, and seeds) (Bailey *et al.*, 2008; Kitani, 1999; Kizilaslan, 2009; Mohtasebi *et al.*, 2008; Ozkan *et al.*, 2004a; Safa and Tabatabaeefar, 2002). Energy inputs in agriculture include the energy used directly and also energy lost during operations like conversion, extraction, refining, and transportation (Barber, 2003; Kitani, 1999; Mohtasebi *et al.*, 2008).

Some researchers categorized energy use into farms in other ways. Wells (2001) categorized energy inputs in crop production processes to three major components. These are direct (fuel and

electricity), indirect, (chemicals, fertilizers, and seed) and capital (i.e. energy used in manufacturing items equipment, such as farm vehicles and machinery). However, most studies considered only direct and indirect energies (Conforti and Giampietro, 1997; Fluck, 1992; Sartori *et al.*, 2005; Saunders *et al.*, 2006).

2.4 Energy Analysis in Agriculture

According to Randolph and Masters (2008), there are four analytical methods that provide the rational information on which to base energy decisions. These analytical methods are energy analysis, economic analysis, environmental analysis and life-cycle analysis. This research adopts energy analysis to estimate energy expended in cassava production in three farm sizes and technologies. Energy analysis method uses statistical processes to determine, measure, foretell energy consumption and efficiency of farms (Randolph and Masters, 2008).

Agricultural production systems and energy consumed in agricultural production are very complex because they are affected by the degree of mechanization, diseases, field size, management conditions, soil physicochemical factors, pests, weather, weeds, oil prices and interaction of many other factors. Crop models usually include materials (carbon, nitrogen, and water) and energy balance (CIGR, 1999; Kuesters and Lammel, 1999; Vlek *et al.*, 2004; USDA, 2008; Liu, 2009). Agricultural energy analysis involves identification, estimation, measurement and of energy consumed in crop production systems (Fluck and Baird, 1980). Energy analysis serves different economic, management, and technical purposes (Stout, 1990).

Kitani, (1999), asserted that the first step in energy analysis is to identify and evaluate the energy inputs and energy outputs. Many researchers have used several processes to analyze energy use in agriculture. These studies consist of three methods: statistical analysis, input-

output analysis, and process analysis (Fluck and Baird, 1980). Odum (1994) attempted to understand the principle of general systems theory in relation to environmental systems. He discussed the correlation between energy inputs and outputs in ecological systems using mathematical methods. Conforti and Giampietro, (1997) concluded that a set of assumptions used in energy studies, such as defining outputs and inputs, and the energy equivalent of inputs would determine results of energy studies.

One important problem in energy analysis is the non-homogeneity of different sources (Fluck and Baird, 1980) and the different norms and coefficients that have been used in different studies. For example, the same amount of fertilizer can have a different energetic cost and value depending on the technical level of the manufacturing industry. Energy contents depend on the distance of transportation, which is variable, but can be taken as an average value for a region (Kitani, 1999) similarly; two different fuels might have the same energy content; while, they have different attributes (Fluck and Baird, 1980).

2.5 Energy Inputs in Cassava Production

2.5.1 Direct energy inputs in production

Direct energy input in agricultural production is defined as energy expended for physical work during operation. Physical energy inputs such as draft animal power, human labour, and mechanical power sources are considered by researchers as direct energy inputs (Chamsing *et al.*, 2006; Singh *et al.*, 1999). Agricultural operations consumed a reasonable amount of energy with most usage being diesel fuel consumption (Bowers, 1992).

2.5.2 Human labour

The use of human hand was the only choice for power generation required for agricultural activities before the invention and introduction of agricultural tractors. Stout (1990) asserted that manpower serves as the major energy input for crop production in developing countries till this present time. Human power is used for most of the operations on the farm; planting, fertilizer, irrigation, spraying, driving, weeding, harvesting, and repairing machinery. The human power has been described as direct energy input in crop production useful for different production processes. The energy equivalent of human labour of an adult male is 1.96 MJ/hr while that of a female worker is 0.98 MJ/hr for (Singh *et al.*, 2002).

2.5.3 Mechanical energy

Mechanical energy input is described as the energy used for manufacturing, maintenance, and repair of agricultural machines (Fluck and Baird, 1980). Farmers use different agricultural types of machineries in the agricultural operations. According to Smil (2008), it is more difficult to estimate the energy cost of field machinery than other agricultural inputs. Kitani (1999) estimated energy used for producing and repairing some agricultural machines (Table 2.1.). Kitani, (1999) considered energy required for producing raw materials used in manufacturing processes, energy consumption in transporting the machines to the end users, and the energy used in repairs and maintenance in calculating the energy coefficients presented in Table 2.2.

Mechanical power is categorized into the indirect embodied energy of the machinery (consumed during manufacturing and transportation) and the direct energy of fuel used by the machines during operations. Direct mechanical energy is used in form of diesel (or petrol) or electricity.

Energy consumption during mechanical operation in agricultural fields depends on the physical characteristics of the soil, weather, farming practices and some other factors. The weight of the machine, its lifespan, and field efficiency are very important to estimate energy inputs from agricultural machines.

2.6 Indirect Energy Inputs

These are described as the energy used to produce equipment, goods and services used in production (Pimentel *et al.*, 2002; Pimentel *et al.*, 2009). Energy inputs from biological, chemical and mechanical power sources are regarded as indirect. Energy equivalents of different farm equipment are presented in Table 2.2. Table 2.3 shows energy coefficients for producing and repairing agricultural machines

2.6.1 Physical energy

The major source of physical energy in crop production is mechanical power. Indirect energy for machine power includes energy used in manufacturing, distribution, repair, and maintenance as shown in Table 2.4.

Table 2.2Energy coefficients (MJ/h) of some farm equipment

Power source	Equipment	Energy coefficient (MJ/ha)
Manual	Spade	0.314
	Sickle	0.836
	Sprayer	0.502
	Hand hoe	0.502
Animal	Plough	0.627
	Cultivator	1.881
	Disc harrow	3.135
	Planter	1.568
	Seed drill	1.254
Tractor	Moldboard Plough	2.508
	Cultivator	3.135
	Disc plough	3.762
	Planter	9.405
	Disc harrow	7.336
	Seed drill	8.653
	Reaper	5.518
	Rotavator	10.283
	Trailer	17.431
	Combine	47.025
Others	Thresher/sheller	7.524
	Centrifugal pump	1.75
	Electric motor 35 hp	0.343
	Diesel engine	0.581
	Tractor 45 hp above	16.416
	Tractor (others)	10.944
	Self-propelled combine	171

Source: Nassiri and Singh (2009)

Table 2.3 Energy coefficients for producing and repairing agricultural machines

Equipment	Energy (MJ/kg)
Tractor	180
Moldboard plough	138
Chisel plough	149
Heavy duty disc	149
Field cultivator	149
Spring tine harrow	149
Rotary cultivator	148
Combine tillage	180
Air seeder	133
Grain drill	133
Fertilizer spreader	129
Boom type sprayer	129
Harvester	116

Source: Kitani(1999)

2.7 Chemical Energy

Energy components in agricultural chemicals are derived majorly from manufacture, packaging, and transporting (Stout, 1990; CIGR, 1999; Kitani, 1999). Agricultural chemicals are mostly formulated in powder, oil or granules (Kitani, 1999). Most of the raw materials used in chemical productions were obtained from petrochemical industries. Chemical energy takes the most significant share of energy inputs in crop production (Stout, 1990). Average chemical energy in chemical fertilizers is usually estimated as a percentage of Nitrogen (N), Phosphorus (P_2O_5) and Potassium K_2O constituents. Energy equivalents of chemical fertilizers, from the literature, are 66.14 MJ/kg, 17.44 MJ/kg and 13.72 MJ/kg respectively (Rafiee *et al.*, 2010; Mobtaker *et al.*, 2012; Demircan *et al.*, 2006). Chemicals are also used in agricultural production purposely to safeguard crops against insects, pest and weeds attack. Energy coefficients of herbicides, fungicides and pesticides are 238, 216 and 199 MJ/kg respectively (Mushtaq *et al.*, 2009; Zangeneh *et al.*, 2010).

2.8 Seed Energy

Agricultural crops may be bulbs, seeds or tubers. However, there is little or no information in the literature about energy requirements for seed production (Kitani, 1999). Farmers buy seeds which are available in different packages from agro stores or seed producer companies. However, some farmers use seeds from the previous harvest. Therefore, different amount of energy is required by seeds under these different conditions. Cassava varieties such as TMS 419, TMS 92/0326, TMS 98/0581, TMS 91/02324, TMS 30572, TMS 95/0289, and TME 419 are planted by farmers in Kwara State. Cassava may be planted manually or mechanically but analysis of energy inputs and output in cassava production has not been carried out

consequently, it is has been difficult to determine viable energy inputs in the production processes and plan for conservation.

2.9 Energy Requirements and Conversion Factor

This study involved three major types of energy inputs. They are biological, chemical and physical energies. Crop production energy inputs may be from animal labour, chemicals (fertilizers and pesticides), human labour, machinery power, fossil fuel, water and seed. Each of the input has its own constituent energy equivalent. Physical units of these inputs and corresponding output were converted into energy units by using the respective energy equivalents.

2.10 Energy Input and Output Ratio

Energy ratio (also known as energy use efficiency) is defined as the ratio of energy output of the production to energy input (Singh *et al.*, 1999). Pimentel *et al.* (2002) defined it as an inverse of multiplication of energy output and all energy inputs (direct and indirect) (Mobtaker *et al.*, 2012). Energy ratio has been extensively used by researchers to estimate energy efficiency in agricultural production systems.

Energy ratio, energy productivity, specific energy and net energy gain can be determined by using Equations (2.1) – (2.3) (Singh *et al.*, 1999; Dermican *et al.*, 2006; Chamsing *et al.*, 2006; Bautista and Minowa, 2010; Mohammadi and Omid, 2010; Zangeneh *et al.*, 2010; Ghorbani *et al.*, 2011; Banaeian and Namdari, 2011; Mobtaker *et al.*, 2012):

$$\text{Energy ratio} = \frac{\text{Energy output (MJ / ha)}}{\text{Energy input (MJ / ha)}} \quad (2.1)$$

$$\text{Energy productivity} = \frac{\text{Cassava output}}{\text{Energy input}} \text{ kgMJ}^{-1} \quad (2.2)$$

$$\text{Net energy} = \text{Energy output} - \text{Energy input} \text{ (MJ ha}^{-1}\text{)} \quad (2.3)$$

Table 2.4Data to calculate energy sequestered and energy required in field operations

Power source	Unit weight (kg)	Energy for R & M (%)	Fuel (L/h)	Working hour/ day	Annual usage	
					days/yr	h/yr
Moldboard plough	50	0.97	2.1	6	10	60
Power tiller	350	0.61		6	70	420
2 disc plough	70	0.97		6	10	60
Comb harrow	75	0.61		6	20	120
4W tractor (<45 hp)	915	0.61	8	8	40	320
3 disc plough	265	0.97		8	20	160
Disc tiller (5 discs)	450	0.97		8	20	160
4W tractor (>45 hp)	2600	0.61		8	60	480
3-4 disc plough	315	0.97		8	40	320
Disc tiller (7 discs)	578	0.97		8	40	320
Irrigation pump	150	0.37		4	30	120
Power sprayer	12	0.37		6	30	180
Thresher (8 hp)	800	0.3	10.8	8	30	240
Thresher (50 hp)	1000	0.3		8	30	240
Thresher (90 hp)	1200	0.3		8	30	240
Rice combine	5700	0.61		6	90	540

Source:Chamsing *et al.* (2006)

2.11 Modeling of Crop Yields

Models are mathematical representations of a concept or system. Models are also described as a set of equations which represent the behavior of a particular system, with the intention of understanding and improving the performance of that system (Martin, 2016). Patricia *et al.*, (2007) concluded that modeling is the use of equations or sets of equations to represent the behaviour of a system. Researchers in developed countries have developed models useful for predicting yields (Kenneth and Okunade, 2008). Safa (2011) noted that as models have been developed to solve biological, ecological, and environmental problems and can be used to predict output, classify data, and understand processes.

Use of yield models is increasingly gaining acceptability among farmers and scientists (Kenneth and Okunade, 2008; El-Sharkawy, 2011; Safa, 2011). Models have been used by researchers to characterize and estimate crop yields under different conditions. Scientists are now using various types of models to understand management and monitoring irrigations and drainage systems (Olakulehin and Omidiora, 2014; Kenneth and Okunade, 2008). Furthermore, crop models help researchers to understand the effects of increased crop yields on soil fertility. Crop models have enhanced the understanding how certain actions taken by farmers performance influenced the performance of farms (Basso *et al.*, 2010; Shahram, 2014; Olakulehin and Omidiora, 2014; Radha, 2015). Modeling is a logical procedure for foretelling outcomes of a process or circumstances that have not been observed before. Modeling as a decision tool helps farmers to know the appropriate steps that should be taken in order to obtain increased yield (Olakulehin and Omidiora, 2014; Radha, 2015).

Yield crop modeling can be useful to scientists in defining research priorities (Van *et al.*, 2013). When a researcher is using a model to estimate the importance and effects of certain

parameters, he can observe factors that should be studied in future research so as to increase the understanding of the system (Van *et al.*, 2013). Crop models have long been used to unravel physiological processes that influence crop yield with respect to the environment (Martin, 2016). In a global context, need to enhance productivity and yield gap analysis are requisite to define useful crops, soil and management factors to properly prioritize research and interventions and to provide an agronomic basis to model assessing food security and land use at different scales (Van *et al.* 2013).

2.11.1 Crop yield simulation models

Crop yield simulation models (CYSM) are mathematical descriptions of crop development, growth and yield as functions of inputs, soil conditions, management practices and weather (Kazeem and Razaq, 2015). CYSM can be used to understand the pattern of crop growth and crop yield from different farms and they have enhanced a deeper understanding of crop physiological processes and evaluation of effects of agronomic practices. These crop yield simulation models may not be able to express some important factors such as diseases, insects, tillage, phosphorus, and weeds because they are only approximations of the real situations (Jones *et al.*, 2003).

Generally, models are classified into simple mechanistic models and complex mechanistic models. Simple models use statistical information on climate and previous yields over a number of years to estimate yield. A simple model also gives little details about the soil-plant system. Complex mechanistic models require a large amount of input data in order to provide detailed information about the soil-plant-atmosphere system (Basso *et al.*, 2010; Kazeem and Razaq, 2015).

Models are also classified into deterministic and stochastic. Deterministic models are used to describe component processes as logical relations and often behave in a fairly predictable way. These can produce specific results for a given condition if all plants and soil within the simulation space are assumed to be uniform. Deterministic models are further classified into three types: functional, mechanistic and statistical (Shahram, 2014; Martin, 2016). Stochastic models are useful when the correctness of information is not certain. Stochastic models are capable of producing results that include uncertainties in the simulations. These uncertainties may be due to spatial variability of abiotic and biotic factors, soil properties, weather conditions that were not accounted for in a deterministic model. Acantara (2012) inferred that crop growth is generally regarded to be stochastic than deterministic because agroecosystem components parts are heterogeneous.

2.11.2 Application of statistical models in agricultural production

Statistical models have been used for large-scale crop yield simulations. Crop yields over many years were regressed onto time to determine the pattern of crop yields (Bharat *et al.*, 2006). Application of statistical models in agricultural production has contributed to management of agricultural inputs especially the use of fertilizers. Lobell *et al.* (2011) applied a statistical model to determine implications of climate change and weather variability on corn yield in five Midwestern states in the USA and later used Crop Stress Index (CSI) to incorporate climate effects. This approach consequently has notably enhanced predictions of corn and soybean yields in the USA. Lobell *et al.*, (2008; 2011) applied model to ascertain the effects of change in temperature on maize yield and concluded that increase in temperature contributed to a reduction in yield.

Prior knowledge of the functional form relationship is required for application of a parametric regression method. The method can model most data sets correctly if the knowledge is correct (Lobell *et al.*, 2011; Shahram, 2014; Rueda-Ayala *et al.*, 2015). Parametric linear models are commonly employed to describe the relationship between dependent variables and explanatory independent variables (Shahram, 2014).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Area

Kwara State is located in the North Central part of Nigeria with Ilorin as its capital city and it is between latitudes $8^{\circ}41' N$ and $10^{\circ}41' N$ and longitudes $4^{\circ}51' E$ and $6^{\circ}51' E$ (Adeyemi and Yusuf, 2015). It covers a total land area of about 32,825 km² and shares boundaries with Kogi, Niger, Osun, Oyo, and the Republic of Benin. Figure 3.1 shows the study areas. The study area is located in the southern parts of the tropical savannah zone of Nigeria. The Raining season usually starts at the end of March or early April till late October while dry season (harmattan) commences from early November till early March. Olanrewaju, (2009) inferred that Kwara state lies within tropical climate region with double rainfall maxima and tropical dry and wet climate. Mean annual temperature of Kwara State ranges between 31.5°C and 35°C (Oladimeji and Abdulsalam, 2013). Relative humidity during wet season is between 70 to 80% and about 65% during dry season. Sun shines brightly for approximately 9 hours daily beginning from November to May (Akpenpuun and Busari, 2013).

Wooded Guinea savannah vegetation of the State is well suitable for cultivation of different types of crops such as cassava, cowpea, yam, maize, fruits, and vegetables. Cassava is one major crop produced in all the Agricultural Development Program (ADP) zones in Kwara state (Fakayode *et al.*, 2008; Matanmi and Adesiji, 2009; NCRI, 1997). Kwara State is blessed with an abundant expanse of arable and rich fertile soils. This has encouraged a larger percentage of the rural populations to engage in agricultural production.

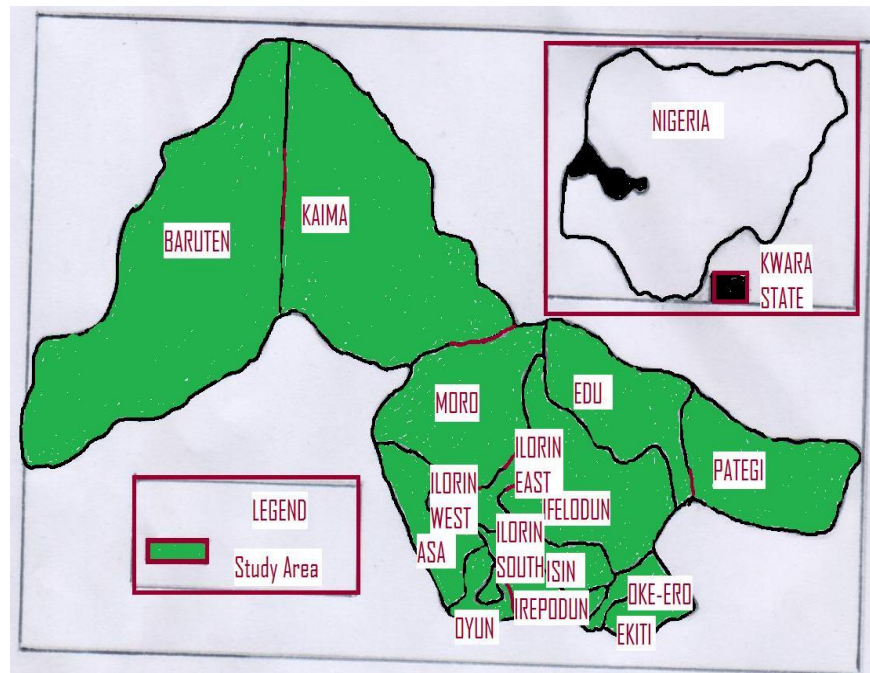


Figure 3.1: Map of the study area

3.2 Data Collection and Sampling Procedure

Data from cassava farms were collected through primary and secondary sources. Primary data was collected through site visits, interaction with farmers and physical measurements for three consecutive cropping seasons (2013/2014, 2014/2015 and 2015/2016). Questionnaires were administered to farmers to collect primary data. The questionnaire (Appendix A) was structured to cover background information of the selected farms, management techniques, tillage operations, types of machinery used, weeding/fertilizer application, harvesting operation, and tractor operators/repair and maintenance. The questionnaire also included information on the socio-economic characteristics of the farmers such as age, gender, level of education, hired or family labour, size of land, and management. Secondary data were principally collected from Kwara State Ministry of Agriculture and Natural Resources (MOANR) and Kwara State Agricultural Development Projects (KWADP). Other secondary data was based on literature.

Agricultural Development Project (KWADP) divided Kwara State into four agricultural zones (Zones A-D) based on agro-ecological and cultural characteristics as presented in Table 3.1 (Oyeleke *et al.*, 2004; Matanmi and Adesiji, 2009). The study sample was spread across the Local Government Areas (LGAs) in zone D which comprises of Ifelodun, Irepodun, Offa, Oyun, Oke – Ero, Ekiti and Isin. The sampling procedure was based on a multi-stage household sampling procedure as described by Abubakar and Ahmed, (2010), Oladimeji and Abdulsalam, (2014) and Oladimeji *et al.*, (2016).

The study was conducted in 7 LGAs of zone D (Table 3.2). The LGAs were purposely selected because cassava is one of the prominent crops produced by the farmers in the areas. The first stage of data collection involved a random selection of four communities from each LGA in zone D. Second stage comprised a selection of ten cassava farmers from each of the four communities

identified in stage one. A total of two hundred and eighty (280) cassava farms were selected for this study (Table 3.2).

Cassava farms in this study were categorized into small, medium and large-scale farmers. There are no specific definitions for small-scale, medium and large-scale farmers (FOS, 1999; Olufunmilayo, 2011; Mgbenka *et al.*, 2015). For this study, categorization was based on size of farm holdings, types of farming (subsistence or commercial), access to loan facilities, level of farming technology (mechanization) and method of processing. Group I, (small-scale), consisted of cassava farmers who cultivated 1 to 5 hectares and used mostly crude (rudimentary) implements such as hoes and cutlasses for production processes (no mechanization), Group II (medium-scale) cultivated 6 to 15 hectares and III (large-scale) farmers used 16 to 50 hectares for cassava production. Groups II and III farmers owned or rented machinery such as tractor and adopted modern management practices.

Data collected was based on the energy inputs resources used in the selected farms for cassava cultivation from land preparation to harvesting. Amounts of inputs used were determined per hectare and were multiplied with a coefficient of energy equivalent. Energy inputs for cassava production were determined by adopting energy equivalents shown in Table 3.3.

Data sets (Appendix B) were analyzed using version 3.3.4 of the R software for statistical computing and graphics. Basic descriptive statistical methodologies were applied to discover important information on cassava production in the study area. Yield predicting models will be developed to predict future cassava output using specific energy requirement. For data analysis; energy efficiency, specific energy, and energy productivity of cassava crop production were determined on a per hectare basis using equations suggested in the literature.

Table 3.1: Kwara ADP Zones

ADP ZONE	LGA
A	Kaima
	Baruten
B	Patigi
	Edu
C	Asa
	Ilorin
	West
	Ilorin
	South
	Ilorin
	East
	Moro
	Isin
D	Ifelodun
	Irepodun
	Offa
	Oyun
	Oke Ero
	Ekiti
	Isin
Total	16

Source: Kwara State Min. Agric. Kwara State (2013)

Table 3.2 Sample outlay for the study

LGA	Selected Communities	No. of farmers
Offa	Ago – Mogaji	10
	Ilemona	10
	Ira	10
	Igbo – Idun	10
Irepodun	Oke- Igbala	10
	Omu – Aran	10
	Ipetu – Igbomina	10
	Oro	10
Oyun	Ago – Offa	10
	Ajebandele	10
	Igosun	10
	Ipee	10
Ekiti	Eruku	10
	Osi	10
	Obbo – Ile	10
	Isale opin	10
Oke Ero	Ayedun	10
	Erinmope	10
	Ekanmeje	10
	Ilale	10
Ifelodun	Igbaja	10
	Omupo	10
	Amoyo	10
	Ajase Ipo	10
Isin	Eleyin	10
	Edidi	10
	Oko	10
	Oke Onigbin	10
Total	28	280

Source: Field survey (2013)

Mechanical energy used on the investigated cassava farms included tractors and diesel fuel. The mechanical energy was calculated based on the total amount diesel fuel (Lha^{-1}) consumed in different operations. Therefore, energy consumed was determined by using the conversion factor ($1 \text{ L diesel} = 48.7 \text{ MJ}$) and expressed in MJha^{-1} (Singh *et al.*, 2002; Khan *et al.* 2004; Ozkan *et al.* 2004a; Canakci *et al.* 2005; Hatirli *et al.* 2006; Zangeneh *et al.*, 2010; Ghorbaniet *al.*, 2011; Mobtaker *et al.*, 2012; Samavastean *et al.*, 2011).

3.3 Energy Equivalents of Inputs and Output

The energy equivalent of human labour is the muscle power used in field operations during crop production. Chemicals and chemical fertilizers energy equivalents refer to energy used for producing, packing and distributing the materials. They are computed on the basis of an active ingredient basis. Farmyard manure is a source of nutrients, therefore, the energy equivalent of farmyard manure is considered as that of mineral fertilizers.

Energy sequestered in diesel fuel is the heating value (enthalpy) and the energy needed to make their energy available directly to the farmers. Seed energy input is the energy used in the production of a crop (Kitani, 1999). Table 3.3 shows energy equivalents of inputs and output adopted for this research. The energy equivalent values of some crop are presented in Table 3.4.

Table 3.3Energy equivalents of inputs and output in cassava production

Variables	Unit	Energy equivalent (MJ)	Source
Inputs			
Human labour			
Man	Man-h	1.96	Mobtaker <i>et al.</i> , 2012
Woman	Woman-h	1.57	Mobtaker <i>et al.</i> , 2012
Machinery	Kg	62.7	Kizilaslan, 2009
Diesel fuel	L	47.8	Heidari and Omid, 2010
Total fertilizer			
Nitrogen	Kg	66.14	Rafiee <i>et al.</i> , 2010
Phosphate	Kg	17.44	Mobtaker <i>et al.</i> , 2012
Potassium	Kg	13.72	Mobtaker <i>et al.</i> , 2012
Chemicals			
Pesticides	Kg	199	Zangeneh <i>et al.</i> , 2010
Herbicides	Kg	238	Zangeneh <i>et al.</i> , 2010
Fungicides	Kg	216	Zangeneh <i>et al.</i> , 2010
Cassava sticks	Kg	5.6	Pimentel, 1999; Dermircan <i>et al.</i> , 2006

Table 3.4: Energy equivalent values of some crops

Crop	Energy equivalent (MJ/kg)
Rice	14.7
Maize	14.7
Sugarcane	2
Cassava	5.6
Soybean	2.5
Wheat	14.7

Source: Mittalet *al.* (1992)

3.4 Computation of Parameters

3.4.1. Evaluation of manual energy input

Manual labour input was converted into energy units by multiplying the number of total human labour (family members and/ or hire workers) with the number of working hours and energy coefficient. The energy equivalent of an average adult male has been given as 1.96 MJ/h and 1.57 MJ/ha for an adult woman (Ibu and Adeniyi, 1989; Nassiri and Singh, 2009; Mobtaker *et al.*, 2012).

Manual energy input (MJ/ha) in cassava production was estimated by using Equation (3.1).

$$M_{EI} = \frac{NT_a \times E_{eqv}}{Planted\ area} (MJ/ha) \quad (Ullah, 2009) \quad (3.1)$$

Where;

M_{EI} = Manual energy input (MJ/ha)

N = Total human labour

E_{eqv} = Energy input of an average adult male, MJ/ha

T_a = Productive time spent by a worker on an operation, h.

But,

T_a = Total time spent by a worker - T_r

T_r = Required resting period of the workers, h

$$T_r = 60 \left(1 - \frac{250}{P} \right) (Olaoye \text{ et al.}, 2017) \quad (3.2)$$

Where;

P = Average power expended by the worker in watt. P is a standard value depending on the farm activity carried out by the worker at a particular time.

3.4.2 Mechanical energy input

Direct energy input from machines was determined by estimating the amount of diesel fuel used during cassava production operations. The quantity of diesel fuel used to refill the tank was taken as the quantity consumed during each operation. Diesel fuel energy, E_D , was estimated using Equation (3.3):

$$E_D = D \times E_{eqv}. \text{(Mobtaker et al., 2012)} \quad (3.3)$$

Where;

D = Amount of diesel fuel consumed, liters

E_{eqv} = Unit energy value of diesel, MJ/L

Machine energy input was determined based on the weight of the machine, lifespan, effective field capacity of the machine and energy equivalent. Machine energy input was determined by using Equation (3.4);

$$M_E = \frac{W \times E_{eqv}}{T \times E_{FC}} \quad (\text{MJ/ha}) \quad (\text{Bamboye and Babajide, 2015}) \quad (3.4)$$

Where;

M_E = machine energy input (MJ/ha),

W = weight of implement (kg),

E_{eqv} = manufacturing energy of the agricultural machines (MJ),

T = economic life of implement (h), and

E_{FC} = effective field capacity (ha/hr).

Total mechanical energy input was determined using Equation (3.5):

$$E_M = E_D + ME_{tractot} + ME_{implement} \quad (3.5)$$

3.4.3 Pesticides, herbicides energy inputs

Boom sprayer mounted on a tractor was used to apply pre-emergence herbicide after planting operation in some large-scale farms. The energy equivalent of the chemicals was estimated using Equation (3.6)

$$C_{EI} = \frac{H_{ar} \times H_{Eqv}}{A_p} \text{ (MJ/ha)} \quad (\text{Ullah, 2009; Bamgboye and Babajide, 2015}) \quad (3.6)$$

Where;

H_{ar} = Application rate (kg) of herbicide

H_{Eqv} = Energy equivalent (MJ/kg) of herbicide applied

A = Application area (ha)

3.4.4 Biological energy inputs

Cassava setts used were considered as the biological energy input. Equation (3.7) was adopted to estimate biological energy input in cassava production.

$$S_E = S_a \times E_{eqv} \text{ (MJ/ha)} \quad (\text{Ullah, 2009}) \quad (3.7)$$

Where;

S_a = seed used, kg/ha

E_{eqv} = energy equivalent, (MJ/kg)

3.5 Evaluation of Energy Ratio

Energy use efficiency and other energy indices for each cassava farm were calculated by using Equations (2.1) – (2.3).

3.6. Experimental Design

3.6.1 Model development for cassava yield

A mathematical function is required to explore the correlation between energy inputs and cassava yield. Several production functions were tried for this purpose before Cobb-Douglass production function was adopted as the best function with respect to statistical significance and expected signs of parameters. The Cobb-Douglass production function is expressed as presented in Equation (3.8) (Hatirli *et al.*, 2005; Mohammadi *et al.*, 2010; Heidari and Omid, 2011):

$$Y_i = f(x) \exp(u) \quad (3.8)$$

Eq. (3.8) can be expressed as Eq. (3.9);

$$\ln Y_i = a + \sum_{j=1}^n \alpha_j \ln (X_{ij}) + e_i \quad i = 1, 2, 3, \dots, n \quad (3.9)$$

Where;

Y_i = yield of the i^{th} farmer

X_{ij} = vector of inputs used in the production process,

α = constant term

α_j = coefficients of inputs which are estimated from the model,

e_i = error term

It was assumed that cassava production is also zero if energy input is zero; Eq. (3.9) becomes Eq. (3.10);

$$\ln Y_i = \sum_{j=1}^n \alpha_j \ln (X_{ij}) + e_i \quad i = 1, 2, 3, \dots, n \quad (3.10)$$

Assuming that cassava yield is a function of all energy inputs, Eq. (3.10) becomes Eq. (3.11);

$$\ln Y_i = \alpha_1 \ln (X_1) + \alpha_2 \ln (X_2) + \alpha_3 \ln (X_3) + \alpha_4 \ln (X_4) + \alpha_5 \ln (X_5) + \alpha_6 \ln (X_6) + e_i \quad (3.11)$$

Where;

Y_i = Cassava yield

X_1 = Human labour energy input

X_2 = Machinery energy input

X_3 = Fuel energy input

X_4 = Chemicals energy input

X_5 = Fertilizer energy input

X_6 = Cassava stem energy input

e_i = error term

To establish the level of correlation between cassava yield and energy types, Cobb-Douglass function was applied to explore the effect of direct, indirect, renewable and non-renewable energies as presented in Equations (3.12) and (3.13);

$$\ln Y_i = \beta_1 \ln (DE) + \beta_1 \ln (IDE) + e_i \quad (3.12)$$

$$\ln Y_i = \lambda_1 \ln (RE) + \lambda_1 \ln (NRE) + e_i \quad (3.13)$$

Where;

Y_i = Cassava yield

DE = direct energy input

IDE = indirect energy input

β_i, λ_i = coefficients of variables

e_i = error term

Eq. (3.9) – (3.13) were estimated by using the Ordinary Least Squares technique. Data on energy inputs and cassava yield were entered into Excel 2010 and simulated using SPSS 19 software and analyzed.

3.6.2 Model assumptions 1:

The basic assumptions of this parametric model were;

- i. predictors (input variables) are independent and are not highly correlated (or associated).
- ii. each input variable has a meaningful association (correlation) with the output variable (cassava yield)
- iii. model residuals assume a normal distribution.

All data and model assumptions will be tested for validity in order to achieve reliable and adequate inference from the study using version 3.3.2 of the R software.

3.6.3 Justification for least squares regression methods

The justification for the choice of multiple linear regression models in this study centers on research interest to answer the following important questions about the relationship between cassava yield and cassava inputs in Kwara State:

- i. Is at least one of the cassava inputs (human labour, machinery, fuel, chemicals, fertilizer and cassava stem) useful in predicting the cassava yield?
- ii. Do all the cassava inputs affect cassava yield, or is it only a subset of the cassava inputs that affect yield?

- iii. How accurately does the model fit the data?
- iv. Can cassava yield value be predicted given a set of inputs, and how accurate would the prediction be?
- v. Is there a relationship between cassava inputs and cassava yield (output)?
- vi. What is the strength of the relationship between input variables and yield?
- vii. Which of the cassava inputs contribute to yield? Do all the six inputs; cassava stem, chemicals, fertilizer, fuel, human labour, and machinery contribute to cassava yield?
- viii. How accurately can one estimate the effects of each input on cassava yield?
- ix. For any given level of Human labour, machinery, fuel, chemicals, fertilizer or cassava sets, what is the prediction for cassava yield, and what is the accuracy of this prediction?

3.7 Parameter Estimation and Hypothesis Testing

Estimation of all model parameters shall be done using the *stats* library of the R software. The following two research hypothesis was used to test the adequacy of the fitted models for the three farms to their data sets and investigate the significance of the cassava inputs (in terms of effects) in predicting cassava yield in each farm. The former hypothesis test is called the global F test and the latter is called an individual t-test.

One: Is there a relationship between cassava yield and cassava inputs

To answer this question with data evidence in this study, the following hypotheses were tested.

Hypothesis one:

Null hypothesis (H_0): $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$ [All the regression coefficients are zeros]

Alternative hypothesis H_1 : at least one β_j is non-zero.

Test Statistic: $F^* = \frac{\text{Regression Mean Square}}{\text{Error Mean Squares}} = \frac{(TSS-RSS)/p}{RSS/(n-p-1)}$

Decision rule: Reject (H_0) in favour of H_1 at $\alpha = 0.05$ critical rejection region if p-value $\leq \alpha$, otherwise there is not enough data evidence to reject H_0

We will also be interested in testing whether a particular subset q of the coefficients is zero, using following hypothesis two.

Hypothesis two:

Null hypothesis (H_0): $\beta_{p-q+1} = \beta_{p-q+2} = \dots = 0$ [True value/effect of inputs subset q is zero]

Alternative Hypothesis H_1 : $\beta_{p-q+1} \neq \beta_{p-q+2} \neq \dots \neq 0$ [True value/effect of input subset q is not zero]

Decision rule: Reject (H_0) in favour of H_1 at $\alpha = 0.05$ critical rejection region if p-value $\leq \alpha$, otherwise there is not enough data evidence to reject H_0

3.8 Analysis of Cassava Energy Input and Output

Energy inputs and output from the different cassava farms was determined and descriptive analysis, analysis of variance and mean comparison were used to ascertain the energy ratios, specific energy, and energy productivity among the three groups of farms.

Cobb-Douglas function was used to model the relationship between energy inputs and yield. The models were linearized using logarithmic transformations in order to eliminate the presence of heteroscedasticity that is, non-constant variance. The models were estimated using Ordinary least

squares estimator. Durbin Watson test for each of the models shows that the error terms in each of the models do not suffer from the problem of auto-correlated error since the values are approximately two. Also, the Coefficient of determinations (R^2) for each of the models is high which shows that the independent variables explained a high amount of percentage variation in the response variables. The signs of each of the coefficients are not different from the expected signs.

CHAPTER FOUR

RESULTS AND DISCUSSION

This study aimed at analyzing the situation of energy consumption in cassava production and attempted a parametric method to examine energy consumption in cassava production in three farm sizes and technologies in Kwara State, Nigeria. Results are presented in the following sub-sections.

4.1 Management Practices in the Cassava Farms

Management practices for cassava cultivation in the study area along with time periods of these practices are presented in Table 4.1. Small and medium scale cassava farmers employed manual labour mostly for land preparation and planting, weeding, fertilizer application and harvesting. Large-scale farmers used manual labour and machinery for these operations, but during the growing season, machinery was used for only for transportation of harvested cassava crops.

4.1.1 Socioeconomic characteristics of cassava Farmers

Socioeconomic characteristics of cassava farmers in the study area are shown in Table 4.2. It shows that out of 175 cassava farmers that responded to the questionnaires, 93 (53.14%) of the farmers cultivated on small-scale (1-5 ha). This reveals that cassava production in the study area was at subsistence level. There are many factors militating against adoption of mechanization by small-scale farmers. These factors include poor capital, land fragmentation, illiteracy etc. Profits from these small-scale farms will not meet the expenses on machinery and other farm inputs (Adekanye, 2014)

53 (30.29%) had farm sizes ranged between 6 -15 hectares while only 29 (16.57%) cultivated on large-scale (above 15 hectares). Table 4.2 also showed that 136 (77.71%) of the farmers were

males. This suggests that cassava cultivation is a male-dominated activity. Also, the majority (82.86%) of the respondents were within the age bracket 41 - 60 years. This suggests that they belong to the economically active population category. This economically active population can, therefore, put more efforts into cassava cultivation for increased output. 32 (18.28%) of the farmers were single, 98 (56%) were married, and 27 (15.42%) were widowed, indicating that majority of the cassava growers were likely to make use of family labour for their activities. Furthermore, the study shows that 146 (83.42%) of the respondents had some forms of education (primary, secondary, HND/BSc or Non-formal) while 29 (16.57%) had no formal education. The implication of this is that the cassava growers are likely to readily adopt new technology and innovation. The results in Table 4.2 also shows that 62.29% of the households had population ranged between 6 -10 persons and 15.43% of the respondents had population of above 10 persons. The household size, therefore, suggests that respondents were likely to enjoy family labour readily. Family size will determine the amount of labour engaged in cassava cultivation. Further analysis revealed that 61.14% of the respondents have other jobs apart from farming. This suggests that they had other sources of income and this is likely to affect the length of time that they devote to farming. Cassava farmers produced other crops like maize, vegetables, millet, rice, yam, cowpea, sorghum, etc.

Table 4.1: Management practices of cassava farms in the study area

Operation	Small scale farms	Medium scale farms	Large scale farms
Name of varieties	TMS 419	TMS 419	TMS 419
Land preparation period	February -March	February-March	February-March
Ploughing	Nil	Moldboard plough,	Moldboard plough,
Harrowing	Nil	Disc harrows	Disc harrows
Tractor used	Nil	MF 55hp	MF 55hp, MF 75hp
Planting time	April – August	April – August	Late March- Early September
Planting method	Manual	Manual	Manual, planter
Fertilizer and pesticide application	Manual (knapsack sprayers)	Manual (knapsack sprayers)	Manual and Boom sprayer
Weeding	Manual (cutlass and hoe)	Manual (cutlass and hoe)	Manual
Harvesting	Manual (cutlass)	Manual (cutlass)	Manual (cutlass), Harvester

Table 4.2: Socio – economic characteristics of cassava farmers

Variable	Frequency	Percentage
-----------------	------------------	-------------------

	(n =175)	(%)
Gender		
Male	136	77.71
Female	39	22.29
Marital status		
Single	32	18.28
Married	98	56
Divorced	18	10.29
Widow/widower	27	15.42
Age		
21-30 years	9	5.14
31-40 years	17	9.71
41-50 years	76	43.43
51-60 years	69	39.43
Above 60 years	4	2.29
Level of education		
Primary	91	52
Secondary	38	21.71
HND/B.Sc	17	9.71
Non-formal	29	16.57
Family size		
1-5	39	22.29
6-10	109	62.29
11 and above	27	15.43
Farming experience		
1-5 years	25	14.29
6-10 years	40	22.86
11-15 years	32	18.29
16-20 years	35	20
21-25 years	27	15.43
Above 25 years	16	9.14
Farm size		
1-5 hectares	93	53.14
6-15 hectares	53	30.29
16 – 50 hectares	29	16.57
Means of land acquisition		
Purchased	35	20
Inherited	103	58.86
Gift	12	6.86
Leased	25	14.29
Occupation		
Farming alone	68	38.86
Farming/trading	51	29.14
Farming/ public service	22	12.57
Farming/civil service	34	19.43

Source: Field survey (2013)

4.2 Analysis of Energy Consumption in Cassava Production

Table 4.3 shows the average amount of inputs used in the cassava farms and the corresponding outputs. Energy equivalents of input and output per hectare in the three farm sizes and technologies are presented in Table 4.4. It was observed from Table 4.4 that total energy used during field operations and energy output was 74,999.62 and 672,000 MJha⁻¹ respectively. Total energy input for various processes in small-scale, medium-scale and large-scale farms were calculated to be 6673.21, 36352.04 and 96257.93 MJ ha⁻¹ respectively. In similar studies, Bamgboye and Babajide (2015) obtained 7,388.6 MJha⁻¹ from a study of ten (10) small scale cassava farmers in Oyo State, Nigeria while (Chamsing *et al.*, 2006) reported 4950 MJha⁻¹ for cassava production in Thailand. Pishgar-Komleh *et al.*, (2012) concluded that input and output energy of potato production in Iran was 47,000 and 79,300 MJha⁻¹ respectively. In Table 4.3, energy input and output was observed to vary from one farm to another. This variation was caused majorly by the different amount of biological and chemical energy inputs, and the difference in the method of equipment acquisitions (Bamgboye and Babajide, 2015).

Table 4.4 also shows the distributions of different energy inputs in cassava production in the three farm sizes. It showed that energy equivalent of 120 MJ ha⁻¹ of human power was required to cultivate a hectare of cassava in the small-scale farms. Medium-scale farms required 162 MJha⁻¹ while large-scale farms required 164 MJ ha⁻¹ of human power. Machine power used in medium and large-scale farms was 130 and 123 MJ ha⁻¹ respectively. In a study conducted by Bamgboye and Babajide (2015), human labour varied between 90.56 and 421.5 MJ ha⁻¹. It has been reported that low energy inputs result to lower yields while high energy input will increase the amount of fertilizers and fuel consumed by machineries (Woods *et al.*, 2010).

Results in Table 4.4 also revealed that energy equivalent of 7,472.57 and 13,527.4 MJha⁻¹ of diesel fuel was used in medium-scale and large-scale farms. Energy input in diesel increased in medium and large-scale farms because many farmers in these groups used more machinery while farmers in small-scale category did not. Diesel was required to power the machinery for field operations like ploughing, harrowing and ridging. And sometimes, a tractor is used to convey farm workers (labourers) and harvested crops. The result also reveals that cassava production in the study area still depends largely on manual labour. Human labour was mostly employed for land preparation, planting operations, weeding operations, chemical/fertilizer applications and harvesting operations.

Figure 4.1 shows the average energy inputs and average energy output in the cassava production. Figure 4.2 shows cassava yields in the three farm sizes and technologies. It was observed that even though small-scale farms were by far more than farms in the other groups, total energy inputs, yield and corresponding energy output was low compared with medium and large-scale cassava farms. This is because farmers in small-scale group did not use machinery, diesel fuel and fertilizers which contribute to increase in energy used in medium and large-scale farms. However, statistically the contribution of farm size to cassava yield was non-significant at 5% significance level. This means that the farm size had no significant effect on the yield as cassava yield increased with respect to total energy input.

In small-scale farms, average cassava yield and corresponding energy output were 19, 220 kg ha⁻¹ and 107,632 MJha⁻¹ respectively. Average cassava output in the medium and large-scale farms were 108, 000 and 360,000 kg ha⁻¹ while the energy outputs in these groups were 604,800 and 2,016,000 MJha⁻¹ respectively. Bamgboye and Babajide, (2015) obtained an average yield of 9600 kg from a study of energy inputs in cassava production by ten (10) cassava farmers in

Ogbomosho, Oyo State, Nigeria. This result agrees with the results reported by Olatunbosun (2007).

Table 4.5 presents energy indices and amount of direct energy, indirect energy, renewable energy and non-renewable energy used in cassava production in the investigated farms. Energy use efficiency, energy productivity and net energy of cassava production were calculated using Equations (2.1) – (2.3). Average value of energy use efficiency (energy ratio) was calculated as 16.13, 16.69 and 20.94 for small-scale, medium-scale and large-scale farms respectively. Energy use efficiency increase with farm size which implies that energy was utilized more efficiently in large-scale farms. These agree with the results obtained by Bamgboye and Babajide (2015) and Chamsing et al., (2006). Canakci *et al.* (2005) reported energy ratio of 2.8 for wheat in Turkey. Rajabi-Hamedani *et al.* (2011) obtained 1.25 as energy ratio for potato production. Pishgar-Komleh *et al.* (2012) obtained 1.71 for wheat.

Average energy productivity of the three farm sizes were 2.88, 2.98 and 3.74 kgMJ⁻¹ respectively. This reveals that 3.74 kg of cassava was obtained per unit energy (MJ) in large-scale farms. Hence, large-scale farms can produce 0.52 kg and 0.76 kg output more than small and medium scale farms respectively. It was observed that energy productivity and net energy increased significantly with respect to the size of farms as a result of the level of technology and other characteristics of the three farm categories (Zangeneh *et al.*, 2010).

Table 4.3: Average amount of input and output in the cassava farms

Inputs	<u>Farm size groups (ha)</u>
--------	------------------------------

	Small (1-5)	Medium (6-15)	Large (>16)
A. Inputs			
1. Human labour	61.45	82.65	83.86
2. Machinery	-	2.07	1.96
3. Diesel fuel	-	156.3	283
4. Fertilizers			
a) Nitrogen (N)	3.72	17.45	76.43
b) Phosphate (P205)	10.51	23.74	111.76
c) Potassium (k20)	10.06	30.18	74.56
5. Chemicals			
a) Herbicides	1.49	1.73	1.73
b) Pesticides	1.52	1.67	1.67
c) Fungicides	0.77	1.65	1.65
6. Seed	606.01	13022.41	9481.35
Total inputs	695.53	13339.88	10117.97
B. Output			
Cassava output (kg)	19220	108000	360000

Table 4.4: Average energy inputs and output in cassava production per hectare (MJ ha⁻¹)

Inputs	Farm size groups (ha)		
	Small (1-5)	Medium (6-15)	Large (>16)
Inputs			
1. Human labour	120.44	161.99	164.36
2. Machinery		129.79	122.89
3. Diesel fuel	-	7472.57	13527.4
4. Fertilizers			
Nitrogen (N)	246.04	1154.14	5055.74
Phosphate(P ₂ O ₅)	183.29	414.02	1949.09
Potassium (K ₂ O)	138.02	414.06	1412.47
5. Chemicals			
Herbicides	354.62	411.74	411.74
Pesticides	302.48	332.33	332.33
Fungicides	166.32	356.4	356.4
6. Seed	3393.66	25393.37	72925.5
Total energy input	6673.21	36240.43	96257.93
 Total energy output	 107, 632	 604, 800	 2,016000

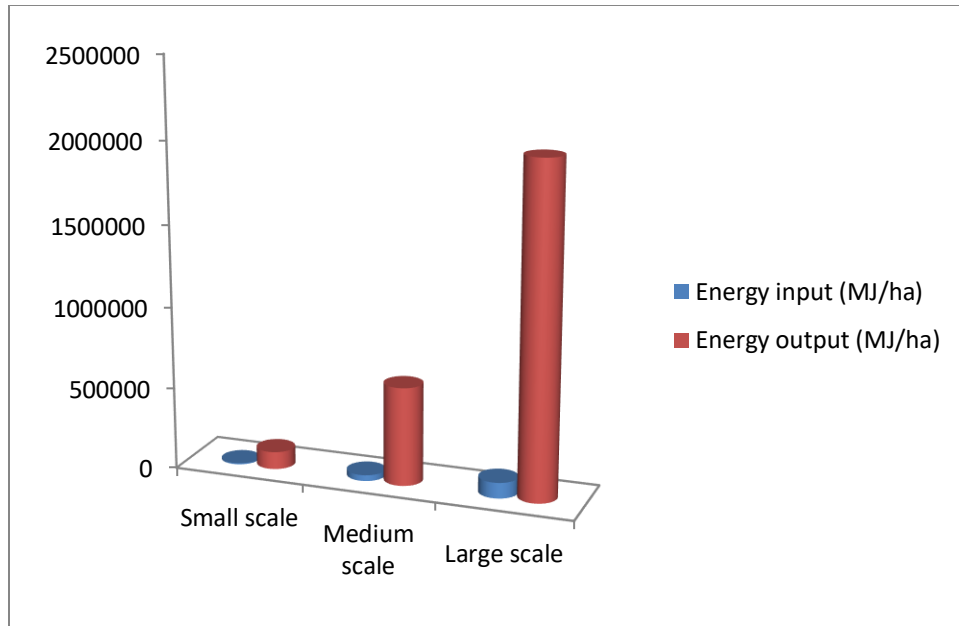


Figure 4.1: Total energy inputs and outputs in cassava production

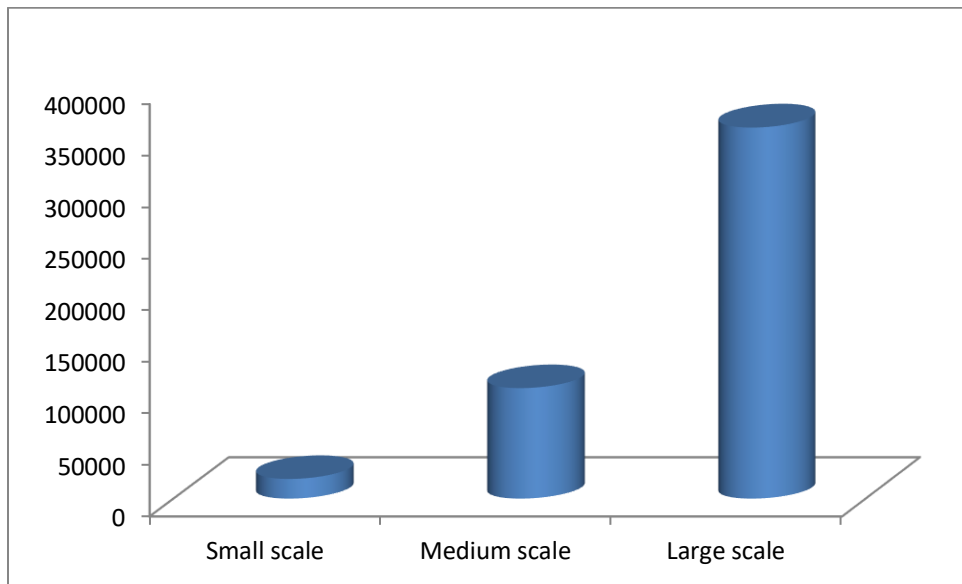


Figure 4.2: Cassava yields in the study farms

Table 4.5 Energy input and output ratio in cassava production

Energy ratio	Unit	Small scale	Medium scale	Large scale
Energy use efficiency	-	16.13	16.69	20.94
Energy productivity	MJha ⁻¹	2.88	2.98	3.74
Net energy	MJha ⁻¹	100959	568560	1919742
Energy forms				
Direct energy ^a	MJha ⁻¹	120	7634.56	13691.8
Indirect energy ^b	MJha ⁻¹	4784.77	28605.9	82566.2
Renewable energy ^c	MJha ⁻¹	3514.1	25555.4	73089.9
Non-renewable energy ^d	MJha ⁻¹	1390.77	10685.1	23168.1
Total energy input	MJha ⁻¹	6673.21	36240.4	96257.9
Energy output	MJha ⁻¹	107632	604800	2016000

Note:

a: includes human labour and fuel

b: includes seeds, machinery, chemicals and fertilizers

c: includes human labour and seeds

d: includes diesel fuel, chemicals, fertilizers and machinery

4.3 Effects of Energy Inputs on Cassava Yield

In an attempt to examine the effects of energy inputs on cassava yield (kg), Cobb-Douglas production function was chosen to investigate the relationship between the energy inputs (chemicals, diesel fuel, fertilizer, human labour, machinery, and seed) as independent variables and cassava yield as dependent variable using ordinary least square technique. Regression analysis results for Eq. (3.11), Eq. (3.12) and Eq. (3.13) as Model I, II and III are presented respectively in Table 4.6, Table 4.7 and Table 4.8 respectively.

Results of regression analysis revealed that the impact of input energy differs in constitution production level in cassava production. It was observed that some energy inputs had positive effects and some had negative impacts on cassava yield. Autocorrelation test was performed using Durbin-Watson test to correlation (Hatirli *et al.*, 2010). The Durbin-Watson values obtained in all the three models were less than 2, implying that there was no autocorrelation at 5% significance level in the estimated model. These results are acceptable with respect to the number of variables, the number of observations, absence of intercept, lower and upper bounds and 0.1% significance level.

4.3.1 Relationship between cassava yield and different energy inputs

Table 4.6 shows the values of coefficients (α_i), t – student (t) and p values. Table 4.6 shows that all the coefficients-human labor, chemical, fertilizer and cassava stem were significant and had positive effects on cassava yield. This implies that the dependent variables of the model in the case of Group I Farms all had positive effects on the energy output. That is, an increase in any of the variables will result in an increase in the energy output. Also, the R-squared value was determined as 0.638 implying that around 0.64 of the variability in the energy inputs was explained by Model I. Durbin Watson Statistic indicates an absence of autocorrelation

at 5% significant level. R^2 value of Group I was observed to be the least. This may be due to the fact that farmers in the group did not use machines and fuel. The yield predictive model is presented in Eq. (4.1);

$$\ln Y_i = 0.078 \ln X_1 + 0.017 \ln X_2 + 0.016 \ln X_3 + 0.945 \ln X_4 + e_i \quad (4.1)$$

Where;

Y_i = Cassava yield

X_1 = Human labour energy

X_2 = Chemical energy

X_3 = Fertilizers energy

X_4 = Cassava stems energy

e_i = error term

For Group II Farms, all the coefficients (human labor, fertilizer, cassava stem, machinery, and fuel) had positive effects on cassava yield except chemical energy input (-0.007). This implies that increase in human labor, fertilizer, cassava stems, machinery and fuel energies will increase the amount of output while an increase in the chemical energy input will result to a decrease in energy output by 0.007%. Table 4.6 shows that contributions of fertilizer, cassava stems and machinery variables were significant at 0.1%, 1% and 5% levels respectively. The R-squared was 0.968 in this case and the Durbin Watson statistic indicates no autocorrelation at 5% significant level. Cassava yield predictive Model is presented in Eq. (4.2):

$$\ln Y_i = 0.017 \ln X_1 + (-0.007) \ln X_2 + 0.259 \ln X_3 + 0.247 \ln X_4 + 0.664 \ln X_5 + 0.173 \ln X_6 + e_i \quad (4.2)$$

Where;

Y_i = Cassava yield

X_1 = Human labour energy

X_2 = Chemical energy

X_3 = Fertilizer energy

X_4 = Cassava stems energy

X_5 = Machinery energy

X_6 = Fuel *energy*

e_i = error term

For Group III Farms, all the coefficients- Human Labor (0.144), Chemical (0.045), Fertilizer (0.028), Cassava Stem (0.271), Machinery (0.271) and Fuel (0.011) had positive effects on cassava production. Human labor and chemical energies were significant at 5% and 0.1% respectively. The variable with the highest impact or significance was cassava setts (considered as seed) followed by machinery. It can, therefore, be inferred that an increase in any of the variables for this Group will lead to an increase in the energy output. The R-squared was 0.926 and the Durbin Watson Statistic indicates no autocorrelation at 5% significant level. The cassava yield predictive model for Group III farms is given as:

$$\ln Y_i = 0.144 \ln X_1 + 0.045 \ln X_2 + 0.028 \ln X_3 + 0.074 \ln X_4 + 0.271 \ln X_5 + 0.011 \ln X_6 + e_i \quad (4.3)$$

Where;

Y_i = Cassava yield

X_1 = Human labour energy

X_2 = Chemical energy

X_3 = Fertilizer energy

X_4 = Cassava stems energy

X_5 = Machinery energy

X_6 = Fuel energy

e_i = error term

Trends of observed and predicted energy output for the model are presented in Figure 4.3, Figure 4.4 and Figure 4.5. The Figures show that there is a significant deviation between the observed and predicted energy output in the cassava production. The energy output predicted by the model was in accordance with the observed energy output at 5% significance level. Therefore, Cobb-Douglas function was considered the best fit relation as also the t-value for the regression coefficients were also significant at 5% per cent level.

4.3.2 Effect of direct energy and indirect energy on cassava yield

Table 4.7 shows the relationship between the cassava yield and direct energy (DE), indirect energy (IDE), renewable energy (RE) and non-renewable energy (NRE). It was observed from Table 4.7 that regression coefficients of DE and RE were positive and significant. In Group I (small-scale) farms, impacts of direct and indirect energies were 0.114 and 0.029, respectively. These results showed that 0.1% increase in indirect energy resulted to 0.029% increase in the yield. The Durbin-Watson statistic was 1.83 at 5% significant level (no autocorrelation) while the R-squared value was 0.721. Table 4.7 also revealed that indirect energy (IDE) had more

impact than direct energy (DE) in group II and group III farms. This result was similar to Hatirli *et al.*, (2005), Mohammadi and Omid (2010).

For Group II farms, both coefficients, DE and IDE were positive with the variable of highest impact being IDE (0.87). Thus, an increase in either variable implies an increase in the energy output. The coefficients of both variables were significant at 5% and 0.1% levels respectively. Durbin-Watson and R-squared value in this model for Group II farms were 1.88 and 0.885 respectively at 5% significant level.

For Group III farms, both coefficients had positive effects on cassava yield. Thus, an increase in either of the variables increased yield. Direct energy was significant at 0.1% level while indirect energy input was significant at 1% level. The Durbin-Watson statistic was 1.86 at 5% significant level showing no autocorrelation while the R-squared was 0.875.

4.3.3 Effects of renewable energy and non-renewable energy on cassava yield

The estimation results of Model III are as presented in Table 4.8. In Group I (small-scale), renewable energy (RE) and non-renewable energy (NRE) were positive. RE had the greatest impact and statistically significant at 0.1% level in group I farms. This means that 0.1% increase in RE or 1% increase in NRE energy inputs resulted to 0.3% and 0.1% increase in cassava yield respectively. The Durbin-Watson statistic was 1.97 at 5% significant level (no autocorrelation) while the R-squared is 0.741.

For Group II farms, renewable energy and nonrenewable energy had positive effects on cassava yield. NRE had greater impact on cassava yield than RE. Thus, an increase in either variable implies an increase in the energy output. The coefficients of both variables

were significant at 5% and 0.1% respectively. The Durbin-Watson statistic was 1.88 at 5% significant level indicating an absence of autocorrelation while the R-squared value was 0.885.

For Group III farms, renewable energy input was significant at 0.1% level while non-renewable energy was significant at 5% level. 0.1% increase in cassava yield was obtained when renewable energy input was increased by 0.1% and 5% increase in non-renewable energy enabled the farmers to increase yield by 0.7%. Thus, an increase in any of the inputs results in an increase in the energy output. The Durbin-Watson statistic was 1.97 implying no autocorrelation at 5% significant level while the R-squared value was 0.838.

Table 4.6: The estimation results for Model I and their coefficients

$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6$									
Model 1:									
Farm	Group I			Group II			Group III		
Independent Variables	α_i	t	$P\ value$	α_i	t	$P\ value$	α_i	t	$P\ value$
Human Labour	0.18	7.523	0.001564 **	0.017	1.879	0.06660	0.144	2.645	0.0148 *
Chemical	0.02	3.264	0.000593 ***	-0.007	-0.784	0.437	0.045	5.45	1.83e-05 ***
Fertilizer	0.016	3.522	0.000682 ***	0.259	7.794	5.97e-10 ***	0.028	0.767	0.4513
Cassava Stem	0.95	9.044	3.33e-14 ***	0.647	3.318	0.0018 **	0.714	0.074	0.4826
Machinery				0.664	2.398	0.0218 *	0.271	1.078	0.293
Fuel				0.173	1.082	0.285	0.011	0.038	0.970
R^2	0.638			0.968			0.926		
Durbin-Watson	1.62			1.88			1.83		

Note:

*** significance at 0.1%, ** significance at 1%, *significance at 5%

Table 4.7: Estimation for model II and their coefficients

$\ln Y_i = \beta_1 \ln DE_i + \beta_2 \ln IDE_i + e_i$									
Model II:	Farm 1			Farm 2			Farm 3		
Farm	β_i	t	$P\ value$	β_i	t	$P\ value$	β_i	t	$P\ value$
Independent Variables									
DE ^a	0.114	0.95	0.335	0.035	2.117	0.0393 *	0.132	12.008	4.13e-12 ***
IDE ^b	0.029	11.54	***	0.872	12.196	***	0.45	2.781	0.00994 **
R^2			0.721			0.885			0.875
Durbin-Watson			1.81			1.88			1.86

Note:

a-includes human labour and diesel fuel energies

b – includes machinery, fertilizer, seeds and chemical energies

*** significance at 0.1%,

** significance at 1%,

* significance at 5%

Table 4.8: Estimation for model III and their coefficients

$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$									
Model III:	Farm 1			Farm 2			Farm 3		
Farm	γ_i	t	$P\ value$	γ_i	t	$P\ value$	γ_i	t	$P\ value$
Independent Variables									
RE	0.298	3.696	0.000376***	0.112	2.61	0.0119 * <2e-16	0.104	10.26	1.24e-10 ***
NRE	0.104	10.906	< 2e-16 ***	0.345	12.9	***	0.725	0.703	0.488**
R^2			0.741			0.893			
Durbin-Watson			1.973			1.83			0.838 1.544

Note:

*** significance at 0.1%,

** significance at 1%,

* significance at 5%

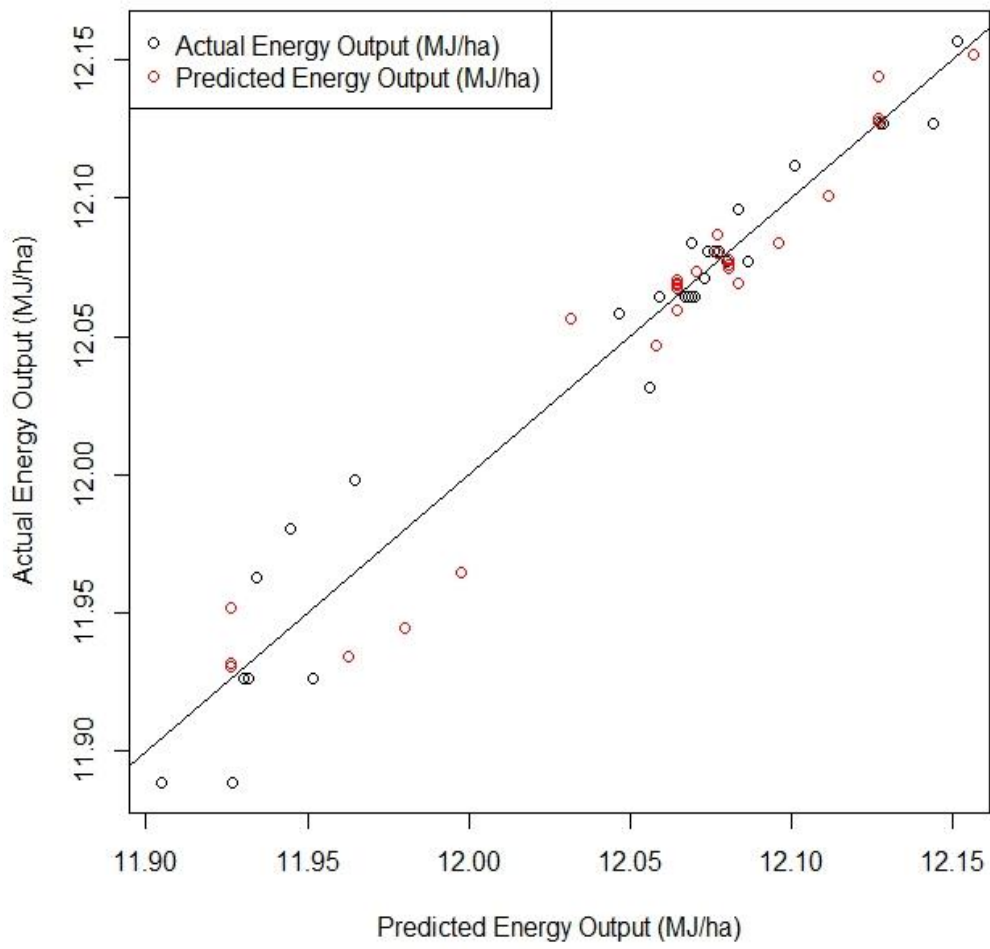


Figure 4.3: Trends of observed and predicted energy output in the small-scale farms

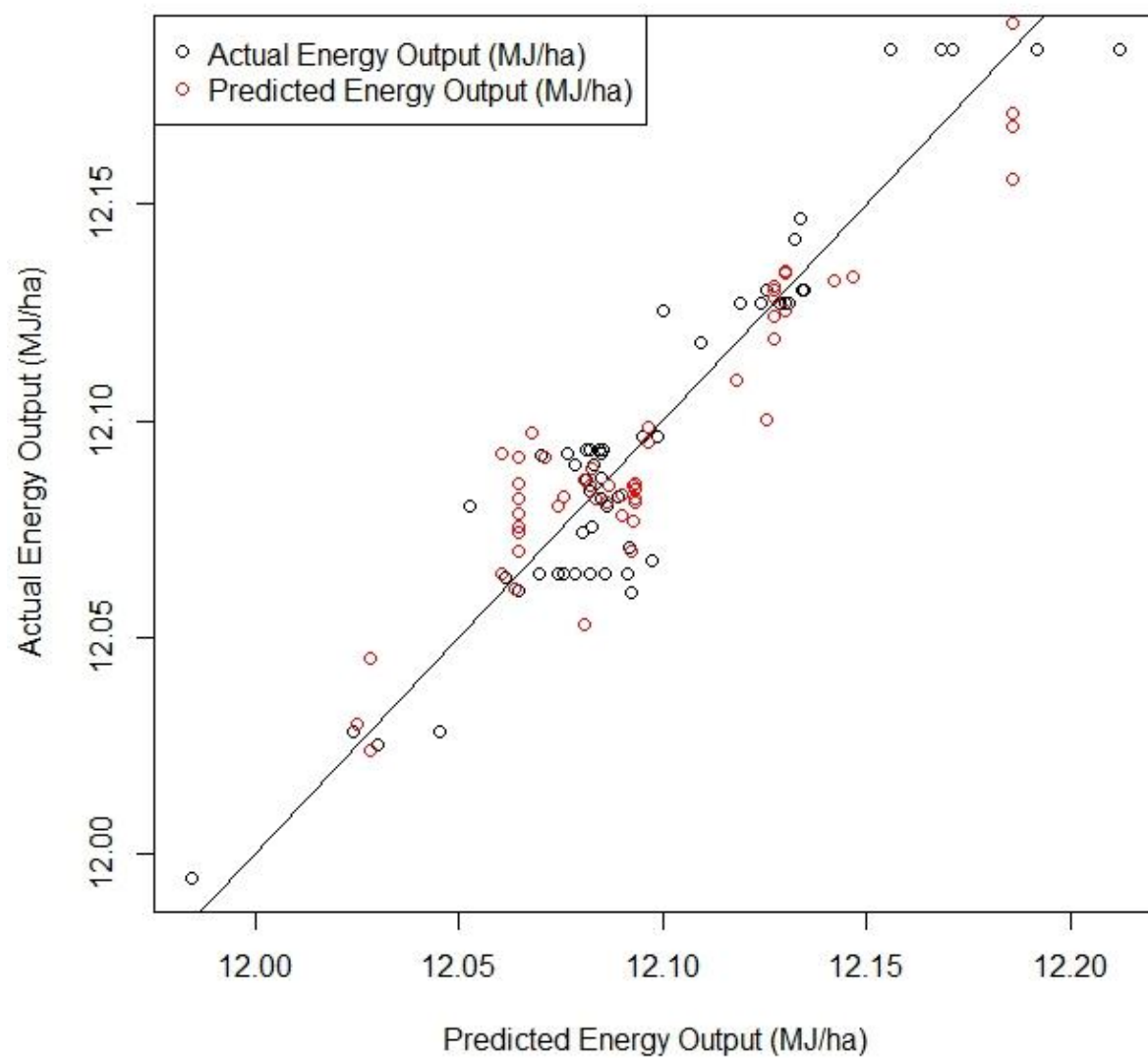


Figure 4.4: Trends of observed and predicted energy output in medium-scale farms

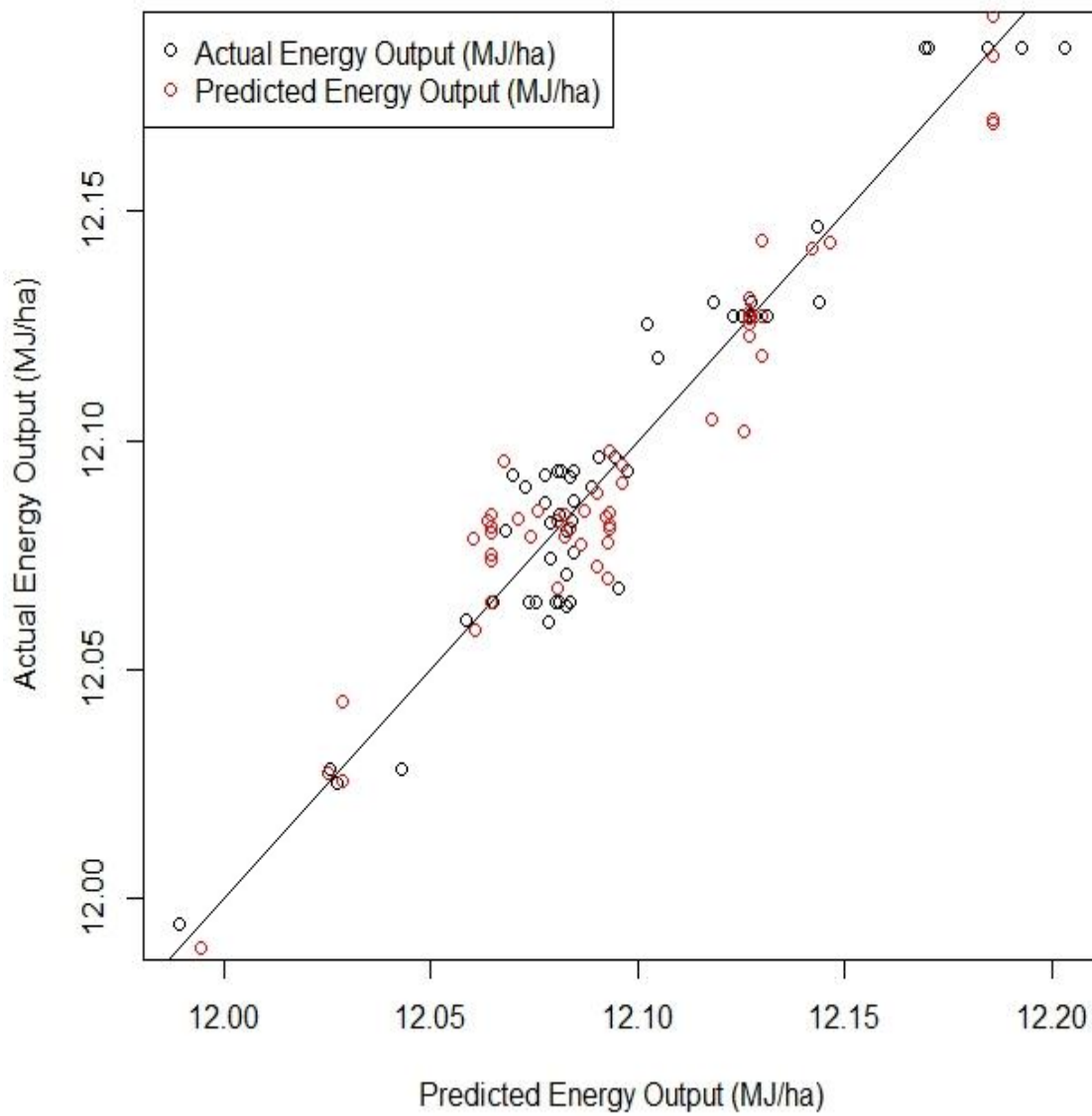


Figure 4.5 Trends of observed and predicted energy output in large-scale farms

CHAPTER FIVE

CONCLUSIONS, RECOMMENDATIONS AND CONTRIBUTIONS TO KNOWLEDGE

5.1 Conclusions

A study was carried out to investigate energy use pattern in cassava production in three farm sizes and technologies in Kwara State, Nigeria and to develop a model for predicting cassava yield using parametric method. Data collected from 175 cassava farms were classified as small-scale (1 to 5 ha), consisted of 92 farms, medium-scale (6 to 15 ha) consisted of 54 farms and large-scale (16 to 50 ha) consisted of 29 farms. The amount for inputs was estimated per hectare and then multiplied with coefficients of energy equivalents. Cobb-Douglas production function and Multiple Linear Regression (MLR) were adopted to develop models for predicting cassava yields. R^2 was used to validate the developed models.

The following conclusions were drawn:

- i. For this study, cassava production consumed a total of 4, 904.87 MJha⁻¹ in Group I farms (small-scale), 36, 352.04 MJ ha⁻¹ in Group II farms (medium-scale) and 96, 257.93 MJha⁻¹ in Group III farms (large-scale).
- ii. Average energy output in cassava production were 107, 632 MJ ha⁻¹, 604, 800 MJ ha⁻¹ and 2, 016, 000 MJ ha⁻¹ in group I, II and III farms respectively.
- iii. Energy use efficiency was 16.13, 16.69 and 20.94 in small, medium and large scale farms respectively.
- iv. Energy productivity for the three group of farms was 2.88 MJ ha⁻¹, 2.98 MJ ha⁻¹ and 3.74 MJ ha⁻¹ while net energy was estimated to be 100, 959 MJha⁻¹ for small-scale farms;

568, 560 MJha⁻¹ for medium scale and 1, 919, 742 MJha⁻¹ for large scale-farms. Large-scale farms utilize energy more efficiently than small-scale and medium-scale farms.

- v. Average values of direct, indirect, renewable and non-renewable energies in the productions were 120 MJha⁻¹, 4784.77 MJha⁻¹, 3514.1 MJha⁻¹ and 1390.77 MJha⁻¹ (small scale farms), 7, 634.56 MJ ha⁻¹, 28, 605.9 MJ ha⁻¹, 25, 555.4 MJ ha⁻¹ and 1, 06, 851.1 MJha⁻¹ (medium-scale farms) and 13, 691.76 MJha⁻¹, 82,566.16 MJ ha⁻¹, 73089.86 MJha⁻¹ and 23168.08 MJha⁻¹ (large scale farms).

- vi. The best of the three yield predictive models developed for predicting cassava yield with model expression;

$$Y = 0.144X_1 + 0.045X_2 + 0.028X_3 + 0.074X_4 + 0.271X_5 + 0.011X_6 + e_i$$

This Model with the highest R² value (0.968) was observed to be the best model for the prediction of cassava yield. It can predict yield with high accuracy and minimum error.

- vii. Impacts of IDE and NRE were higher in medium and large scale farms than that of DE and RE in cassava production. The reverse was the case in small scale farms.
- viii. In small-scale farms, average cassava yield was 19, 220 kg/ha and energy output was 107, 632 MJ/ha. Average cassava output in the medium and large-scale farms was 108, 000 and 360, 000 kg/ha while the energy output in these groups were 604,800 MJ/ha and 2,016,000 MJ/ha respectively.

5.2 Recommendations

From the results of this study, it is recommended that;

- i. Additional use of machinery and increasing mechanization level can help farmers to achieve more cassava yields, particularly in small-scale farms. Cassava production in the

study area still depends largely on manual labour. Human labour was mostly employed for land preparation, planting operations, weeding operations, chemical/fertilizer applications and harvesting operations.

- ii. More researches should be conducted with respect to energy input and output in the production of other arable crops. This will further improve the efficiency of energy inputs in the production of such crops.

5.3 Contributions to Knowledge

This study has made the following contributions to knowledge;

- i. There is presently inadequate research information on the relationship between energy input and crop yields in Nigeria. Energy use in Nigerian agriculture has generally received very little attention from scientists and researchers. This study has contributed to information on energy input and output patterns in cassava production in Kwara State, Nigeria. Efficient energy use in cassava production is one of the requisites conditions for promoting cassava production in Nigeria.
- ii. Cassava yield predictive models developed in this study revealed the level of interaction of various inputs used in cassava production. These simple mathematical equation models for predicting cassava yield will promote cassava production encourage investments in cassava research; facilitate multidisciplinary collaborations and rational policymaking.

The use of models for predicting cassava yield will help a lot of cassava farmers in the in the areas of budgeting during the successive farming season. Prediction of

yield in cassava production is necessary to minimize costs, to achieve more consistent product and to manage different processes. The importance of this study lies in the fact that it will provide farmers with a formula that predicts cassava yields. With this study, cassava farmers will be able to plan properly.

- iii. Results of this study would be useful to cassava farmers in Kwara State and elsewhere with similar soil characteristics and operating conditions.

REFERENCES

- Abubakar, M.S. and D. Ahmed. 2010. Pattern of Energy Consumption in Millet Production for Selected Farms in Jigawa, Nigeria. *Australian Journal of Basic and Applied Sciences.*, 4(4), 665 - 672.
- Acantara, C. K. 2012. Mapping abandoned agriculture with multi-temporal MODIS satellite data. *Remote Sens. Environ.* , 124(1), 334 - 347.
- Adekanye, T.A., S.I Ogunjimi. and A. O. Ajala. 2013. An Assessment of Cassava Processing Plants in Irepodun Local Governments Areas, Kwara State, Nigeria. *World Journal of Agricultural Research*, 1(1), 14 - 17.
- Adekanye, T. A. 2014. Assessment of Mechanization Problems of Peasant Farmers in Irepodun Local Government Area, Kwara State of Nigeria. *Advances in Agriculture, Sciences and Engineering Research*, 4(6), 1665 - 1672.
- Adeyemi, M. A. and O. Yusuf. 2015. Structure, production and constraints of honey hunting and traditional beekeeping activities in Patigi, Kwara State, Nigeria. *Egypt. Acad.J.Biolog.Sci.(A.Entomology)*, 8(1), 441-52.
- Akinlosoye, A. A. 2009. Design and Fabrication of a Stone - Free Garri Processing Plant.Unpublished B.Eng. Thesis, Department of Mechanical Engineering. University of Ilorin, Ilorin, Nigeria.
- Akoroda, M.O. and J. M. Teri. 2004. Food Security and Diversification in SADC Countries: A case study of Western Nigeria Cassava Farmers. *Indian Journal of Agricultural Economics*, 27 (2), 56-66.
- Akpenpuun, T. D. and R.A. Busari. 2013. Impact of Climate on Tuber Crops Yield in Kwara State, Nigeria. *American International Journal of Contemporary Research*, 3(10), 52-57.
- Alam, M.S., M. R. Alam and K. K. Islam. 2005. Energy flow in Agriculture: Bangladesh. *American Journal of Environmental Science.*, 27(2), 56-66.

- Bailey, J. A., R. Gordon., D. Burton and E. K. Yiridoe. 2008. Energy Conservation on Nova Scotia farms: Baseline energy data. *Energy*, 33(7), 1144-1154.
- Bamgboye, A. I. and S. K. Babajide. 2015. Energy Input in the Production of Cassava. *Energy and Environment Research*, 5(1), 42-48.
- Banaeian, N. and M. Namdari. 2011. Effect of ownership on energy use efficiency in watermelon farms - A data envelopment Analysis Approach. *International Journal of Renewable Energy Research.*, 1(3), 75 - 82.
- Barber, A. 2003. Case study of total energy and carbon indicators for New Zealand arable and outdoor vegetable production. *Agricultural Engineering Consultant Agril INK*.
- Basso, B., D. Cammarano., A. Troccoli., D. Chen., J. T. Ritchie. 2010. Long-term wheat response to nitrogen in a rainfed Mediterranean environment: Field data and simulation analysis. *European Journal of Agronomy* , 33(2), 132 - 138.
- Bautista, E.G. and T. Minowa. 2010. Analysis of the Energy for Different Rice Production Systems in the Philippines. *Philipp Agric Scientist*(93), 346–357.
- Bayramoglu, Z. and E. Gundogmus. 2009. A comparative analysis between certified and uncertified greenhouse tomato producers in Turkey. *Energy Convers. Manag.*, 52-56.
- Beheshti-Tabar, I., A. Keyhani. and S. Rafiee. 2010. Energy balance in Iran's agronomy (1990 – 2006). *Renew Sustain Energy Rev.*, 14(2), 849 – 855.
- Bharat, M. U. 2006. An Innovative Approach for Modeling Crop Yield Response to Fertilizer Nutrients. Montreal, Quebec: Selected Paper CEA-CAES annual meeting, May 25th - 28th.
- Bowers, W. 1992. Agricultural Field Equipment in: R.C. Fluck (Ed). *Energy in Farm Production*. Amsterdam: Elsevier Science Publishers. Netherlands.

- Canakci, M., Topakci M., Akinci I. and Ozmerzi A. 2005. Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. *Energy Conversion and Management*, 46, 655-666.
- Chamsing, A., M. S. Vilas and G. Singh. 2006. Energy Consumption Analysis for Selected Crops in Different Regions of Thailand. *Agricultural Engineering International*, 6(13), 1-18.
- CIGR. 1999. *CIGR Handbook of Agricultural Engineering*. International Commission of Agricultural Engineering. St. Joseph, MI: St. Joseph, MI: American Society of Agricultural Engineers.
- Conforti, P., and M. Giampietro. 1997. Fossil energy use in agriculture: an international. *Agriculture, Ecosystems & Environment*, 63(3), 231-243.
- Demircan, V., K. Ekinci., H. M. Keener., D. Akbolat. and C. Ekinci. 2006. Energy and Economic analysis of sweet cherry production in Turkey: A case study from Isparta Province. *Energy Convers Manage.*, 47(2), 1761-1769.
- Dhavan, K.C. and J. P. Mittal. 1989. Energy requirement for cotton and sorghum crop with intercrop of green gram and cowpea under bullock and tractor farming in Southern India. *Econs. Affairs (Calcutta)*, 34, 29-46.
- Dovì, V.G., F. Friedler., D. Huisingh. and J. J. Klemes. 2009. Cleaner energy for sustainable future. *Journal of Cleaner Production*, 17, 889-895.
- Ebrahim, A. 2012. Determination of energy balance and energy indices in wheat production under watered farming in north of Iran. *ARPJ Journal of Agricultural and Biological Science.*, 7(4), 34-38.
- Eke-Okoro, O.N., O. U. Okeene. and J. E. Okeke. 1999. Effects of weather change and planting sett on growth and productivity of cassava in South-eastern Nigeria. *Afr. J. Root Tuber Crops*, 34-38.

- Elemo, G. 2013. The prospects and challenges of cassava bread and confectioneries in Nigeria. Premier Hotel, Ibadan, Oyo State., Nigeria: A paper presented at the NISER research seminar series.
- El-Sharkawy, M. A. 2011. Overview: Early history of crop growth and photosynthesis modeling. *Biosystems*, 103(2), 205 - 211.
- Esengun, K., Gunduz, O. and Erdal, G. 2007. Input – output energy analysis in dry apricot production of turkey. *Energy Convers. Management.*, 48, 592-598.
- Fakayode, S. B., R. O. Babatunde. and R. Ajao. 2008. Productivity Analysis of CassavaBased Production Systems in the Guinea Savannah: Case Study of Kwara State, Nigeria. *American-Eurasian Journal of Scientific Research*, 3(1), 33-39.
- FAO. 2000. The energy and Agriculture Nexus. Environment and natural resources. Working Paper. Rome.
- FAO. 2002. State of food insecurity in the world. Agricultural Services Bulletin. Rome.
- FAO. 2004. Online Statistical Database. Rome, Italy.
- Farzad, M. and K. Mohammed. 2012. A comparative study on energy use and economic analysis of commercial and traditional potato production farms of Kurdistan province of Iran. *International Journal of farming and allied sciences*, 1(1), 1-8.
- Fluck, R. C. 1992. Energy analysis in agricultural systems In Energy in farm production. (R. Fluck, Ed.) Amsterdam, Netherlands: Elsevier Science Publishers B.V.
- Fluck, R. C. and C. D. Baird. 1980. Agricultural energetics. *Westport, Conn.*
- FOS. 1999. Federal Office of Statistics. Poverty and Agricultural Sector in Nigeria: Poverty Incidence of Farmers by Region. Bulletin. Pp. 22-23.
- Franklin, E. N. and S. B. Kue. 2015. Status of Cassava Farmers and Implication for Agricultural Extension and Rural Sociology in Gokana Local Government Area of Rivers State, Nigeria. *International Journal of Applied Sociology*, 5(5), 175-179.

- Gezer, I., M. Acaroglu, and H. Haciseferogullari. 2003. Use of energy and labor in apricot agriculture in Turkey. *Biomass and Bioenergy*, 24, 215-219.
- Ghorbani, R., F. Mondani., S. H. Amirmoradi., H. Feizi., S. Khorramdel., M. Teimouri., S. Sanjani., S. Anvarkhah. and H. Aghel. 2011. A case study of energy use and econometric analysis of irrigated and dry land wheat production systems. *Applied energy*., 88, 283-288.
- Hahn, S.K., N.M. Mahungu, J.A Otoo, M.A M. Msabaha, N.B. Lutaladio, and M.T. Dahniya. 1987. Cassava and African food crisis. *Proceedings of Third Triennial Symposium of the International Society for tropical Root Crops - Africa Branch.*, (pp. 17-23). Owerri, Nigeria.
- Handan, A., O. Orhan. and K. Hatice. 2009. Analysis of energy use for pomegranate production in Turkey. *Journal of Food, Agriculture and Environment*., 7(2), 475-478.
- Hatirli S. A., B. Ozkan. and C. Fert. 2005. An economic analysis of energy Inputs- output in Turkish agriculture. *Review Sustain Energy Rev.*, 9(6), 608-623.
- Heidari, D. and M. Omid. 2011. Energy use pattern models of major greenhouse vegetable productions in Iran. *Energy*., 36, 220-225.
- Ibrahim, H.Y. and H.I. Ibrahim. 2012. Energy use analysis for rice production in Nasarawa State, Nigeria. *Tropical and Subtropical Agro ecosystems.*, 15, 649-655.
- Ibu, J. O., and K. O. Adeniyi. 1989. A manual of Practical Physiology. Jos University Press. 1st Ed. Pp. 17-32.
- Iheke, O. 2008. Technical efficiency of cassava farmers in South Eastern Nigeria. *Agricultural Journal*, 3(2), 152-156.
- IITA. 2006. Cassava the Multipurpose Crop. Bulleting. International Institute of Tropical Agriculture. Oyo Road, Ibadan, Nigeria.
- Jekayinfa, S. O. 2001. Energy accounting in industrialized agriculture – A review. *Journal of Applied Sciences*., 1562-1577.

- Jones, J. W., Hoogenboom, G., Porter, C. H., Boote, K. J., Batchelor, W. D., Hunt, L. A. 2003. The DSSAT cropping system model. *Euro. J. Agron.*, 18(3), 235–265.
- Kazeem, O. R. and B. Razaq. 2015. A Review of Crop Growth Simulation Models as Tools for Agricultural Meteorology. *Agricultural Sciences*, 6(1), 1098 - 1105.
- Kenneth, O. A. and D. A. Okunade. 2008. Evaluation of crop yield models for cowpea in Nigeria. *Irrig Sci.*, 26(2), 385 -393.
- Khan, M. A., S. Ahmad, Z. Hussain, M. Yasin, M. Aslam, and R. Majid. 2004. Efficiency of water and energy use for production of organic wheat. *Journal of Science, Technology and Development.*, 24(1), 25-29.
- Kitani, O. 1999. *CIGR Handbook of Agricultural Engineering, Volume V - Energy and Biomass Engineering*. ASAE Publication.
- Kizilaslan, H. 2009. Energy use and input-output energy analysis for apple production in Turkey. *J. Food Agric. Environ.*, 7(2), 419-423.
- Kuesters, J., and Lammel, J. 1999. Investigations of the energy efficiency of the production of winter wheat and sugar beet in Europe. *European Journal of Agronomy*, 11(1), 35-43.
- Liu, J. 2009. A GIS-based tool for modelling large-scale crop-water relations. *Environmental Modelling & Software*, 24(3), 411-422.
- Lobell, D.B., M. B. Burke., C. Tebaldi., M. D. Mastrandrea., W. P. Falcon., R. L. Naylor. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science.*, 607–610.
- Lobell, D.B., W. Schlenker., J. Costa-Roberts. 2011. Climate Trends and Global Crop Production Since 1980. *Science*, 33(3), 616 -620.
- Mandal, K.G., K. P. Saha., P.K. Ghosh, K. M. Hati., and K. K. Bandyopadhyay. 2002. Bioenergy and economic analysis of soybean – based crop production systems in central India. *Biomass Bioenergy.*, 23, 337-345.

- Mgbenka, R.N., E.N. Mbah and C.I. Ezeno. 2015. A Review of Small holder Farming in Nigeria: Need for Transformation. *Agricultural Engineering Research Journal*, 5(2), 19-26.
- Matanmi, B.A. and G. B. Adesiji. 2009. Comparison of Use of Improved Agricultural Practices by Contact and Non-contact Farmers in Kwara State, Niigeria. *Bulgarian Journal of Agricultural Science*, 15(2), 146-153.
- Martin, K. 2016. The role of crop modelling in agricultural research. *International Crop Modelling Symposium. 15-17 March . Berlin*.
- Mittal, J. P., B.S. Bhullar, S. D. Chhabra, and O. P. Gupta. 1992. Energetics of wheat production in two selected villages of Uttar Pradesh in India. *Energy Conversion and Management.*, 33(9), 855-865.
- Mobtaker, H.G., A. Akram. and A. Keyhani. 2012. Energy use and sensitivity analysis of energy inputs for alfalfa production in Iran. *Energy for Sustainable Development.*, 16, 84-89.
- Mohammadi, A. and M. Omid. 2010. Economic analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. *Appl. Energy.*, 87(1), 191-196.
- Mohammadi, A., A. Tabatabaeefar., S. Shahin., S. Rafiee. and A. Keyhani. 2008. Energy use and economic analysis of potato production in Iran a case study: Ardabil province. *Energy conversion and Management.*, 49, 3566-70.
- Mohtasebi, S. S., M. Behrooz Lar., M. Safa. and M. R. Chaichi. 2008. Comparison of Direct and Indirect Energy Coefficients for Seeding and Fertilizing in Irrigated Wheat Production. *World Applied Sciences*, 3(3), 353-358.
- Moulik, T.K., B. H. Dholkia and P. R. Shukla. 1992. Energy demand for agriculture in India. *Trans. ASAE.*, 3, 88-89.
- Mushtaq, S., T. N. Maraseni., J. Maroulis. and M. Hafeez. 2009. Energy and water tradeoffs in enhancing food security: A selective international assessment. *Energy Policy*, 37, 3635-3644.

- Nassiri, S.M. and S. Singh. 2009. Study on Energy Use Efficiency for Paddy Crop Using Data Envelopment Analysis (DEA) Technique. *Applied Energy*. 86, 1320-1325.
- NCRI. National Cereal Research Institute. 1997. *Rice Production in Nigeria: Problems and Prospects*. Report.
- Nweke, F.I., R.E. Kapinga, A.G.O. Dixon, B.O. Ugwu, O. Ajobo, and C. L. A. Asadu. 1988. Production prospects for cassava in Tanzania. Collaborative study of cassava in Africa. *Working paper*, 16.
- Odoemenem, I.U. and L.B. Otanwa. 2011. Economic Analysis of Cassava Production in Benue State, Nigeria. *Current Research Journal of Social Sciences*., 3(5), 406-411.
- Odum, H. T. 1994. Ecological and general systems: an introduction to systems ecology. University Press. Colorado. Revised edition.
- Ohadike, D. 2007. The influenza pandemic of 1918-19 and the spread of cassava cultivation on the lower Niger. *A study in Historical linkages. J. Afr. History*, 22, 379-391.
- Oladimeji, Y. U. and Z. Abdulsalam. 2014. An Economic Analysis of Dry Season Irrigated Farming in Asa River. *Journal of Sustainable Development in Africa*, 16(7), 1-15.
- Oladimeji, Y. U., Z. Abdulsalam, A.F. Lawal, R. Suleiman. and T.O. Olarewaju. 2016. Energy Use and Economic Analysis of Melon (*Colocynthis citrullus*) Production Technologies in Kwara State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*., 12(3), 162-168.
- Olaoye, J.O., T.R. Amusa and T.A. Adekanye. 2017. Evaluation of the Degree of Agricultural Mechanization Index on the Performance of Some Farm Settlement Schemes in Southwestern, Nigeria. *Ethiopian Journal of Environmental Studies and Management (EJESM)*, 10(7), 905-916.
- Olakulehin, O. J. and O. E. Omidiora. 2014. A genetic algorithm approach to maximize crop yields and sustain soil fertility. *Net Journal of Agricultural Science*, 2(3), 94-103.

- Olanrewaju, R. M. 2009. Climate and the Growth Cycle of Yam Plant in the Guinea Savannah Ecological Zone of Kwara State, Nigeria. *Journal of Meteorological and Climate Science*, 7(1), 43-48.
- Olatunbosun, S. 2007. Evaluation of Energy Expenditure in Cassava Production in Rain Forest Zone of Nigeria. Unpublished B.Eng. Thesis, Department of Agricultural Engineering. Federal University of Technology, Minna, Nigeria.
- Olufumilayo, O. 2011. Issues and Challenges in Cassava Production for Small-scale Farmers in Nigeria: Trends and Post harvest Management. Unpublished MSc. Thesis, Agricultural Sciences. Graduate School of Tennessee State University.
- Oni, K. C. and O.A. Oyelade. 2013. Mechanization of Production and Processing of Cassava for Value Addition in Nigeria. *An ASABE Meeting Presentation Paper No: 131595976, presented at ASABE AIM, July 21 -24. Kansas City, Missouri, USA.*
- Oppong-Apene, K. 2013. Cassava as animal feed in Ghana: Past, Present and Future. (C. I. Berhanu Bedane, Ed.) Ghana: P.S. FAO.
- Oyeleke, I.F., J.O. Olaoye and S.A. Faseyi. 2004. Capacity Utilization of wet land (Fadama) Infrastructure in Kwara State, Nigeria. *Nigerian Journal of Technological Development (NJIDO)*, 4(1 and 2), 64-72.
- Ozkan, B., H. Akcaz. and C. Fert. 2004a. Energy input–output analysis in Turkish agriculture. *Journal of Renewable Energy*, 29(1), 39-51.
- Ozkan, B., A. Kurklu. and H. Akcaoz. 2004b. An input–output Energy analysis in greenhouse vegetable production: A case study for Antalya region of Turkey. *Biomass and Bioenergy*, 26, 89-95.
- Patricia, O. S., S. Yeboah, N. T. Addy, S. Amponsah and E. O. Danquah. 2013. Crop modeling: A tool for agricultural research –A review. *E3 Journal of Agricultural Research and Development*, Vol. 2(1), 1-6.

- Pervanchon, F., C. Bockstaller. and P. Girardin. 2002. Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. *Agricultural Systems*, 72, 149-172.
- Pimentel, D. 1999. Energy inputs in Production Agriculture. In: Fluck, R.C. Energy in Farms Production. *The Netherlands: Elsevier Science Publishers*.
- Pimentel, D., R. Doughty., C. Carothers., S. Lamberson., N. Bora., and K. Lee. 2002. Energy inputs in crop production: comparison of developed and developing countries: Boca Raton, FL. *CRC Press*.
- Pimentel, D., A. Marklein., M.A. Toth., M. N. Karpoff., G. S. Paul., R. McCormack. and J. K. T. Kyriazis. 2009. Food Versus Biofuels: Environmental and Economic Costs Human Ecology. 37(1), 1-12.
- Pishgar-Komleh, S.H., M. Ghahderijani, and P. Sefeedpari. 2012. Energy consumption and CO₂ emissions analysis of potato production based on different farm size levels in Iran. *Journal of Cleaner Production*, 33, 183-191.
- Radha, K. M. 2015. Crop Growth Modeling and Its Applications in Agricultural Meteorology. *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*, pp. 235 - 261.
- Rajabi-Hamedani, S., Shabani, Z. and Rafiee, S.H. 2011. Energy inputs and crop yield relationship in potato production in Hamadan province of Iran. *Energy*, 2367-2371.
- Randolph, J. and G. M. Masters. 2008. Energy for sustainability: technology, planning, policy. *Washington, D.C.: Island Press*.
- Rueda-Ayala, V., K. Seshadri and M. Javierc. 2015. Development of Yield Prediction Models in the Maize Crop using Spectral Data for Precision Agriculture Applications. *Ecuador Es Calidad: Revista Científica Ecuatoriana*., 2(1).
- Safa, M. 2011. Determination and Modelling of Energy Consumption in Wheat Production Using Neural Networks. Pennsylvania: Unpublished Ph.D thesis of Department of

Environmental Management Faculty of Environment, Society and Design, Lincoln University.

- Safa, M. and A. Tabatabaeefer. 2002. Energy Consumption in Wheat Production in Irrigated and Dry Land Farming. *In: Proc. Intl. Agric. Engg. Conf.*
- Samavastean, N., S. Rafiee. and A. Mohammadi. 2011. An analysis of energy use and relation between energy inputs and yield, cost and income of garlic production in Iran. *Renewable energy.*, 36, 1806-1813.
- Sartori, L., B. Basso., M. Bertocco. and G. Oliviero. 2005. Energy Use and Economic Evaluation of a Three-Year Crop Rotation for Conservation and Organic Farming in NE Italy. *Biosystems Engineering*, 91(2), 245-256. doi:10.1016/j.biosystemseng.2005.03.010
- Saunders, C., A. Barber. and G. Taylor. 2006. Food miles: comparative energy/emissions performance of New Zealand's agriculture industry. *Agribusiness & Economics Research Unit, Lincoln University.*
- Shahram, F. 2014. A comparative study of parametric and non-parametric regressions. *Iranian Economic Review*, 16(30), 19-43.
- Shrivastava, N. 2006. Farm power sources their availability and future requirement to sustain agriculture production: Status of farm mechanization in India. *New Publication.*, 57-68.
- Singh, S. and J.P. Mittal. 1992. *Energy in production agriculture*. Mittal Publications. New Delhi, India.
- Singh M.K., Pal, S.K, Thakur. and U. N. Verma. 1999. Energy input – output relationship of cropping systems. *Indian Journal of Agricultural Science.*, 67(6), 262-266.
- Singh, G., S. Singh and J. Singh. 2004. Optimization of energy inputs for wheat. *Energy Conversion and Management*, 45(3), 453-465.
- Singh, H., D. Mishra and N. M. Nahar. 2002. Energy use pattern in production agriculture of a typical village in arid zone, India—part I. *Energy Conversion and Management.*, 43, 2275-2286.

- Singh, J. 2000. On farm energy use pattern in different cropping systems in Haryana, India. Unpublished MSc. Thesis. University of Flensburg.
- Smil, V. 2008. Energy in Nature and Society: General Energetics of Complex Systems. Cambridge: The MIT Press.
- Stout, J. 1990. Wind erosion within a field. *Transaction of ASAE*, 33(5), 1597 - 1600.
- Thankappan, S., P. Midmore. and T. Jenkins. 2005. Conserving Energy in Small Holder Agriculture: A Multi – Objective Programming Case – Study of Northwest India. *Ecological Economics*., 56, 190-208.
- Uhlin, H. 1998. Why energy productivity is increasing: An I-O analysis of Swedish agriculture. *Agric Syst.*, 56(4), 443-65.
- Ullah, A. 2009. A Comparative Analysis of Energy Use Patterns in Small and Large Scale Irrigated Rice Farming Systems: A Case Study in Ayutthaya Province in the Central Region of Thailand. Unpublished Master of Science Thesis of Asian Institute of Technology, Thailand.
- USDA. 2008. U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. *Washington, D.C: United States Department of Agriculture (USDA)*.
- Van Ittersum, M., M. Cassman, K. P. Grassini. 2013. Yield gap analysis with local to global relevance – A review. *Field Crops Research*, 14(3), 4-17.
- Vlek, P. L. G., G. Rodríguez-Kuhl. and R. Sommer. 2004. Energy Use and CO₂ Production in Tropical Agriculture and Means and Strategies for Reduction or Mitigation. *Environment, Development and Sustainability*, 6.
- Wallgren, C. and M. Høger. 2009. Eating energy: Identifying possibilities for reduced energy use in the future food supply system. *Energy Policy*, 37(12), 5803 - 5813.
- Wells, C. 2001. Total energy indicators of agricultural sustainability: dairy farming case study (No. 0478079680 (pbk.). Wellington. Ministry of Agriculture and Forestry.

Woods, J., A. Williams., J. K. Hughes., M. Black and R. Murphy. 2010. Energy and food system. *Phil. Trans. R. Soc.*, 36(5), 2991-3006.

www.factfish.com. Accessed 02/09/2017

Yilmaz, I., H. Akcaoz. and B. Ozkan. 2005. An analysis of energy use and input cost for cotton production in Turkey. *Renewable energy*, 30, 145-155.

Zangeneh, M., M. Omid. and A. Akram. 2010. A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. *Energy*, 35, 2927-2933.

APPENDICES

Appendix A: Sample Questionnaire

UNIVERSITY OF ILORIN, ILORIN, NIGERIA
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF AGRICULTURAL AND BIOSYSTEMS ENGINEERING

QUESTIONNAIRE No: _____

Please tick (✓) where necessary

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS

1. Village of the respondent
2. Marital Status: (a) Single (b) Married (c) Widowed (d) Divorced (e) Separated
3. Sex (a) Male (b) Female
4. Age
5. Occupation
6. How many are your household members (family size)
7. Education attainment: (a) Primary (b) S.S.C.E (c) NCE/OND (d) HND/B.Sc. (e) Higher Degree.
8. What is the size of your farm in hectares?
9. By which of the following ways did you acquire your farm land? (a) Inheritance (b) Gift (c) Lease
(d) outright purchase (e) Rented
10. For how long have you been in farming?
11. What type of farming system do you practice in your farming? (a) Mono cropping
(b) Mixed cropping (c) Backyard system (d) Mixed farming
12. What is the cost of land used for cassava (Naira)?
13. How many days were used for land clearing (Man days)?
14. How much did you spent for land clearing (Naira)?
15. How many days were used of cultivation (Man days)?
16. How many people did the cultivation?

17. How much did you spent for cultivation (Naira)?
18. How many people were used for planting the cassava cuttings in your farm?
19. How many days did you use for planting the cassava cultivars in your farm?
and how much did it cost?
20. What was the cost of the cutting (Naira)?
21. What is the average amount that you paid each worker for weeding (Naira)?
22. How many people did the weeding?
23. What type fertilizer did you apply to your farm?
24. How many men applied fertilizer to your farm?
25. What is the cost of the fertilizer used (Naira)?
26. What is the cost of the fertilizer transportation (Naira)?
27. What is the cost of feeding the labourers?
28. What is the cost of harvesting per hectare?
29. How many days were used for the harvesting of your cassava tubers?
30. And how many people did the harvesting job?
31. What is the total quantity of cassava tuber harvested per hectare?
32. What quantity was consumed?
33. What are the implement used in your farm? (a) Cutlass (b) Hoe
(c) Wheel Barrow (d) Basket (e) Machines (tractor) (f) Cars
(g) Others.....
34. What are your farm bi-products?
35. What are the final farm product e.g. Garri, fufu, tapioca, glue, starch, wine, among others?
.....
36. What are the farm machineries, equipment and implements used in your farm?
37. What is the source of water for the farm? (a) Rainfall only (b) Irrigation
38. What type of disease and pest are prevalent in the area?
39. Do you have an urge to expand your cassava farm?
40. How did you obtain your initial capital? (a) Government assistance (b) Savings
(c) Co-operative (d) Loan (e) Others
41. Do you keep records of your farm activities? (a)Yes (b) No

Farm operations	Cost per person per day (N)	Quantity of labour / operations (Mhrs)		Quantity of hired labour (Mhrs)	Total amount paid to hired labour (N)
		Male	Female		
Land clearing					
Tillage					
Planting					
Weeding					
Fertilizing					
Harvesting					
Carriage of Produce					

S/N	Inputs	No of days	Implement/machine used (Plough, Harrow, Ridger, etc)	Diesel / Petrol fuel (Lt)	
1	Planting operation				
2	Fertilizer				
3	Weeding				
4	Spraying				
5	Harvesting				
6					

S/N	Inputs	No of days	Implement/machine used (Plough, Harrow, Ridger, etc)	Diesel / Petrol fuel (Lt)	Mass (kg) Of implements	Effective field. capacity, Ce
1	Planting operation				Plough	
2	Fertilizer				Harrow	
3	Weeding				Tractor	
4	Spraying					
5	Harvesting					
6						

Appendix B: Raw Data from the cassava farms

Group 1 (Small scale farms: 92)

Farm	Human labour	Machinery	Fuel	Herbicide	Pesticide	Fungicide	Nitrogen fertilizer	Phosphorus fertilizer	Potassium fertilizer	Cassava stem
Farm 1	73	56.5	15	2.5	2.5	0	250	100	100	560
Farm 2	90.05	56.5	52	2.5	2.5	0	250	100	100	615
Farm 3	215.38	56.5	45	1.8	1.4	0	250	100	100	615
Farm 4	211.86	56.87	44.01	1.4	1.4	0	250	100	100	759
Farm 5	145.41	56.87	52	1.8	1.4	0	250	100	100	650
Farm 6	168.37	56.5	40.96	2.6	2.5	0	300	100	100	650
Farm 7	71.94	56.5	44.01	2.6	2.5	0	335	50	50	758
Farm 8	53.38	56.87	52	2.6	2.5	0	350	50	50	565
Farm 9	76.15	56.5	42.79	2.6	1.4	0	350	100	100	560
Farm 10	80.74	56.5	50	2.6	2.5	0	100	345	155	650
Farm 11	46.20	56.87	5.13	2.6	2.6	0	100	345	200	560
Farm 12	72.96	56.5	44.01	2.7	2.7	0	100	355	210	560
Farm 13	211.86	56.5	52	2.7	2.7	0	100	375	250	565
Farm 14	145.41	56.5	40.96	2.4	2.5	0	345	345	100	563
Farm 15	168.37	56.87	44.01	2.4	2.4	0	345	100	100	650

Far m 16	71.94	56.5	52	2.4	2.4	0	355	50	0	758
Far m 17	53.38	56.5	40. 96	1.8	1.8	0	375	100	100	508
Far m 18	76.15	56.5	45	1.8	1.8	0	345	100	100	560
Far m 19	80.74	56.87	44. 01	1.8	1.8	0	100	355	200	563
Far m 20	72.81	56.87	52	1.8	1.8	0	100	200	200	560
Far m 21	90.05	56.5	40. 96	1.8	1.6	0	100	210	200	563
Far m 22	215.3 8	0	0	1.8	2.3	0	100	250	200	758
Far m 23	211.8 6	0	0	1.8	1.4	0	355	100	265	650
Far m 24	145.4 1	56.5	42. 79	1.8	1.4	0	200	100	100	759
Far m 25	168.3 7	56.5	52	1.5	1.4	0	210	100	100	560
Far m 26	71.94	56.87	52	1.5	1.4	2.2	250	100	100	758
Far m 27	53.38	56.5	40	1.5	1.4	2.6	100	100	200	560
Far m 28	76.15	56.5	39. 75	1.5	1.4	1.5	100	200	200	508
Far m 29	80.74	56.5	40. 54	1.1	1.5	1.8	100	200	300	560
Far m 30	168.3 7	56.5	52. 01	1.1	1.5	1.9	100	200	340	563
Far	71.94	56.87	40.	1.1	1.5	2.1	100	200	100	758

m 31			95							
Far m 32	53.38	56.87	52	1.1	1.5	1.2	200	265	100	650
Far m 33	76.15	0	0	1.3	1.5	2.5	200	100	100	759
Far m 34	80.74	0	0	1.3	1.5	2.2	200	100	100	560
Far m 35	72.81	0	0	1.2	1.4	1.2	200	100	100	758
Far m 36	90.05	56.5	52	1.2	1.5	1.3	265	200	200	560
Far m 37	215.3 8	56.5	51. 99	1.2	1.4	1.5	100	200	200	508
Far m 38	211.8 6	56.87	46. 97	1.6	1.5	1.3	100	300	300	560
Far m 39	145.4 1	56.5	42. 79	1.6	1.4	1.5	100	340	340	758
Far m 40	168.3 7	56.5	52	1.6	1.5	1.4	200	100	100	560
Far m 41	71.94	56.5	52	1.2	1.4	1.5	200	100	100	508
Far m 42	53.38	56.5	40	1.2	1.45	1.45	300	100	100	563
Far m 43	76.15	56.87	40. 95	1.2	1.5	1.3	340	250	145	758
Far m 44	80.74	56.87	45. 71	1.2	1.45	1.6	100	300	145	650
Far m 45	168.3 7	56.5	46. 97	1.35	1.4	1.5	100	335	145	759
Far m	71.94	0	0	1.35	1.35	1.3	100	350	155	560

46										
Far m 47	53.38	0	0	1.35	1.35	1.5	100	350	155	759
Far m 48	76.15	56.5	45	1.35	1.4	1.5	100	100	100	560
Far m 49	80.74	56.5	44. 01	1.4	1.4	1.5	350	100	100	758
Far m 50	72.81	56.87	52	1.4	1.4	1.5	350	100	100	560
Far m 51	90.05	56.5	40. 96	1.4	1.4	1.5	350	100	100	508
Far m 52	215.3 8	56.5	44. 87	1.4	1.4	1.5	350	345	145	560
Far m 53	211.8 6	56.5	46. 90	1.4	1.4	1.5	350	345	200	560
Far m 54	145.4 1	56.5	42. 79	1.4	1.4	1.6	355	355	210	563
Far m 55	168.3 7	56.87	53	1.4	1.8	1.5	100	375	175	758
Far m 56	71.94	56.87	55	0	0	0	100	345	100	759
Far m 57	53.38	0	0	0	0	0	100	100	100	560
Far m 58	76.15	0	0	0	0	0	100	100	100	758
Far m 59	80.74	0	0	0	0	0	100	100	100	560
Far m 60	72.96	0	0	0	0	0	100	100	100	508
Far m 61	90.05	56.5	41	0	0	0	100	355	200	508

Far m 62	215.3 8	56.87	52	0	0	0	100	200	200	563
Far m 63	211.8 6	56.5	45	1.8	1.8	1.8	100	210	200	758
Far m 64	145.4 1	56.5	44	1.8	1.8	1.5	100	250	200	650
Far m 65	168.3 7	56.5	52	1.8	1.8	1.1	100	100	265	560
Far m 66	71.94	56.5	40. 96	1.8	1.6	1.5	200	100	100	563
Far m 67	53.38	56.87	41. 17	1.6	2.3	1.5	200	100	100	758
Far m 68	76.15	56.87	40. 92	2.3	1.4	1.5	200	100	100	460
Far m 69	80.74	56.5	42. 79	1.4	1.4	1.5	275	100	200	508
Far m 70	211.8 6	0	0	1.4	1.4	1.5	275	200	200	560
Far m 71	145.4 1	0	0	1.4	1.4	2.2	215	200	120	508
Far m 72	168.3 7	0	0	1.4	1.4	2.1	300	200	140	560
Far m 73	71.94	56.5	52	1.4	1.4	1.2	310	200	100	565
Far m 75	53.38	56.87	50	1.4	1.5	2.1	310	265	100	650
Far m 76	76.15	56.5	47	1.5	1.5	0	310	100	100	508
Far m 77	80.74	56.5	41	1.5	1.5	2.5	335	100	100	560
Far	72.81	56.5	52	1.5	1.5	0	335	100	100	759

m 78										
Far m 79	90.05	56.5	45	1.5	1.5	0	278	200	100	510
Far m 80	215.3 8	56.87	44. 01	1.5	1.5	0	555	200	100	458
Far m 81	211.8 6	56.87	52	1.5	1.4	0	585	300	100	560
Far m 82	145.4 1	56.5	41	1.4	1.5	0	585	340	140	650
Far m 83	168.3 7	0	0	1.5	1.4	0	685	100	100	560
Far m 84	71.94	0	0	1.4	1.5	0	375	100	100	510
Far m 85	121.2 2	56.5	42. 8	1.5	1.4		375	100	100	510
Far m 86	125.0 5	56.5	53	1.4	1.5	0	375	100	100	560
Far m 87	128.4 4	56.87	48	1.5	1.4	0	385	100	100	650
Far m 88	125.5 6	56.5	40	1.4	1.45	0	345	200	100	560
Far m 89	217.5 4	56.5	42. 70	1.45	1.5	0	345	200	100	560
Far m 90	215.8 8	56.5	52. 01	1.5	1.45	0	335	300	100	560
Far m 91	222.4 3	56.5	44. 04	1.45	2.5	0	425	340	140	759
Far m 92	158.8 6	0	0	1.4	2.9	1.1	435	100	100	510
Far m	172.5 5	0	0	0	0	0	345	100	100	508

93										
Far m 94	176.2 5	0	0	0	0	0	385	100	100	508

GROUP 2 (Medium scale farms: 54)

Far m	H. labou r	Machi nery	Fu el	Herbi cide	Pesti cide	Fungi cide	Nitro gen fertili zer	Phosph orus fertilize r	Potass ium fertiliz er	Cass ava stem	Yiel d
Far m 1	285.1 1	68.78	16 4	2.85	2.5	2.2	1200	985	355	5040	200 000
Far m 2	178.8 7	86.85	20 8	2.85	2.4	2.6	1500	985	350	5040	150 000
Far m 3	155.5 6	125.86	18 0	3.6	2.4	1.5	1200	680	350	5850	150 000
Far m 4	148.4 5	227.24	17 8	3.45	2.2	1.8	1200	645	350	5850	150 000
Far m 5	156.6 7	227.4	20 8	3.65	2.2	1.9	1200	645	350	5850	150 000
Far m 6	156.4 5	223.4	16 4	2.8	1.8	2.1	1200	645	345	5850	150 000
Far m 7	158.5 5	226.24	17 6	2.8	2.2	1.2	1200	700	345	5850	150 000
Far m 8	145.8 9	223.28	20 8	1.8	1.8	2.5	1650	685	355	5850	150 000
Far m 9	167.8 8	227.16	17 2	1.6	2.3	2.2	1650	550	355	5850	150 000
Far m 10	167.5 6	223.4	20 0	2.3	1.4	1.2	1650	955	300	5850	150 000
Far m 11	156.3 3	227.4	35 7	1.4	1.4	1.3	1600	955	355	4550	145 000
Far m 12	146.7 6	223.28	30 8	1.4	1.4	1.5	900	945	200	4550	145 000
Far m 13	145.6 6	200.44	36 4	1.4	1.4	1.3	900	755	325	4550	145 000
Far m 2	283.1 2	223.44	29 4	1.4	1.4	1.5	900	565	345	4550	145 000

14											
Far m 15	167.3 2	279.1	30 8	1.4	1.4	1.4	685	560	355	4550	145 000
Far m 16	265.1 1	279.25	36 4	1.4	1.5	1.5	550	500	300	4550	145 000
Far m 17	165.2 1	278.8	28 7	1.5	1.5	1.45	500	500	355	4550	145 000
Far m 18	183.1 1	282.8	54 0	1.5	1.5	1.3	500	555	355	4550	145 000
Far m 19	176.1 1	279.25	52 8	1.5	1.5	1.6	1000	555	355	4550	145 000
Far m 20	182.4 5	284.25	62 4	1.5	1.5	1.5	1000	555	385	3594	145 000
Far m 21	182.6 5	281.25	62 4	1.5	1.5	1.3	1200	555	385	3594	200 000
Far m 22	181.0 1	281.25	62 4	1.5	1.4	1.5	1000	555	385	3594	200 000
Far m 23	171.3 3	281.25	62 4	1.4	1.5	1.5	1500	455	355	3594	200 000
Far m 24	183.7 3	284.05	63 0	1.5	1.4	1.5	1500	450	385	3594	197 300
Far m 25	182.0 2	227.24	78 0	1.4	1.5	1.5	1500	900	385	3594	198 800
Far m 26	174.3 5	227.4	78 0	1.5	1.4	1.5	1500	900	400	3594	150 000
Far m 27	144.6 1	223.4	60 0	1.4	1.5	1.5	1550	900	400	3594	150 000
Far m 28	174.3 5	226.24	55 5	1.5	1.4	1.5	1500	500	400	3594	150 000
Far m 29	134.5 3	223.28	60 0	1.4	1.45	1.6	1200	500	400	3594	150 000

Far m 30	125.5 3	227.16	78 0	1.45	1.5	1.5	1200	700	550	3594	150 000
Far m 31	130.8 6	223.4	61 5	1.5	1.45	1.8	1100	700	550	3594	145 000
Far m 32	100.2 5	227.4	67 6	1.45	1.4	1.9	1200	700	550	3594	145 000
Far m 33	126.1 3	223.28	58 5	1.4	1.35	2.1	1100	700	550	3594	145 000
Far m 34	167.3 4	200.44	58 5	2.3	1.35	1.2	1100	700	555	3594	145 000
Far m 35	130.1 2	223.44	58 5	1.4	2.3	2.5	1100	680	480	3594	145 000
Far m 36	165.3 3	279.1	67 6	1.4	1.4	2.2	1100	670	455	3594	145 000
Far m 37	146.1 4	279.25	45 9	1.4	2.2	1.2	1000	670	485	3594	145 000
Far m 38	167.5 5	278.8	42 3	1.4	1.4	1.3	1000	690	455	5850	145 000
Far m 39	156.4 4	282.8	38 7	1.4	1.5	1.5	800	600	455	5850	145 000
Far m 40	143.0 867	279.25	46 8	1.4	1.4	1.3	800	900	555	3594	145 000
Far m 41	129.7 755	284.25	46 8	1.5	1.5	1.5	950	900	555	3594	200 000
Far m 42	120.8 776	281.25	36 0	1.5	2.2	1.4	940	900	555	3594	200 000
Far m 43	131.7 194	281.25	36 9	1.5	1.5	1.5	950	900	455	3594	200 000
Far m 44	130.6 684	281.25	41 4	1.5	2.1	1.45	1300	900	455	3594	197 300
Far	131.5	284.05	41	1.5	1.45	1.3	1200	900	455	3594	145

m 45	714		4								000
Far m 46	125.3 98	227.4	27 0	1.8	1.5	1.6	1250	900	455	3594	145 000
Far m 47	126.6 429	223.28	25 8	1.4	1.45	1.5	1245	700	355	5850	145 000
Far m 48	129.9 745	200.44	27 0	2.3	2.2	1.8	1245	900	485	5850	145 000
Far m 49	126.6 735	223.44	26 4	1.4	2.2	1.9	1250	855	485	5850	145 000
Far m 50	210.4 4	279.1	31 2	1.4	1.35	2.1	1250	900	400	5850	145 000
Far m 51	182.4 745	279.25	24 6	1.4	1.4	1.2	900	645	470	5850	145 000
Far m 52	225.3 3	278.8	26 4	1.4	1.4	2.5	1300	900	450	5850	145 000
Far m 53	181.2 5	282.8	28 2	1.4	2.5	2.2	1250	900	450	5850	145 000
Far m 54	210.4 4	279.1	31 2	1.4	1.35	2.1	1250	900	400	5850	145 000

GROUP 3 (Large scale farms: 29)

Far m	H. labo ur	Machi nery	Fuel	Herbic ide	Pestic ide	Fungic ide	Nitrog en F	Phospho rus F	Potassi um F	Cass ava
Far m 1	147. 23	125.86	3569	3.6	2.5	1.2	620 0	1760	185 5	1040 0
Far m 2	211. 51	156.81	2285	3.45	2.4	2.5	620 0	1685	195 5	1040 0
Far m 3	142. 23	156.85	2214	3.65	2.4	2.2	620 0	1950	195 5	1235 0
Far m 4	126. 42	155.85	3153	2.8	2.2	1.2	620 0	1955	100 0	1235 0
Far	142.	156.56	2129	2.8	2.2	1.3	570	1955	100	9750

m 5	54						0			0		
Far m 6	158. 25	155.82	2229	2.8	1.8	1.5	520 0		1945		105 0	1105 0
Far m 7	91.1 5	156.79	2456	2.6	2.2	1.3	450 0		2075		190 0	9750
Far m 8	147. 23	155.85	3339	3.3	1.8	1.5	520 0		2165		190 0	9750
Far m 9	150. 14	176.85	2498	3.4	2.3	1.4	520 0		1960		100 0	9750
Far m 10	146. 42	185.82	2255	3.4	1.4	1.5	400 0		1800		105 5	9750
Far m 11	147. 23	150.11	3696	3.4	1.4	1.45	499 0		1990		104 5	1040 0
Far m 12	248. 85	155.86	3574	3.4	2.5	1.3	490 0		1855		105 5	1040 0
Far m 13	167. 33	155.82	3754	2.4	2.4	1.6	490 0		2855		108 5	1105 0
Far m 14	259. 92	155.85	3849	2.4	2.4	1.5	490 0		1955		145 5	1170 0
Far m 15	145. 63	155.76	3256	2.5	2.2	1.3	488 0		1955		145 0	1755 0
Far m 16	143. 45	196.56	2885	2.5	2.2	1.5	400 0		1000		170 0	1755 0
Far m 17	158. 66	155.85	2856	2.5	1.8	1.5	400 0		1000		297 0	1755 0
Far m 18	269. 87	156.85	3965	2.5	2.2	1.5	400 0		1050		285 5	1755 0
Far m 19	155. 85	56.25	3867	2.5	1.8	1.5	400 0		1900		195 5	1755 0
Far m 20	155. 85	45.34	3985	2.5	2.3	0	400 0		1900		195 5	9750
Far m 21	153. 45	56.85	3775	2.4	1.4	1.5	500 0		1000		100 0	1040 0

Far m 22	145. 63	55.85	3785	2.5	1.4	1.5	650 0		1055		100 0		1040 0
Far m 23	265. 55	56.86	3934	2.4	2.2	1.6	670 0		3045		950		1105 0
Far m 24	149. 94	56.81	3885	2.5	1.8	1.5	490 0		3055		900		1170 0
Far m 25	241. 15	56.86	3969	2.4	2.2	1.8	470 0		1085		900		1755 0
Far m 26	149. 46	45.32	3734	2.8	1.8	0	495 0		1455		900		1755 0
Far m 27	109. 92	56.25	3999	2.8	2.3	0	480 0		2450		105 5		1755 0
Far m 28	135. 14	56.25	3965	2.8	1.4	1.5	495 0		2700		100 5		1755 0
Far m 29	100. 92	156.79	3987	2.6	1.4	1.5	495 0		3970		105 5		1755 0