The Energy Center, KNUST

RENEWABLE ENERGY FOR EFFICIENT FOOD PROCESSING TO IMPROVE RURAL LIVELIHOODS (RE4FOOD) PROJECT

REPORT ON ENERGY INPUT FOR MAIZE FOOD PRODUCTION ALONG THE VALUE CHAIN IN GHANA: CASE STUDY OF EJURA-SEKYEREDUMASI MUNICIPALITY

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Table of Contents

LIST OF FIGURES

LIST OF TABLE

1. SUMMARY

This report forms part of the work undertaken by The Energy Centre, KNUST as contribution to the Renewable Energy for Food Processing (RE4Food) project. The reports presents analyses on post-harvest maize food chain and assess the energy input for maize production along the maize value chain in Ghana using Ejura Sekyeredumasi Municipality as a case study.

For this study, data on energy related activities during cultivation of maize was collected using questionnaires from 150 farmers during the 2013/2014 minor season. Through purposive and simple random sampling, 150 farmers from maize farming communities across 10 cluster zones base on geographical location of their farm within the Municipality were selected for the study.

To estimate the amount of energy required across the maize value chain, a desktop software called *Energy Expect Plus* was developed using Visual Basics Language, Integrated Development Environment (IDE) and Microsoft visual studio. The developed desktop software provides an alternative for calculation of energy required depending on the type of energy used and the operation involved.

It was found out that maize production in the study area mainly depends on human labour inputs with little usage of machinery which was mainly for land preparation, maize shelling and transportation activities. To produce a hectare of maize, it was estimated that 1,636.45MJ of energy will be required.

2. INTRODUCTION

The crops produced in Ghana are grouped into cash crops (cocoa, cashew nuts) and staple foods (maize, rice, millet, cassava, yam, plantain). Given current socio economic trends, it seems likely that, so much attention, in terms of research work, funding, subsidies from the government and research centers, will be given to the cash crop since it could potentially have a positive impact on Ghana's economy directly. Nevertheless the production of staple foods for local consumption as well as international market through export is of critical importance to the country.

Maize is one of the most consumed food crops and a very important staple food, which has enormous benefit to the livelihoods of Ghanaians. Among the approximately 26 million people living in Ghana, about 70% of the population is directly or indirectly into agriculture. Maize is the most important cereal crop on the domestic market in Ghana. However, it is only the 7th largest agricultural commodity in terms of value of production over the period 2005-2010, accounting for 3.3% of total agricultural production value (FAOSTAT, 2012). Maize accounts for 55% of grain output followed by paddy rice (23%), sorghum (13%) and millet (9%).

Maize as staple crops is produced largely, by small holder farmers in rural areas of the country. The agriculture production is tedious and laborious due to the low level of mechanization. Rain-fed agriculture is also the main mode of water accessibility to these small scale farmers, limiting most farming activities during the year. Knowledge of energy consumption and demand at every stage of maize production is important for estimation of production. Similarly, the energy use efficiency (output energy to input energy ratio) and specific energy, i.e., input energy to yield ratio (MJ/Kg) of farmers in crop production systems are indices, which can define the efficiency and performance of farms.

3. MAIZE PRODUCTION IN GHANA

Maize (*Zea mays*) is the highest produced cereal crop and the most widely consumed food in Ghana, with increasing production since 1965 (FAO, 2008; Morris et al., 1999). Maize is cultivated in all the ten regions of the country, however, the leading producing areas are mainly in the middle-southern part (Brong Ahafo, Eastern and Ashanti provinces) where 84% of the maize is grown, with the remaining 16% being grown in the northern regions of the country (Northern, Upper East and Upper West provinces). In 2012, maize accounted for over 60% of all grain output followed by paddy rice, sorghum and millet (MoFA 2013). Since the last decade, production has been fairly stable with a significant increase starting from year 2008 (see Figure 2). Maize is also an important component of poultry feed, and to a lesser extent the livestock feed sector as well as a substitute for the brewing industry. In Ghana, maize is produced predominantly by smallholder poor farmers under traditional production methods and rain-fed conditions. Ghana's agricultural sector's workforce is mainly manual labor, with some mix of machinery and animal traction. Animal traction is on the decline but studies conducted in the northern part of Ghana indicated that 38% of farmers interviewed admitted to using animal traction for various farm activities.

Yields are well below their attainable levels; maize yields in Ghana average approximately 1.9 metric tons per hectare. However, achievable yields as high as 6 metric tons per hectareif farmers use improved seeds, fertilizer, mechanization and irrigation (MoFA, 2013).

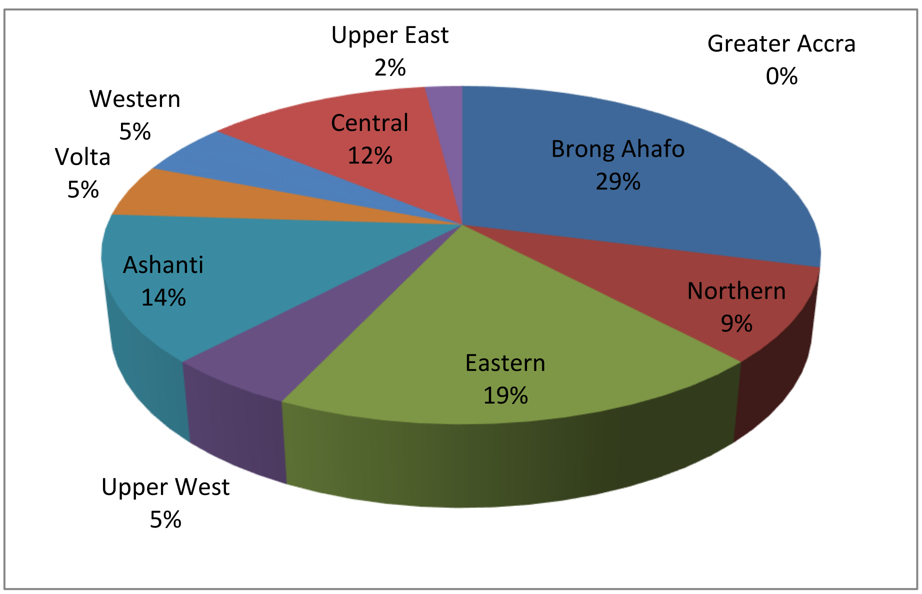

Figure 1: Distribution of production of maize in Ghana by region over the period 2006-2010

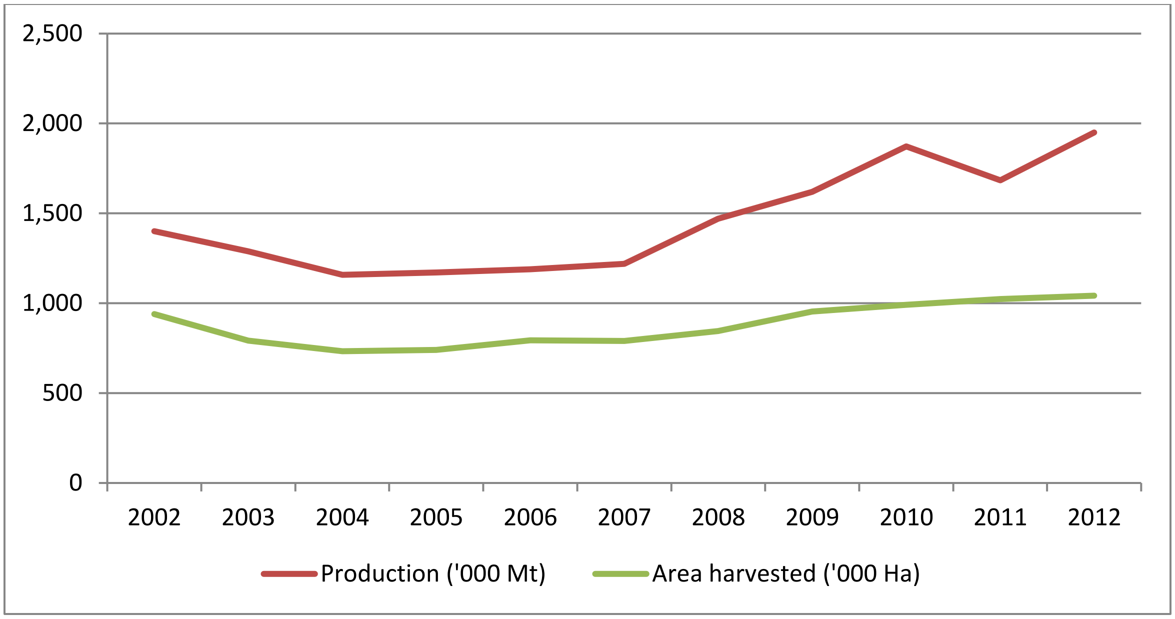

Figure 2: Maize area and production trends in Ghana (2002-2012)

3.1 Socio-economic Impacts of Maize

The estimated level of per capita consumption of maize in Ghana was 43.8kg in 2010 (MOFA SRID, 2011). As an important commodity in Ghanaian diet, maize is used to prepare local and traditional dishes such as *banku*, *apkle*, *kenkey, and tuo zaafi*. Maize is also used as poultry feed. In Ghana, yellow maize is imported to feed poultry. While there is no reliable data for maize used in animal feed, the Government of Ghana estimates that 85% of all maize grown in Ghana is destined for human consumption, and the remaining 15% is used as animal feed (mainly poultry). Maize makes a greater quantity of epigeous mass than other cereal plants, so can be used for fodder. Digestibility and palatability are higher when ensiled and fermented, rather than dried. Starch from maize can also be made into plastics, fabrics, adhesives, and many other chemical products. The corn steep liquor, a plentiful watery by-product of maize wet milling process, is widely used in the biochemical industry and research as a culture medium to grow many kinds of microorganisms. Chrysanthemums is found in purple corn and used as a food colouring (Liggett et al, 1948). Maize is increasingly used as a feedstock for the production of ethanol fuel. Ethanol is mixed with gasoline to decrease the amount of pollutants emitted when used to fuel motor vehicles. High fuel prices in mid-2007 led to higher demand for ethanol, which in turn lead to higher prices paid to farmers for maize. This led to the 2007 harvest being one of the most profitable maize crops in modern history for farmers. Because of the relationship between fuel and maize, prices paid for the crop now tend to depend on the price of oil.

3.2 Soil conditions necessary for maize production

Maize has been grown under conventional agricultural practices in Northern Ghana for years. The basis of conventional tillage is the annual ploughing or tilling of the soil, but this is usually supplemented with a number of other practices, including the removal or burning of crop residues, land levelling, harrowing, fertilizer application and incorporation, etc.

The soils of the major maize growing areas in Ghana are low in organic carbon (<1.5%), total nitrogen (<0.2 %), exchangeable potassium (<100 mg/kg) and available phosphorus (< 10 ppm) (Adu, 1995, Benneh et al. 1990). Maize thrives in well drained sandy loam soil with a pH of 5.7-7.5 and 500-800 mm of rainfall evenly distributed throughout the growing season for good yield. Fertilizer nutrient application in Ghana is approximately 8 kg ha-1 (FAO, 2005) while depletion rates range from about 40 to 60 kg of nitrogen, phosphorus, and potassium (NPK) ha-1 yr-1 (FAO, 2005) and among the highest in Africa.1

The preference of most field crops is for fertile, well-drained loamy soils. Maize is relatively well adapted to a wide range of soils with from pH 5.0 to 8.0. It does not do well in acidic soils. Aluminium toxicity could become a problem on soils with pH less than 5.0 (Al > 40%). Maize is moderately sensitive to salinity, which reduces uptake of nutrients and decreases total dry matter production. Hence, low soil water storage is more of a problem for maize. Maize yields vary a lot depending on the soil type where the crop is grown.

3.3 Land Preparation

The land is usually prepared after the first two or three rains by hand, animal traction or tractor. Agriculture and maize production in Ghana are mostly done by human labour, only a few farmers own and use animal traction for ploughing or other difficult farming activities. Tractor service is available, but especially near bigger cities and less in remote areas. The tractors are often owned by richer people in the towns, who offer the service to farmers who are not able to invest in their own equipment. Energy in the form of fuel is used to operate the tractors. Both animal traction and human power are used to prepare the land.

3.4 Fertilizer Use

Over the last 30 years, fertilizer consumption in sub-Saharan Africa has increased. In recent years, growth in fertilizer application on cereals, particularly, maize has contributed substantially to this increase. Nonetheless, current application rates remain low. Currently in Ghana, the importers of fertilizers to the various sectors of food production and other uses are numerous, with a growing interest in the fertilizer import business. Between 2004 and 2007, Ghana imported 674000.55 metric tonnes of fertilizer (MoFA, 2008). The end users of fertilizers in the food production sector of Ghana, consists of a large number of small scale farmers in units of large households especially in the Northern, Brong Ahafo and parts of the Ashanti region. Energy is used in the application of fertilisers.

3.5 Temperature requirements

The optimum temperature for maize growth and development is 18 to 32 °C, with temperatures of 35 °C and above considered inhibitory. The optimum soil temperatures for germination and early seedling growth are 12 °C or greater, and at tasselling 21 to 30 °C is ideal. Low temperature is rarely a limiting factor for maize production (FCRI, 2001).

3.6 Rainfall requirements

Maize can grow and yield with as little as 300 mm rainfall (40% to 60% yield decline compared to optimal conditions), but prefers 500 to 1200 mm as the optimal range. Depending on soil type and stored soil moisture, crop failure would be expected if less than 300 mm of rain were received in crop. However, through practising reduced tillage, maintaining ground cover or applying crop residues such as rice straw, the impact of drought can be greatly reduced by lowering soil temperature and surface evaporation. In one upland experiment maize yield was increased by 61% by simply adding crop residues to the soil (known as mulching).

3.7 Planting operation

Maize is not as drought tolerant as some of the other upland crops such as beans, so good soil moisture at sowing time is required before the crop is planted. It is recommended that there be at least 30 cm of wet soil throughout the soil profile before sowing. Because of this higher water requirement, the majority of corn is planted in places where rainfall is more reliable, and there is more of it. Planting can be done mechanically by the use of a planter or manually by using a dibber or cutlass. Mechanical power is used to plant on a large scale farm whiles small scale farmers make use of human power.

3.8 Weeding

The most labour-intensive time is the weeding phase. Three times weeding is usual in the transition area, whereas two times are most common in the south. However, the majority of farmers use herbicides to control the weeds. Due to financial constraints, this is often only possible for parts of the cultivated land; additional labour therefore has to be hired.

3.9 Harvesting

Traditionally, when red maize cobs have dried down and it is time for harvest, the cobs are handpicked, hand shelled and dried in the sun. This is very labour intensive, which has a significant impact on the gross margin for maize. Harvesting is generally done by hand, mostly by family labour. Another option is to use machine harvest when moisture levels drop below 18% to 24% and then dry down to below 14% for delivery or storage.

3.10 Drying

After threshing, the maize kernels are dried in the sun either on mats, plastic tarpaulins or on a cement pad until the moisture content is below the storage level (11%), when the kernels are ready for sale. During the drying process, the kernels are raked across the pad to ensure even drying. The moisture level in maize must remain below 11% if the maize is stored for long periods, otherwise aflatoxin may develop, producing toxic side effects for consumers of the grain Energy from the sun is used to dry the kernels. Some big farms employ the use of mechanical dryers. This can be found at Pens Food Bank at Ejura-Sekyedumase.

3.11 Storage

Maize is packaged in sacks and placed in warehouse with a room temperature of 25^{o}C. Maize is susceptible to a lot of pest during storage, thus the storage environment must be free from pest. The environment must not have too much moisture which can cause decay of the maize. In storing, human power is basically used in transporting and arrangement of the maize in warehouses.

3.12 Energy input in maize production value chain

A value chain is the whole series of activities that create and build value at every step. In the production of maize, energy is used. From the preparation of the land till the crop is harvested, energy is required. This energy can be in various forms including fuel for tractors, human power and animal traction.

Land Preparation
↓
Planting
↓
Weeding
↓
Fertilizer Application
↓
Pesticides Application
↓
Harvesting
↓
Drying
↓
Storage

Figure 3: Flowchart of value chain in terms of areas of energy application in maize production

3.13 Value chain analysis of maize

This is a series of activities a product must go through until it serves its final purpose of solving a customer need. In each phase of the value chain the product gains some value. If a phase is malfunctioning the chain will break down and the mission of generating value for the customer will not be accomplished. The flow of seeds to farmers and grains to the market occurs along chains (Figure 4). These can be referred to as value chains because as the product moves from chain actor to chain actor e.g. from producer to intermediary to consumer, it gains value (Jon and Madelon, 2006). The value chain analysis is a useful strategy in understanding overall trends of industrial reorganization. It can be used to identify key players, change agents and leverage points for policy and technical interventions. The main value chain actors in maize production in Ghana include:

- Ministry of Food and Agriculture
- Producers (farmers)
- Marketers (traders)

- Processers (processing factories and local food vendors)
- Consumers

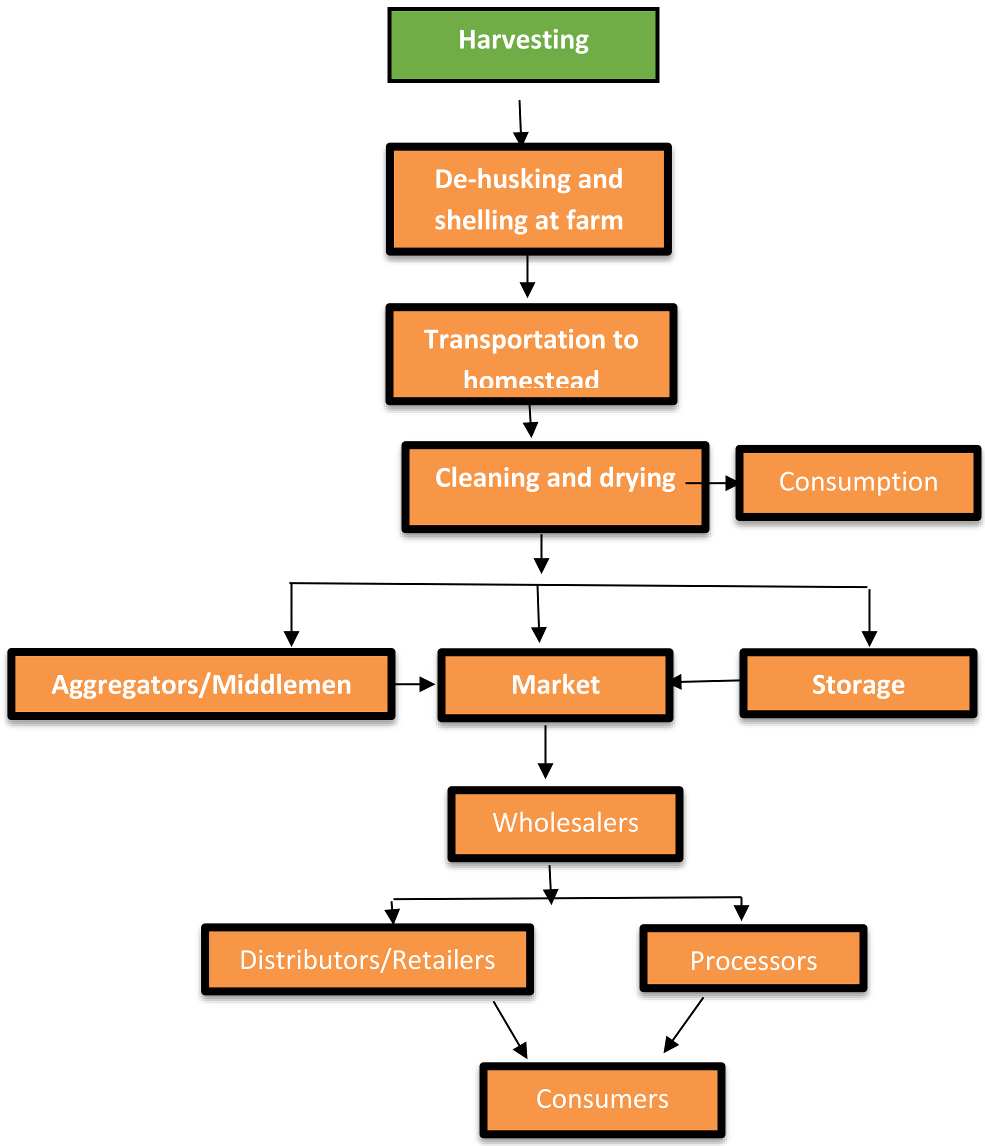

Figure 4: Supply flow chart of maize in the study area

4. STUDY SITE

The Ejura-Sekyedumase District is located in the Northern part of Ashanti Region, and is borderded in the North by Nkroanza North and Atebutu District of the Brong Ahafo Region, to the East by the Sekyere Central, to the South by Sekyere West and Mampong and to the West by the Offinso North District, Nkoranza North and Nkoranza South Districts. The District covers an area of 1,782.2 sq km, which is about 7.3% (one third of its land area lying in the Afram Plains) of the total land area of the Ashanti Region. Ejura, the District capital, is 106 km from Kumasi, the Regional capital. Ejura-Sekyedumase District has a population of 81,115.51 with 51.77% being males and 48.23% are females. The population is 2.2% of the population of Ashanti Region. About 48.8% of the people live in the urban centres namely Ejura and Sekyedumase whilst 51.2% live in rural areas. The district is located within longitudes 1˚5W and 1˚39’ W and latitudes 7˚9’N and 7˚36’N (City and Town Planning Unit, Kumasi). It has a large land size of about 1,782.2sq.km. (690.781sq.miles) and is the fifth largest district in Ashanti region.

4.1 Climate and Vegetation

Ejura-Sekyedumase lies within the transitional zone of the semi-deciduous forest and Guinea Savannah zones. Thus, it experiences both the forest and savannah climatic conditions. The district is marked by two rainfall patterns; the bi-modal pattern in the south and the uni-modal in the north. The District experiences both forest and savannah climatic conditions. The rainy periods are associated with very high humidity. Relative humidity is as high as 90% experienced in June and as low as 55% in February. The District is the driest in the Ashanti Region (Ghana Meteorological Service).

4.2 Topography, Soils and Drainage

The landscape in the southern part of the district is fairly rolling with valleys and peaks. Averagely, the valleys have a depth of about 135m whilst the peaks rise to about 315m above sea level. The highest point in the district is made up of a range of hills, found in the eastern part and passes through Ejura and Mampong, forming part of the Kintampo-Koforidua range. Examples of the hills found in the district include; Kwasi Mahu Hills (1,350), Ejurachem Scarp (1,000) and Dente Scarp (rock outcrop) with a greater part of the districts reserve being a scarp (MOFA, Ejura Sekyedumase District, 2014).

On the other hand, the northern part is undulating and fairly flat with heights ranging between 150-300m. Ejura is located on an altitude of about 225m. The district is dissected and well-drained by a number of rivers, streams and their tributaries. The drainage is dendritic in nature and has a west-east and northwest-southeast directional flow. Major rivers include; Affram, Akobaa, Chirade, Bresua whilst minor ones include Aberewa, Yaya and Baba (MOFA, Ejura-Sekyedumase District, 2014).

4.3 Agricultural and Other Economic Activities

The occupational distribution in the district shows that, the agricultural sector, industrial sector and services/commercial sector employs 68.2%, 8.0% and 23.8% in the district (www.ghanadistricts.com accessed on 3rd March). The structure of the Ejura-Sekyedumase District economy remains an agrarian one. This shows that the agricultural sector dominates in terms of employment. The manufacturing industry involves sawmilling, carpentry, bakery, pottery and blacksmithing. The agro-industry includes oil palm production, rice mill, com mill, floor mill, mushroom cultivation, beekeeping and carbolic soap production.

5. DATA COLLECTION

The primary data, which pertained to the 2013/2014 minor maize season, were collected from the sampled maize farmers using structured questionnaires. The questionnaire included both close and open-ended questions. The close-ended questions were mainly for quantitative data whilst the open-ended questions were for qualitative data. Before starting the actual data collection, the questionnaire was pre-tested, enabling the modification of some of the questions which were either irrelevant to the theme of the study or out of context. In addition, effort was made to ensure that the wording and sequence of questions were right. For each section, the questionnaire sort to find out the source of energy required. These sources include machinery, human labour and draught animal. The questionnaire also sort to find out the sources of labour in use; family, hired etc. and the ownership of machinery and draught animals in use.

The 150 farmers were selected to be interviewed based on the agricultural operational areas of the community. The Ejura-Sekyeredumase district consists of 18 operational areas with 134 communities. 10 operational communities were selected and 15 farmers interviewed in each operational area. This method provided a fair representation f orespondents in the Municipal as a whole.

5.1 Method of Data Analysis

Following data collection, the data were coded and entered into SPSS Version 16 computer software and used together with Excel software for analysis. SPSS was chosen because of its appropriateness in coding and entering of qualitative data for analysis as well as its ability to handle large data sets.

5.2 Theoretical Framework

In order to calculate input-output ratios and other energy indicators, the data were converted into output and input energy levels using equivalent energy values for each commodity and input. The input and output values were calculated per hectare, and then, multiplied by the coefficient of energy equivalent. The data was transformed to energy term by appropriate energy equivalent factors given in Table 3.Energy equivalent values shown in Table 3 were used for estimation (Ozkan *et al*., 2004; Moradi and azarpour, 2011; Rathke *et al*., 2007). Firstly, the amounts of inputs used in the production of maize were specified in order to calculate the energy equivalences in the study. Energy input includes human labour, animal traction and machinery.

A comprehensive literature review was undertaken to investigate previous calculation methods and data sources. The energy inputs for maize production were assessed for direct energy consumption. Direct energy use is in the form of tractor fuel and electricity used on the farm. Indirect energy includes production inputs for products such as fertilizers, herbicides, pesticides and seed were neglected. This estimation also neglected solar energy input and inputs for manufacturing machinery taking into account of the energy used on the farm.

Table 1: Inputs and their energy equivalent

Input	Unit	Energy equivalent MJ/unit	Reference
Human labour	H	1.96	(Bojaca and Schrevens, 2010)
Draught Animal Ox Donkey	H	 10.0 3.0	(FAO, 1994)
Fuel (Diesel)	L	62.70	(Erdal et al., 2007; Esengun et al., 2007)

Seed	kg	17.50	(Singh, 2000)

The direct energy use per hectare for each field operation was computed by Equation 1 as presented by Moerschner and Gerowitt, (2000):

$$ED = h \times AFU \times PEU \times RU \text{ --------- Equation 1}$$

ED = Specific direct energy use (fuel) for a field operation, MJ/ha.

h = Specific working hours per run, h/ha

AFU = Average fuel use per working hour, L/h

PEU = Specific energy value per litre of fuel, MJ/L

RU = Runs, number of applications in the considered field operation

The rate of labour used in the maize production process was determined for each operation. The labour energy input (MJ/ha) at every stage in the production process was estimated by the following equation:

$$LABEN = \frac{LABOUR \times TIME \times LABENF}{AREA} \text{ ------------- Equation 2}$$

Where, LABEN= labour energy, MJ/ha

LABOUR = number of working labourers

TIME = operating time, h

AREA = operating area, ha

LABENF = labour energy factor, MJ/h.

5.2.1 Development of Software

To estimate the amount of energy required across the maize value chain, a desktop software was developed.

5.2.2 Importance of the Software

- It reduces the drudgery associated with calculation of energy for a large number of farms.
- It also reduces the stress and mistakes associated with calculation.

5.2.3 Features of the Software

The software makes use of the equations above to calculate the energy required. The operations are arrayed in the order in which they are performed on the farm with land preparation being the first operation on the software.

The software provides alternatives for calculation of energy required depending on the type of energy used and the operation involved.

5.2.4 Development tools used

1. Language used- Visual Basics(VB)
2. Integrated Development Environment(IDE)
3. Microsoft visual studio

6. RESULTS AND DISCUSSIONS

6.1 Sample demographics

Questionnaires were administered to 150 respondents (Table 2). Out of the said number of respondents, 64.7% were males which shows that maize production is male dominated as compared to 35.3% being females. More than half of the respondents (80.7%) had low education. Most respondents (70.5%) were between the ages of 30 and 50 indicating a balance between the youth and the old in the farming community. About 89.1% of the respondents had more than five members in their household, implying that they had access to human labour thereby reducing labour cost.

Table 2: Personal characteristics of respondents

Variables	*Frequency*	*Percentages*
Gender		
Male	97	64.7
Female	53	35.3
Marital Status		
Married	131	87.9
Single	5	3.4
Divorced	6	4.0
Widowed	7	4.7
Educational Level		
No education	58	41.4
Primary school	36.2	39.3
Secondary school	15.8	2.1
Post-secondary school	2.0	
Age(years)		
30 and below	12	8.1
30-50	105	70.5
50 and above	32	21.5
Farm Size(acres)		
2 and below	11	7.3
2-5	82	54.7
5 and above	150	38.0
Household Size		
4 and below	16	10.9
5-9	82	55.8
10-14	37	25.1
Above 14	12	8.2

6.2 Farm Operations

6.2.1 Land Preparation

Table 3 reveals the major land preparation method used by the respondents and the regularity of use; The results indicate the use of tractor (83.3%) as the most widely used Out of the percentage of tractors used, 4.6% were owned by individuals whereas 95.4% was hired. Also for the number of days the tractors were used, 87.3% used a day, 10.3 percent used 2 days and 1.6 percent used 3 days, with 0.8% using 4 days. The use of tractors reduces drudgery and saves time. However, it is costly, and since most of the respondents (95.4%) hired tractors, most respondents (87.3%) used I for a day.

Table 3: Land preparation method

Method used	*Frequency*	*Percentage*
Draught animal	1	0.7
Tractor (Mechanical)	120	83.3
Manual labour	23	16.0

Moreover for respondents using human labour, 4.8% used family labour, 76.2% hired permanent labourers while 19.0% hired casual labour.

6.2.2 Maize Planting

For maize planting, human labour was mainly used. Table 4 reveals the major type of human labour used. The type of planting labour used included family (18.6%), hired permanent (56.6%), casual labour (24.1%) and others (0.7%). This findings show that majority (80.7%) hired people to work on their farms.

Table 4: Type of labour used in planting

Type of Labour used	*Frequency*	*Percentage*
Family labour	27	18.6
Permanent labour	82	56.6
Casual labour	35	24.1
Others	1	0.7

From Table 5, it can be seen that the majority of respondents (53.5%) use a day to plant maize. The number of days worked is directly proportional to the rate of energy consumption and the cost of labour.

Table 5: Number of days spent in planting

Number of days spent	*Frequency*	*Percentage*
1	61	53.5
2	29	25.4
3	13	11.4
4	8	7.0
5	2	1.8
8	1	0.9

6.2.3 Weeding

Analyses of the responses from farmers indicated that, 65.8 % weeded their farms once, whereas 34.2 % weed their farms twice. Weeding is the most intensive and energy demanding stage of maize production. The result of table 6 shows that 22.9% used family labour, 45.7% used hired permanent labour and 31.4% used casual labour.

Table 6: Type of labour used for weeding

Type of labour	*Frequency*	*Percentage*
Family labour	24	22.9
Permanent labour	48	45.7
Casual labour	33	31.4

6.2.4 Fertilizer Application

Results of Table 7 indicate that, most of the respondents (89.3%) applied planting fertilizer NPK with 1.4% applying other fertilizers while 9.3% did not use fertilizer on their farms. The use of fertilizers for planting gives the crop more yields.

Table 7: Type of fertilizer used

Type of fertilizer	*Frequency*	*Percentage*
None	13	9.3
NPK	125	89.3
Others	2	1.4

The quantity of fertilizer applied had 300kg as 13.5% the highest with 1, 7, 20, 28, 30, 225, 357, 816 and1200 (kg) all recording 0.8% being the lowest. The variations in the quantity are as a result of the farm sizes.

After the maize plant has sprouted, fertilizer is applied to the soil to provide the plant with more nutrients. From Table 8, it is seen that 7% didn't apply fertilizer, 32.5% used urea, 60% used other fertilizers while 0.9% used CAN fertilizer.

Table 8: Type of fertilizer used for dressing

Type of fertilizer for dressing	*Frequency*	*Percentage*
None	8	7.0
Urea	37	32.5
Other	68	59.6
CAN	1	0.9

6.2.5 Harvesting

Approximately 70% of respondents harvested maize s at moisture content less than 14%, while 30% harvested their maize crop between 14-20% moisture content. With high moisture content, more energy has to be used to dry the produce. The type of labour used for harvesting and gathering included family labour (28.8%), hired permanent (39.0%), casual labour (30.1%) and those who used all the other labour types (1.4%).

Table 9: Type of labour used for harvesting

Type of labour	*Frequency*	*Percentage*
Family labour	42	28.8
Permanent labour	57	39.0
Casual labour	45	30.8
All above	2	1.4

6.2.6 Shelling

For method of shelling maize, 1.3% beat maize in a sack while 98.7 % used a sheller. The use of a sheller (98.7%) is mostly used by the respondents because it is fast, efficient and saves labour.

Table 10: Method of Shelling

Method of Shelling	*Frequency*	*Percentage*
Use of sheller	147	98.7
Beating maize in sacks with sticks	2	1.3

6.2.7 Transportation

In relation to means of transporting their harvested produce, 1.3% of the respondents indicated they use head porters, 90.5% use trucks while 5.2% use tricycle. The remaining respondents (2.6%) indicated they use other means of transportation.

Table 11: Means of transporting harvested produce

Means of Transportation	*Frequency*	*Percentage*
Head porters	2	1.7
Trucks	104	90.4
Tricycle (*aboboyaa*)	6	5.2
Other	3	2.6

6.2.8 Drying

Field drying and open air/sun drying relies on the sun’s energy which is free. Due to this and the cost of mechanical drying, 79.9% of respondents’ sole rely on field drying (i.e. delay harvesting to allow the crops to dry on the field) while 20.3% dry their produce using the open sun/air with only 0.7% resorting to a mechanical dryer.

Table 12: Method of drying

Method of drying	*Frequency*	*Percentage*
Field drying	117	79.0
Open air/sun drying	30	20.3
Mechanical	1	0.7

7. VALUE CHAIN ANALYSIS OF ENERGY INPUT FOR MAIZE PRODUCTION

To estimate the amount of energy required across the maize value chain, the desktop software tool developed was used. Figure 5 shows the overlay of activities to select on the home page for further calculation.

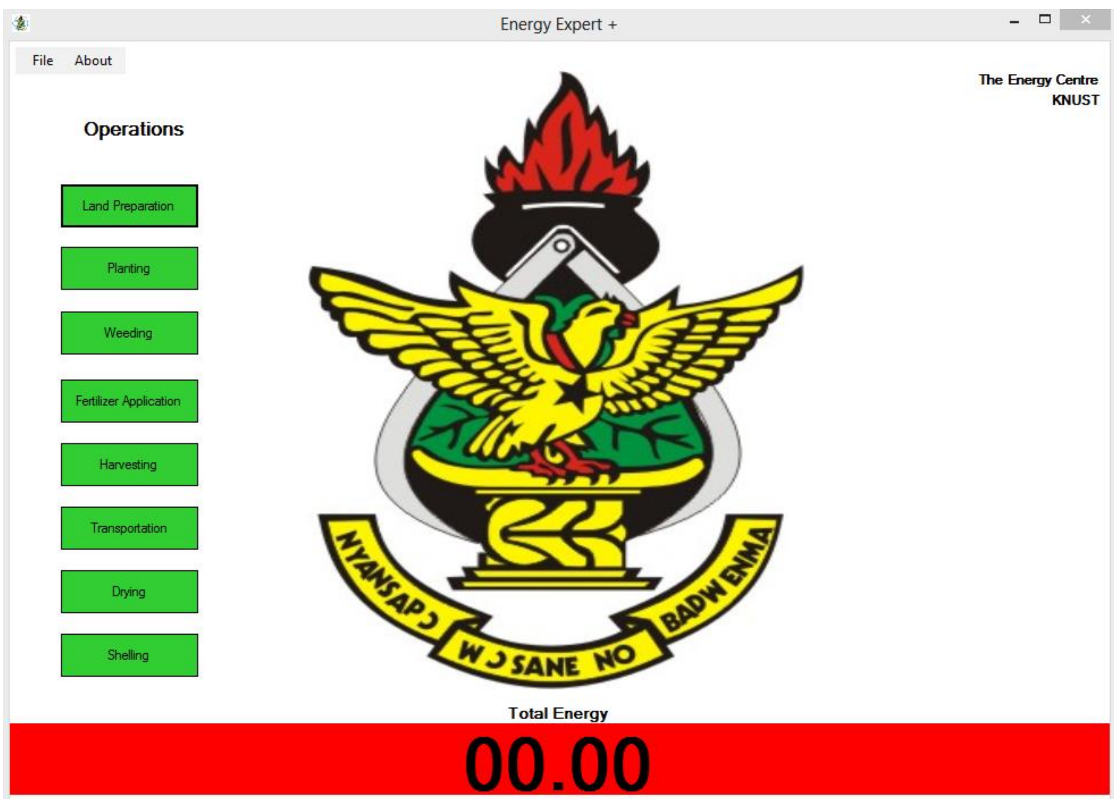

Figure 5: Energy estimator for maize production along the value chain

7.1 Energy for land preparation

Analyses of data collected from 150 questionnaires administered showed that 83.3% of farmers in the Ejura-Sekyeredumasi district employ the use of tractors in land preparation; this is evident in the abundance of tractors in the district. 16% of the farmers consented to the use of manual labour for land preparation; this practice though stressful was understandable because most of the farmers were smallholder farmers with farm sizes below 5 acres. The use of draught animals for land preparation is still in use by a very small minority of farmers in the district, about 0.7% of the farmers interviewed responded in the affirmative. The estimated energy for land preparation using the Energy Expect Plus was 501.6 MJ. The interfaces based on type of power, type of application or method used for the land preparation activities are shown in Figures (6, 7 and 8) in Appendix 1.

7.2 Energy for planting and weeding

Another major farm operation along the maize value chain is planting. Planting in the district is done manually; most of the labour required for planting is from hired permanent labourers, with casual labourers contributing at some stage. Family members also support during planting activities. For all these sources of labour, it was seen that adult males form the majority of the work force. The energy estimated for planting using a farmer's farm as case study 11.76MJ. The interface for calculating the energy is shown in Figure 9 in Appendix 1.

During the maintenance phase of maize production, there is the need to clear out weeds and others plants that are impeding the growth of the maize. Weeding is the most intensive and energy demanding stage of maize production. The software interface for estimation of energy for weeding is shown in Figure 10 in Appendix 1.

7.3 Fertilizer application

To enable the plants grow well, it is essential to apply fertilizer to the plants after planting. The most common type of fertilizer used in Ghana is NPK. The application of fertilizer to the plants is mostly done manually with the exception of large plantations the utilize machinery. The interface for energy input for fertilizer application which was estimated as5.23MJ is presented in Figure 11 in Appendix 1

7.4 Energy input for harvesting

Analyses of the questionnaire showed that most of the farmers had farm sizes of 5 acres and below, and as such are smallholder farmers. Harvesting is done manually. Labour for harvesting is mostly from hired labour. Other sources include casual labour and family labour. Family labour increases a lot during harvesting and gathering because this operation is considered to be less strenuous than the others. Mechanical harvesting exists but it is only used by big plantations. The energy estimated for manual harvesting was 23.52 MJ per hectare. The interface for estimating the energy required is as presented in Figure 12 in Appendix 1.

7.5 Energy input for Shelling

In the Ejura-Sekyeredumasi district, there are two main methods of shelling maize identified include the use motorized Sheller and beating maize in sacks with sticks. However, majority of farmers (98%) in the study area use the motorized shelling machine which does both both dehusking and shelling simultaneously. The use of the motorized sheller involves some labour in the form of causal labourers who are hired to fetch and pour the unhusked maize into the hopper of the sheller. The manual shelling is normally done by adult women. The estimated energy for shelling maize of a hectare was estimated as 1003MJ. Figure 13 and 14 in Appendix 1 provides the interface in the Energy Expert Plus for calculating the energy required for such activities.

7.6 Energy for drying

Open sun drying is the main process involved in the drying of the harvested produce as stated by most of the farmers. Some also leave their produce on the farm during the minor season for drying to take place naturally. However these practices leave the produce to the mercies of thieves and unexpected rain. Since the farmers do not employ any technology and has no scientific background regarding drying, the produce normally do not attain the optimum moisture content.

7.7 Estimating energy demand for maize production using developed desktop software:

Table 13 shows the energy consumed in various farm operations for maize production on a farmer's field at the study area. In his land preparation activities, the tractor was used to prepare the land while manual labour was used for planting, weeding and harvesting operations due to the farm size. Natural drying was used to dry the maize. For shelling of maize, the mechanised shelling machine was used for both dehusking and shelling operations.

Table 13: Energy inputs for a case study farm

Operation	Energy Estimated(MJ)
Land preparation	501.6
Planting	11.76
Weeding	15.68
Fertilizer application	5.23
Harvesting	23.52
Transportation	75.46
Drying	-
Shelling	1003.2
Total	**1,636.45**

8. CONCLUSIONS

Energy is required along the value chain of maize production for various processes, and especially during the following farm operations: land preparation, planting, maintenance (weeding), fertilizer application, harvesting etc. Knowledge of energy consumption and demand at every stage of maize production along the value the chain is important for estimation of the real cost of production. This project activity sought to identify the various activities along the maize value chain that required energy in the study area, Ejura Sekyeredumasi and to estimate the amount of energy required across the value chain for maize production. It was noted through the survey conducted that, the major energy input for maize production in the study area was from manual labour, with some mix of machinery and animal traction. Major value chain activities that were identified from the survey which requires high energy input from farmers were:

- land preparation; 83% of the respondent confirmed this;
- shelling operations (99%); and
- transportation of produce from farm to homestead or market (90%).

All the other activities such as planting, weeding and fertilizer application were undertaken manually with farmers using hired labour and in some instance family labour was used especially during harvesting.

To accomplish the objective of estimating the energy required across the maize value chain, a desktop software called *Energy Expert Plus* was developed. The development of the software took into account the various farming operations that require energy; land preparation, planting, weeding, fertiliser application, harvesting and gathering and shelling. The friendly interface of the software allows the user to make inputs using real data to calculate or estimate the energy required at any stage of the maize production value chain. Using a case study of a farm, an estimated amount of 1,636.45 MJ **of energy** was required to cultivate a hectare of maize.

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APPENDIX 1

The various interfaces for estimation of energy for maize production along the value chain is present.

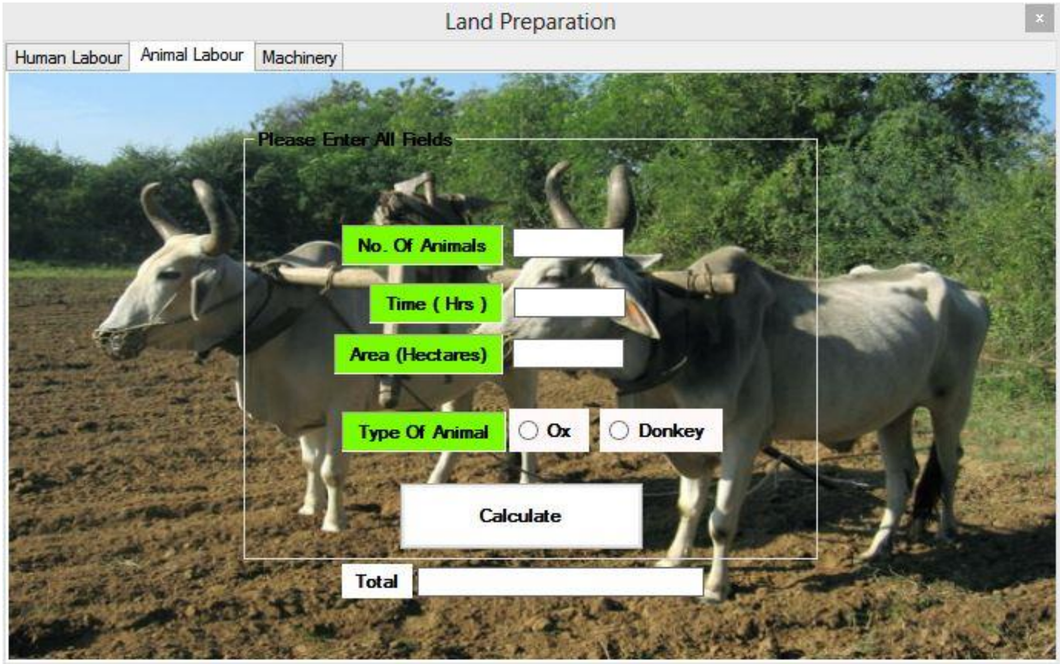

Figure 6: Software interface for energy estimation for land preparation using animals

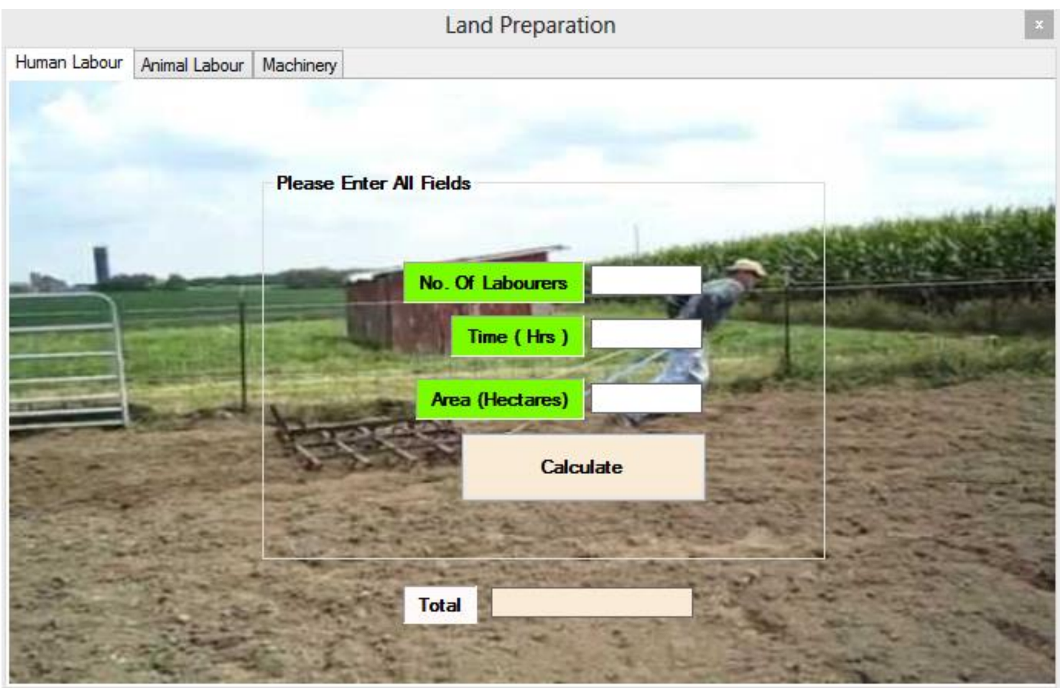

Figure 7: Software interface for energy estimation for land preparation using human labour

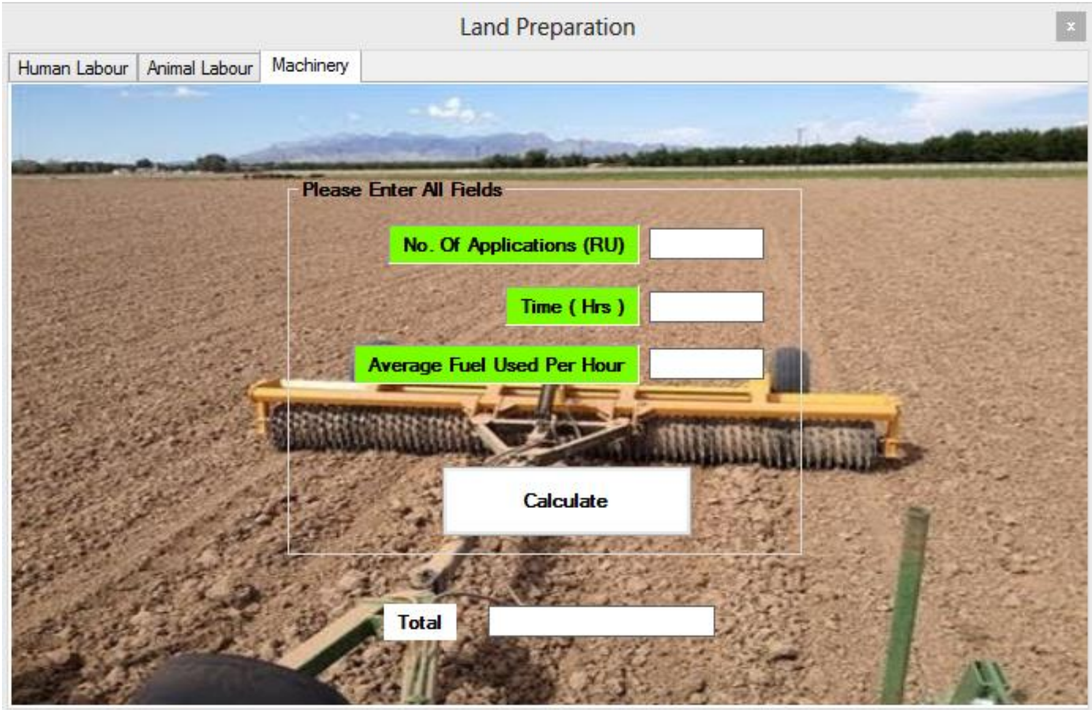

Figure 8: Software interface for energy estimation for land preparation using tractor

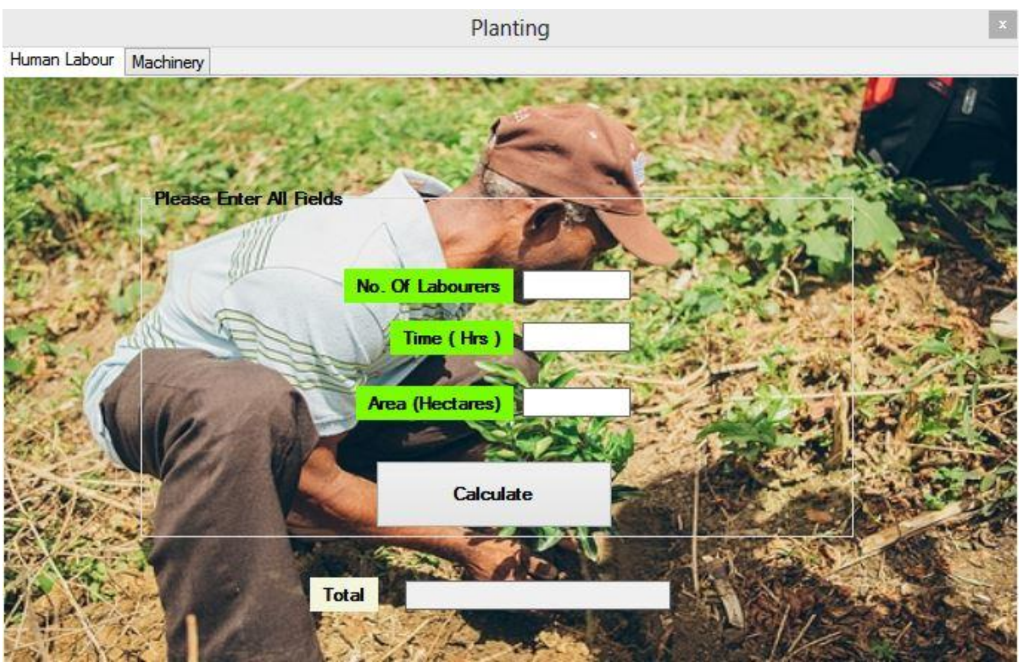

Figure 9: Software interface for energy estimation for maize planting.

Figure 10: Software interface for energy estimation for weeding

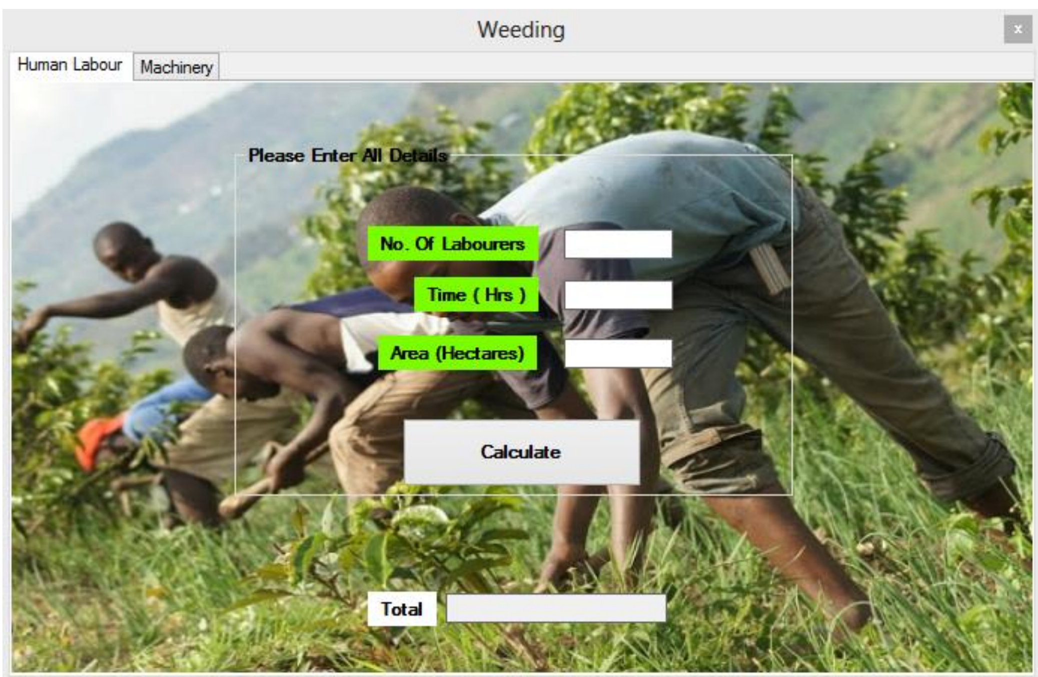

Figure 11: Software interface for energy estimation for weeding

Figure 12: Software interface for energy estimation for fertilizer application

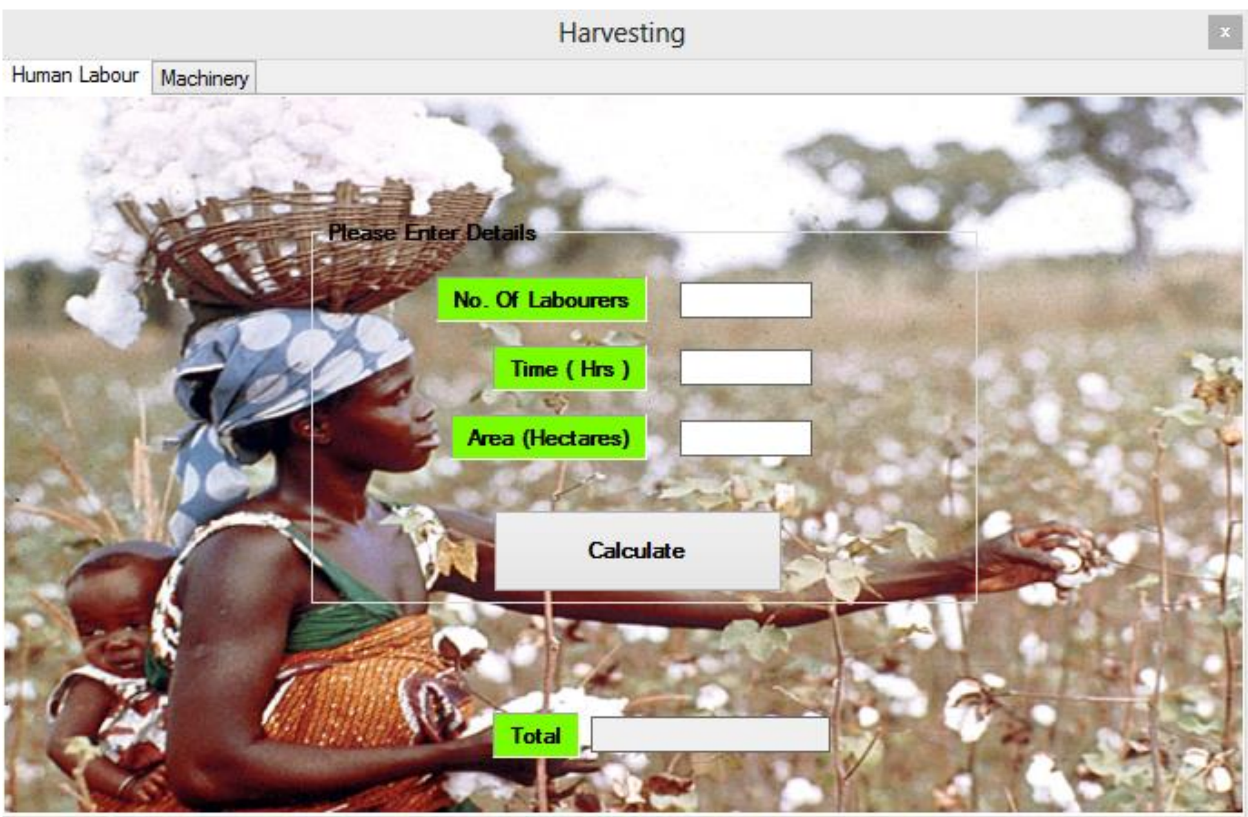

Figure 13: Software interface for energy estimation for manual harvesting

Figure 14: Software interface for energy estimation for mechanized shelling

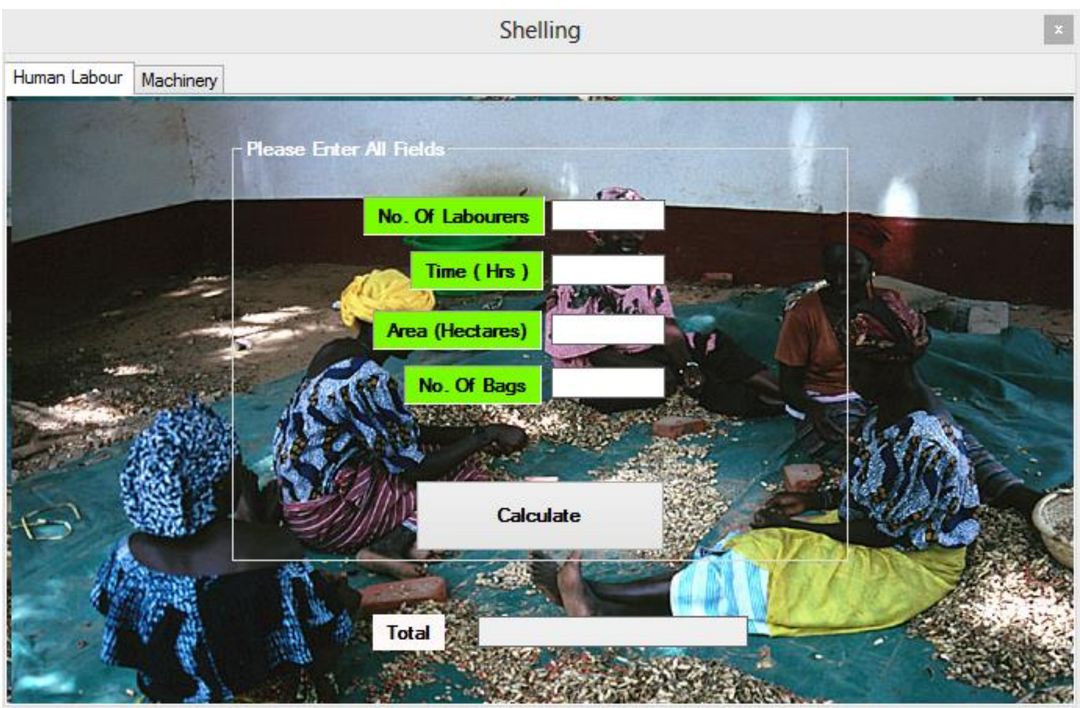

Figure 15: Software interface for energy estimation of energy for manual shelling

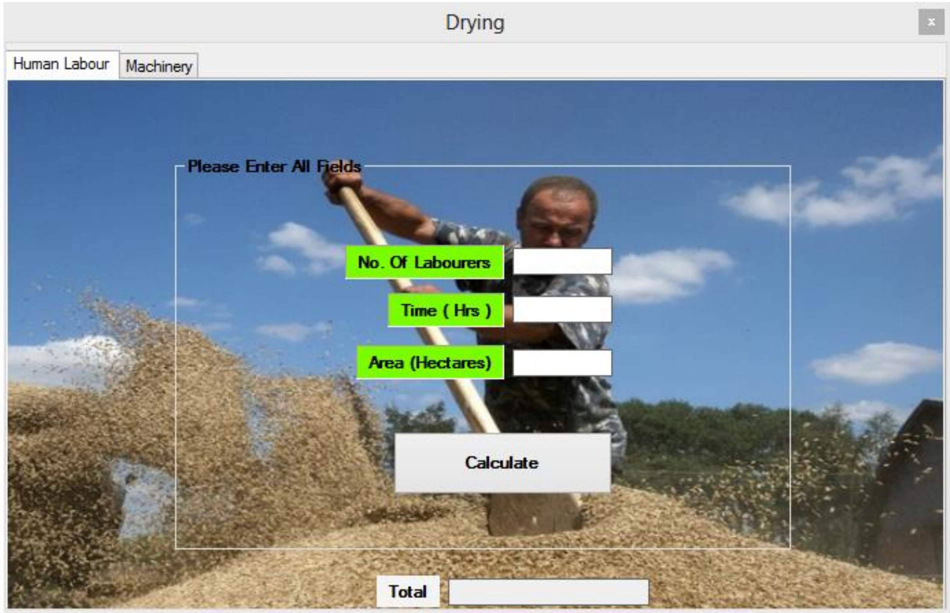

Figure 16: Software interface for energy estimation for open air/sun drying

Figure 17: Software interface for energy estimation for mechanised drying