





<p style="text-align: center;"><i>School Innovative Technology for Agri-Food and Environmental Sciences</i></p> <p style="text-align: center;">Cycle XXVII</p> <p style="text-align: center;"><b>Dr. Joseph B. Tholley</b></p> <p style="text-align: center;">Tutor: Prof Marco Fiala</p>		
	<p style="text-align: center;"><b>PhD Thesis</b></p> <p style="text-align: center;"><i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
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## Dedication

I would like dedicate this work to my wife (Mrs. Adama Tholley), children and parents (Pa Sorie Tholley and Ya Mballu Sesay).

Their love and care have inspired me to achieve this level in search of knowledge for the common good of humanity.

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Not forgetting Madam Zainab Khanu and family, whose tireless affection, care and assistance always re-energizes me during my tedious hours of work.



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I will not end my thanks if fail to mention the entire University of Makeni (UNIMAK) staff and students, for whose purpose this work is meant to yield more fruits in the near future.

My heartfelt thanks are due to Rev. Fr. Prof. Joseph A. Turay (Fr Joe), whose sincere purpose of life, concern for all and balanced human interaction capability have played some leading roles in making me achieve this level. I indeed owe him immense thanks.

God bless all those whose names are not mentioned here but have virtually played vital roles in enhancing the completion of this work.

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## General introduction of the study

Sierra Leone is characterised by diverse natural geographic features that range from ocean coastal mangrove swamps to high mountains, as high as 1,948 meters (6,390 ft).

The country is strategically located slightly above the equator at latitude 8° 49' N and Longitude 13° 24' W. It has two seasons; the rainy or wet and dry seasons. The rainy or wet season is from May to October, while the dry season ranges from November to April (**Figure 1.4**).

The two seasons can be described as having tremendous advantages to agricultural life but can as well be considered as aggressive and have adverse climatic effects in agriculture especially when technology is yet at its low ebb in the country. The rains during the rainy season can yield 2,070 mm in the far north to 3,250 mm of water in the South. Temperatures can grow between the ranges of 15° to 35° centigrade within the year. The relative humidity is normally high during the onset of the rainy season and at the end of it. It falls between the ranges of 1918.3-2412.6 mm.

The country (Sierra Leone) currently has a human population of 5,836,220 of which 51% are women (**Table 1.1**).

The land surface area is about 71,740 km<sup>2</sup> or 7.23 million hectares (WHO Country Cooperation Strategy: Sierra Leone 2004-2007), of which 5.4 million are potentially cultivable but only less than 23% is currently cultivated (**Table 1.2**).

There are five ecological areas where farming is practiced in the country. These are Upland, Inland Valley Swamp (IVS), Mangrove Swamp, Boliland and Riverine Grassland. The bolilands, mangrove and the riverine swamps are all lowland ecologies. The upland ecology represents approximately 80% of the total land under crop and animal cultivation; and the rest are lowlands with high potential for crop yield under sound management practices (**Table 1.2**).



The total arable land resource of Sierra Leone for agricultural activities is 74.2% (5.4 million ha). The lowland area, which is the most fertile, occupies 16.1% (1,165,000 ha) of which 690,000 ha are inland valley swamps (IVS), 130,000 ha are the Bolilands and the Mangrove swamps occupy 200,000 ha. It should be noted that these vast cultivable land areas are not only owned by the public sector- a large proportion is being owned by small-holder farmers [**atpsnet.org, 2008, Sierra Leone**].

The ecological landscape of Sierra Leone largely determines the agricultural production pattern of the country (**Figure 1.1**). There are however some variations due to the traditional or inter-cultural or inter-community relations amongst the farmers.

The country is made up of 13 tribes; three of which form majority of the total population, namely: the Mende, Themne and Limba who are strategically located in all the four regions of the country, making the Northern, Eastern, Southern and Western provinces.

The Themne and Limba are located in the North West of the country while the Mende mainly occupy the South-East. There are other minority tribes, such as the Kono, Vai, Krim, Kissi and Shebro who are



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infused amongst the Mendes in the South-East, while the Kuranko, Mandingo, Susu, Yalunka, Fulla, Loko and Krio (a progeny of the freed slaves from the West) are found in the North West.

With the exception of the Krio (Creole is the pigeon English Language) who are mainly found in the urban areas of Freetown and its municipality, all of these tribes are mainly farmers in diverse ways in the rural and sub-urban areas. They are either crop cultivators (i.e Themne, Limba, Mende, Kuranko, Kono) or fishermen (i.e Shebro, Loko, Susu, Vai) or pastoralists (i.e Fulla, Mandingo, Yalunka). The Fulla, Mandingo and Yalunka are mainly located in the North which has adequate savannah grass for the grazing of their animals.

Sierra Leone has potentials to develop an advanced agricultural sector in the future because of its natural endowments. The topography, natural soil conditions and human resources in the country are suitable for both small and large scale agricultural production if managed sustainably well.

As a result of their high illiterate level in formal education, the Resource Poor Framers (RPF) or Small Scale Farmers (SSF) are most times considered ignorant and therefore have no business to be included in research to generate innovations that can be of help to alleviate them from their predicaments. Instead, the society created an intermediary system called 'extension services', in this case agricultural extension services, which is meant to transfer the new innovations or knowledge gained by researchers or institutions to them.

This is the beginning of series of problems with the SSF in linking up with the world of new knowledge, skills, techniques and technologies. These problems could range from inaccurate transfer of knowledge, cost of transfer, timeliness of transfer, effectiveness of transfer, the manner of transfer, the level used to transfer etc. Eventually, instead of the RPF see this intervention as an aid to development, it becomes a burden. They (RPF) therefore prefer to do their farming in their own old ways and hence branded "conservative to innovations".



Coupled with lack of resources, the non-inclusion of the SSF or RPF in creating new knowledge through research has created inevitable stagnation or setback in the world food security especially for developing countries like Sierra Leone.

Since independence in 1961, Sierra Leone has been experiencing a steady growth in population density while the food production has been staggering (**Figure 1.3**). This has led to the increasing food insecurity that has led to series of economic and social problems. The effects the 11-year civil war has also precipitated massive migration of able bodied men and women to urban centres for low wage jobs, hence decreasing the work force in agricultural production.



The study is therefore geared towards investigating the effects of introducing minimal mechanisation into agriculture together with basic modern techniques in the production of rice and other intercrops with the SSF in the upland ecology.

The lack of social amenities and other opportunities in rural areas has been seen to contribute to the migration of youths to urban areas. One of the reasons for this is lack is electric energy in rural areas. The study intends to therefore investigate the introduction of jatropha which is an energy producing crop that is capable of producing Pure Vegetable Oil (PVO) that can be used in specially designed internal combustion (i.c.) engine to produce electricity in the rural village with local farmers.

In essence, the study is gearing towards providing means to increase food and electric energy production in the rural communities with local farmers by introducing modern technology (minimal mechanisation) and modern techniques combined with the existing traditional methods and tools.

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The study shall be investigating the technical, social and economic advantages and disadvantages of these interventions in the rural settings in other to enable the development of these RPF in their local communities.

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### Main objectives of the study



With the component of rice cultivation through the introduction of minimum mechanisation and modern techniques of row planting of crops in comparison with the traditional method, the study shall be carefully investigating the following:

1. how the use of simple farm machinery such as tractor with minimum mechanisation can influence the rice cultivation activities with the small scale farmers at rural community level in the upland ecology as follows:
  - a) impact on the *time spent* by farmers on field operations on rice cultivation together with its allied crops (*sesame*, pigeon pea and sorghum) when compared with the traditional method in the upland ecology;
  - b) investigate the *cost* through the use of machinery in the cultivation in comparison with the traditional method of the hoe and cutlass or machetes and
  - c) the work capacity of the tractor compared with the traditional manual method.
2. the use of crop (rice, *sesame*, pigeon pea and sorghum) spacing and other modern techniques can influence productivity when compared with the traditional method in the following aspects:
  - a) impact on the crops (rice, beni-seed, pigeon pea and sorghum) *growth responses* within the growing season;
  - b) impact on the *yield rates* per hectare of the modern row planting compared with the traditional random broadcasting method and
  - c) influence on the *post planting operations* of the farm such as weeding, erosion control and harvesting when compared with the traditional method of random broadcasting.
3. with the component of rural electrification the study shall investigate how bio fuel in the form of Pure Vegetable Oil (PVO) can be used for rural electrification by small scale farmers through the growing of energy producing crop called jatropha in the upland ecology:
  - a) to investigate the varieties of jatropha crops with the potentials to produce Crude Vegetable Oil (CVO) in Sierra Leone;
  - b) to investigate the effects or impacts of such production in relation to food production at local community level and
  - c) how jatropha can be grown to produce seeds that can be transformed to produce PVO for use in an i.c. engine to generate electricity for rural electrification at village level with the local farmers;
4. the use of machinery is highly limited in Sierra Leone due to lack of the initial capital and technical-know especially with the small scale farmers in rural areas. The running cost of such machinery is also another key limiting factor for successful utility and sustainability by these resource poor farmers in their rural communities. Although other costs are underlying, the day to day running costs of the machines in most agricultural operations is likely impossible by the RPF due to the high cost which they cannot afford thus the following are some of the consequences:
  - a) traditional tools and equipments through manual methods;
  - b) small acreage cultivation by farmers due to the heavy manual labour involved;
  - c) low yields per hectare;
  - d) poor seed bed preparation for crop cultivation;

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- e) high limitation to food transformation, hence short duration of food stuffs, low quality and market value and
- f) low standard of life, hence the urge for rural urban migration especially with youths in search of better standards of living. This has precipitated lots of problems such as health, crimes, inadequate housing, food shortage, poor or low level education etc in Africa and Sierra Leone in particular.

The study is therefore intending to look out for ways to reduce these problems by capacitating the RPF through the introduction of modern technologies and techniques and their active involvement into research activities in their local communities for their own development.

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## Extended abstract

### 1 - General background of the research in Sierra Leone

There is critical and crucial shortage of both food and energy in Africa of which Sierra Leone is an integral part in the West African region. The lasting solution to this problem might be obtained from adequate knowledge to secure sustainable means of producing these essential needs (**food and energy**) through the people of Africa themselves and Sierra Leone in this case.

This can be achieved through acquiring **skills, knowledge and techniques** which can be obtained mostly through research and implementation with the very people in the country or the African continent itself.

Sierra Leone, which is ranked 183rd country [**UNDP, 2014**] in the **human development index**, is yet to make very strong and conscious efforts in combating the problems of the most significant pillars of human development needs, which are food and energy. **The achievement of securing adequate food and energy in any country will lead to improve education, health, infrastructure, communication and other social amenities**; making the lives of its citizens meaningful and worth living in consonant with the rest of the living standards of the rapidly growing world.



It can be argued that anchoring research in the needs and opportunities of the farmers is as important as it is to anchor the research in the international scientific literature [**N.G. Roling et Al., 2004**]. Agriculture, which is practiced by 75% of the total population of Sierra Leone, is considered to be the most appropriate means of sustainably solving these key issues if properly practiced in the country. This research is geared towards getting **possible means of minimizing the problem of food and energy shortages through the use of the local farmers by introducing basic but essential skills in minimal mechanization and modern agronomic methods in their farm sites to produce rice-staple food and bio-fuel from jatrophia seeds that can be used locally by the people themselves**.

The approach which is coupled with scientific research methods will not only look out for solutions to the problems of food and energy shortage but also:

1. teach the farmers some basic science skills to acquire new knowledge;
2. look for solutions to their farm problems by enabling them use the research knowledge gained more relevantly in the agricultural activities and
3. to create positive new levels of food production and processing in their local communities.

In other to achieve this goal the use of **On-Farm Research (OFR)** method was applied; according to this method, the farmers are integral component or part of the entire research work from start to finish. By so doing, the **farmers will not only gain from the results of the research but also learn the techniques** such as:

1. careful field observation;
2. comparison of events and technical situations;
3. use of scientific skills and simple instruments or equipments, such as measurements and spacing and
4. independently develop the ability to make judgments from the field as a living laboratory where they live and interact every day.

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This makes the skills, techniques and knowledge which the farmers gain as **real property of their own** and can be readily used when they confront any situation during their production process and NOT as an outside or strange research results or techniques handed over to them to be used to improve their production level by researcher(s) or research institution(s).

## 2 - Rice cultivation with modern method of minimal mechanization and intercropping compared to the traditional method in the upland ecology

### 2.1 Introduction and general objectives

The objectives of the research on traditional and modern methods of upland rice cultivation with small scale farmers in the Bombali district of Sierra Leone are:

1. to assess the impacts of minimum mechanical cultivation through soil tillage (ploughing and harrowing-1st and 2nd harrowing) and traditional method of using the hoe and cutlass in the upland rice cultivation with small scale farmers in Sierra Leone;
2. to assess the intensity of labor used in the modern and traditional methods of upland rice cultivation by the rural small scale farmers;
3. to investigate the crop response in terms of vegetative growth and yield rate of rice and its related intercrops from the field cultivated by 4 small scale farmers in 2 hectares using the traditional and modern methods of cropping system of farming in the upland ecology;
4. to assess and compare the economic input and output of the modern and traditional methods of upland rice cultivation with small scale farmers in rural communities.

The 75% of the total population of Sierra Leone are engaged in agriculture and over 70% of these are **small scale farmers** [ATPS, 2011] involved in **upland cultivation**. This has encouraged this research to be carried out to investigate what improvements could be made in trying to increase the **rice yield rate** ( $\text{t}\cdot\text{ha}^{-1}$ ) per farmer of this rural Resource Poor Farmers (RPF) in an economically viable input-output relationship at the same time conserving the soil potential and its superficial ecology.

It is an evident fact that most, if not all of the farm operations by the small scale farmers **are done manually** in Sierra Leone and elsewhere in Africa.



This militates heavily against increase in production due to high farm drudgery or intensive labour used by the farmers, resulting to limited acreage per farm family, poor agronomic practices and late completion of farm operations.

The research is geared towards **investigating the relevance of introducing minimum mechanization and modern agronomic practices** that could stimulate increase in yield per hectare ( $\text{t}\cdot\text{ha}^{-1}$ ) with less economic burden on the already poor resourced farmers at the end of the production season.

The research is therefore focused on what agronomic, mechanical and economic strategies could be combined:

**to improve** on:

1. the yield rate per hectare ( $\text{t}\cdot\text{ha}^{-1}$ );
2. the acreage worked per farmer ( $\text{ha}\cdot\text{farmer}^{-1}$ );
3. the quality of the agronomic practices in the field such as soil tillage, pest and weed management strategies and

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4. the timeliness of completing farm operations ( $\text{h}\cdot\text{ha}^{-1}$ ).

**to reduce** on:

1. the field time for farmers ( $\text{h}\cdot\text{ha}^{-1}$ ) and labor intensity as well;
2. the input factors (water, seeds, chemicals etc.) and
3. the services (contractors, manpower etc.) necessary for production.

The research is also geared towards introducing modern agricultural technology transfer to farmers by working with them in their farms through **Participatory Research Approach** (PRA).

This field laboratory approach where the farmers will learn new skills, discover new knowledge and can easily use what they have learnt during the research will help in their future agricultural engagements to improve the socio-economic and agricultural status **without** the researcher.

This is one of the **main pillars of this work**.

This will **help bridge the gap between the agricultural research results and the users (farmers in this case) of the results**. In addition, the research also aimed at stimulating and developing the farmers' acumens in being inquisitive and curious to find out solutions to their problems from the field which is their most **immediate** and most permanent laboratories.

This will minimize the dependent syndrome on distant research designs and researchers to solve their local existing production problems in their fields. Concomitantly, it will also shorten the time it takes to solve their problems that are eminent in the field of production since they are active participants of the research work therefore can act now instead of waiting for far-fetched researchers to look out for solutions to their problems, especially where there are limited resources to make this becomes feasible. It was said by this writer that, the approach to the problems of farming must be made from the field, not from the laboratory. The discovery of things that matter is three-quarters of the battle. In this, the observant farmers or labourers, who have spent their lives in close contact with nature, can be of the greatest help to the investigator [Sir Albert Howard, 1943].



The introduction of minimal mechanization and modern agronomic practices will eventually save time and excessive labour, though much more costly. This will reduce the drudgery or intensive manual labour suffered by the farmers, save their time for **other farm and social activities** and increases the yield per hectare.

Consequently, it will also improve some of their social amenities, **especially the women and children such as their health, education, domestic chores and social status, since they will now have much time to rest and share time with the family members at home**.

In this research, the farmers are placed as central focal entity for them to fully participate in their own development as both learners and beneficiaries of the knowledge, skills and techniques used or discovered during the entire production process. **They are both creators and users of the research results**.

## 2.2 Methods

The research was carried out through a sensitization and mobilization of the farmers on **meetings** held in their communities as first entry step from which 4 farmers were selected.

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The community of the research participated in the **selection and lay-outing of the site** for the entire field work. Where?

A total land surface area of **0.5 ha** was allotted to each farmer for the research; this 0.5 ha was again further divided into two halves (0.25 ha).

The **0.25 ha** was used as a treatment for the **Traditional Method** of mix cropping while the other **0.25** was used for the **Modern Method** of rice intercropped with 3 different crops (pigeon peas, sesame and sorghum).

The 0.25 ha of the modern method was tilled by the same tractor (FIAT 780; 4WD), implements and operator in a sequential manner for all the 4 farmers, while the 0.25 ha was cultivated by the farmers using the traditional tools: **cutlass** (machetes) and **hoes** (slash and burn).

In the Modern Method, 5 treatments were used by combining rice and the intercrops named above as follows:

1. pure or sole rice only;
2. rice combined with pigeon peas only;
3. rice combined with sesame only;
4. rice combined with sorghum only;
5. rice combined with all the 3 intercrops.

Each of these treatments in the Modern Method had an area of 0.05 ha. The total number of treatments for the entire research was 6 including the traditional method for each farmer.

Random broadcasting of rice and the other crops was done in the Traditional Method, while row planting of rice and its intercrops was carried out in the Modern Method with definite spacing after measuring the quantities of seeds to be used in each treatment.

The **population density** of rice was assessed by using the 1 m<sup>2</sup> quadrant method with 5 repetitions in each treatment while that of the intercrops was done by 'manual head counting' in each treatment.

The **growth rates** of rice was assessed by measuring its height and counting the tillers while for the other intercrops the height and canopy spread were measured at an interval of 3 months after planting.



The **weed prevalence** in the 6 different treatments was assessed by counting the weed population density per square meter. The Traditional Method of weed control method was used by physically removing the weeds from the crops by the farmers in all the 6 treatments recording the **time** and **number of workers** involved in the entire exercise.

The effects of **insect pests** were qualitatively observed, while the **rodents and birds** were controlled using manual traditional means of fencing and bird scaring respectively.

**Harvesting and processing** of both the rice and the intercrops was done manually using local tools such as knives and winnowers.

The **rice yield** was assessed by using the 1 m<sup>2</sup> quadrant method with 5 samples from a centrally located point in each treatment. The 5 harvested samples were threshed individually, naturally dried to about 14% moisture content and weighed. This was repeated in all the 4 plots of the 4 farmers. The **intercrops yield** was assessed by harvesting 20 stands in each treatment, processed the harvested stands and weighed.



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### 2.3 Main results

- The **working time** for seed-land preparation (land clearing and soil tillage) show that in Modern Method plough and harrow (1<sup>st</sup> and 2<sup>nd</sup> harrowing) took **48 h·ha<sup>-1</sup>** (i.e. a **work capacity**  $C = 1.078 \text{ ha} \cdot \text{h}^{-1}$ ) while -in the Traditional Method- it took **128 h·ha<sup>-1</sup>** to do the land clearing ( $C = 0.008 \text{ ha} \cdot \text{h}^{-1}$ ) and **168 h·ha<sup>-1</sup>** for manual hoeing ( $C = 0.006 \text{ ha} \cdot \text{h}^{-1}$ ).
- This shows that there was approximately **88% of time saved** by the farmers through Modern Method.
- The rice **plant population density** was observed to be higher in the Modern Method with **178 plants·m<sup>-2</sup>**; the **seed rate** in this treatment was **55 kg·ha<sup>-1</sup>** when compared with the Traditional Method with a population density of **150 plants·m<sup>-2</sup>** but **60 kg·ha<sup>-1</sup>**.
- This implies there is **better seed germination capacity** with the Modern Method.
- The **weed population density** was recorded to be lower in the Modern Method with an average of **51 weeds·m<sup>-2</sup>** while in the Traditional Method it was **60 weeds·m<sup>-2</sup>**.
- This implies more resources (time and energy) were needed to control the weeds in the Traditional than in the Modern Method.
- The **growth** performance of rice was better in terms of height and tillers in the Modern Method than in the Traditional. The **average height** (measured 120 days after planting) of rice was recorded to be: **116 cm** and **108 cm** in Modern and Traditional Method, respectively. The **tillering and panicle bearing** of the rice stands was also seen to be better in the Modern Method with an average of 5 or 6 tillers per stand with a tiller without rice panicle, whilst in the Traditional treatment there was average of 5 stands with 2 without rice panicles.
- The **yield rate of rice** was **2.34 t·ha<sup>-1</sup>** (14% moisture content) in the Modern Method as compared to the **2.20 t·ha<sup>-1</sup>** in the Traditional Method.
- This implies there is **better yield returns per hectare** with the Modern Method;
- The **total cost of production** (both for the rice and three intercrops) in the Modern Method was however higher (5,183,870 Le·ha<sup>-1</sup>; **978 €·ha<sup>-1</sup>** approximately) when compared to the Traditional Method (3,948,386 Le·ha<sup>-1</sup>; **745 €·ha<sup>-1</sup>** approximately); expressing the cost of production by Euro per ton, the results are: **354** and **326 €·t<sup>-1</sup>** for Modern and Traditional Method, respectively.
- There was less **time spent to complete the entire production process** in the Modern Method (1960 h·ha<sup>-1</sup>) compared to Traditional Method (2000 h·ha<sup>-1</sup>).

**Table 1.** Traditional Method compared with Modern Method: main results obtained in the field tests The index values (%) shows that Modern Method assures better results for each parameters, except for the total cost of production (€·t<sup>-1</sup>).

PRODUCTIO PARAMETERS	UNIT OF MEASURE	TRADITIONAL METHOD	MODERN METHOD
SEED-LAND PREPARATION TIME	h·ha <sup>-1</sup>	396 (100%)	48 (12%)
SEED-LAND PREPARATION WORK CAPACITY	ha·h <sup>-1</sup>	0.008 machete 0.006 hoe	1.078
PLANT POPULATION DENSITY	plants·m <sup>-2</sup>	150 (100%)	178 (125%)
SEED RATE	kg·ha <sup>-1</sup>	60 (100%)	55 (92%)
WEED POPULATION DENSITY	weeds·m <sup>-2</sup>	60 (100%)	51 (85%)
AVERAGE HEIGHT	m	1.08 (100%)	1.16 (107%)
TILLE RING	n.	5 (100%)	6 (120%)
PANICLE BEARING	n.	4 (100%)	5 (125%)
YIELD RATE OF RICE	t·ha <sup>-1</sup>	2.20 (100%)	2.34 (106%)
YIELD RATE OF ALL INTERCROPS		0.082 (100%)	0.422 (515%)
<b>TOTAL</b>		<b>2.282 (100%)</b>	<b>2.762 (121%)</b>
TOTAL COST OF PRODUCTION (rice <u>and</u> all intercrops)	€·ha <sup>-1</sup>	745 (100%)	978 (131%)
	€·t <sup>-1</sup>	326 (100%)	354 (108%)
TOTAL INCOME OF PRODUCTION (rice <u>and</u> all intercrops)	€·ha <sup>-1</sup>	914 (100%)	979 (107%)
<b>TOTAL PROFIT OF PRODUCTION</b> (rice <u>and</u> all intercrops)	€·ha <sup>-1</sup>	<b>169 (100%)</b>	<b>1 (0.6%)</b>
TIME IN ENTIRE PROCESS OF PRODUCTION	h·ha <sup>-1</sup>	2000 (100%)	1880 (94%)

The number of hours (2000-1880 = 120 h) is not convincing at this moment to reach an economical threshold with the Modern Method, but can be further improved by engaging additional activities such as basic mechanical seeding.

The manual modern method of seeding took 192 h·ha<sup>-1</sup> in this experiment. If this time is reduced to 3 or 4 hours per hectare by using a seed sowing equipment with the same tractor, the time the farmer will save will dramatically increase from 120 to approximately 300 h·ha<sup>-1</sup>.



The same equipment can also be used to sow other seeds such as millet in another field; making the value of the equipment to be increased during the cultivation season. This will improve the economic value of both the machine and the equipment during the year.

### 3 - The cultivation of jatropha crop as source of energy from Jatropha seeds as bio-fuel

#### 3.1 Introduction and general objectives

Across the continent of Africa, **only 10% of individuals have access to the electrical grid**, and of those, 75% come from the richest two quintiles in overall income. Electrical provisioning in Africa has generally only reached wealthy, urban middle class, and commercial sectors, bypassing the region's large rural populations and urban poor. According to the forum of Energy Ministers of Africa, most agriculture still relies primarily on humans and animals for energy input [Energy in Africa, 2012].

This acute shortage of energy has led to the tremendous snail pace rate of development of the countries in the continent whilst the rest of the developed world is taking advantage of the deficiency to exploit the natural wealth through the importation of most of the resources in their raw or crude form to the

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developed countries for processing and later returned to Africa at higher costs at the expense of the impoverished people; rendering them poorer and poorer and hence branded as underdeveloped.

One of the ways to avert this unpleasant situation is to explore **more sustainable means of generating energy which can be produced, processed and used in the African continents by local people.**

**Renewable Energy Sources (RES)** could be one of the answers to achieve this objective.

This research is geared towards exploring means of animating farmers **to produce energy through the cultivation of jatropha crop locally in their rural communities, which can produce Pure Vegetable Oil (PVO) that can be used as bio-fuel in a reciprocating i.e. engine to provide electricity in the rural community.**

Jatropha is an introduced crop from the Western and Asiatic world that has been observed to grow well in diverse tropical soils in Africa. This crop's products (seeds) used as a source of energy is scarcely known in the continent of Africa until late in the 20<sup>th</sup> century. The crop is known in Sierra Leone as an ornamental plant around houses in urban and rural settlements.



**The growing of jatropha as a crop is a completely new phenomenon** in Sierra Leone which the research is investigating to know what agronomic, economic and social impacts such a venture could have in the rural communities in relation to energy and food production. On the aspect of agronomy, the research is to investigate the growth and reproductive effects of the plant when cultivated solely as a mono-crop and as an intercrop with another crop that can be eaten by the farmers.

The research also aimed at investigating the effects of pests, weeds and other agronomic managements in relation to the growth and reproductive abilities of the crop in the field using traditional and modern method approaches by local farmers. The aspect of variety of the crop was also involved into the research to investigate which of the varieties could best suit the production process in terms of agronomic management, growth response, life cycle, and yield rate per hectare.

On the economic sphere, the research is investigating the **cost of production of the crop with no mechanization but with some modern agronomic methods.** The study further investigates the input-output relationship of the entire production process for one production season to acquire a first knowledge of what are the economic consequences will this venture have on the farmers in terms of food security in their community.

On the social sphere, the research will be investigating the interactive impacts of the production of other food crops and jatropha (as PVO to generate electricity) and ground nut (as food and income for the farmers). This can be achieved by:

1. investigating how much time and energy that maybe needed to produce the needed seeds for the production of bio-fuel that can be used to generate energy for the consumption of the village community;
2. discovering what challenges or positive effects the production of the crop will have on the farmers that will be involved in the activities;
3. investigating the mutual benefits shared by the farmers working together in groups to produce the seeds in the sole and intercrop methods in the field and
4. engaging modern agricultural skills and techniques that could be beneficial to the farmers from the research activities during and after the field exercises in the cultivation process.

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It is eminent that the national electricity grid of Sierra Leone will hardly reach the rural poor communities; therefore one of the means of acquiring sustainable energy by the rural poor is to involve in activities that can enable them get a **readily available source of energy that can be produced and used locally through the use of local resources such as land, traditional tools and crops they can cultivate**. These are available and sustainable thus influence their social lives to improve their socio-economic status.

The ability to grow jatropha and generate electricity through the use of engine-generator set at rural level (**very low power: < 10 kW**) will improve the **quality of life** in the community.

The energy produced by the generator depends on the available mass of jatropha seeds (yield per hectare) and the ultimate mass of PVO (efficiency of the process). From **1 to 5 years** after planting, about **4.0-5.0 t·ha<sup>-1</sup>** of seeds can be produced, which will eventually produce **1.5 t·ha<sup>-1</sup> of PVO** [Matsuno et al., 1984; Foidl et al., 1996].

This can run only a **low power reciprocating i.c. engine** for a short time due o the limited quantity of PVO that can be produced by the small scale rural farmers.

In other to maintain **equilibrium between food and energy**, the production of jatropha as should therefore be sustained by increasing, in order of priority: (i) the seeds yield, (iii) the plant duration in the field and **eventually** (iii) the acreage of jatropha cultivation.

The **electricity** produced can be used for diverse **small scale purposes** such as:



1. village houses lighting and small domestic appliances (e.g. fans, radio and TV sets, PC, internet connection, phone etc.), (ii) schools, community and health clinic (maintain cold chain of the drugs)centers;
2. small scale agricultural machinery such as water pumping machines for irrigation and refrigerators for food preservation (meat and fish, in particular) and
3. cottage (small scale) industries such as wood carving, polishing and light metal welding.

These and a lot more will positively impact the socio-economic status of the people in the rural areas by improving their standard of living, consequently preventing or minimizing the incidence of rural-urban migration especially by the youths.

As a result, there will be a **reduction in the urban population pressure**, hence minimizing problems such as the crime rates, prostitution, health hazards, unemployment, inadequate housing facilities, transportation etc.

The **objectives** of this study are to investigate:

1. the controversial perception about the impacts of land use for the production of jatropha as fuel for energy and the production of food by farmers at the same time. This is a highly debatable issue in the village community and the global arena [FAO, 2013]. This study will carefully investigate the integration of jatropha cultivation together with an edible crop; in this case, ground nut. This is to dismiss the fears of the farmers for prioritizing energy production more than food, hence creating equilibrium between food and energy which are all essential components for better standard living and development;
2. the varieties of jatropha that can be cultivated in Sierra Leone, that has the potentials to produce more seeds for PVO;

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3. how jatropha can be grown to produce seeds for the production of PVO for the use of farmers in a special diesel engine at local community level to generate electricity for domestic consumption and
4. how PVO can be locally produced and used by farmers through the growing of the energy crop for the generation of energy at community level.

### 3.2 Methods

Concrete and clear explanations were made to the farmers to know what benefits could be obtained in their community through the provision of energy in the form of electricity by using a local crop they can produce and process.

The community accepted the research work to be carried out in the land which was selected together with the researcher.

**Five groups of 11 people each** were initially formed to carry the work but later degenerated to 4 due to the effects of pests (rodents) in one of the groups plot.

Each group was allotted to a **plot of 0.5 ha**. The 0.5 ha was further divided into **two parts of 0.1 ha and 0.4 ha**.

The 0.1 ha was to be planted with **jatropha only** while the 0.4 was to be planted with **jatropha intercropped with ground nut**.

The work in the entire research was collectively done by all the members of the groups in one day week, for 4 hours.

The **entire work was totally manual** with the use of **traditional tools**, such as cutlasses, hoes, sticks and ropes. However, the researcher introduced some modern **technical activities**, such as lay-outing, spacing, mulching and weighing. Therefore the use of some **basic instrument and equipment** was introduced to the farmers, such as the scale and tape measure. The land clearing was carried out (machetes) and the soil tillage was done using local manual tools (hoes).



The jatropha seeds were obtained from different communities outside the research site and were weighed and countered for the planting purpose (plant density). The planting was done together with the farmers; the spacing of **jatropha** seeds was **2.0 x 2.0 m** apart while the **ground nut** was planted with a spacing of about **0.25 x 0.15m**.

The **weed prevalence** in the two treatments of jatropha with ground nut and jatropha without ground nut was done by using the 1 m<sup>2</sup> quadrant method with 5 repetitions in each. This was done both before the harvesting of ground nut (2 months after planting) and 2 months after harvesting of the ground nut. The ground nut straws were used as mulch for the jatropha crop together with the farmers.

The **growth response** of jatropha in the two treatments was assessed by measuring the **height, number of leaves, branches** and **fruits produced**. The reproduction period of jatropha was also recorded.

The ground nut was harvested and plugged manually. The harvested product was weighed to know the yield rate per hectare.

The activities of **pests**, especially insects such **grasshoppers** observed and record qualitatively, as there was – at the moment - no control measure engaged to minimize their large invasion.

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From energy point of view the whole process of PVO production (**seeds → PVO → electricity**) has been theoretically examined and closely followed to be used at local community level in Sierra Leone.

The seeds, which have acquired dry weight by with about 40% moisture content, are placed in a **mechanical press**, manually operated machine-and the lever is lowered by the farmers.

The **Crude Vegetable Oil** (CVO) produced by the press is collected and placed into **continuous containers** to be purified by sedimentation. The resulting PVO -which has a density of about 0.85 kg/dm<sup>3</sup> – can feed a special designed **Diesel Cycle engine**, directly connected with the **generator of electricity**.

### 3.4 Main results

The successful involvement of farmers in the integrated cultivation of jatropha as a crop and ground nut at local community level is a breakthrough as an entry point to bio-energy production in rural areas in Sierra Leone.

**Total time** taken for the cultivation of jatropha together with its intercrop, ground nut was **580 h·ha<sup>-1</sup>** and a **work capacity** of  $C = 0.107 \text{ ha} \cdot \text{h}^{-1}$  in a period of 7 months.

The **germination rate** of jatropha seeds was very poor (10%) compared to that of ground nut (95%).

The **growth response** of jatropha was:

1. height of jatropha curcas in treatment with ground nut as intercrop (61 cm) was much better than that of jatropha in sole cropping (31 cm) while that of *Jatropha gossypifolia* with ground nut was (91 cm) and the sole cropping (43 cm) at age 5 months after planting;
2. leaf production in the treatment of jatropha intercropped with ground nut was much better than the sole cropping;
3. *Jatropha curcas* had an average of 16 leaves per tree in the treatment with ground nut while there were 9 in that of sole cropping at the 5<sup>th</sup> month;
4. In *Jatropha gossypifolia*, it had 11 leaves in intercropped treatment with ground nut and 9 leaves in the treatment without and
5. The branching ability of *Jatropha gossypifolia* is better than that of *Jatropha curcas*.

In connection with **seed reproduction** *Jatropha gossypifolia* was able to reproduce fruits at 4 months, while *Jatropha curcas* was at 6 after planting.

**Weed prevalence** was less in the treatment of jatropha with ground nut (57 weeds·m<sup>-2</sup>) while in the jatropha without ground nut (62 weeds·m<sup>-2</sup>).

### Pest infestation qualitative observations

1. **Rodents** had tremendous adverse effects on the ground nut crops at 2 months after planting by eating the ground pods under the ground. While **birds** and some **insect** such as crickets, ants had some damages done on the seeds planted in the field.
2. Insects, such as **grasshoppers** and **leaf worms** had some damaging effect by eating the leaves of jatropha especially with *Jatropha gossypifolia*, which was observed to be more susceptible to grasshoppers.

### Jatropha seeds production cost-benefit analysis



1. the total cost of production was recorded to be 482 €ha<sup>-1</sup>;
2. the average yield rate of ground nut was 0.820 t ha<sup>-1</sup>;
3. the total income from the ground nut yield was 1,160 €ha<sup>-1</sup>;
4. the profit made at the end of the first cropping season without the jatropha produce was € 678ha<sup>-1</sup>.

**Table 2.** The cultivation of Jatropha as “sole crop” compared with “jatropha intercropped” with another crop: main results obtained in the field tests with index values (%) show that jatropha intercropped with ground nut assures better results for each parameter, including the total income return of production.

PARAMETER	UNIT OF MEASURE	JATROPHA CURCAS		JATROPHA GOSSYPIFOLIA	
		SOLE CROPPING (JSC)	INTERCROPPED WITH GROUND NUT (JIG)	SOLE CROPPING (JSC)	INTERCROPPED WITH GROUND NUT (JIG)
TOTAL TIME OF PRODUCTION	h ha <sup>-1</sup>	580(100%)		580(100%)	
WORK CAPACITY	ha h <sup>-1</sup>	0.107		0.107	
GERMINATION PERCENTAGE- JATROPHA	%	10	10	10	10
GERMINATION PERCENTAGE-GROUND NUT	%	-	95	-	95
HEIGHT AT 5 MONTHS (JATROPHA)	Cm	31 (100%)	61(197%)	43 (100%)	91 (212%)
LEAVES AT 5 MONTHS	n.	9 (100%)	16(178%)	9 (100%)	11 (122%)
BRANCHING ABILITY AT 4 MONTHS (JATROPHA)	n.	0	2(100%)	3 (100%)	4 (133%)
SEED REPRODUCTION AGE (JATROPHA)	months	6 (100%)	6(100%)	4 (100%)	4 (100%)
WEED POPULATION DENSITY	weed-m <sup>2</sup>	62 (100%)	57(92%)	62 (100%)	57 (92%)
GROUND NUT YIELD RATE	t ha <sup>-1</sup>	0.00	0.820(100%)	0.00	0.820 (100%)
INCOME FROM GROUND	€ ha <sup>-1</sup>	0.00	1160 (100%)	0.00	1160 (100%)
	€ t <sup>-1</sup>		1415 (100%)		1415 (100%)
TOTAL PRODUCTION PROFIT AT 7 MONTHS	€ ha <sup>-1</sup>	0.00	678 (100%)	0.00	678 (100%)

It can be observed from the parameters that there is **total advantages in cultivating jatropha with ground nut in terms of the both the technical and economic aspects of production.**



Although it is not stated from the data, but the weed population densities shown from the two systems of jatropha cultivation (sole cropping and intercropping) indicated that there was more time and energy used in weeding the sole cropping treatment plot. This may even be one of the reasons why the jatropha performance in the sole cropping is weaker.

### Rural chain to transform jatropha seeds in PVO and electricity

The field activities are closely followed by the transformation of the harvested seeds to PVO for the use of the generator-set.

A **local chain of processes** must be carried out in other to obtain a pure oil (not refined) to be used for the production of electricity. This chain includes:

1. storage of seeds;
2. extraction of crude oil, by mechanical device (press);
3. purification of crude oil into PVO (sedimentation, filtration or flotation in water);
4. storage of PVO and
5. use in the Diesel Cycle special engine.

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### Storage of seeds

The seeds are stored for either oil extraction or for further propagation into the field. The viability of the seeds diminishes as they stay longer in the store. The ideal time the seeds should be stored is 9 months for maximum utility [K. J. Sowmya et al., 2011].

Seed storage is **key factor** in other to obtain good PVO; the seeds should be placed in **bags and kept in very low humidity place**, especially during the rainy season. The use of materials -such as jute and other related fibres (easy to find locally) - as bags for storing the seeds has shown better results of good quality in crude oil production and germination in India [A. Kumar et al., 2010; S. Karaj, J. Müller, 2010].

### Seed germination potential

The condition to maintain good germination potential of jatropha seeds is closely related to the storage period, containers used to store and the humidity.

The most appropriate period of storing the seeds for effective germination has been proven to be 9 months. The germination is more vigorous between 1 to 3 months after harvesting (60-70%). The viability begins to reduce after this period until the 12 month when they will become completely unviable. However, studies have further shown that the most suitable materials in which such seeds should be stored is jute or other local fibres bags [A. Kumar et al., 2010, S. Karaj, J. Müller, 2010]. In spite of these two conditions, the humidity of the environment in the store must also be low in other to avoid moulding hence losing its viability.

### Extraction

From theoretical point of view oil extraction from jatropha seeds can be carried out in two ways:

1. Mechanical and
2. Chemical.

The mechanical method involves the use of machine through the application of **high pressure** to remove the oil. This mechanical method can be **manual** or **motorised**. The manual method involves compressing the seeds in a machine called **ram press** [K. Bielenberg, 1985].

The manual and mechanical methods tend to show different **oil extraction efficiency** when the in-put and oil-put oil materials were compared. The motorized mechanical method showed  $\eta_{EXT} = 98\%$  while the **manual method showed  $\eta_{EXT} = 65\div 75\%$** .

The chemical method involves the use of **solvents** to remove the oil with a good efficiency, but is not simple to apply. There are series of problems between the oil and the solvent such as the viscosity, temperature and miscibility.

When the two systems were compared the oil extraction efficiency was seen to be better with the mechanical ( $\eta_{EXT} = 95.9\%$ ) than the chemical ( $\eta_{EXT} = 79.3\%$ ) [C. Ofori-Boateng et al., 2012].



For **local community level, the use of the manual mechanical method is most appropriate**.

### Crude oil purification

This involves the cleaning up of the extracted from series of **impurity** that may cause damage if used as crude oil into the machine. Three main methods are involved here:

1. sedimentation;



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2. filtration and
3. flotation in water.

Sedimentation: it is the **easiest and most economical** as it involves the use of force of gravity in conjunction with the different densities that characterize the liquid extracted (oil and solid waste). More tanks are placed in series; in each of them is the separation of the phases and only the lighter part has access to the next tank. Sometimes it is also required a **pre-filter** (to eliminate rubbers) and/or a finishing filtration. The process is **very slow**: in each tank is provided a minimum time of sedimentation of **2-4 days**, at a temperature of 20°C; for these reasons, sedimentation is not recommended in industrial supply chains. It is however **ideal for local community use because of it has low cost, simple implementation, structural simplicity, lack of energy inputs, and the certainty of a good quality of PVO**.

Filtration: this is a method widely used. It involves the passing of the oil through **series of highly standardized filters** at different levels to get the desired quality of oil at the end. This needs careful monitoring, cleaning and consecutive changing of filters in the system. Some of the filters are quite expensive. It **cannot be suitable for rural community purposes**.

Flotation in water: this is a method that is relatively unknown but seems to be very appropriate to refine the extracted oil. The method can guarantee the removal of most impurities such solid particles and other liquids from the oil. However, this system needs auxiliary activities such pre-heating of oil to 60°C, continuous mixing and the final separation of the emulsion [W. Rijssenbeek, 2010]. It **cannot be suitable for rural community purposes**.

#### Storage of PVO

This is an important stage before feeding the i.c. engine. Like any other oil, it should be placed in **plastic containers** (to eliminate reaction with metal wall) and placed in an ambient store with moderate temperature. The oil can be stored from **4 to 12 months** to show good quality when used in an appropriate engine [www.kimminic.com].

#### Use of PVO for i.c. engine (Diesel Cycle)

The PVO be used directly into special Diesel engine Cycle, without going through the trans-esterification reaction [K. Nahar, S.A. Sunny, 2011], industrial process developed to produce a bio-fuel (called bio-diesel) very similar to the gasoil. Of course, the trans-esterification process is not suitable for rural community use.

Consequently, the use of a **specially designed engine** (for example, Lister engine) -that can carry out effective combustion of the PVO- is necessary in this case for the local rural communities.

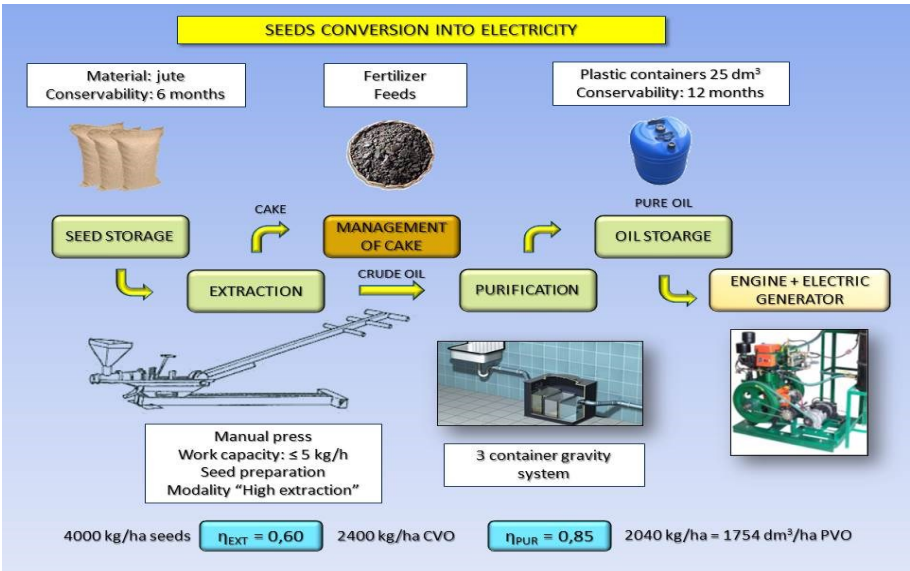






Figure 1. Jatropha seeds transformation processes from seed to rural electrification.

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## Chapter 1 – Rural community approach on On-Farm Research (OFR) on systems of upland rice cultivation using modern method intercropping and traditional mix cropping and the cultivation of energy producing crop called jatropha in the upland ecology

### Abstract

During the last decades of intensifying research work in agriculture and its related disciplines to improve techniques and skills of farmers for better production, a lot of rural communities have been used as the basis for these interventions. Intensive agricultural research and production are mainly practised in rural areas in Africa and Sierra Leone in particular. This signifies the importance of these communities in agriculture as a result of the accessibility of natural resources required to accomplish functional research work.

The introduction of agricultural research to Small Scale Farmers (SSF) has been a recent phenomenon. This development initiative has been detected to be more effective since both farmers and researchers can gain tremendous benefits from the collaboration.



Population and income growth are inducing an intensification of agriculture, which threatens the sustainability of natural resources in rural environments and the livelihoods of small-scale farmers who depend on those resources to survive. Though no single action will reduce poverty and increase the sustainability of agricultural production, technical change can play a prominent role in alleviating these problems [Javier Ekboir, 2001].

This research is therefore geared towards totally involving the community small scale farmers into the activities of the experimentation from beginning to finish as active participants in order to be able to gain knowledge, skills and experience from the entire process based on their abilities.

This OFR with small scale farmers is meant to shorten the chain of transfer of knowledge, skills, technology and experience to farmers during and after the process. OFR is simply the use of the farmers farming site to carry out investigations in relation to the production processes in the field. In this case, agricultural investigations. It is closely linked with Participatory Research Approach (PRA) or Farmers Participatory Research (FPR), which in its simplest term is where the farmer becomes an integral part of the research process together with the researcher or research institution. The two can be merged; that is, where the research is taking place in the farm of the farmer who also participates in the process. In other words the farmer participating in a research carried out in his or her farm (OFR-FPR). In some cases research can be carried out in the farmer's site but he/she does not participate in any activities concerning the research, whilst the opposite can also be true.

The involvement of SSF in research is geared towards cutting down the cost of 'extension services' which have been the usual procedure of passing research results to farmers.

The farmers who are part of the entire process can carry out concrete judgements of the work themselves and consequently if the results are positive can serve as motivation to continue engaging the steps used to improve the production.

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This does not only lead to increase in production but also helps to improve the capability of farmers in identifying, solving production problems and sharing such experiences with others based on what they have practically learnt and achieved from the field with little or no cost.

The OFR is also meant to minimise and consequently dismiss the mythology once spread that the illiterate or semi-illiterate farmers are conservative i.e. they do not easily accept scientific discoveries to change their production patterns. The reason is because they have not been involved as part of the discovery or innovation process that makes the research results. Thus they regard such knowledge or innovation as an alien or strange phenomenon introduced to them from a pool of strange source whose outcome when used they may not be sure of achieving their production goals.

In short, the farmers reluctantly reject outside research result because they fear failures in their yearly production activities since they have an obligation to feed their families; a physiological and social obligation.



### **1.1 Introduction and transfer of skills and technology to illiterate and semi illiterate small scale farmers in rural areas**

By the year 2025, 83% of the expected global human population of 8.5 billion will be living in developing countries, yet the capacity of available resources and technologies to satisfy the demands of this growing population for food and other agricultural commodities remains uncertain. Agriculture has to meet these challenges, mainly by increasing production on land already in use and by avoiding further encroachment on land that is only marginally suitable for cultivation [**F. M. Abbott, 1993**].

More than 75% of the world's poor live in rural areas and are predominantly farmers [**World Bank report, 2012**]. World Bank research on agriculture and rural development is multi-sectoral and focused on improving the well-being of rural people by building their productive, social, and environmental assets. These rural people are predominantly Resource Poor Farmers (RPF) doing agriculture with minimal traditional crude tools, using mostly animal and human energy.

In Africa such farmers are mostly illiterate or semi-illiterate, therefore have very small or no influence in making national decisions and policies that can help to protect and develop their interests in their daily or yearly subsistence activities to feed their dependants. To worsen their situation, they have limited abilities to participate in the global trade as their products are sometimes branded as sub-standard or unfit for international consumption in the global trade platform. However, the massive movement towards industrial agriculture can bring a variety of economic, environmental, and social problems, including negative impacts on public health, ecosystem integrity, food quality, and in many cases disruption of traditional rural livelihoods, while accelerating indebtedness among thousands of farmers [**M. A. Altieri, 2014**].

Sierra Leone, which is ranked 183rd country [**UNDP, Human Development Report 2014**] in the human development index, is yet to make very strong and conscious efforts in combating the problems of the most significant pillars of human development needs, which are food and energy. The achievement of securing adequate food and energy in any country can lead to improve education, health, infrastructure, communication and other social amenities; making the lives of its citizens meaningful and worth living in consonant with the rest of the living standards of the rapidly growing world.

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In other to achieve these needs, the involvement of the SSF in all aspects of agriculture including research is the new inevitable hub that can provide sustainable answers. It can be argued that anchoring research in the needs and opportunities of farmers is as important as it is to anchor the research in the international scientific literature [N.G. Roling, 2004]. However, the process of making deliberate choices to ensure the relevance of agricultural research to small-scale farmers has received relatively little attention [Castillo, 1998].

In the situation of the developing countries where majority of the food is being produced by the SSF, ignoring their participation in acquiring the desired knowledge, skills, techniques and technologies to increase their production is tantamount to creating food and energy insecurity in the world. Over the years, very little attention has been paid to these RPF instead colossal amounts of money are being spent on institutions and individuals in the bid to generate innovations that most times are being used by mostly big commercial producers that have huge resources and capital to continue enriching themselves while the poor farmers remain poorer and hungry together with the silent majority of the world's population.

Cross-checking the problem perception with stakeholders, especially with farmers, helps to focus scarce resources on useful and relevant activities [Castillo, 1998]. Very little effort and few resources are usually devoted to anchoring research in the needs and opportunities of farmers [Reijntjes et al, 1992]. This makes the farmers feel that they are not part of the new knowledge generation because their needs and opportunities are not catered for.



Numerous experimental and empirical studies have convinced us that West African farmers would be able to considerably expand their production with their *existing* technologies if the right conditions could be created at higher scales [Hounkonnou, 2001].

It is evident therefore if we want to transfer skills, technology and innovations to our RPF we must get them involved in the procedures and processes that can lead us to achieve this. Such processes and procedures are embedded mainly in research work with the farmers. This will lead to sustainability and upgrading of their standard. Doing research (effectively) with farmers generate technologies that do not need the usual “*packaging and pushing for adoption*” [D. Hounkonnou, 2004]. This will definitely save **time** and **money**.

The ability to enable SSF respond to innovations, skills and technology is to close the gap between the sources (research) of these utilities and them. Apart from the learning by doing during the processes, they also need to improve their production output which is their ultimate goal; since as it was stated earlier, they have the responsibility to feed and satisfy the other social welfare needs of their families every day. While there are series of problems (See figure 1.2) that impede the rapid development of agriculture in Africa and Sierra Leone in particular, this study is geared towards investigating how farmers can gain agricultural education and minimum mechanisation to increase their scope of knowledge and the reduction of drudgery in their everyday field activities.

## 1.2 Linking traditional and modern methods and skills in farming with small scale farmers

The strategy of this OFR with small scale farmers in this research is to use the field as an active laboratory where the farmers can compare between the modern and traditional methods of rice

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cultivation in the upland ecology. This is to make the complexities involved in the two farming systems simple; bringing out the consequences for them to make their own judgement as to which is more realistic and beneficial for their own development.

For a long time, innovation has been regarded as the technical output of research and as something to be transferred to the users [E.N.A. Dormon, 2007]. There has been a complete disregard of the experience and potential knowledge of the farmers.



The research is also geared towards exposing and shortening the complex institutionalised research chain that has the consequences of high risk of inadequately transferring the results or outcomes to the farmers from the researcher(s) or research institution(s) through extension services. The research is tailored to suit the needs and interests for the improvement of the SSF. This shall be accomplished by bringing on board what they are doing in comparison with a new approach called modern method. The introduction of infrastructure and new technologies is not effective if they are not appropriate for the context in which they are promoted and not adapted to users' realities [A.J. Hall, 2003].

It is realistic to carefully sensor what kind of innovation through research that should be introduced to the SSF since these people already have set of knowledge and experience based on what they have been doing for years on end. Despite these qualities, the farmers need to go further to explore and acquire new levels of knowledge, skills and technology to improve themselves since they also want to attain better standard of living like any other person in the world. In order to achieve this, the OFR must have these qualities:

1. linking the usual farming practice of the farmers to the new methods and techniques introduced to the farmers;
2. simplifying the technology or skills to be introduced to the farmers since most of them are either illiterates or semi-illiterates;
3. the research was tied up or orientated to concrete productive results that can be observed to improve the lifestyle of the farmers and not just a mere source of soliciting information (qualitative or quantitative) for data analysis;
4. the research work was in consonant with the farmers' normal farm production activities; since this can enhance the effective alignment of their time use factor and the research. This is to minimise the total dependence of the farmers on either the researcher or research institution for their family survival for the entire production season or year and
5. there was confidence building bridge between the farmers and the researcher based on the spelt out objectives of the research. Empirical studies demonstrate that innovation involves a simultaneous reconfiguration of the social and technical dimensions of use [L. Klerkx, 2010]. The farmers must therefore be provided with ambient conditions and time in the search for innovations in order to make sustainable shifts or modifications from their old systems to modern approaches.

The farmers have limited time to do research work at the same time engage in producing food for their families' needs, hence the research activities carried out with them must be observed to be socio-economically viable and can yield knowledge that will be useful to them in the future without the researcher's presence.



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The research has to become a readily available tool for the empowerment of the farmers in their production and or processing activities in the future. This is a good prerequisite for their sustainable development in Science and Socio-economic spheres.

Individual researchers, institutions and Universities must therefore look out for ways of working together with farmers, with a strong orientation on participatory research paradigm. This will sharpen the teaching, learning and discovery ability of both the researcher and farmers. This can eventually create sustainable scientific and socio-economic platforms through which innovative networks between and amongst farmers, researchers and institutions can be built. For centuries the agriculture of developing countries was built upon the local resources of land, water, and other resources, as well as local varieties and indigenous knowledge. This has nurtured biologically and genetically diverse smallholder farms with robustness and a built-in resilience that has helped them to adjust to rapidly changing climates, pests, and diseases [W. M. Denevan, 2004]. This implies there is already some amount of adaptability of the farming in their farming systems, therefore the introduction of the modern method must be done inclusively with the existing experience and skills and other opportunities the farmers have in their natural habitats.



The scenario will precipitate useful resource centre of knowledge that could be generated from the concerted effort of the research entity of the researcher and the farmers. This will give hope to the farmers for improvements in the production capabilities based on their abilities to use the acquired scientific knowledge gained in solving their food production problems with some amount of flexibility in adapting and adopting the new results or outcomes.

### 1.3 The hope and benefits of the small scale farmers from research work

In Africa and Sierra Leone in particular, most of the development activities are localised in urban centres. This has led to massive rural-urban migration of youths in search for greener pastures, although this is not achieved by all. The changing dynamics of life in urban areas are also immensely influencing and affecting the rural areas such as the use of mobile phones, radios, TVs, schooling, health facilities, and other technologies. In order to maintain equilibrium in these dynamics the introduction of innovations in knowledge, technology and skills in rural areas, especially with the farmers is a strong and suitable option to maintain holistic development in any country such as Sierra Leone. It has been discovered through series of research work that farmers have tremendous hopes and benefits they would like to gain from research work. These are some of the hopes expressed for the future:

1. to increase their yield rate per hectare; they always look out for ways to achieve this through trial and error with little or no technical know-how and technological resources;
2. to reduce or minimise the intensive labour they expend in their farms every season or year; this makes them to be interested in modern technology; such as mechanisation;
3. to increase their income per capita; they are in close link in establishing means to sell their produce always at better prices;
4. the desire for new varieties that could better their yields per hectare or per head; thus the exchange of different crop varieties and animal breeds between and amongst them is always eminent;





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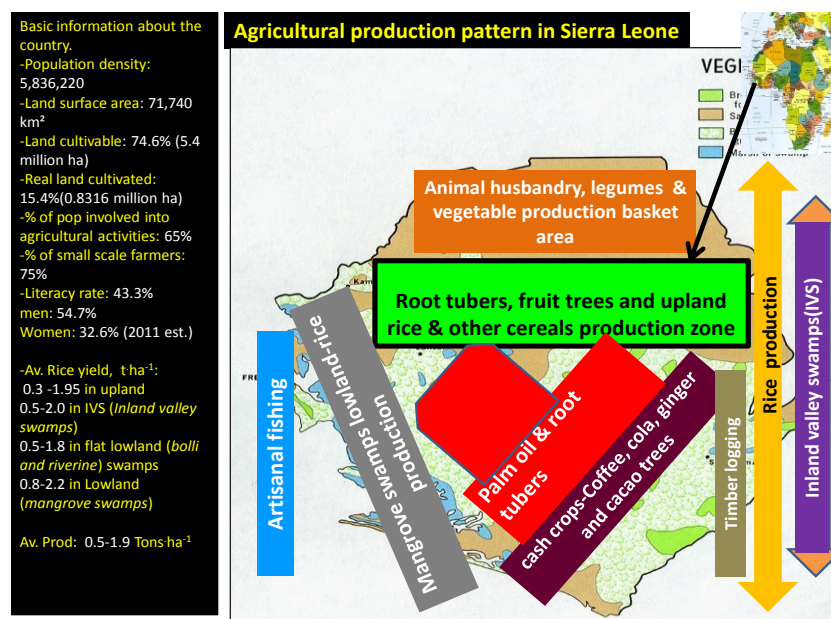
5. the desire for better socio-economic standards of living such as schooling, health facilities, road network, communication etc. This has led to the establishment of community supported schools and the proliferation of drug pedlars to help solve the problems of illiteracy and inadequate health facilities which cannot be fulfilled by the central government through the urban centres and
6. the ability to be able to use scientific techniques, skills and knowledge to solve their production problem locally without having to spend additional resources on people from outside their rural domain.

It is as a result of these, the involvement of farmers in research is of fundamental importance to their development in the rural sector and the nation as a whole.

Although it is very necessary for institutional research to continue since they may have issues that may need specific concentration, the inclusion of farmers in any farm research can yield very high benefits, aspire hopes and develop the maturity in them to be able to cope with the challenges in fulfilling their desires for advancement.

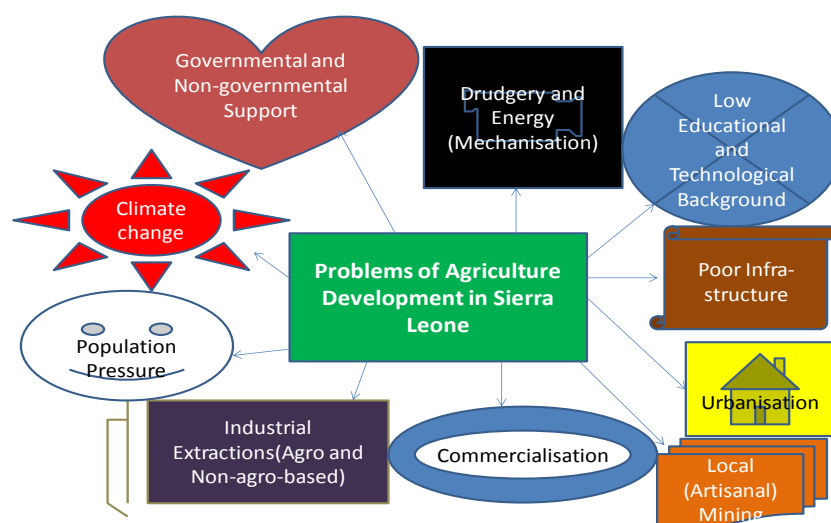
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## Figures



**Figure 1.1.** Agricultural production pattern in Sierra Leone in accordance with the ecology.

## The problems of Agriculture Development in Sierra Leone



**Figure 1.2.** A schematic diagram of the problems of agricultural development in Sierra Leone.



**PhD Thesis**

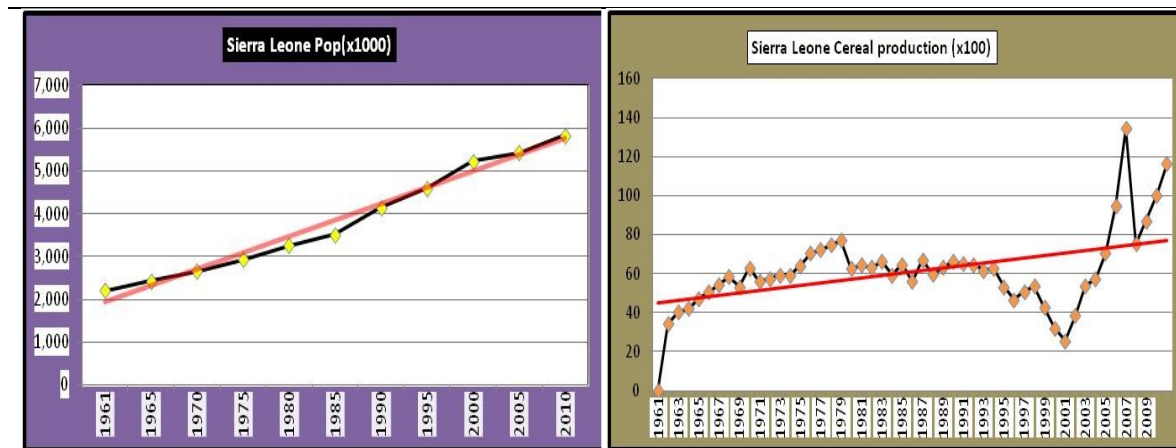
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**Chapter 1**

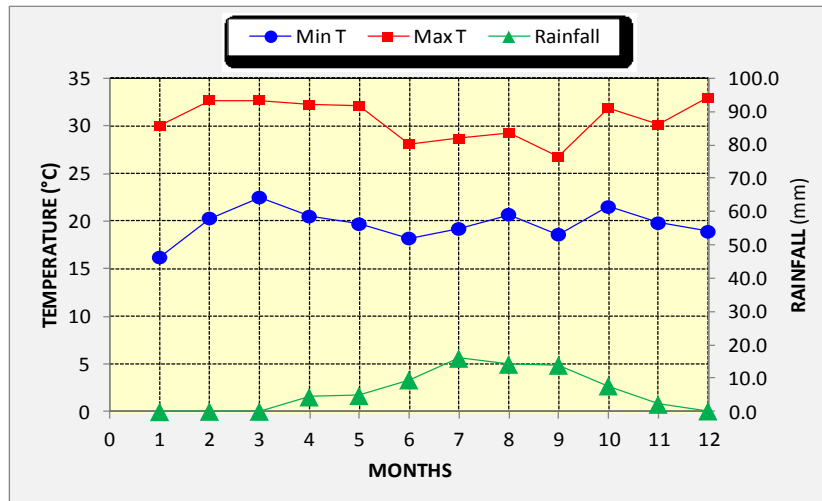
*Rural community approach on On-Farm Research (OFR) on systems of upland rice cultivation using modern method intercropping and traditional mix cropping and the cultivation of energy producing crop called jatropha in the upland ecology*

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**Figure 1.3.** Trend of population and food production in Sierra Leone since independence in 1961. The red line represents the tendency of both the figures.

[Source: Statistics Sierra Leone - 15th Conference of Commonwealth Statisticians in New Delhi, India – February 2011].



**Figure 1.4.** Climatic conditions in Sierra Leone showing the average rainfall and temperature pattern during the year.

[Source: Ministry of Agriculture, Forestry and Food Security (MAFFS) 2010, through the Metrological station].

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## Tables

**Table 1.1.** Population by sex: 1974-2011 (% of total population).



[Source: Statistics Sierra Leone - 15<sup>th</sup> Conference of Commonwealth Statisticians in New Delhi, India –February 2011].

YEAR	MALE (% TOTAL POPULATION)	FEMALE (% TOTAL POPULATION)
1974	50	50
1985	50	50
2004	49	52
2011	49	51

**Table 1.2.** Potential Area under cultivation of rice per hectare.



[Source: Ministry of Agriculture, Forestry and the Environment, Freetown, 1996]

ECOLOGY	POTENTIAL AREA $10^3 \text{ m}^2$	AREA CULTIVATED $10^3 \text{ m}^2$	AREA CULTIVATED (% POTENTIAL AREA)
Upland	792	286	36%
Inland Valley swamp	690	114	17%
Mangrove swamp	200	25	13%
Boliland	145	10	7%
Riverine Grassland	130	20	15%
Total	1955	455	Av. 23%

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## Chapter 2- Assessment of the traditional mix cropping method using local tools and the modern method of rice cultivation using machinery with minimum tillage and row planting with intercrops in the upland ecology

### Abstract

Traditional upland rice-based cropping systems in West Africa rely on periods of fallow to restore soil fertility and prevent the build up of pests and weeds. Population growth and increased demand for land are forcing farmers to intensify their rice production systems. The farmers have shortened the fallow periods and increased the number of crops they grow before leaving the land to extended fallow. The result has being a significant yield reduction. Promising cropping systems include alternating the use of Site-specific, weed-suppressing, multipurpose cover legumes as site duration fallows [M. Becker, D.E. Johnson, and Z.J. Segda, 2000].



The 75% of small scale farmers involved in upland cultivation of the 65% total population of farmers in Sierra Leone has prompted this research to be carried out to investigate what improvements could be made in trying to increase the yield rate per hectare ( $\text{t ha}^{-1}$ ) of these rural Resource Poor Farmers (RPF) [ATPS, 2011] in an economically viable input-output relationship at the same time conserving the soil potential and its superficial ecology. This phenomenon implies to a lot of West African countries [Nye and Greenland 1960, Johnson and Adesina 1993].

It can be argued that anchoring research in the needs and opportunities of the farmers is as important as it is to anchor the research in the international scientific literature [N.G. Roling et Al., 2004]. Agriculture, which is practiced by 75% of the total population of Sierra Leone, is considered to be the most appropriate means of sustainably solving these key issues if properly practiced in the country. This research is geared towards getting possible means of minimizing the problem of food and energy shortage through the use of the local farmers by introducing basic but essential skills in minimal mechanization and modern agronomic methods in their farm sites to produce rice-the staple food and bio-fuel from jatropha seeds that can be used locally by the people themselves.

It will further investigate the relevance of introducing minimum mechanisation, technical skills and modern agronomic practices that could stimulate increase in yield per hectare with less economic burden on the already poor resourced farmers at the end of the production season. This is because agricultural production is not only for direct human consumption as food but also as primary resource materials as food and other needs. This venture must therefore involve the interplay of series of factors ranging from natural resources (soil, sun, water, and air), capital and management [G. Pellizzi and M. Fiala, 1996].

It is an evident fact that most, if not all of the farm operations of the small scale farmers are done manually in Sierra Leone and elsewhere in Africa. This militates heavily against increase in production levels due to high farm drudgery or intensive labour used by the farmers, resulting to limited acreage per farm family, poor agronomic practices and late completion of farm operations.

The research is therefore focused on what agronomic, mechanical and economic strategies could be combined:

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**to improve on:**

1. the yield rate per hectare ( $t \cdot ha^{-1}$ );
2. the acreage worked per farmer ( $ha \cdot farmer^{-1}$ );
3. the quality of the agronomic practices in the field such as soil tillage, pest and weed management strategies and
4. the timeliness in completing farm operations ( $h \cdot ha^{-1}$ ).

**to reduce :**

1. the field time for farmers ( $h \cdot ha^{-1}$ ) and labour intensity as well;
2. the input factors (water, seeds, chemicals etc.) and
3. the services (contractors, manpower etc.) necessary for production.

This could be achieved by working with the farmers themselves who shall be the custodians and ultimate users of the results of the research.



The research is also geared towards introducing modern agricultural technology transfer to farmers by working with the researcher in their farmers; on-farm research approach or Farmers Participatory Research (FPR) together with the farmers themselves. This field laboratory approach where the farmers will learn new skills, discover new knowledge and can easily use what they have learnt during the research for their future agricultural engagements to improve the socio-economic and agricultural status without the researcher is one of the main **pillars** of this work. This will bridge the gap between agricultural research results and the users of the results, in this case the farmers. In addition, the research also aimed at developing the farmers' acumens in being inquisitive and curious to find out solutions to their problems from the field which is their most immediate and most permanent laboratories. This will minimize the dependence syndrome on distance research designs and researchers to solve their local existing production problems in their field. Concomitantly, it will also shorten the time it takes to solve their problems that are eminent in the field of production since they are active participants to research work therefore can act now instead of waiting for far-fetched researchers to look out for solutions to their problems, especially where there are limited resources to make this becomes feasible.

The introduction of minimal mechanisation saves time, though much more costly. This will reduce the drudgery or intensive manual labour suffered by the farmers and save their time and energy for other farm activities. It will also improve some of their social amenities, especially for the women and children such as health, education, domestic chores and other socialization since they will now have time to rest and share interpersonal relationships with the families at home.

The approach which is coupled with scientific research methods will not only look out for solutions to the problems of food and energy shortage but also:

1. teach the farmers some basic science skills to acquire new knowledge;
2. look for solutions to their farm problems by enabling them use the research knowledge gained more relevantly in the agricultural activities and
3. to create positive new levels of food production and processing in their local communities.



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In other to achieve this goal the use of OFR method was applied. According to this method, the farmers are integral component or part of the entire research work from start to finish. By so doing, the **farmers will not only gain from the results of the research but also learn some techniques** such as:

1. careful field observation;
2. comparison of events and technical situations;
3. use of scientific skills and simple instruments or equipments, such as measurements and spacing;
4. independently develop the ability to make judgments from the field as a **living laboratory** where they live and interact every day and
5. developing curiosity about the field and production.



This makes the skills, techniques and knowledge which the farmers gain as real property of their own and can be readily used when they confront any situation during their production process and NOT as an outside or strange research results or techniques handed over to them to be used to improve their production level by researcher(s) or research institution(s).

The introduction of minimal mechanization and modern agronomic practices will eventually save time and excessive labour, though much more costly. This will reduce the drudgery or intensive manual labour suffered by the farmers, save their time for other farm and social activities and increases the yield per hectare.

Consequently, it will also improve some of their social amenities, especially the **women and children** such as their **health, education, domestic chores and social status**, since they will now have much time to rest and share time with the family members at home.

In this research, the farmers are placed as **central focal entity** for them to fully participate in their own development as both learners and beneficiaries of the knowledge, skills and techniques used or discovered during the entire production process. They are both **creators** and **users** of the **research results**.

The approach to the problems of farming must be made from the field, not from the laboratory as it was said by this writer. The discovery of things that matter is three-quarters of the battle. In this, the observant farmers or labourers, who have spent their lives in close contact with nature, can be of the greatest help to the investigator [**Sir A. Howard 1943**].

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## 2.1 Objectives of the study

The objectives of the research on traditional and modern methods of upland rice cultivation with small scale farmers in the Bombali district of Sierra Leone are:

1. to assess the impacts of minimum mechanical cultivation through soil tillage (ploughing and harrowing-1<sup>st</sup> and 2<sup>nd</sup> harrowing) and traditional method of using the hoe and cutlass in the upland rice cultivation with small scale farmers in Sierra Leone;
2. to assess the intensity of labour used in the modern and traditional methods of upland rice cultivation by the rural small scale farmers;
3. to investigate the crop response in terms of vegetative growth and yield rate of rice and its related intercrops from the field cultivated by 4 small scale farmers in 2 hectares using the traditional and modern methods of cropping system of farming in the upland ecology;
4. to assess and compare the economic input and output of the modern and traditional methods of upland rice cultivation with small scale farmers in rural communities.



## 2.2 Introduction

Agriculture is the largest economic activity in sub-Saharan Africa (SSA). Despite the obstacles it is facing and it has to face. It sustains the livelihood of millions of people [S. Costa et al., 2013].

Food production in Sub-Saharan Africa is characterized by small scale farmers who have limited resources and sometimes lack adequate modern technical know-how to maximize production and transformation of what they produce. This has led to huge losses of even the little that is produced. For example, in many African countries, the post-harvest losses of food cereals are estimated at 25% of the total crop harvested. For some crops such as fruits, vegetables and root crops, being less hardy than cereals, post-harvest losses can reach 50%. In East Africa and the Near East, economic losses in the dairy sector due to spoilage and waste could average as much as US\$90 million/year [FAO, 2004]. In Kenya, each year around 95 million liters of milk, worth around US\$22.4 million, are lost. Cumulative losses in Tanzania amount to about 59.5 million liters of milk each year, over 16% of total dairy production during the dry season and 25% in the wet season. In Uganda, approximately 27% of all milk produced is lost, equivalent to US\$23 million/year [FAO, 2004].

These are very tangible reasons as to why minimum mechanisation and improved technical skills must be introduced to the small scale farmers at all levels of production schemes in Africa and Sierra Leone in particular. Farm mechanisation can lead to increase in acreage per farmer. The Soil manipulation, in the form of tillage can change fertility status markedly and the changes may be manifested in good or poor performance of crops [Ohiri and Ezumah 1991]. The combination of minimal tillage and modern agricultural skills can lead to increase in the production of crops such as rice.

Soil is a fundamental natural resource on which civilization depends. Agricultural production is directly related to the quality of soil. In view of the rapidly expanding global population and its pressure on the finite amount of land available for agricultural production; maintaining soil quality is essential not only for agricultural sustainability, but also for environmental protection. Maintenance of soil quality would reduce the problems of land degradation, decreasing soil fertility and rapidly declining production levels that occur in many parts of the world which lack the basic principles of good farming practices.

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Intensification of agricultural production has been an important factor influencing the Green House Gases (GHG) emission and affecting the water balance. Currently, agriculture accounts for approximately 13% of total global anthropogenic emissions and is responsible for about 47% of total anthropogenic emissions of methane (CH<sub>4</sub>) and 58% nitrous oxide (N<sub>2</sub>O).

Although there are series of disadvantages associated with mechanisation, appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem stability [Lal 1981 and Greenland 1981]. Minimum tillage provides the best opportunity for halting degradation and for restoring and improving soil productivity [Lal 1983; Parr *et al.* 1990].

According to Antapa and [Angen 1990], tillage is any operation or practice taken to prepare the soil surface for the purpose of crop production. Different crops need different soil preparation before planting. Some of them may need only minimum soil tillage. Soil tillage is one of the very important factors in agriculture that would affect the soil physical properties and yield of crops [Keshavarzpour and Rashidi, 2008]. Therefore for a successful crop production care must be taken as to what soil preparation can be appropriate for a particular set of plant in the field.



In Sierra Leone, of the 75% of the population involved in agriculture, 55% are women and they produce 60% of the total food, handling processing and storage [J.S.Sesay, 2013].

The African Development Bank (ADB) has found that activities such as crop farming, household poultry raising, fish processing and marketing, and gathering of fuel wood, vegetables, herbs, fruits and nuts from forests are predominantly done by females while cattle raising, hunting and logging for timber, fuel wood, and charcoal are dominated by males. As part of their dominant role in the crop sector, women process, preserve, store, and transport all food crops for marketing [ADB, 2012]. Despite their significant contribution to agriculture, women in rural Sierra Leone are disadvantaged by prevailing customary practices that do not allow women to inherit land, leaving women with limited property rights [IRIN News, SIERRA LEONE, 2012]. Therefore, special attention should be paid to crop cultivation, especially rice; through the use of minimum mechanisation, since 98% of the Sierra Leone population depends on it as their daily food. This mechanisation can reduce the intensive labour carried out by farmers especially the 55% of women that are directly involved in it.

Rice, which is Sierra Leone's staple food, is mainly produced by small scale farmers described above as subsistent farmers. Mechanisation in Sierra Leone, like in most African countries is minimally practiced by most of these small scale farmers. Since the number of these small scale farmers form more than 75% of the rice production with very low yield per hectare (0.5-2.0), there is therefore very high rice import rate in the country.

Global rice imports have increased by 80% - from 2.5 billion tons (grain) in the early 1990s to 4.5 billion tons in 2004. During the same period, African countries increased rice imports by 140% - from 5 million tons in the early 1990s to 12 million tons in 2004. This is equivalent to about a quarter of the world import, with an import value estimated at US\$2.5 billion.

West African countries show the same increasing trend of rice import, increasing from 4 million tons (US\$ 0.8 billion) in early 1990s to 8 million tons (US\$1.6 billion) in 2004-2005, accounting for two-thirds of Africa's rice import. Annual import value exceeds US\$200 million [JICA 2007]. Rice imports are projected to be between 6.5 and 10.1 million tons in 2020 [F. Lançon *et al* 2002].

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In recent years, rice production in Africa has been expanding at a rate of 60% per annum, with 70% of the production increase due mainly to land expansion and only 3% being attributed to an increase in productivity [ARC, 2007 National Rice Development Strategy]. Much of the expansion has been in the rain fed systems, particularly in two ecosystems, (The upland and rain fed lowland) that make up 78% of rice land in West and Central Africa. Africa cultivated about 9 million hectares of rice in 2006 and production, which is expected to increase by 7% per year, surpassed 20 million tons.

The Green Revolution taught us that technological innovation; higher yielding seeds and the inputs required to make them grow - can bring enormous benefits to poor people through enhanced efficiency, higher incomes and lower food prices. This virtuous cycle of rising productivity, improving living standards and sustainable economic growth has lifted millions of people out of poverty [Evenson and Gollin, 2003]. But many remain trapped in subsistence agriculture especially in Africa and with the small scale farmers in particular.



Less than 5% of farmers in the agricultural sector have access to chemical fertilizers, herbicides, insecticides or motorized farm equipment. Widespread use of unimproved varieties, coupled with unchanged cultural practices, adversely affects rice production [A. Abdelrasoul]. There are multiple constraints commercializing smallholder production. Higher levels of agricultural technology are not affordable due to low economic returns from commodities. There is a lack of rice milling facilities, feed mills and mechanics to ensure that farmers can benefit from sales of their final products, and use of mechanized technologies. Fertilizer use at 4kg/ha<sup>-1</sup> compared to 9kg/ha<sup>-1</sup> for sub-Saharan Africa is low due to high prices and lack of commercial markets for fertilizable commodities such as rice.

Furthermore, the absence of irrigation infrastructure significantly constrains agricultural productivity. Mean annual rainfall is around 2500 mm but distribution is not uniform, resulting in water surplus during the rainy season (i.e. May – October) and water deficit during the dry season (i.e. November – April). Some 20 –50 percent of the total annual rainfall is “lost” to runoff resulting in water deficits as much as 500 mm per annum in some agro climatic regions. The persistence of such deficits in some areas limits crop and animal production activities during the period.

Increased production of rice has been reported to be hampered predominantly by weeds. Weed is a plant growing where man does not want it to be. Almost any kind of plant can therefore be a weed, as long as it exists in a location or situation where it is considered undesirable [U. Ismaila et al, 2012].

Rice yield gaps were attributed to weeds and nitrogen, based on yield response to researchers’ management in intensified systems. Increased cropping intensity and reduced fallow duration were associated with yield reduction, which was largest at the sites in the derived savannah.

Crop (including rice) intensification-induced yield loss was about 25% and appeared to be related mainly to increased weed infestation (72% more weed biomass) and declining soil quality (about 20%) less soil organic carbon (C) content and nitrogen (N) supply. Weeds were the dominant factor responsible for rice yield loss in the forest area (explaining 65% of the yield gap) and appeared to play a lesser role in the savannah [M. Becker and D.E. Johnson, 1998]. Conversely, [Idem and Showemimo, 2004], noted that competition of weeds with upland rice for moisture, nutrient and light resulted into a substantial yield reduction to the tune of 80-100%, depending on the local weed flora, growth characteristics and environmental factors at the time of crop production.

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Legume fallows and associated management practices must be considered in the context of the cropping systems in which they are used (including farmers' resource base and aspirations). Because farmers are looking for direct returns on their investments, legumes in most situations have to perform functions in addition to providing N; in particular, they also have to reduce labour requirements or increase returns per unit of labour. They may achieve this by suppressing weeds or by providing additional harvestable products, such as food, fodder, or fuel. Improved productivity through reduced requirements for labour and for maintenance of soil fertility, without additional cash investment, is likely to achieve progress in this direction [**M. Becker, D.E. Johnson, and Z.J. Segda, 2000**].

Upland rice is dibble, broadcast, or row seeded, the former being commonly used in shifting cultivation. The most common method of weed control is by hand, often with the aid of hoes or machetes. In Asia, Africa and parts of Latin America upland rice is typically grown with few, if any, purchased inputs. A wide range of weeds infest upland rice, many of which are pan-tropical, including the grass weeds. The variability of weed species composition in upland rice tends to be greater than in the other production systems, and is dependent upon ecology, the cropping system and management practices [**D. E. Johnson, 2013**].

The weed flora in a rice field is greatly influenced by the rice culture practiced. Continuous rice cultivation with an unchanged cultural system encourages the build up of weeds adapted to that system. In contrast, where crop rotation is practiced, a diverse weed flora will result. Perennial weeds increase in non-tilled rice fields [**K. Ampong-Nyarko and S. K. De Datta 1990**].



The common practice of weed control in lowland rice is hand pulling which makes the practice to be labour intensive and many a times not satisfactorily executed. As a result,

Yields in farmers' fields are low ( $0.8 - 1.5 \text{ t ha}^{-1}$ ) whilst in well managed researchers' fields with the use of chemicals averaged  $2.5 - 3.5 \text{ t ha}^{-1}$ . The identification and development of competitive rice varieties may be effective in weed suppression and provide a tool for integrated weed management. Contrary to other weed control methods, improved varieties have proven well for ease of adoption [**S. S. Harding and A. B. Jalloh**].

The economic benefit of weed control must exceed the cost. The primary aim of a rational farmer is to optimize profits. One way to achieve that is to reduce weed control costs. It is logical, therefore, that where one or a combination of methods exists, and both are equally effective, the farmer will choose the least costly [**Fryer and Matsunaka 1977, Fryer 1983**].

Thus, weed control is major prerequisite for improved rice productivity and production therefore must be controlled to prevent yield losses [**Zimdahl, 1988, 2004**].

Irrespective of the method of rice establishment, weeds are a major impediment to rice production through their ability to compete for resources and their impact on product quality. Through development and adoption of improved weed management technologies, improved rice productivity and production could be achieved to meet the demands of increasing population [**N. Rao Adusumilli, 2012**].

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## 2.3 Materials and methods

The entire research work was divided into three main phases based on the production processes, methods and materials used to carry out the research. These are the pre-planting, planting and post planting phases of the activities. The three phases were sequentially carried out and each has resulting effects and impacts on the other during and after their implementation in the field. The impacts of these activities can be psycho-social, agricultural and traditional; based on the needs and purposes of the entire research objectives and processes.

### 2.3.1 Pre-planting phase

This involved all the activities that were carried out by either the farmers or and the researcher before the seeds were sown into the soil. They can be concrete or abstract but are relevant to enable the entire field work be carried out.

#### 2.3.1.1 Community sensitization and mobilization

Rotebainkoh (**Figure 2.1**) is a farming settlement established by the people from Patebana Marank, which is located 5 Km South-East of Makeni. Makeni is the regional headquarter town of the Northern Province of Sierra Leone. Rotebainkoh is 2 Km from Patebana Marank and 7 Km from Makeni.



The population of Patebana is about 1,500 inhabitants and their occupation is mainly agriculture, of which Rotebainkoh is an integrated small settlement with a population of about 54 people, totally involved in agricultural activities throughout the year alongside some other economic activities such as charcoal burning, fresh water artisan fishing and sand mining. They are also inevitably involved into other development projects undertaken by the larger Patebana village community during the year as they carry out their farm work.

The rice research project was initially introduced to the larger Patebana community but eventually accepted to be carried out at Rotebainkoh inhabitants who totally accepted and expressed readiness to involve into the research as a result of the spelt out objectives and the benefits associated with it by the researcher. This was done in general meetings held at the Patebana community and then continued later at the Rotebainkoh farming settlement community.

There were three levels of meetings held in all the research communities before and during the field research activities. They are:



1. first level;
  2. second level and
  3. third level community meetings.
1. The first level community meetings included the town chief, community elders, women, youths and the farming population together with the research team. The objectives of the first level meeting are to:
    - a) clearly explain the aims and objectives of the research and its consequent benefits to the farmers and the larger community;



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- b) enable the community chief and land owners accept the use of their land for the research activities and
  - c) be able to select the farmers or farm families that will be participating into the entire research processes from the community resident farmers *only*.
- 2. The second level meeting included the selected farmers and any other interested person (s) that would like to know what the research will be doing during its course of activities in the field. The purpose of this meeting is to:
  - a) select a leader of the selected 4 farmers for the field research work;
  - b) to develop basic rules or guidelines that will facilitate the entire research work between and amongst the farmers and the research team, for example communication flow, time of working in the field, acquaintance with social community problems etc;
  - c) identify and select the required hectares of land for the research from site already being allotted for the research by the community land owners and the village chief;
  - d) concretely explain the research field design and the purpose of such design to the 4 selected farmers;
  - e) draw the activities timeline of the research together with the 4 farm families to be involved into the research work to avoid clash of activities during the field operations of the research work by these farmers as they have other activities to do during the cropping season and
  - f) explain the different roles and responsibilities of the farmers and the research team during the research period. For example; the farmers should be doing all the manual field work without being paid, provision of the seeds they have to use in their research plots, protection of the research plot against pests and other related calamities and the total ownership of the yield of the crops cultivated. The researcher should in the other hand, provide for example; the external resources such as the tractor to till the soil, the fuel, the payment of the tractor operator(s), other farm equipment or inputs such as the furrow marker, garden lines, tape measure and the technical support on the modern methods of the field activities.
- 3. The third level meetings included the leader of the farmers and the researcher or research team. The purpose of this meeting is to enable a smooth flow of information or communication between the farmers involved into the research and the researcher or research team. This is to shorten the chain of command and enable efficient use of time and resources in the passing on of information needed for the smooth running of the field activities and other related issues that may pertain to the farmers and or the researcher.

In all these meetings, the general rules are that every member of the community and the selected farmers were given the opportunity to express their opinions or ideas about the research and must be listened to; including the women, youths and other farmers. This enabled the entire process to be easy to understand and share all the information before, during and after the research activities that led to the conclusion of the entire research work (Figure 2.2). This is because everybody's contribution was essential as long as it followed the objectives and design of the research.

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### **2.3.1.2 Research site identification and selection**

The research site was identified at Rotebainkoh farming settlement land by the farm families that were selected and accepted to participate on the research exercise. The site selected was a four year bush-fallow land interspersed with savannah grass and trees. The farmers, who know their farming land better, led the research team to the site.

The area was demarcated using cutlasses or machetes to cut through the thick bush, together with the 50 m tape measure and pegs. The 3, 4, 5 triangular method was used by the researcher to create an area that has a definite rectangular surface area to ease the lay-outing of the plots of the farmers in the future after the land clearing and tillage activities.

The researcher indicated to the farmers the land inclination and showed how the research plots were to be laid across the gentle slope of the land surface.

Each farmer accepted to have an area of half hectare of land within the same location; all parallel to each other and lying along the same contour belt to avoid any vast differences in the topo-sequence variability on the treatments. Pegs were used to indicate the 4 different plots of the 4 farm families; each measuring 50 m x 100 m as shown below diagrams (**Figures 2.3 and 2.5**).

The half hectare allotted to each farmer was further divided into two equal parts i.e. 0.25 ha (2,500 m<sup>2</sup>), measuring 25 m x 100 m in each farmer's plot.

One of the 0.25 ha was used for the traditional method of mix cropping of rice and its allied crops (pigeon peas, beni-seeds and sorghum) to be broadcasted at random, while the remaining 0.25 ha was to be cultivated with rice and its allied intercropping of pigeon peas, sorghum and beni-seeds in rows after the mechanical tillage (ploughing and harrowing) of the area with the selected tractor.

The plot layout exercise was concretely demonstrated to the 4 farmers on the ground with a diagram drawn on the floor by the researcher in order for them to have an understanding of what the entire field layout and its work would look like before starting any field operations. Every farm family made his/her choice of plot allocations in the site they selected for the research. Documentation of the names of farmers and plot numbers was carried out by the research team.

### **2.3.1.3 Soil sample collection and laboratory analysis for the two research sites (at Rotebainkoh and Bumbang)**



Two sets of soil sample tests were carried out for the entire research process. One was done before the planting of the crops and the other after the harvesting of the crops in the field. The soil sample collection pattern from the field for the two soil analysis was different:

#### **1. soil sample collection before the planting of crops.**

Before the planting of crops a soil sample map was designed for the 2.5 ha experimental research block for 20 soil samples to be collected at a depth of 20 cm in each collection point (**Figure 2.4**).

Each plot of 0.25 ha has two collection points with quantity of soil weighing 80 g, excavated at a depth of 20 cm using a shovel and a hand trowel. The 10 soil samples collected from the 2.5 ha were all mixed together to make a total of 800 g (0.8 kg). This soil was dried for three days under room temperature and 100 g was then measured from the 800 g (0.8 kg) homogenous sample and



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placed in an airtight plastic bag. The 100 g soil was taken to the soil laboratory for analysis for macro-nutrients, CEC, pH range, and some physical features such as texture and organic matter contents. This was done for both the rice and the jatropha research locations at Rotebainkoh and Bumbang communities respectively before the planting of the desired crops;

2. soil sample collection after rice and ground nut harvesting at Rotebainkoh and Bumbang respectively.

#### **At Rotebainkoh**

After harvesting of the rice, another set of 6 soil samples were collected from the 6 different treatments of the experimental block. A quantity of 100 g of soil was collected from the field from each of the 6 treatments in the 4 farmers' plots making a total of 400 g per treatment. The 400 g of soil from the 6 treatments of the 4 farmers' plots was thoroughly mixed to make a homogenous mixture and a 100 g was measured out of that quantity as the sample for laboratory analysis. This was repeated for each of the 6 treatments contained in the 4 experimental plots, making a total of 6 soil samples each weighing 100g ([Table 2.1 below](#)).

#### **At Bumbang**

After the harvesting of the ground nuts in September, soil samples were collected from the two treatments of ground nut and jatropha (JIG) and jatropha without ground nut (JSC). This was done by collecting 100 g of soil from each treatment in each of the 4 plots ([Table. 2. 1](#)). The collected samples from each treatment of the 4 plots were then mixed together, making a homogenous mixture and a 100 g was measured as in the case of Rotebainkoh. Two different samples of 100 g each were obtained for laboratory analysis.

Tools used in the collection process are: a) the soil sample collection map of the experimental block ([Figure 2.4](#)), b) shovel, c) hand trowel, d) spring balance, e) polythene bags, f) plastic sheet, g) identification tags and h) measuring tape.



The collected samples were analyzed in the laboratory and results recorded. The laboratory was located in Lunsar which is a town located 50 Km away from Makeni where the research was carried out. The laboratory belongs to an agricultural vocational centre owned by the Catholic Mission, meant to train youths in the field of Agricultural Science in Sierra Leone.

#### **2.1.3.1.4 Mechanical soil tillage for modern method rice and its intercrop planting.**

The mechanical soil tillage was done in a land that was left fallowed for 4 years with thick grass and stumps in an upland ecology.

The 0.25 hectare land surface area was prepared for seed planting through the use of a four wheel-drive tractor machine with model FAIT. Three soil tillage operations were carried out as follows:

1. ploughing;
2. first harrowing and
3. second harrowing.
1. Land preparation was done with the same tractor throughout the processes of soil tillage. A disc plough equipment measuring 120 cm wide was used in the ploughing process which was the first

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land preparation process for the modern method of the rice cultivation. The ploughing orientation of the machine was done against the gentle slope or along the contours of the land. The soil tillage was done with the natural vegetation incorporated or ploughed together into the soil. No burning of the natural vegetation was required or carried out here in the modern plots of the farmers.

The tractor used was an Italian model with double traction. See (Table 2.3) for detailed technical information about the tractor used in this research.

The plough used was an Italian type called Nardi, with 3 discs. It was a 1.55 m long flat steel frame with 3 point linkage which can be adjusted vertically or horizontally. The disc has a profile whose diameter was 0.63 m, with each implement (disc) a length of 0.56 m and then distance between one disc and another was 0.55 m; making a total width of work of 1.10 m. The mass of the plough was 225 kg.

2. The harrow was an Italian off-set type, with a brand name Gherardi.

The disc harrow had a hydraulic lift control. It had 11 notched front discs and 11 rear discs, each one with diameter of 0.7 m with spacing of 0.23 m. The entire weight of the implement was 1300 kg to 1400 kg and its width was about 2.30 m.

The level of the fuel put in the tank of the tractor was recorded before the ploughing of each 2,500 m<sup>2</sup> (25 m x 100 m) plots.

The time taken to complete the ploughing of 2,500 m<sup>2</sup> (0.25 ha) and the depth and width of plough were recorded.

The time taken for the tractor to plough a given length of 30 m was recorded repeatedly 10 times by the research team members during the ploughing exercise to calculate the average speed of the machine during the tillage operation in the upland ecology of the research site.

The first harrowing was done with the same tractor that was used to plough, using the off-set disc harrow equipment with a dimension of 230 cm (2.3 m) wide.

The quantity of fuel in the tank of the machine was again recorded before and after the harrowing of the entire 2,500 m<sup>2</sup> plot surface areas of each farmer's plot. The depth, width and time taken to complete the entire 0.25 ha area of each farmer's plot was recorded. This was repeated in all the 4 farm family plots of the experimental block.



3. The second harrowing was also carried out using the same tractor and the same soil harrow equipment used for the first harrowing in the respective farmers' plots; recording the tillage parameters such as fuel consumption, depth and width of harrowing.

#### **2.3.1.5 Research treatments lay outing in the modern method of rice cultivation and its intercrops**

The 2,500 m<sup>2</sup> (0.25 ha) mechanically cultivated (ploughed and harrowed) plot of each farmer was now subdivided into 5 equal parts, each measuring 500 m<sup>2</sup> (25 m x 20 m) as one treatment of the research experiment. These treatments were each separated from each other by a meter.

The entire experimental plot of each farmer was having 6 treatments; namely, a traditional treatment, measuring 2,500 m<sup>2</sup> (0.25 ha) and 5 modern treatments each measuring 500 m<sup>2</sup> (0.05 ha).

The 6 treatments were all labelled as follows: Traditional treatment (TT), Modern treatment with rice only (MTRR), Modern treatment with rice and pigeon peas as intercrop (MTRP), Modern treatment with

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beni-seeds as intercrop (MTRB), Modern treatment with rice and Sorghum as intercrop (MTRS) and Modern treatment with rice, pigeon peas, beni-seeds and sorghum as intercrops (MTTC). The number suffixes were added to each of the treatment labels for plots 1, 2, 3 and 4 to distinguish plots 1 to 4 in the entire block (Figure 2.5).

The lay outing exercise was done using a 50 m tape measure, pegs, lay-out design or plan and garden lines together with the farmers.

The farmers were allowed to know what a meter is and using garden lines to measure the dimensions of the respective treatments in all the plots by the research team members, in which they (farmers) were allowed to participate actively in all the processes.

#### **2.3.1.6 Traditional method of land clearing (Slash and burn method)**

The 0.25 ha (2,500 m<sup>2</sup>) traditional plot of each farmer was cleared off the natural vegetations manually using traditional tools such as cutlasses and big hoes by the farmers and their family relatives or dependants (Figure 2.6). The process was carried out by cutting down trees, other vegetations and mowing tall elephant grass of the four-year fallow land. The cut and mowed vegetations were allowed to dry for one week and then burnt by the farmers. The remaining vegetative debris and some stumps were cleared again using cutlasses to create a clear soil surface suitable for the introduction of seeds through the random broadcasting method. This land clearing was done mainly by the men in April when the place was adequately dry and temperatures were high, 35-40°C.

### **2.3.2 Planting phases**



#### **2.3.2.1 Traditional mix cropping (random seed broadcasting seed rice and other crops) and ploughing with small hoes)**

The traditional and modern method treatments were all planted simultaneously in each of the 4 farmers' plots. In plot 1, the planting of both the traditional and modern method treatments was done on the 24<sup>th</sup> of May; plot 2 on the 27<sup>th</sup> May, plot 3 on the 30<sup>th</sup> May and plot 4 on the 2<sup>nd</sup> June, 2013.

In connection with seeds used in this experiment, there was no pre-testing for viability to ascertain the germination percentage on both the rice and the intercrops. Also, the purity of these seeds was not taken into consideration as every farmer treated his or her own seeds in accordance with their traditional local methods generally applicable in their farming ecology.

The seed rice, pigeon peas, beni-seeds and sorghum of the 4 farmers were first weighed using a spring balance for each treatment of the 4 experimental plots and the weights recorded. The weighed quantities were given back to the farmers to plant. After planting, the farmers returned to the researcher with the quantities of seeds remaining and these were reweighed to know how much quantities have been used in all the treatments including the traditional ones in the 4 farmers' plots.

The traditional method of mixed cropping was done by the farmers who mixed the rice together with the other crops they intended to sow in the farm. A plastic sheet or any suitable sheet was spread on a flat floor where the rice was spread and the other crops such as the pigeon peas, beni-seeds and the sorghum were added and physically mixed together. This seed mixture was placed into smaller

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containers that could be easily carried with the hands by the farmers who randomly scattered or broadcasted the seeds into the cleared 0.25 ha traditional plot. After the spreading of the rice and its allied seed mixture on the soil surface, smaller hoes made up of metal blade with diameter of about 5 to 10 cm wide were used to scratch and cover the sown seeds to a depth of between 3 to 5 cm deep depending on the exerted force of the person using the hoe, surface debris, weed population density on the soil surface, soil moisture, texture and structure.

These smaller hoes used to plough the soil surface manually were made of either short wooden handle of about 0.6-0.90 m for mostly women and children or long wooden handles of about 1-1.5 m for men, depending on the height of the user (Figure 2.7). The traditional seed planting method was done to accomplish two purposes; to cover the seeds sown in the field and to remove the weeds that have germinated or remained on the soil surface after the clearing process. The time taken to accomplish this exercise was recorded in every traditional plot of the 4 farmers of the research in the experimental block.

#### **2.3.2.2 Modern row planting of rice and intercrops**

The modern method of seed rice, pigeon peas, beni-seeds and sorghum planting in the modern treatments plot was done in the already demarcated treatments of the 4 plots of the 4 farmers' experimental block. Like in the traditional method, the weighed seeds (rice, pigeon peas, beni-seeds and sorghum) were introduced into the furrows created by the furrow marker machine which was manually drawn by the farmers after being taught by the researcher (Figure 2.8).



This furrow marker was made by the researcher to enable the seeds being planted in precise rows and distances. The machine has two metal wheels that were spaced 1 m apart. The circumference of these wheels is 1 m. A point was made on the metal wheel to create an impression in the soil as the wheel rolls round, making a distance of 1 meter on the ground. This rolling of the metal wheel which is 1m long and 1m apart of the two wheels, creating a space of 1 m x 1 m (1 m<sup>2</sup>), which was used to plant the intercrops of pigeon peas, beni-seeds and sorghum. The furrow marker has three metal prongs in between the two metal wheels, spaced at 0.025 m (Figure 2.8). The furrow marker machine was manually pulled by the farmer; creating 3 furrow marks with the metal prongs for the seed rice drilling and 2 rows by the metal wheels for the planting of the intercrops. The rice seeds were spaced 0.025 m apart between rows and about 0.015 m between rows, while the intercrops were spaced 1 m<sup>2</sup>.

The farmers then drilled the seed rice into the furrows created by the furrow marker's prongs at a depth of about 5 to 10 cm and covered the seeds with the soil. The intercrops were also sown into the holes indented by the metal wheel punch created at a distance of 1m apart. The intercrops were sown at a depth of about 5 to 7 cm and covered with soil by the farmers.

#### **2.3.3 Post planting phase**

##### **2.3.3.1 Crops (Rice and intercrops) population density assessment**

In this research, the process of rice and its intercrops population density assessment was carried out after the crops have completely germinated and well established in their respective stands or hills; in

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this case 30 days after planting (DAP). The two main types of assessment used were the one meter square ( $1\text{ m}^2$ ) quadrat and the individual stand head count methods.

### **One meter square ( $1\text{ m}^2$ ) quadrat method**

The  $1\text{ m}^2$  quadrat method was used to assess the population density of rice in both the traditional and modern methods, (Figure 2.9) whilst the individual stands head count method was used to assess the population density of the intercrops (Pigeon peas, beni-seeds and sorghum) in all the treatments of the experimental block.

The central point situated away from the border of each treatment was selected. This was to avoid borderline effects and minimize variations on the data collected. A  $250\text{ m}^2$  was selected centrally of the  $500\text{ m}^2$  for the modern method and of the  $2,500\text{ m}^2$  for the traditional treatment respectively in every experimental treatment of the research plot. A distinctive yellow colored rope, measuring 4 m long was used with 4 small pegs. The 4 pegs were driven into the ground at a distance of 1m with a  $90^\circ$  angle, making a one-meter square.

The researchers then counted the rice seedlings in the quadrat and the result recorded. This was repeated 5 times in each treatment and in each farmer's plot and the entire farmers' research block. The results were recorded in all the treatments for the entire block of the farmers.

### **The head count method**

The population density assessment of the intercrops was done in both the traditional and the modern methods by the head count method. This involved the physical counting of the desired crop to get the total number in the entire treatment. The physical head count of every intercrop in each treatment was done 30 days after planting (DAP). The results of these intercrops in all the treatments were recorded.



#### **2.3.3.2 Crops growth response assessment**

The seeds planted during the experimental period germinated at different periods based on their types. The rice seeds germinated at 5 days after planting (DAP), closely followed by the pigeon peas and beni-seeds which germinated at 5 to 6 days after planting (DAP) and lastly sorghum which germinated at 6 to 7 days after planting (DAP). The assessment of the growth responses of these crops was done at different periods of their growth.

Growth response observations and assessments on:

**Rice crop:** the first growth assessment of rice in terms of vertical height was done 30 days after planting, whilst the 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> were carried out at 60, 90 and 120 days after planting (DAP) respectively. A 50 m tape measure or 1 m plastic ruler was used to measure the vertical height of rice at 30, 60, 90 and 120 days after planting respectively and the data recorded. In each treatment in the experimental plot, 5 rice plants or stands were selected at random in the central  $250\text{ m}^2$  portion of the treatment and their heights measured. The exercise was repeated every 30 days to obtain the respective heights of the rice in the different treatments. No width or number of leaves of the rice was counted. This exercise was done in all the treatments of the entire experimental plots of the research block.

**Intercrops:** the intercrops growth responses were also assessed based on the height and canopy of the three crops (pigeon peas, beni-seeds and sorghum). This was done at two intervals of 90 and 120 days

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after planting (DAP). In all the crops the height and width of 5 plants were measured using a 50m tape measure or 1 m flat plastic ruler in each treatment at the central 250 m<sup>2</sup> portion of the treatment. The data collected for both height and width of the intercrops were recorded. The process was replicated in every farmer's plot in the experimental block and results recorded, ([Figure 2.10](#)).

**Growth response assessment of rice on tillers and their reproductive potentials:** to assess the growth response of rice in terms of its tillers and panicle production ability, 20 rice stands were selected from the centrally located 250 m<sup>2</sup> portion of the treatment. This selection was done at random within the specified central zone of the treatment. The tillers were physically counted in each of the stands and the numbers recorded. Thereafter, the same counted tillers were observed and recounted the tillers with rice panicles only and results recorded. The exercise was carried out when the rice has fully tasseled or produced panicles at 120 days after planting. Rice stands affected by pests were completely avoided and the selection of the rice stands used was purely at random using normal stands amongst the crops.

#### **2.3.3.3. Assessment of nitrogen content through the rice crop growth response using Leaf Colour Chart (LCC)**

The use of a standard leaf colour chart (LCC) was carried out during the research in all the 4 plots of the farmers in all the treatments. The was done during 60 days after planting (DAP) to assess the growth response of rice with respect to the nitrogen content in the respective treatments of the plots of the farmers. Five different rice stand leaves were observed by the researcher in each treatment and the colour readings were recorded ([Figure 2.11](#)). This was done in all the 24 treatments of the 4 plots of the 4 farmers within the same day. A single person did all the leaf colour readings of the entire research treatments to avoid differences based on the variations of different individuals.

#### **2.3.3.4 Weeds assessment and weeding**



Weeds and Weeding are key farming aspects that have diverse effects on the yields of all crops cultivated in different crop cultivation ecologies in the world. In Africa and Sierra Leone in particular very little or no modern innovations have been adapted to control the tremendous negative effects of weeds on crop production, especially with small scale farmers. This has thus had tremendous negative impacts on crop yields and the amount of labour intensity involved in its management.

Yield reductions in rice caused by uncontrolled weed growth throughout a cropping season have been estimated to be from 44 to 96%, depending on the rice culture. In practice, almost all farmers control weeds in their rice fields. Worldwide, some 10% loss of rice yield can be attributed just to weeds that grow after weed control. These losses can amount to 46 million tons (based on 1987 world rough rice production). There is considerable variation in yield loss to weeds among countries. There is a need to improve farmers' weed control practices. Improved weed management will contribute significantly to future gains in rice yield in many countries [[Kwesi Ampong-Nyarko, Surajit K. De Datta](#)]. It is therefore essential to investigate the weed prevalence in this research, especially in the upland ecology where most of the small scale farming population is engaged in Sierra Leone.

#### **1. Weed prevalence and population density assessment**

Weed prevalence is the amount of weeds present in a piece of cultivated crop land. It is known by estimating the population density that exists in the field of crop cultivated in an agricultural enterprise. This concept is significant in any crop production venture because it has agronomic,



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environmental and economic effects on the farmer involved in that production process. To know the weed prevalence, the weed population density must be calculated through the use of the quadrat method. In this research a one meter square quadrat ( $1 \text{ m}^2$ ) was used to calculate the weed prevalence before and after weeding in the respective treatments in the research block.

The  $1\text{m}^2$  quadrat is used in every treatment in the centrally located  $250 \text{ m}^2$  zone of the experimental treatment. The weeds in each meter square were counted and recorded to get an average number of weeds per meter square in all the respective treatments as shown in (Figure 2.12).

The quadrates Q1 to Q5 represented the 5 quadrates spaces in the treatment from which the weeds present in the treatment was assessed. This was also applied for the traditional treatment that measured  $2,500 \text{ m}^2$  to get the average number of weeds in those treatments. The assessment was done two months after sowing the crops and one and half months after weeding. In this research, there was only one weeding done during the period of the entire reproduction cycle of the crops. This was to investigate the weed prevalence before weeding and the weed re-emergence after weeding amongst the respective crop combinations called treatments in this case.

## 2. Weeding

Weeding is the intentional removal of the unwanted plants that grow within the crops cultivated in the field. Weeding can be done in diverse ways by different farmers based on their agricultural Science technology and economic levels. It can be a mechanical, chemical, biological and physical process done by the farmer to protect the crops from being dominated in terms of growth and reproduction. It can also be done through appropriate agronomic practices. In this research, the farmers did the weeding physically or manually with their hand and local tools such as cutlasses and hoes (Figure 2.12). Each farm family used its own labour of four to six people to remove the weeds two months after planting. The family engages each plot and weeds the treatments one after the other within the same period in July. The weeds were placed in spaces there were not occupied by the crops in the treatment.



Labour intensity assessment of weeding in the respective treatments was also recorded in each of the treatments of the farmers together with the time taken to accomplish the task.

### 2.3.3.5 Pests identification and control

Pests are another big challenge in crop production in Africa and Sierra Leone in particular. Major insect pests of rice can cause yield losses from 10–100% in farmers' fields in some West African countries [Nacro et al, 1996; Ukwungwu et al, 1989]. This can be a dramatic loss to farmers especially the resource poor farmers (RPF) of the upland ecology who form majority of the food production sector in Sierra Leone. The process of pest identification and control form a critical and crucial aspect of the farmers' activities during the production season.

This research focuses on the qualitative identification of the different pests' prevalence in the different treatments and what kind of impacts these can cause in relation to their control and crop yield rates.

## 1. Insect pests observations

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Insects are one of the major pests are widespread in every crop ecology especially in the upland in Sierra Leone. The prominent effects of insects were mainly observed in the treatments at 2 months after planting due to the signs and symptoms of the damages and visible appearances they make on the crop plants. The identification of insect pests was carried out in all the 6 different treatments at different times of the day. The identification was done in the morning hours when most of the insects were seen to be active on the crops in some of the treatments. Only qualitative observations were made and no numerical data were collected. Different insect pests waged attack on different crops in all the treatments in experimental plots (**Figure 2.14**).

## 2. Bird and rodent pests' observation and control

Birds and rodents are macro pests that inflict damage on the crops cultivated in all ecologies and at different stages of growth and reproduction.

**Birds:** In the upland ecology where this study was conducted, prominent amongst the macro pests observed were birds. The birds existed in different species such as weavers (black headed and chestnuts weavers), bush fowls, guinea fowls, pigeons, African collared doves, sparrows, bishop birds and the red billed quelea (**Figure 2.13**). These were amongst the prominent ones identified in the treatments during the seeding (seed sowing) and panicle bearing stages of the rice. All these were observed to have some destructive effects of eating the rice seeds sown in the field and the eventual products of these crops at fruit bearing stage.



Bird scaring was carried out mainly after the tasselling or panicle bearing period of the rice to maturity. It took 30 days after tasselling for the rice to mature for harvesting. Bird scaring was done by erecting farm garrets with height of about 2 meters above ground level where the youths deployed for the bird scaring task stood to sling the birds with stones and or molded hard earth balls (**Figure 2.13**). This activity lasted for one month i.e. onto when the rice became mature for harvesting. Two youths were involved in the scaring exercise for the two hectares of the experimental plots and the days it took for the rice to mature for harvesting it were recorded as 30.

**Rodents:** Amongst the rodents observed during the research were the cane rats, rats and Squirrels. These rodents were observed to be very active in destroying the crops especially the rice and sorghum, during their vegetative stage by cutting down the stems and eating the internal soft parts. On the bid to protect the rice and sorghum crops which were the main crops attacked by the rodent pests, a fence was constructed with bush sticks, ropes, mature elephant straws and palm frond round the experimental block; creating a temporary barrier between the peripheral bush hosting the pests and the crop cultivated site. This minimized the destructive activities of the rodent pests until harvesting of the crops was done. However, destruction was inflicted by these rodents on the rice and sorghum plants by cutting the succulent vegetative stems and removing the inner cortex as food (**Figure 2.15**). The number of men involved in this activity and the time taken to complete the fence were recorded.

### 2.3.3.6 Yields assessment and harvesting of the crops

Harvesting is a critical farm operation in crop production since it represents an important step towards the end of on-farm activities. It is a very high determinant that surmounts the quantity and quality of



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yield obtained in any crop since it involves various parameters such as the time a particular crop should be harvested, method, tools used to harvest, handling of the harvested materials etc. The further processes of the yield until it reaches the final consumer or the store or market is what is referred to as post harvest activities. In this research greater attention was paid to the harvesting operation with careful instructions to the farmers so as to know the yield or output of their labour and the resources so far used during the entire cultivation process.

#### 1. Crops yield assessment

##### a) Rice yield assessment

The rice yield assessment was carried out using the quadrat method in the mature rice field. In each treatment, the mature rice panicles were harvested in the 1m<sup>2</sup> quadrat using a medium size knife of about 20-30cm long. This is repeated five times in 5 different spots in the centrally located 250m<sup>2</sup> portion of the treatment to make 5 sample spaces in each treatment (Figure 2.16). Each bundle of the harvested 1m<sup>2</sup> rice panicles was carefully placed into a polythene bag and placed under open shade; to be threshed after three days. This is to allow the easy detachment of all the grains from the straw. The threshed rice was dried for 3 days to acquire a moisture content of about 14%. The dried grains were then weighed to acquire the weight of rice per each meter square of the treatment. This was done in all the 6 treatments of each of the 4 farmers plot in the experimental block. The materials used were the knife, fiber plastic bags, 1 liter polythene bags, winnower, spring balance, identification tags and a meter square quadrat.



##### b) Beni-seed yield assessment

The beni-seed plant was matured in November, 25th, 2013. It took 180 to 183 days to mature after planting. The beni-seed yield was assessed by harvesting 20 beni-seed plants in the 250m<sup>2</sup> centre location of each treatment with beni-seed as intercrop. The 20 plants were all tied together in a bundle and taken to the farm house. This was repeated 5 times from the identified central portion of the treatment, with each 20 plants making a bundle. The 5 bundles as 5 sample spaces were separately dried under the sun in clean plastic sheets for 6 days after harvest. Each dried bundle was vigorously shaken tilting the bundle downwards to allow all the beni-seeds to fall off their capsules. The seeds were then winnowed with a neatly plated winnower to avoid the beni-seeds from escaping into the ground. The winnowed seeds from the 20 plants bundle was then weighed using a spring balance and the weight recorded (Figure 2.17).

The materials used in harvesting the beni-seeds were a 30cm long knife or small cutlass, an open plastic or metal bowl, bush ropes, plastic sheets, spring balance, winnower and 1 liter plastic bags.

##### c) Sorghum yield assessment

Sorghum was matured in December, 30, 2013. It took 212 to 217 days after planting. The mature panicles were harvested using knives that were used for the harvesting of the rice. The harvesting was done by cutting only the panicles from the entire crop stand.

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In assessing the yield of sorghum, 5 sorghum stands were harvested in the 250 m<sup>2</sup> in the modern plot (500 m<sup>2</sup>). The same number of stands in the central portion of the traditional (2,500 m<sup>2</sup>) plot were identified and harvested. In each treatment, 5 sorghum stands were harvested and tied to make a bundle. This was repeated 5 times to make 5 different bundles of sorghum each containing 5 stands of the plants in every treatment. The tied bundles were each separately placed in a plastic container and taken to the farm house for further processing. The sorghum grains were completely separated from the straws of the panicles by using a mortar and pestle. Every 5 stands sample was placed in a mortar and pounded with a pestle. With the use of a winnower all the chaffs were separated from the grains by winnowing. The grains, which have already dried in the field, were weighed in each sample and the weights recorded (Figure 2.18).

Materials used in the process included knives, mortar, pestle, winnower, 500ml plastic bags, spring balance and plastic bowls.

d) Pigeon peas assessment



Pigeon peas matured in the January, 15th, 2014. It took 230 to 245 days to mature after planting. Like sorghum, the crop is harvested when the pods are completely mature and almost dry in the field. However, over drying in the field was totally avoided since the pods can split open through a natural explosive mechanism; a means of natural seed dispersal by the plant. The farmers used a big and open metal or plastic bowl to harvest the pods by bending the entire plant into this bowl and pulled out all the fruits from the numerous branches.

To assess the yield rate of pigeon peas, 5 plants were selected as 1 sample and this was repeated 5 times to make 5 samples for each treatment. Again the plants were selected in the central portion of the treatment to avoid borderline effects. The pods of every 5 pigeon pea plants were collected and placed in a plastic container for further processing at home. The harvested pods were further dried for three days to ensure every pod was dry enough to open and release the seeds out. With the use of a wooden mortar and pestle the pods of each sample were gently pounded to allow all the seeds to be removed from the pods and a winnower was used to separate the pigeon pea seeds from the rest of the chaffs. This was repeated for every sample to obtain clean seeds needed to be weighed. With use of a spring balance, the cleaned seeds of every sample (Samples: 1, 2, 3, 4 and 5) were separately weighed and results recorded (Figure 2.19).

2. Harvesting and processing of rice

a) Harvesting of rice

Harvesting of rice is an important stage of the post planting phase of farm operations in Sierra Leone. Culturally, it is the season and farming activity that is observed to bring a lot of family joy and happiness. It reunifies lots of families and relations between and amongst rural settlements. In fact harvesting is observed to be a sign of peace and reward for all the family members for every cropping season after a tedious and hard work for the whole season or year. Simply put, it is a season of excitement and joy since there is enough to eat for every family member and the entire community. This period will however last for only for a short while (1-2 months) and the whole village community is seen to return to the usual state of

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food inadequacy (hunger) which makes life unbearable and subsistent, especially for young people.

Harvesting is the physical collection of the yield of an agricultural farming activity after a certain period of investment into the venture. With the traditional small scale farmers, it is the collection of their farm produce at maturity period for further processing for either direct consumption, sale and or storage purposes. Harvesting of any crop is seen to be followed by series of other post harvest processes to accomplish the objectives of producing that crop. They vary from one crop to another based on the desired need of that crop and its utility by either the farmer or another end user.

In this research, rice harvest is a major farm operation that was carried out by the farmers that participated in the field work. Unlike the mechanical harvesting which is carried out when the rice is fully dried in the field, traditional or manual harvesting is done when the rice is just fully mature and ripe with a seed moisture content of about 40% (Figure 2.20). The early harvesting of rice at just the ripe or mature stage is to avoid the grains from being immensely shed in the field by the manual human harvesting.

The harvesting in the treatments was done traditionally or manually through the use of knives that were about 25 to 30cm long. The rice panicles were collected by the harvesters; by holding the rice stems at a convenient height above the ground that could allow them to cut the straws just below the panicles. The cut rice straws with the panicles were tied together to make rice bundles which were left in the field for three to 5 days to dry.

The dried rice bundles were then collected by the farmers and put in a single pile for further drying, saving it from field pests and for easy access when threshing is to be carried out.



In all of these activities there are a lot of losses of the rice grains been experienced in the fields by the farmers due to the movements of the rice from one position to the other. This is what is referred to as field post-harvest losses. There is very little or nothing the farmers can do to control these losses, hence they form additional major factors responsible for the low returns of the farmers' total yield in any production season.

In this research the attention of the farmers was drawn to these factors to avert the incidence of losing high quantities of the rice yield per hectare of their labour. This made every farmer became aware, hence were conscious about how the rice harvests and the post-harvest activities were to be treated during and after harvesting in their plots.

The fairly dried bundles were collected and taken to a site prepared within the plots put in a single pile. This rice pile is allowed again to stay there for a week or more depending on when there will be enough labour to do the threshing of the rice bundles in the pile as shown in (Figure 20.20).

b) Threshing of rice

Threshing is done by using long wooden sticks obtained from the bush by strong young men who physically swindle these sticks on the piled rice bundles in a circle round the rice pile

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(Figure 2.20). In some cases, for example in this research, a tarpaulin sheet was spread on the ground where the rice bundles were placed to minimize the wastage of the rice grains during the process. The threshed rice was separated from the straws and winnowed either in-situ (on the spot) or carried to the village by the farmer to be winnowed.

c) Winnowing and drying of rice



Winnowing is another important post-harvest operation that signifies the final field activity in the production cycle of rice. The winnowed rice can be used in diverse ways such as for further processing for eating or for sale as husk rice or stored for future use. Winnowing is the separation of the rice grains from the chaffs or straws. It is done manually by using a winnower. This operation, like many other farm operations is mainly carried out by women. They use a device called winnower which is made out of canes from either raffia palms or palm trees. It is a circular device that can hold about 6 kg of rice, depending on its size. The rice is separated from the chaff or straws by creating an oscillatory up and down movement of the rice in the device. This creates an air pressure that makes the lighter weight materials (chaffs and straws) mixed with the rice to fly out of the winnower, leaving the heavier rice grains at the centre (Figure 2.21). The winnowed rice was dried again for at least three days to acquire the correct moisture content of about 14% for storage. The dried rice grains are placed in jute, sacks or fiber plastic bags and stored in dry places inside the house.

However, some upland farmers keep their rice together with the harvested straws without threshing in traditional rice barn. The rice should be dried by heating it through the setting of adequate fire using fire wood to allow the rice panicles to dry to a point that will not allow fungus attack or easy insect pests attack on the grains. This is rarely done now due to the availability of storage facilities in the country, especially with the advent of fiber plastic bags that are imported together with the cleaned rice from the West or Asian countries such as China, India etc. In all these processes there are tremendous losses of the rice grains due to poor environmental facilities available to farmers and the traditional method used to carry out most of the activities without chemicals. Although this may have an advantage of keeping the ecology safe and friendly but the indiscriminate proliferation of pests might militate against the food security in the country which might precipitate economic, social and physiological problems for the growing population. Therefore, the minimum use of machinery and chemicals such as pesticides might create a vast positive difference in improving the food security situation in the country. This can be even more feasible and effective if it is coupled with the introduction of modern agronomic skills to the farmers through field-based scientific research and extension of research results to increase the yield per farm family and creating an ecologically friendly environment to enhance the continuation of the food production process for generations yet unborn.

## 2.4 Results and discussions

### 2.4.1. Pre-planting phase

The results obtained from this research are both qualitative and quantitative based on what aspect that is being investigated.

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### 1. Community sensitisation and mobilisation

The community sensitization and mobilization has being a fundamental aspect for the completion of this work. It formed the solid basis for the enhancement of proper planning with the general community and the specific participants of the research work that has lead to the successful completion and achievement of the entire research, ranging from site selection to harvesting and processing by both the researcher and farmers.

From the meetings held there was the selection of farmers' leader who communicates with the researcher while the researcher also links up with the farmers through him for any information necessary for the enhancement of the research work throughout the research period. A clear flow of communication strategy was designed and used by both the farmers participating in the research and the researcher.

### 2. Research site identification and selection

The research site was identified by both the farmers participating in the research and the researcher. The size of the plots intended to be cultivated by the farmers for the research were measured together with the farmers side by side learning the use of the 50 meter tape measure during the exercise. They (the farmers) were able to know roughly the size of a half (50 x 100 m) or one hectare (100 x 100 m) in the field as they participated in measuring all the plots of the four farmers using tape measure and pegs.

The initial experimental plots were laid as shown in the first part of the (Figure 2.5).

This lay-out was however changed during the ploughing operations due to a problem of the tractor that was engaged that could not perform the task well as a result of its low horse power and inappropriate equipment. The already first ploughed plot was changed which resulted to the new lay-out as shown in (Figure 2.5) with the use of another tractor of the model FIAT 780.

The data analysis of this research was done using the complex system in which various parameters regarding all the field activities in the entire crop production processes were used. The parameters were streamlined into three categories, namely: labour, consumables and machinery. For the component of labour, key issues such as the number of people involved in the activity (ies), number of hours spent and amount paid in hours were considered. With respect to consumables, all the materials used in the research work such as seeds and equipment were calculated.

In terms of machinery, the cost of the use of the machine (rent), the machine operator and the fuel consumed were calculated.

The total cost of each operation was obtained by summing up the three parameters of labour, consumables and machinery.



The work capacity of every operation was also calculated to show the quantitative effects of each operation per area per day.

The entire production process was analyzed by obtaining the difference between the total cost and the total income.

#### **2.4.1.1 Mechanical soil tillage in modern method plots**

##### 1. Ploughing

The use of tractor in soil tillage involves lots of parameters that will necessitate its accomplishment in enabling the soil to become suitable for satisfactory crop performance. Such factors range from

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the power of the machine, soil condition, topography of the land, tractor operator, fuel consumption and time.

Results of this experiment show:

The **working time** for seed-land preparation (land clearing and soil tillage), in Modern Method ploughing and harrowing (1<sup>st</sup> and 2<sup>nd</sup> harrowing) took **49 h·ha<sup>-1</sup>** (i.e. a **work capacity**  $C = 1.078 \text{ ha} \cdot \text{h}^{-1}$ ) while in the Traditional Method- it took **128 h·ha<sup>-1</sup>** to do the land clearing ( $C = 0.008 \text{ ha} \cdot \text{h}^{-1}$ ) and **168 h·ha<sup>-1</sup>** for manual hoeing ( $C = 0.006 \text{ ha} \cdot \text{h}^{-1}$ ).

This shows that there was approximately **88% of time saved** by the farmers through Modern Method.

On the economic aspect of the mechanical ploughing, the average cost was recorded to be 1,419,580 Le·ha<sup>-1</sup> (Figure 2.23).

The average work capacity of the machine was  $0.13 \text{ ha} \cdot \text{h}^{-1}$  (Table 2.4) while the average work output was recorded to be  $1.1538 \text{ ha} \cdot \text{day}^{-1}$ .

The time taken to complete the ploughing of 0.25 hectare was recorded to be 1.9 hours; which implies it took  $7.6 \text{ h} \cdot \text{ha}^{-1}$  was used.

The average speed of the machine was  $2.4 \text{ km} \cdot \text{h}^{-1}$  while the fuel consumption to complete the ploughing of 0.25 ha was  $10.3 \text{ dm}^3$ ; this implies  $40.2 \text{ dm}^3 \cdot \text{ha}^{-1}$  of fuel was used.

The width and depth of plough were recorded to be 113.0 and 31.9 cm respectively.

It was observed from the data that there were some variations in the depth of ploughing, quantity of fuel consumed, the speed of the tractor and the time taken to complete the exercise in the 4 experimental plots as a result of factors such as the soil condition (texture and water capacity), the dexterity of the tractor operator, the topography of the land and the natural vegetation cover (Figure 2.22).

## 2. Harrowing

### a) First harrowing

The total cost of the first harrowing was recorded as 506,640 Le·ha<sup>-1</sup> (Figure 2.23).

The average work capacity of the machine was  $0.37 \text{ ha} \cdot \text{h}^{-1}$  while the total work output was  $2.9683 \text{ ha} \cdot \text{day}^{-1}$ .

The fuel consumption to complete the 0.25ha was  $3.0 \text{ dm}^3$ , while the time taken was 0.7h. This implies the total fuel consumption and time taken to complete the hectare were  $12 \text{ dm}^3 \cdot \text{ha}^{-1}$  and  $2.8 \text{ h} \cdot \text{ha}^{-1}$ .

The depth and width of harrow were 18 and 230 cm respectively, while the average speed was recorded to be  $5.1 \text{ km} \cdot \text{h}^{-1}$  (Figure 2.22).



### b) Second harrowing

The data shows that the total cost of the second harrowing was 316,700 Le·ha<sup>-1</sup> (Figure 2.23).

The average work capacity of the machine was  $0.57 \text{ ha} \cdot \text{h}^{-1}$  whilst the total work output was recorded to be  $4.5956 \text{ ha} \cdot \text{day}^{-1}$ .

The average width and depth of harrow were 230 and 11.5cm respectively.



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The fuel consumption, speed and time taken to complete the harrowing of the 0.25 ha were 2 dm<sup>3</sup>, 6.2 km h<sup>-1</sup> and 0.4 hours respectively.

This implies the total fuel consumption and time taken to complete the second harrowing of the hectare were 8 dm<sup>3</sup> ha<sup>-1</sup> and 1.6 h ha<sup>-1</sup>.

It can be observed from the data that there are variations in the cost of tillage, work capacity, fuel consumption, speed and time taken to accomplish the tillage activities of ploughing, first and second harrowing in the land preparation of the experiment.

The work capacity of the machine was lowest in ploughing (0.14 ha h<sup>-1</sup>) when compared with 1<sup>st</sup> and 2<sup>nd</sup> harrowing (0.37 and 0.57) respectively, due to the conditions expressed above. This eventually affected the speed and fuel consumption of the machine (Figure 2.22).

There was more fuel consumed in ploughing (40.2 dm<sup>3</sup> ha<sup>-1</sup>) more than in 1<sup>st</sup> (12 dm<sup>3</sup> ha<sup>-1</sup>) and least in 2<sup>nd</sup> (8 dm<sup>3</sup> ha<sup>-1</sup>) harrowing.

#### **2.4.1.2 Traditional method of land preparation in the plots (brushing/slash and burn method)**

In the traditional land clearing exercise there were no consumables and machinery involved. To clear a piece of one hectare 4 people were engaged and they spent 128 hours in the exercise.

The total cost of such activity was 240,000 Le ha<sup>-1</sup> (Table 2.2).

The data shows that the work capacity of the labour involved in this exercise was 0.008 ha h<sup>-1</sup> (Table 2.2).

This means the total output of the people involved in this task will be 0.064 ha day<sup>-1</sup>.

### **2.4.2 Planting phase**

#### **2.4.2.1 Traditional random seed broadcasting and ploughing (mix cropping) in the plots**

In this exercise some consumables were used such as the rice and mix crop seeds.

Six people were engaged to accomplish the seed application exercise per hectare. The average total time involved was 42 h ha<sup>-1</sup>, while the total cost was 438,386 Le ha<sup>-1</sup>.

It can be observed that more labour and time were spent in ploughing than in land clearing. Eventually ploughing (Le 438,386) was more expensive than land clearing (Le 240,000).



#### **2.4.2.2 Modern method of manual row planting of seed rice and the intercrops**

In the modern method of seed planting 6 people were involved in the activity of rice and the intercrops sowing in the 0.25 ha using an average of 48 hours to complete the exercise. This implies 192 h ha<sup>-1</sup> was used to accomplish the modern method of row planting per hectare (Table 2.10).

An average of 1,165, 640 Le ha<sup>-1</sup> was used to accomplish the planting task (Table 2.10).

The work capacity was (0.01 ha h<sup>-1</sup>) for this exercise.

In terms of seed application in the traditional and modern methods, more cost and time were involved in the modern (1,165,640 Le ha<sup>-1</sup>) and (192 h ha<sup>-1</sup>) than in the traditional (438,386 Le ha<sup>-1</sup>) and (42 h ha<sup>-1</sup>)

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method. This implies seed planting in the modern method is more labour intensive than in the traditional.

### 2.4.3 Post planting phase

#### 2.4.3.1 Seed rate and crop population density

Rice seed rate, germination ability and population density

##### 1. Rice seed rate and population density

The rice **plant population density** was observed to be higher in the Modern Method with **178 plants·m<sup>-2</sup>**; the **seed rate** in this treatment was **55 kg·ha<sup>-1</sup>** when compared with the Traditional Method with a population density of **150 plants·m<sup>-2</sup>** but **60 kg·ha<sup>-1</sup>**;

This implies there is **better seed germination capacity** with the Modern Method than the traditional (**Figure 2.24**).

The reasons might be due to (i) better seed placement into the soil in the modern method than in the traditional; (ii) better water and temperature contact to stimulate germination in the seeds in the modern than the traditional method and (iii) better protection of the seeds from pests, such as birds, rats, crickets, etc in the modern method than the traditional.

##### a) Rice seed rates.

The data shows varying quantities of seed rice sown into the traditional and modern treatment plots of the experiment.

An average of 60 kg·ha<sup>-1</sup> of seed rice was sown into the hectare of the traditional treatment plot while an average of 55 kg·ha<sup>-1</sup> was used in the modern treatments excluding the treatment with pure rice (MTRR). The data further shows that in the pure rice treatment the seed rate was highest with 90 kg·ha<sup>-1</sup> (**Figure 2.24**).

It can be observed from these data that the highest quantity of seed rice (90 kg·ha<sup>-1</sup>) was used to plant into the treatment with only rice (MTRR) whilst the traditional treatment (TT) got (60 kg·ha<sup>-1</sup>) and the average of the modern treatments (MT\_Ave) (55 kg·ha<sup>-1</sup>).



The table shows the seed rice rates and the respective costs per hectare in the different treatments of the experiment (**Table 2.5**).

##### b) Rice germination ability and population density in the treatments

According to the rice population density per meter square it can be seen that there are different rates of rice seed germination in the treatments.

The data shows different rice plant population in the traditional treatment (TT) which has a higher average rice seed rate of 60 kg·ha<sup>-1</sup> than the modern treatments (MT\_Ave) with 55 kg·ha<sup>-1</sup>.



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There is higher rice population density in the modern treatments with 178 plants·m<sup>-2</sup> which has a lower seed rate of 55 kg·ha<sup>-1</sup> than in the traditional treatments with a population density of 150 plants·m<sup>-2</sup> with a higher seed rate of 60 kg·ha<sup>-1</sup>.

## 2. Intercrop seed rate, germination ability and population density

### a) Intercrop seed rates in the different treatments.

Unlike rice which was of the same variety and quality, the 3 intercroops were all different from each other in terms of weight, physiological and morphological features. The data shows that in the traditional treatment the average mix crop seed rates of pigeon peas, beni-seeds and sorghum were 0.91 kg, 0.07 kg and 0.11 kg·ha<sup>-1</sup> respectively. While in the modern treatment with only each of these 3 intercroops in the treatment the seed rates were 1.9 kg, 0.25 kg and 0.39 kg·ha<sup>-1</sup> respectively. In the modern treatment where all the 3 intercroops were applied, the quantity of seed rate was almost the same as in the traditional treatment. The pigeon peas, beni-seeds and sorghum were 0.64 kg, 0.08 kg and 0.13 kg·ha<sup>-1</sup> respectively (**Figure 2.25 and Table 2.6**).

### b) Intercrops germination ability and population density.

The germination percentage of intercroops has been very difficult to determine during the experiment especially in the traditional method where the seeds were just scattered at random and ploughed into the soil.

However, with the introduction of a definite spacing in the modern treatments it was easier to determine the number of stands of the intercroops in each treatment. In the modern method, since the spacing of each intercrop was 1m<sup>2</sup>, it was easy to establish that a hectare contains 10,000 stands of each intercrop in the respective treatments with only one intercrop. In the modern treatment where all the 3 intercroops were introduced there were 3,333 stands of each intercrop in the treatment.

This makes it easy to establish the percentage germination rate in the treatments.

The results show an overall average of 37% germination of pigeon peas being the highest, closely followed by beni-seeds with 22% and 21% for sorghum.



With the individual treatments of both the traditional and modern methods of intercrop seed application, the data shows that the germination percentage of all the intercrop seeds is much better in the modern than the traditional method (**Figure 2.25**).

Based on these germination percentages it can be seen that the intercroops population densities will be largely dependent on the germination percentage of the seeds (**Figure 2.25**).

One of the problems identified was the poor seed management by the farmers in the community. Since different seeds have different storage conditions in order to maintain their viability, the farmers in this community **stored** their **intercrop** seeds in much the same way like they did for the **rice**. This could be one of the reasons for the poor germination of these intercroops seeds in the treatments.

It was also detected that the farmers did not vary the planting depths of the different seeds during sowing; this could also be another factor that might have affected the germination.

In terms of the duration of seed storage, they confessed that the previous year's harvested seeds were used hence might not be the problem of poor germination if the above conditions were satisfied.

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#### 2.4.3.2 Crops growth response assessment

The **growth** performance of rice was better in terms of height and tillers in the Modern Method than in the Traditional. The **average height** (measured 120 days after planting) was recorded to be: **116 cm** and **108 cm** in Modern and Traditional Method, respectively (Figure 2.26).

The **tillering and panicle bearing** of the rice stands was also seen to be better in the Modern Method with an average of 5 or 6 tillers per stand with a tiller without rice panicle, whilst in the Traditional treatment there was average of 5 stands with 2 without rice panicles (Figure 2.27).

##### 1. Vertical height growth response of rice

The data analysis shows some growth responses of rice in the different treatments of the experiments.

The rice growth in terms of height is highest (122 cm) in the treatment with pigeon peas (MTRP) (Figure 2.26), whilst the least growth is obtained from the modern treatment with rice only (MTRR) with (107 cm) during its life cycle of 158 days.

The growth rate of rice intercropped with sorghum (117 cm) was observed to be second to that of the pigeon peas, while the rice with the beni-seeds closely followed.

On the average, the growth rate of rice in the modern method treatment (MT\_Ave) with (116 cm) was seen to be the better when compared with the growth rate in the traditional treatment (TT) (108 cm), while the modern treatment with purely rice showed the least growth rate (107 cm) during the same life cycle of the crop.

The growth of rice takes place at different periods during the 158 days of its life cycle after planting in the different treatments.

The results of the growth response of rice show that the rice responded with the highest growth rate (38 cm) in 30 days in the treatment intercropped with pigeon peas (MTRP) at the third month after planting whilst it experienced the minimum growth rate at the second month (24 cm).



In the treatment intercropped with beni-seeds (MTRB), the rice growth rate was highest in 30 days within the period (90-120 days) after planting whilst it attained the least growth rate during the second month after planting.

This was also true with the treatments with sorghum (MTTRS), the total combination of the 3 intercrops (MTTC), the pure rice (MTRR) and the traditional treatment (TT) (Figure 2.26).

##### 2. Tillering and panicle bearing assessment of rice

The tillering capacity of the rice variety used in the experiment was assessed using 3 parameters; the total number of tillers (*TOT*), the panicle bearing tillers (*PBT*) and the non-panicle bearing tillers (*NPBT*).

The data shows that the rice variety used has an average tillering capacity of 5 to 6 tillers per stand. It further shows that not all the tillers are capable of producing panicles. There is an average production of 4 rice panicle per stand in all the treatments.

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In all the modern treatments (MTRR, MTRP, MTRB, MTRS, MTTC) there is at least 1 tiller that does not produce rice panicle while in the traditional treatment (TT), there are 2 tillers without rice panicles (**Figure 2.27**).

The figure shows that an average of 5 tillers were obtained per rice stand of which 4 produced rice panicles and 1 without in the modern treatment of rice intercropped with pigeon peas.

### 3. Growth response of intercrops

The growth response of the 3 intercrops (pigeon peas, beni-seeds and sorghum) was assessed using 2 parameters; the height and canopy of the crops.

This was done at two strategic intervals of 90 and 120 days after planting (DAP).

The (**Figure 2.26**) shows that the vertical growth response of rice in height in the treatment with pigeon peas (MTRP) is highest than in the traditional and the other modern treatments with rice.

At 120 days after planting, the modern treatment of rice and pigeon peas (MTRP) shows the height and canopy spread of pigeon peas are 180 and 71 cm respectively.

The figure further revealed the height and canopy spread of sorghum at 120 days was 159 and 59 cm respectively.

In the modern treatment of rice and beni-seed (MTRB), the height and canopy spread of the beni-seed plants at 120 days after planting (DAP) was 127 and 42 cm respectively.

The pigeon had the highest height and most spread canopy, followed by sorghum and the least was beni-seeds plants (**Figure 2.28**).

In spite of the pigeon pea plants having the highest height and most spread canopy, the orientation of this canopy was observed to have some adverse effects of the growth of rice.



It is evident that the canopy shape of the 3 intercrops in the experiment were different, therefore their effects on the rice growth could also be different.

The canopy of pigeon pea crop has an umbrella shape with thick floral leaves, casting tremendous shade on its underneath, while the canopy of sorghum, being a monocotyledonous plant has laterally oriented leaves that can allow adequate sunlight penetration on its underneath. The canopy of beni-seed is fairly conical (**Figure 2.29 b**), thus casting very small shade on its underneath.

Comparing the height of rice and the height of the 3 intercrops and their canopies in the modern treatments, it is evidently shown that the height and canopy of the pigeon pea plant (180 and 71 cm) is greatest and covers the height of the rice (122 cm) completely (**Figure 2.29 a**). This could be one of the reasons why there was less rice yield rate in this treatment (**Figure 2.34**).

In the treatment with beni-seed as intercrop, the height and canopy of the intercrop (127 and 42 cm) are not much different from that of the rice (112 cm).

With the sorghum as intercrop, although the height and canopy of the intercrop are greater (159 and 58 cm) when compared with the height of rice (117 cm), the lateral orientation of the leaves

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allows more sunlight on the rice crop beneath it, thus adequate penetration was enhanced during growth.

#### **2.4.3.3 Assessment of nitrogen availability in the soil through the rice leaf colour chart (LCC)**

The nitrogen availability in the soil was assessed through the use of leaf colour chat (LCC) showed the the average results indicated in **Table 2.14**.

These numbers on the table show the nitrogen content that supported the growth of rice during its life cycle. The highest number was found with the treatment with pigeon peas as intercrops (MTRP) which is 4. This implies there was more nitrogen available for the use of the rice in this treatment than any of the others, whilst the treatment with rice only (MTRR) had the number 2, meaning there was less nitrogen available for the use of the crops in this treatment.

#### **2.4.3.4 Weeds and weed prevalence assessment**

The weed population density was recorded to be lower in the Modern Method with an average of **51 weeds·m<sup>-2</sup>** while in the Traditional Method it was **60 weeds·m<sup>-2</sup>** before weeding. This implies more resources (time and energy) were needed to control the weeds in the Traditional than in the Modern Method.

The average population density of weeds before weeding in then traditional treatment (TT) was 60 weeds·m<sup>-2</sup> and 64 weeds·m<sup>-2</sup> 2 months after weeding.

In the modern treatment (MT\_Ave) the weed population density was 51 weeds·m<sup>-2</sup> in 2 months before weeding and 53 weeds·m<sup>-2</sup>, 2 months after weeding.

This shows that the weeds population density was less during the first 2 months before weeding the treatments.

However, the level of weed prevalence in the different treatments was observed to be different (**Figure 2.30**).



It is also evident that the treatment of rice intercropped with pigeon peas showed the least weed prevalence of 21 weeds·m<sup>-2</sup> before weeding and 22 weeds·m<sup>-2</sup> 2 months after weeding. This might be attributed to the ability of pigeon peas' rapid growth, hence providing canopy that is capable of suppressing weeds (**Figure 2.29 b**).

In relation to the cost of weed control the data shows that there is higher cost in the traditional treatments than the modern ones due to the higher weed infestation in the former.

An average of 240,000 Le·ha<sup>-1</sup> was used to control weeds in the traditional treatment, while only 150,000Le·ha<sup>-1</sup> was used in the modern treatment (**Figure 2.31**).

The most common weeds identified in these plots were: *imperata cylindrica* (langlang grass), *Ageratum coinyzoides* (goat weed), *Mimosa pudica* (sensitive mimosa), *paspalum ssp*, *cynodon dactylon*(carpet grass), *Pennisetum pupuerum* and *Rottboellia cochinchinensis*.

#### **Pest identification and control**

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The cost of rodent pest control was recorded to be 720,000 Le.ha<sup>-1</sup> in each of the traditional and modern methods, while for bird scaring it was 1,800,000 Le.ha<sup>-1</sup> for each of the treatments (Figure 2.32).

The rodents ate the rice and sorghum vegetative parts mostly in the field while the birds damaged both the young and mature rice grains of the plants.

This shows that pest control is one of the major challenges in the production of rice and its intercrops in the upland ecology since it incurred the highest single operation cost per hectare in the production process.

These farm operations are very crucial in small scale farming because if not well managed can lead to 100% losses of the entire farm products by these two types of pests.

The two pest control activities; fencing and bird scaring also consumed the highest human time of 384 h.ha<sup>-1</sup> and 960 h.ha<sup>-1</sup> respectively in the production process (Table 2.10).

Some insect pests were identified during the vegetative stage of the crops. Prominent amongst them were: The short horned brown and grey grasshoppers, long horn brown grass hoppers, green grasshoppers, leaf worms and leaf beetles (Figure 2.14). These pests, though their damages were not quantitatively calculated but they caused some tremendous damages on the crops, especially with beni-seed plants which were highly susceptible to their attacks. The crops seem to be resistant to these insect pests 3 months after planting when their damage effects were seen to have subsided.

#### **2.4.3.5 Yields assessment and harvesting of crops**

The **yield rate of rice** was **2.34 t.ha<sup>-1</sup>** (14% moisture content) in the Modern Method as compared to the **2.20 t.ha<sup>-1</sup>** in the Traditional Method.

This implies there is **better yield returns per hectare** with the Modern Method.

##### **1. Harvesting of rice**

The analysis shows that 1000 m<sup>2</sup> was harvested in one day in the modern method while only 625 m<sup>2</sup> was done within the same period per day in the traditional treatments.



In terms of cost, it took Le 150,000 to harvest a hectare of rice in the modern treatment while in the traditional Le 240,000 was spent per hectare (Table 2.10 and Figure 2.33). This is very likely that the rice planted in rows was easier to handle and cut by the farmers than the one randomly broadcasted in the field in which more time is needed to get the straw together before cutting.

This shows that harvesting of rice is easier, faster and less costly to do in the modern treatments than in the traditional.

##### **2. Threshing and winnowing**

The data shows that more money (240,000 Le.ha<sup>-1</sup>) was spent in the threshing of the rice in the modern treatment than in the traditional (150,000 Le.ha<sup>-1</sup>).

This is very likely that there was more quantity of rice harvested to be threshed from the modern treatment than in the traditional. However, the amount of money spent in the winnowing of the

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rice in both the traditional and modern treatments was the same per hectare (60,000 Le·ha<sup>-1</sup>) (Figure 2.33).

### 3. Harvesting and processing of intercrops

The data shows that less cost was involved in the harvesting and processing of the intercrops in the modern treatments (60,000 Le·ha<sup>-1</sup>) than in the traditional (135,000 Le·ha<sup>-1</sup>) (Table 2.10).

### Yield rates and income of rice

The rice yield rates in the respective treatments show varied performances.

In terms of singled out treatment, the one of rice intercropped with sorghum shows the highest yield rate per hectare (2.535 t·ha<sup>-1</sup>).

However, in the modern treatment of rice and pigeon peas, the rice yield was seen to have the least yield rate of 2.105 t·ha<sup>-1</sup>.

The average yield rate of rice in the traditional (TT) and modern (MT\_Ave) treatments were compared and the data shows the modern treatment with 2.339 t·ha<sup>-1</sup>, while in the traditional it was 2.199 t·ha<sup>-1</sup> respectively (Figure 2.34).

Comparing the traditional (TT) modern treatment with rice only (MTRR) and the average of the other modern treatments with intercrops (MT\_Ave), the data shows that the traditional treatment (TT) had the least (2.199 t·ha<sup>-1</sup>) yield, while the modern method treatment with intercrops (MT\_Ave) had the highest (2.339 t·ha<sup>-1</sup>), closely followed by the modern treatment with rice only (MTRR) with a yield rate of 2.203 t·ha<sup>-1</sup>.

The costs of the yields of rice were expressed in consonant with the yield rates per treatment per hectare (Figure 2.35 and Table 2.8).

### Yield rates and income of intercrops



The yield rates of the intercrops vary markedly based on the two main methods of cultivation used in the experiment; the traditional and modern method treatments. The intercrops in the modern method of intercropping rice with pigeon peas, beni-seeds and sorghum showed higher yield performance than the traditional method treatments (Figure 2.36 and Table 2.9).

The yield rates of the intercrops are highly affected by the germination rate of the seeds in the field which eventually led to these plant population densities in the treatments (Figure 2.25).

The income value of the intercrops in the treatments varies largely based on the market prices. The beni-seed showed the highest market value despite not having the highest yield rate in this experiment, closely followed by the pigeon peas and lastly the sorghum. However, the pigeon peas had the highest yield rate of 0.343 t·ha<sup>-1</sup>, closely followed by sorghum with 0.248 t·ha<sup>-1</sup> and lastly beni-seed with 0.042 t·ha<sup>-1</sup> (Figure 2.36).

However, in terms of market values of these yields, pigeon peas has the highest (799,659 Le·ha<sup>-1</sup>) because of its quantity and not its cost per kilogram, while beni-seed had higher value of (622,875 Le·ha<sup>-1</sup>) despite its low yield of 0.042 t·ha<sup>-1</sup>. Sorghum had the least income of 495,787 Le·ha<sup>-1</sup> (Figures 2.36 and 2.37).



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### Field operations summary

There was less **time spent to complete the entire production process** in the Modern Method (1960 h·ha<sup>-1</sup>) compared to Traditional Method (2000 h·ha<sup>-1</sup>).

The **total cost of production** (both for the rice and three intercropping) in the Modern Method was however higher (5,183,870 Le·ha<sup>-1</sup>; **978 €·ha<sup>-1</sup>** approximately) when compared to the Traditional Method (3,948,386 Le·ha<sup>-1</sup>; **745 €·ha<sup>-1</sup>** approximately); expressing the cost of production by Euro per ton, the results are: **354** and **326 €·t<sup>-1</sup>** for Modern and Traditional Method, respectively (**Figure 2.14**).

The work capacity, the human time spent, the machinery used, the labour involved and the consumables used are essential components to evaluate the various production interventions of rice and its intercropping in the upland ecology using the traditional and modern methods.

The data shows that the total amount of human time expended to accomplish the cultivation of a hectare of rice and its intercropping is greater in the traditional method (2000 h·ha<sup>-1</sup>), while the modern method was (1960 h·ha<sup>-1</sup>) in the upland ecology.

In spite of this amount of time spent in the field to cultivate a hectare, the human work capacity in the traditional method (0.142 ha·h<sup>-1</sup>) i.e. 142 m<sup>2</sup>·h<sup>-1</sup> is very small when compared to the modern method with 1.175 ha·h<sup>-1</sup> in the rice cultivation activities in the upland (**Figures 2.41**).

On the contrary, the average cost of production in the traditional method (3,948,386 Le·ha<sup>-1</sup> ≈ € 745) is far less costly than in the modern method (5,183,870 Le·ha<sup>-1</sup> ≈ € 978) (**Table 2.14**).

Looking at the economic value of the profit margin, it is evident that the traditional method (894478 Le·ha<sup>-1</sup>) yields more financial returns than the modern method (3181 Le·ha<sup>-1</sup>) (**Figures 2.38 and 2.39**).



The cost-benefit relationship of the traditional and modern methods is clearly expressed as being more favorable for the traditional method than the modern method (**Figure 2.42**). However, the social and psychological benefits obtained in the modern method by the farmers' far surpasses those in the traditional method as expressed by the farmers themselves and the results of the data of the research process (**Table 2.10**).

### 2.5 Conclusion

The results of the research show that the introduction of minimum mechanisation and modern agronomic practices have some relevant socio-economic impacts on the production process of rice and its allied intercropping as well as on the lives of the small scale farmers.

The minimum mechanisation practiced through ploughing and harrowing of the farm land has resulted to saving 6% (40 h·ha<sup>-1</sup>) of the time of the farmers that would have been spent in the farms and reducing 5% (210,000 Le·ha<sup>-1</sup>) of the labour cost of the farmers. This increase in the time availability to the farmers can lead to positive contributions to the betterment of the lives of farmers such as:

1. increase the men's engagements into other economic activities apart from just cultivating rice;
2. creating room for women and children especially to be able to have adequate time to rest and take better care of the social welfare of the young ones and some domestic chores and

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3. enabling adequate time to rest from the intensive field drudgery on the farm, hence improving the physiological and health status of the rural poor farmers by building up better resistance to diseases and the adverse environmental or climatic conditions.

The high level of work capacity ( $1.175 \text{ ha} \cdot \text{h}^{-1}$ ) in the modern method approach can also lead to the establishment of bigger farms by the farmers when compared with the traditional method that has a low work capacity of ( $0.142 \text{ ha} \cdot \text{h}^{-1}$ ) (Tables 2.10 and 2.11).

This effect can lead to not only the establishment of bigger farms but also the timely accomplishment of the farm activities as a result of the speedy rate at which the field activities were carried out to completion.

The higher level of field work capacity with the modern mechanical method can also lead to better performance of the crops since there is the possibility for the farmers to complete the planting of the crops on time, hence creating an enabling conditions and environment for the crops to realize the **full use** of the **edaphic** and **climatic** conditions for their **growth** and **reproduction**.

Generally, although there is higher yield per hectare through the use of the modern method, economically the results of this research show that there is higher income returns with the traditional method per hectare when compared with the modern method approach (Figure 2.13). This is due to the high cost of the use of machinery.

However, this economic benefit cannot be compared with the social and health returns enjoyed by the farmers during the production season. Quite apart, the use of the time and energy saved through the modern method can lead to families engaging into other economic activities that can yield them additional financial returns through the profitable ventures they undertake in their respective communities.



Eventually, the introduction of modern method approach does not only create socio-economic and psychological gains but also exposes the farmers to new skills, knowledge and techniques that will enable them improve their farming career by adopting new systems of production to help increase their yield per hectare and look out for lasting solutions or answers to their day to day farming activities or problems in the field.

The number of hours ( $2000-1960 = 40 \text{ h}$ ) is not convincing at this moment to reach an economical threshold with the Modern Method, but can be improved further by engaging additional activities such as basic mechanical seeding (Tables 2.11 and 2.12).

The manual modern method of seeding took  $192 \text{ h} \cdot \text{ha}^{-1}$  in this experiment. If this time is reduced to 3 or 4 hours per hectare by using a seed sowing equipment with the same tractor, the time the farmer will save will dramatically increase from 40 to approximately  $228 \text{ h} \cdot \text{ha}^{-1}$ . This is a convenient time for the farmer and his family to have some extra activities in their lives and also rest to secure their health and social welfare in their community.

The same equipment can also be used to sow other seeds such as millet in another field; increasing the value of the equipment during the cultivation season. This will improve the economic value of both the machine and the equipment and eventually the entire farming profitability during the year for the farmers.



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## Figures



**Figure 2.1.** Typical rural community settlement (left) and community research organisational meetings (right) [Source: C. Vigano].

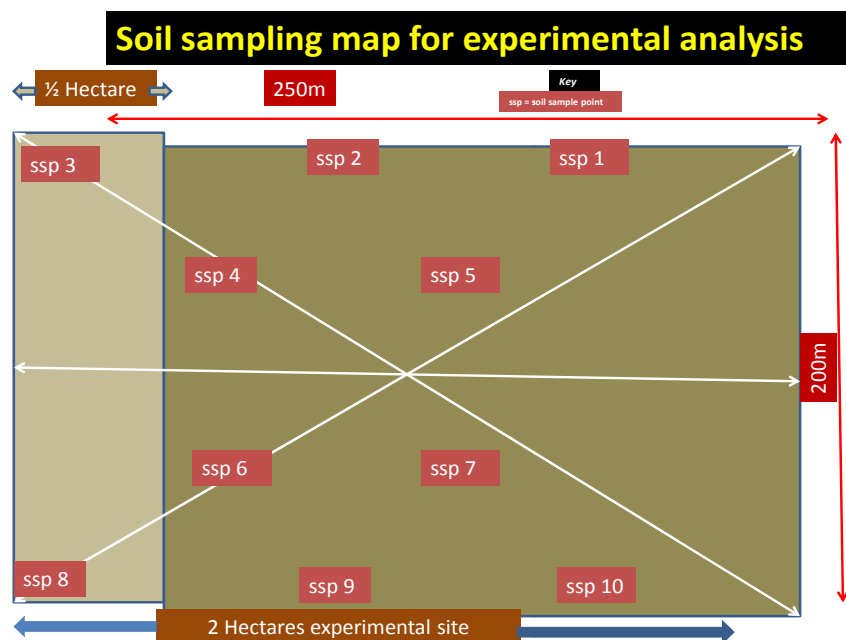


**Figure 2.2.** Community organisational structure for research.



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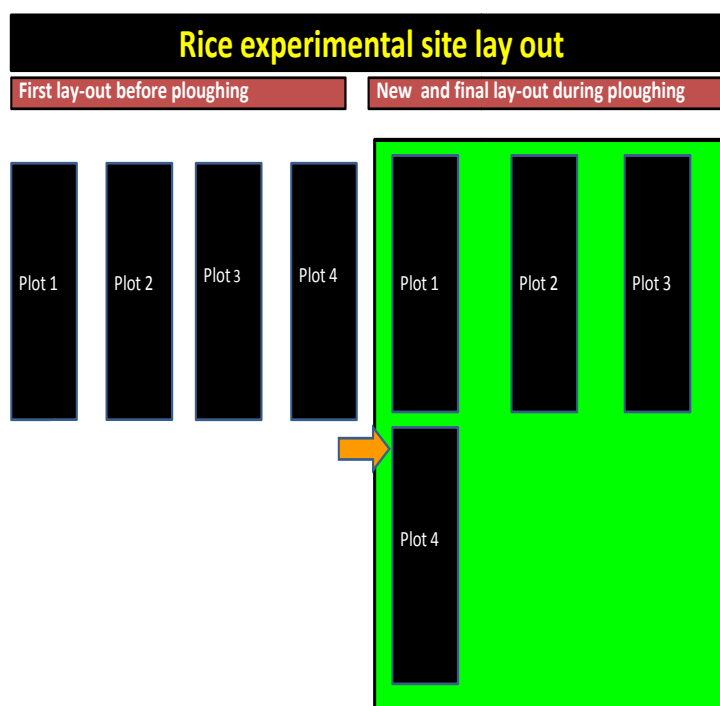
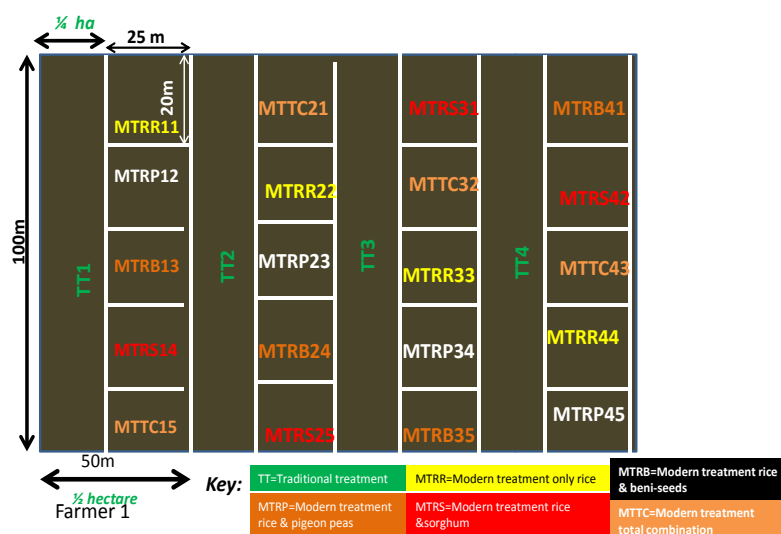
**Figure 2.3.** Identifying, selecting and lay-outing the experimental plots with the farmers in the field of the research. [Source: C. Vigano].





**Figure 2.4.** Soil sampling map of the research area.

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## Field Research Treatment Lay-out



**Figure 2.5.** Experimental treatment lay-outs for the field research.

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### Traditional land clearing with cutlass and hoe before cropping





**Figure 2.6.** Traditional land clearing method with cutlass and hoe (slash and burn) [Source: C. Vigano].

### Types of small wooden hoes used for traditional seed planting through soil tillage (ploughing)-mix cropping



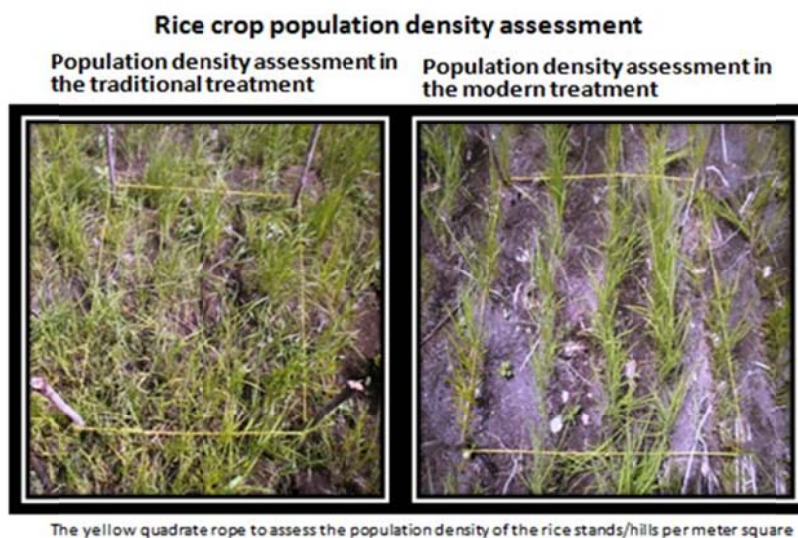
**Figure 2.7.** Types of hoes used by the farmers in traditional soil tillage for seed planting [Source: C. Vigano].





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**Figure 2.8.** Plant spacing and use of the furrow marker for spacing in rows for rice and intercrop planting [Source: C. Vigano].

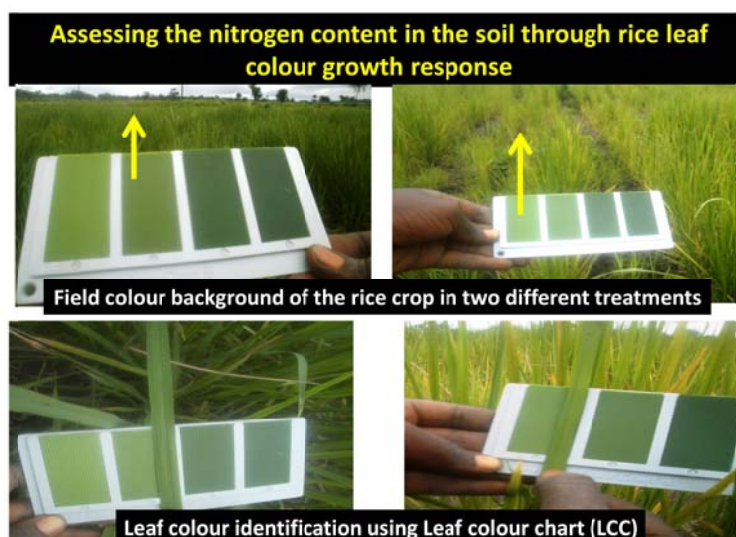


**Figure 2.9.** The one meter square quadrates showing the rice plant population density assessment in the traditional and modern methods.



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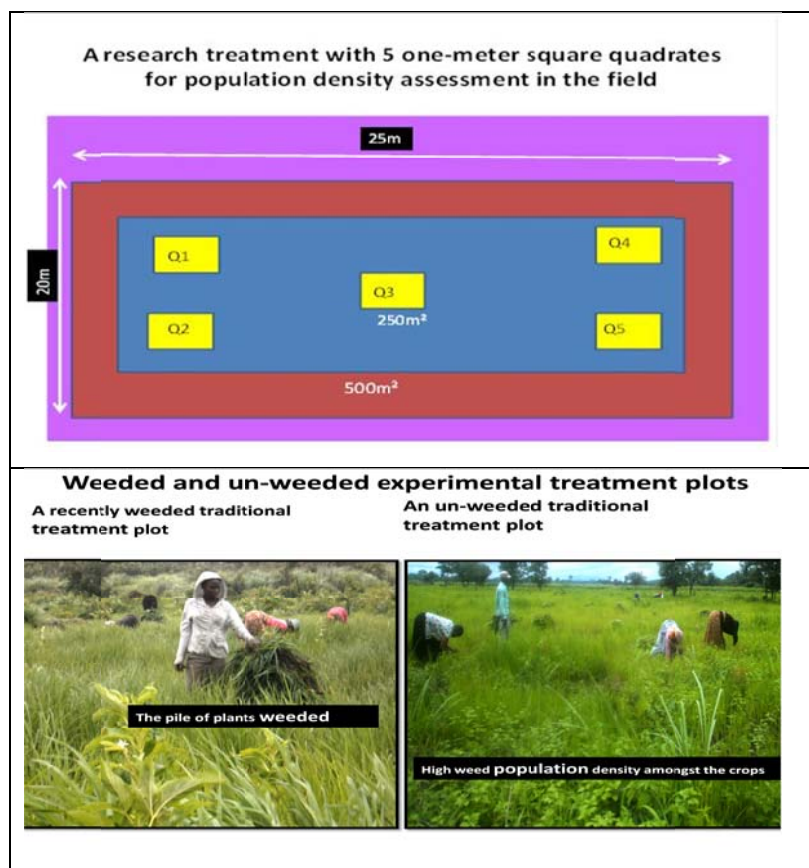


**Figure 2.10.** Assessing the growth rate in height and width of the intercrops in the experimental plots.



**Figure 2.11.** Soil nitrogen content assessment using leaf colour chart (LCC) with the rice.

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**Figure 2.12.** Weed population density assessment design and weeding exercise in the plots.

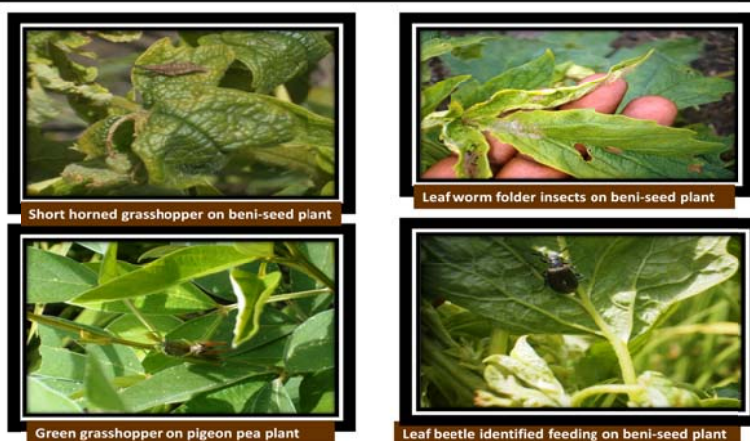


**Figure 2.13.** Damages caused by birds on rice (left) and a sling to control birds (right).



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### Crop damages by insect, bird and rodent pests in rice and its allied crops

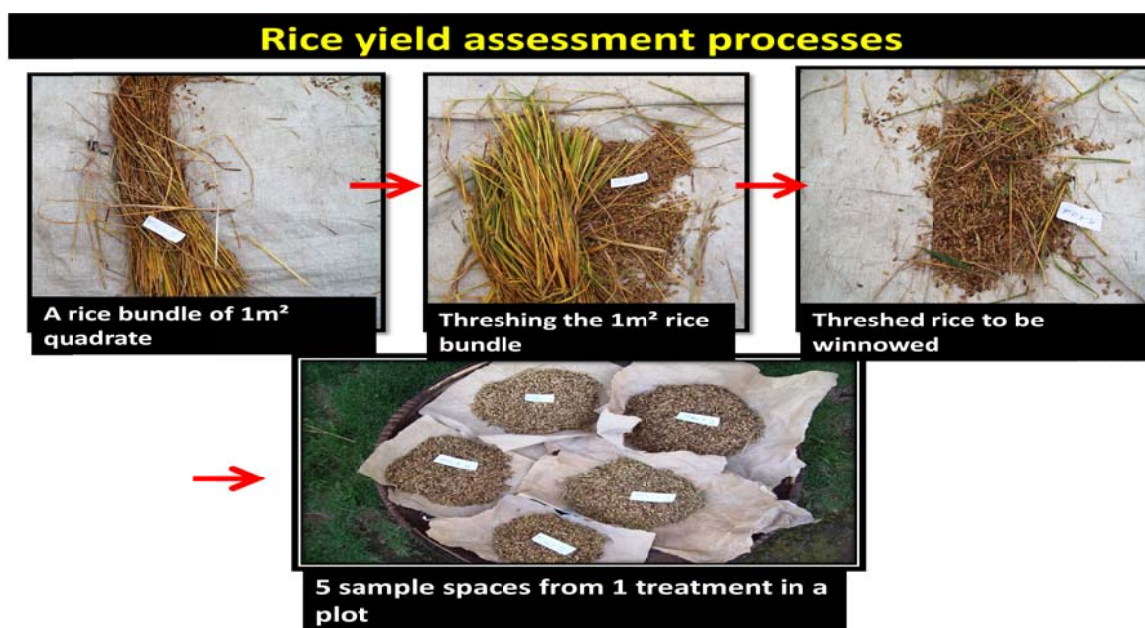


**Figure 2.14.** Some common insect pests identified in the field of rice cultivation together with its intercrops.

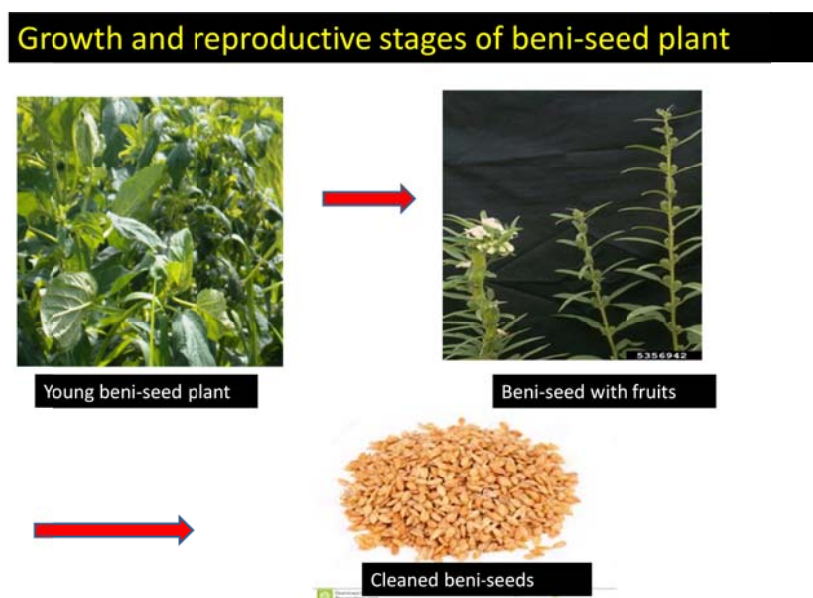


**Figure 2.15.** Some common rodent pests (squirrel, cane rat and rat) of cereals and the damaged and undamaged plots.

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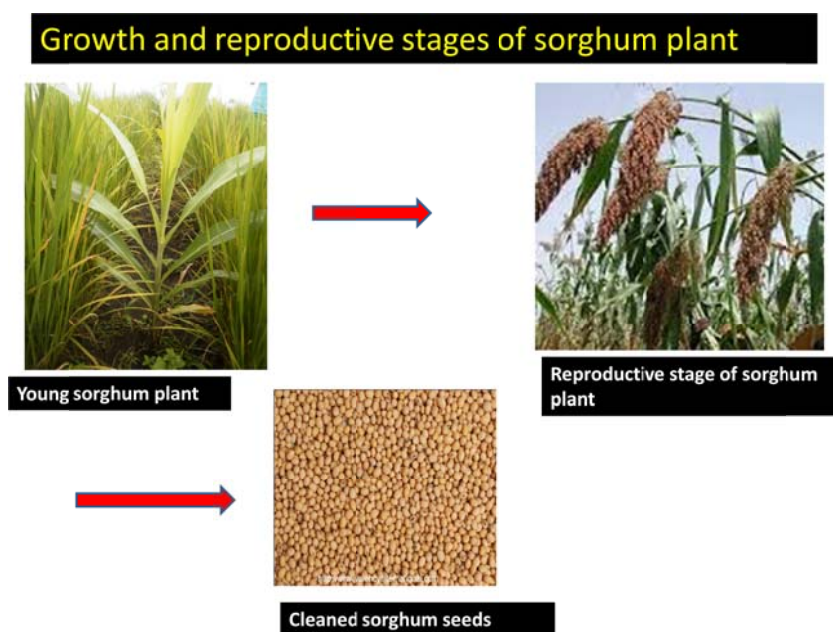
**Figure 2.16.** Rice yield assessment process from the treatment in a farmers plot.



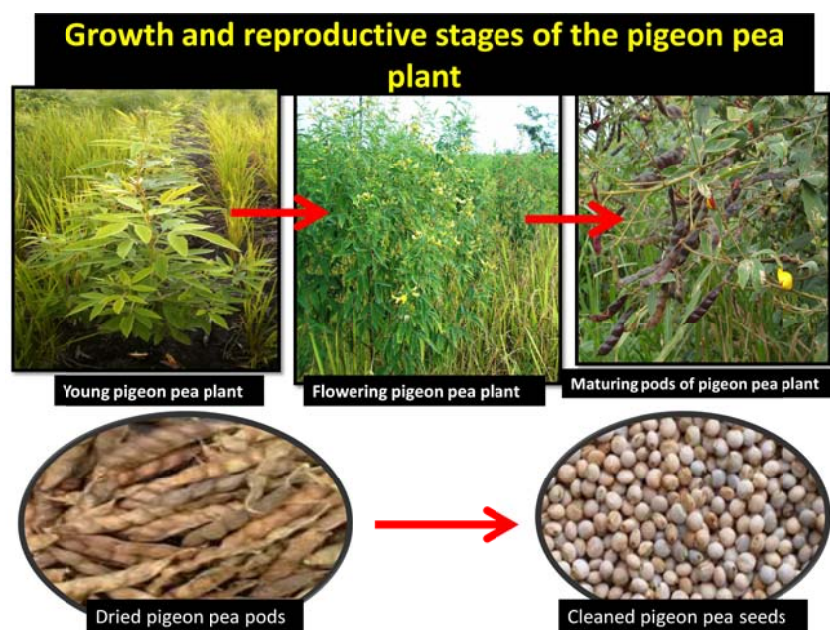
**Figure 2.17.** Stages of growth and reproduction of beni-seed (sesame).





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<p style="text-align: center;"><b>Chapter 2</b>  <i>Assessment of the traditional mix cropping method using local tools and the modern method of rice cultivation using machinery with minimum tillage and row planting with intercrops in the upland ecology</i></p>		<p style="text-align: right;">page 45/73</p>



**Figure 2.18.** Growth and reproduction stages of sorghum plant.





**Figure 2.19.** Growth and reproductive stages of pigeon peas.

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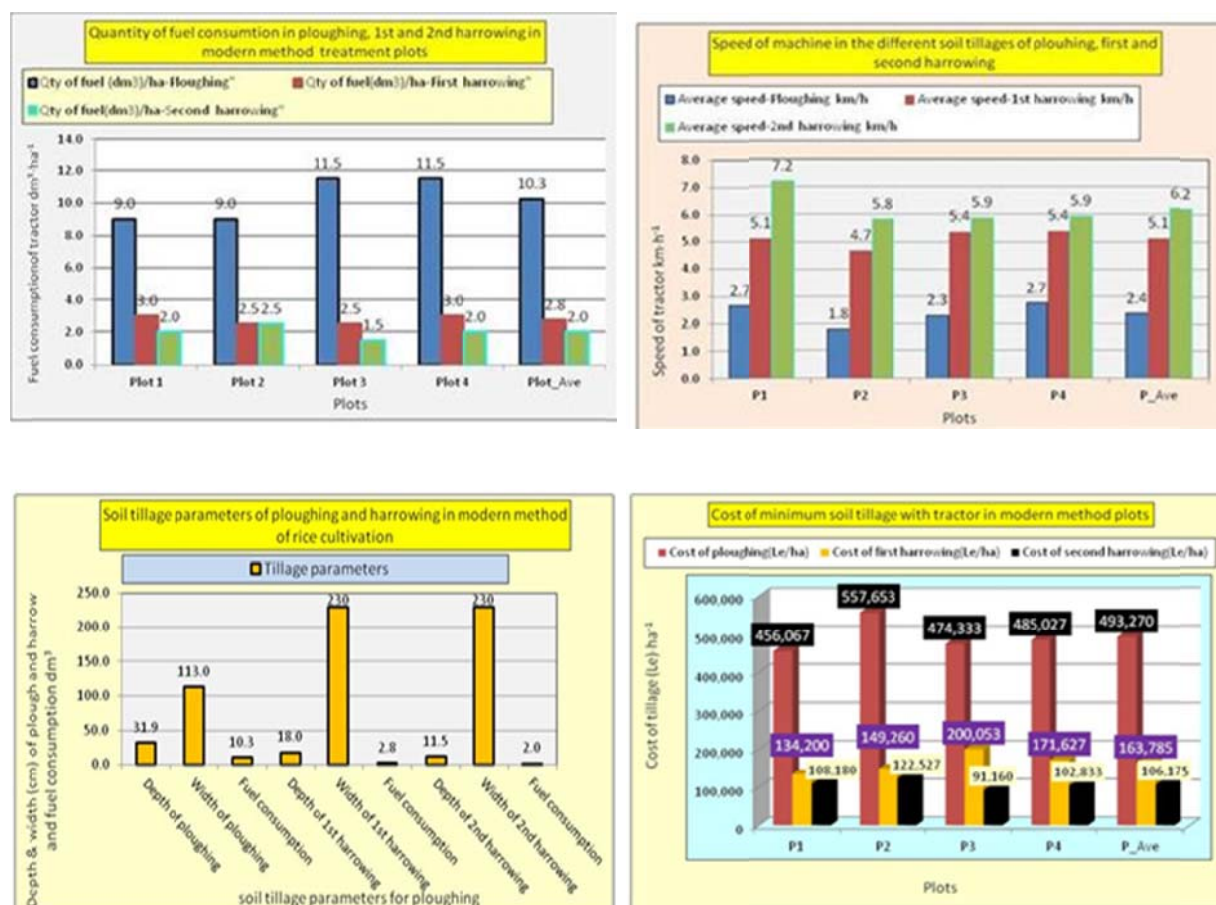


**Figure 2.20.** Field activities before and during threshing of rice.

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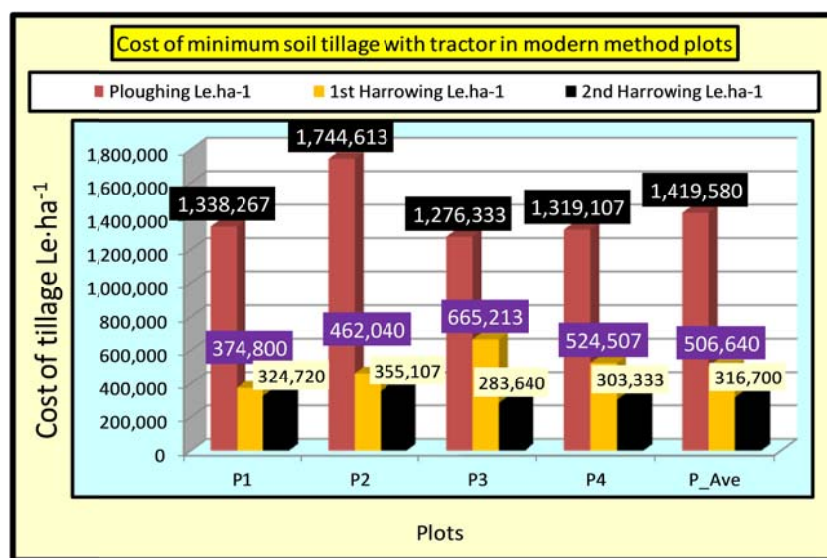
**Figure 2. 21.** Winnowing of rice grains during milling [Source: M. Fiala].



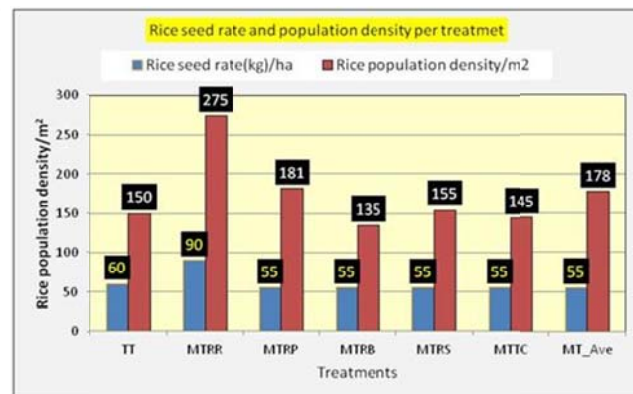
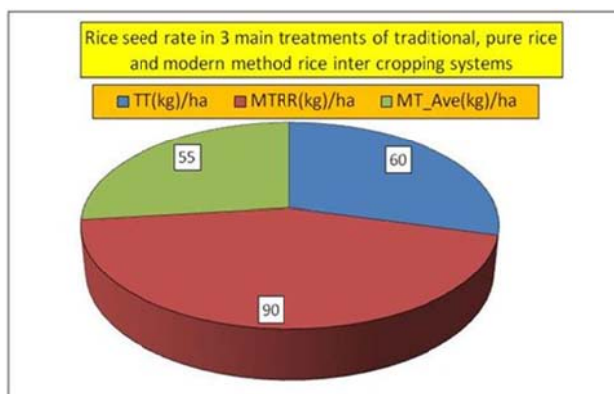
**Figure 2.22.** Minimum soil tillage parameters for ploughing, 1st harrowing and 2nd harrowing in modern treatment plots.



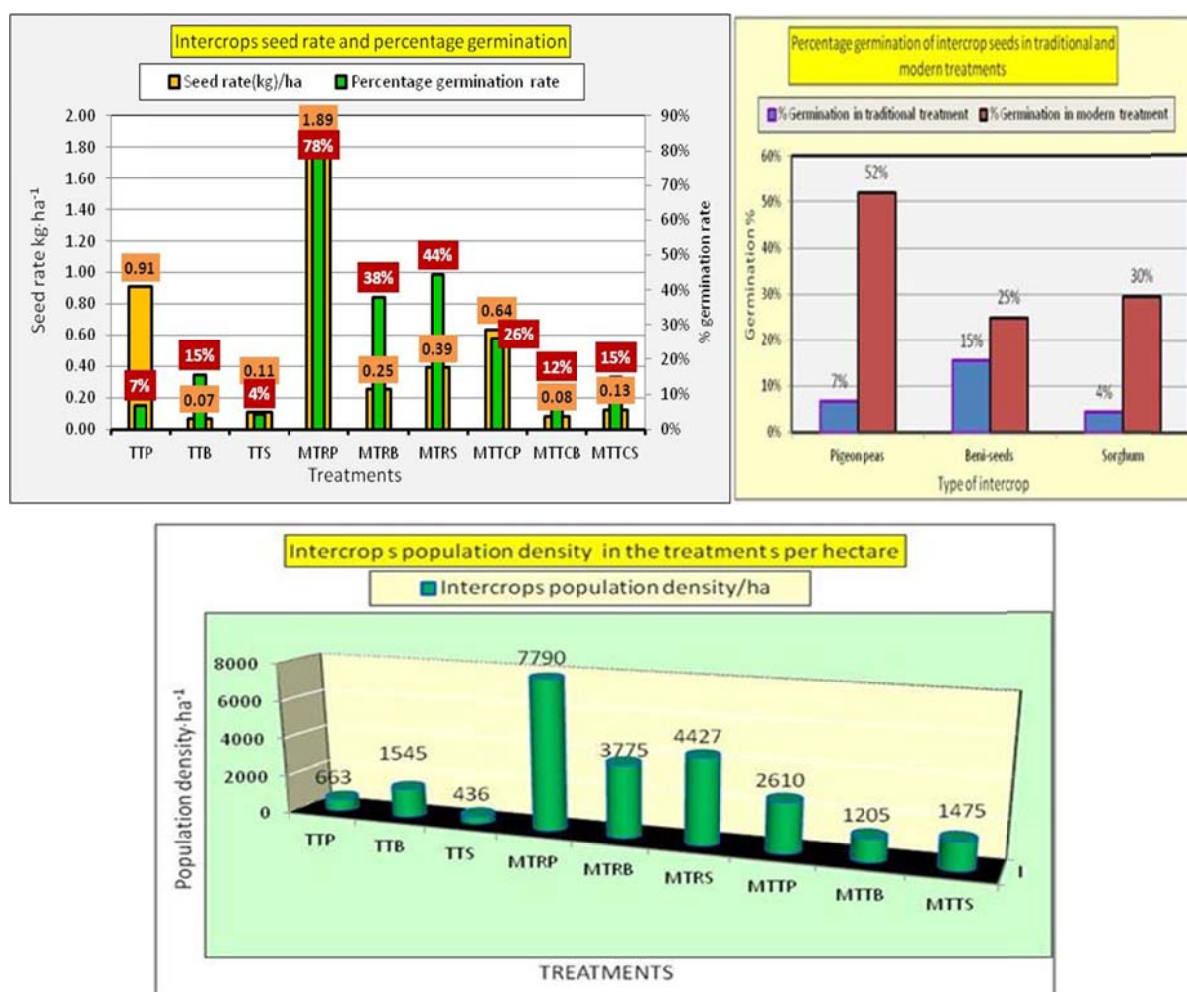
<p style="text-align: center;">School Innovative Technology for Agri-Food and Environmental Sciences Cycle XXVII</p> <p style="text-align: center;"><b>Dr. Joseph B. Tholley</b> Tutor: Prof Marco Fiala</p>		
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**Figure 2.23.** Showing total time and money spent in traditional land clearing, seed sowing and ploughing in the traditional plots.





**Figure 2.24.** Rice seed rate and rice stand population density per meter square based on the germination rate of the applied seeds in the different treatments.

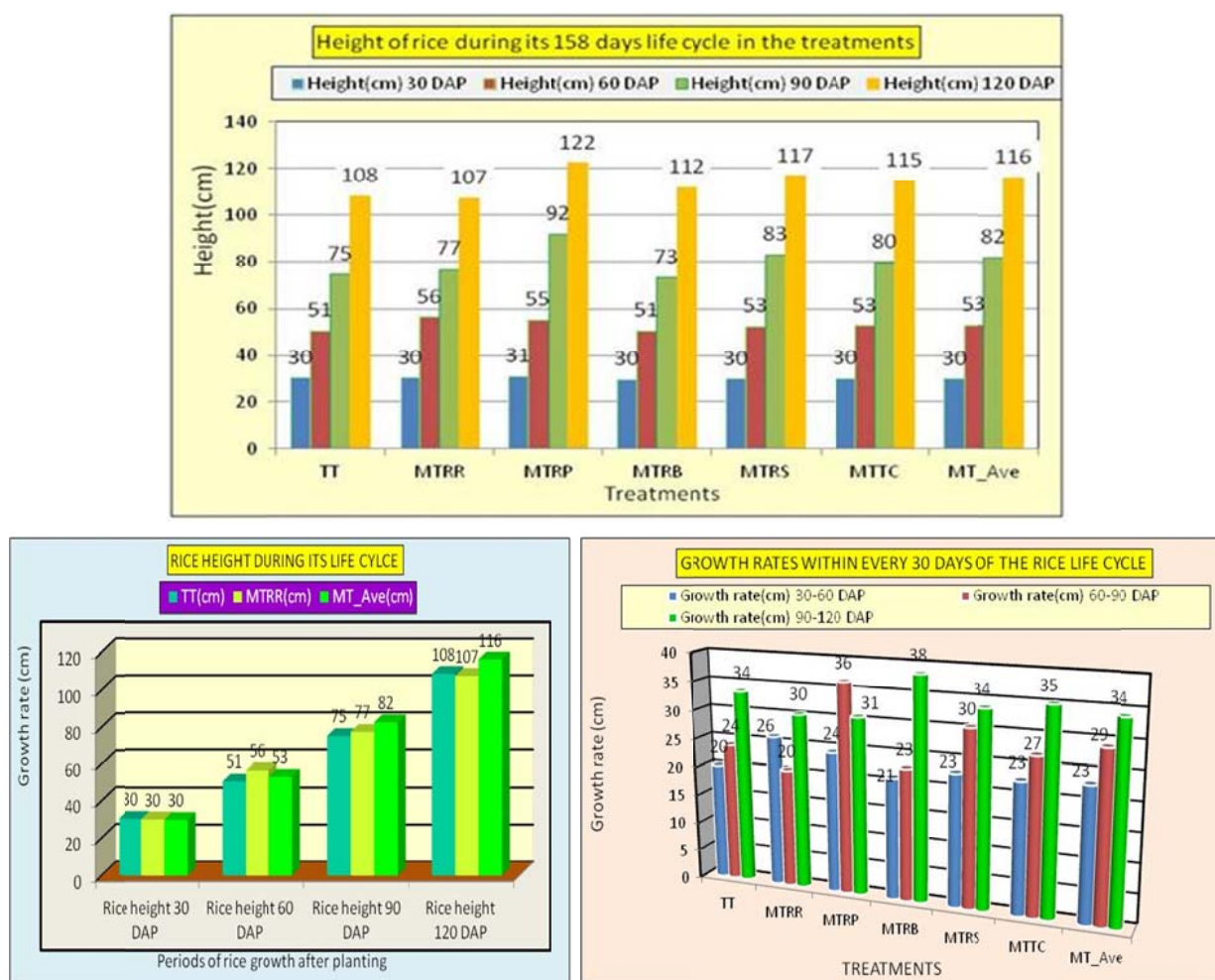


**Figure 2.25.** Intercrop seed rate, germination percentage and plant population density in the treatments.

The intercrop seed rates in the different treatments (TTP = pigeon peas in traditional treatment, TTB = beni-seeds in traditional treatment, TTS = Sorghum in traditional treatment, MTRP = only pigeon peas with rice in modern treatment, MTRB=Only beni-seeds with rice in modern treatment, MTRS = Only sorghum with rice in modern treatment, MTTCP = pigeon peas in all 3 intercroops combined, MTTCB = Beni-seeds in all 3 intercroops combined and MTTCS=Sorghum in all 3 intercroops combined).





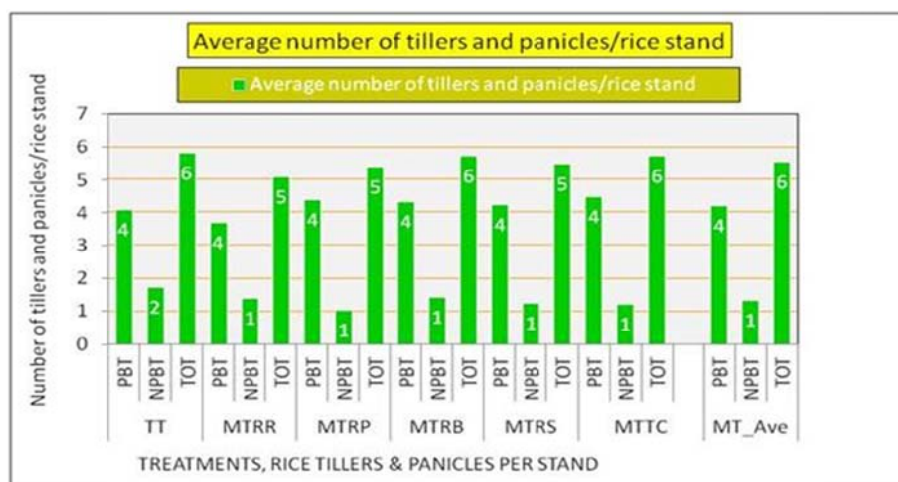
<p style="text-align: center;">School Innovative Technology for Agri-Food and Environmental Sciences Cycle XXVII</p> <p style="text-align: center;"><b>Dr. Joseph B. Tholley</b> Tutor: Prof Marco Fiala</p>		
	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
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**Figure 2.26.** shows the growth rate of rice in the different treatments.

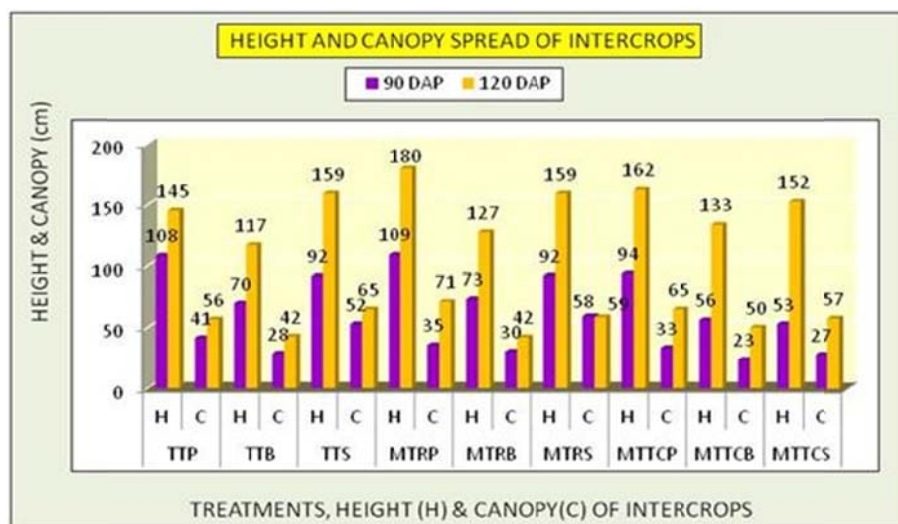
TT = Traditional treatment with rice mixed with all the 3 alien crops of pigeon peas, beni-seeds and sorghum, MTRR=Modern treatment with rice only, MTRP=Modern treatment with rice and pigeon peas only, MTRB = Modern treatment with rice and beni-seeds only, MTRS = Modern treatment with rice and sorghum only, MTTC = Modern treatment with rice and the 3 intercrops combined and MT\_Ave= Average results for modern treatments.

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**Figure 2.27.** Shows the tillering and panicle bearing capacities of the rice variety (Pakiamp) used in the different treatments.

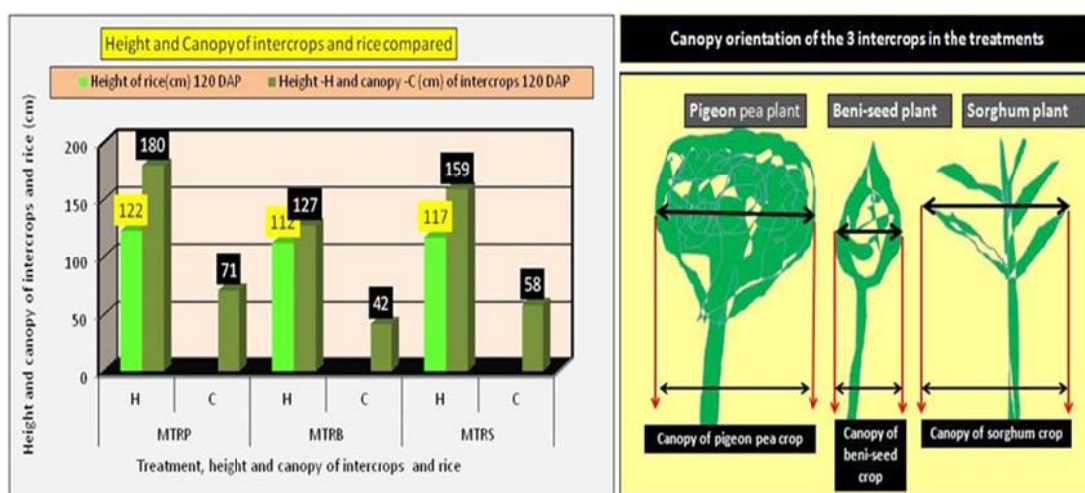
PBT = Panicle bearing tillers, NPBT=Non panicle bearing tillers and TOT = Total number of tillers in the stand.



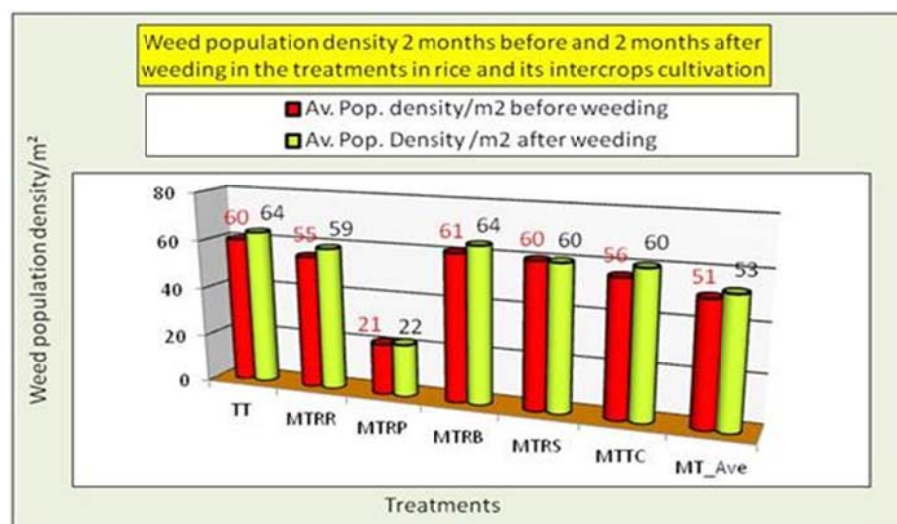
**Figure 2.28.** Shows the height (H) and canopy (C) of the intercrops in the treatments.

TTP-Traditional treatment with pigeon peas, TTB-Traditional treatment with beni-seeds, TTS-Traditional treatment with sorghum, MTRP-Modern treatment with pigeon peas, MTRB-Modern treatment with beni-seeds, MTRS-Modern treatment with sorghum, MTTC-Pigeon peas with all 3 intercrops combined, MTTCB-Beni-seeds with all 3 intercrops combined and MTTCs-Sorghum with all 3 intercrops combined.



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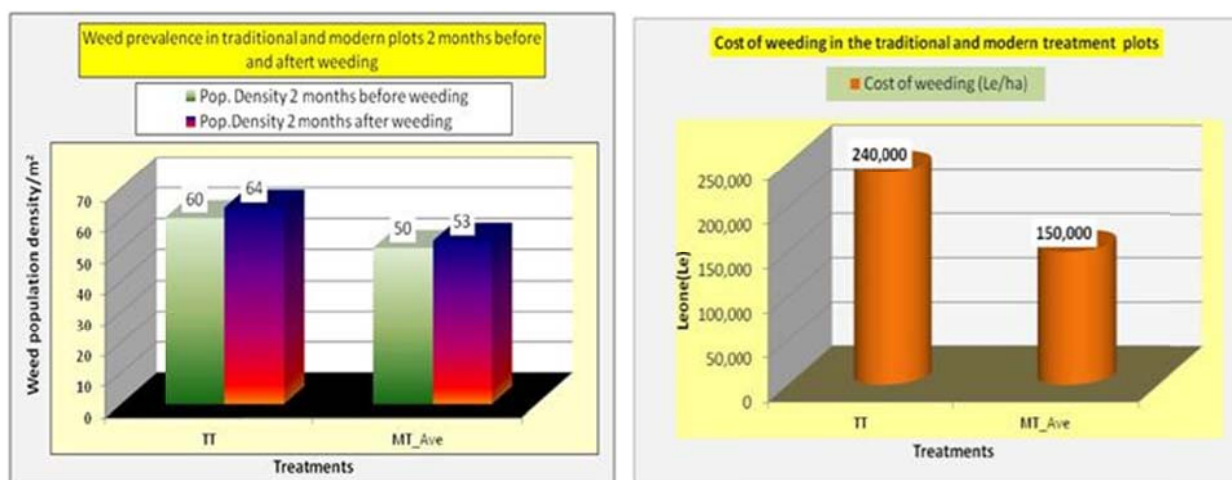


**Figure 2.29.** Shows the height and canopy of the 3 intercrops (pigeon pea, beni-seed and sorghum) and the height of rice in the modern treatments (left). The canopy shapes of the 3 intercrops after 120 days after planting (DAP) (right).

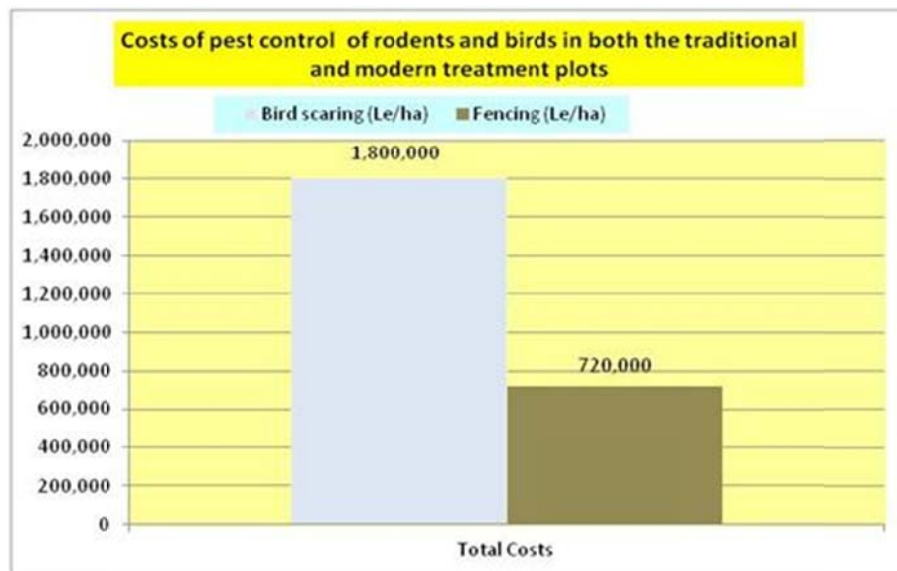


**Figure. 2.30.** Shows the weed population density in the respective treatments in the treatments.



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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 2</b> <i>Assessment of the traditional mix cropping method using local tools and the modern method of rice cultivation using machinery with minimum tillage and row planting with intercrops in the upland ecology</i></p>		<p style="text-align: right;">page 53/73</p>

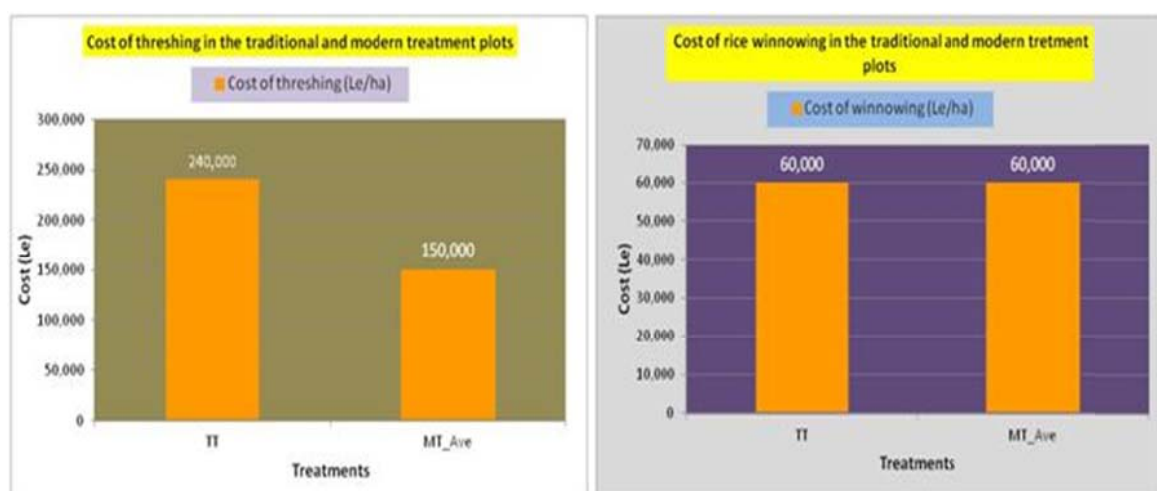


**Figure 2.31.** Shows weed population density and cost of weeding in the traditional (TT) and modern (MT\_Ave) treatments of the experiment.

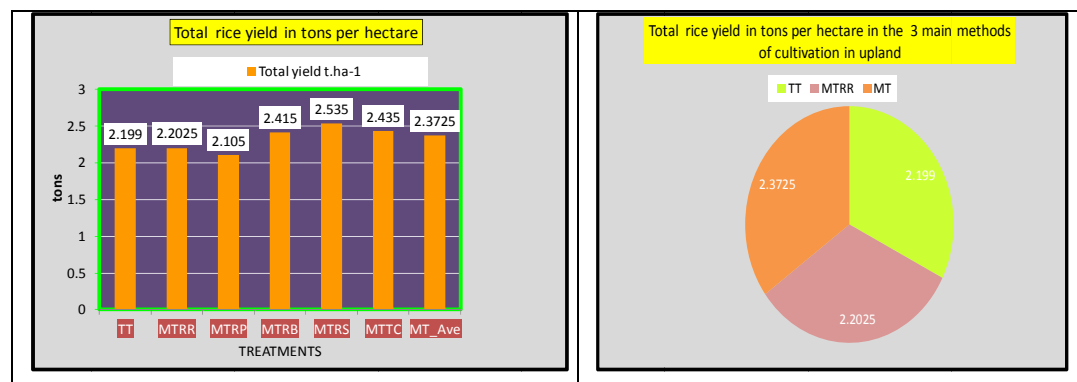


**Figure 2.32.** shows the average costs of pest control per hectare in the different treatments of the traditional and modern methods.

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 2</b> <i>Assessment of the traditional mix cropping method using local tools and the modern method of rice cultivation using machinery with minimum tillage and row planting with intercrops in the upland ecology</i></p>		<p style="text-align: right;">page 54/73</p>



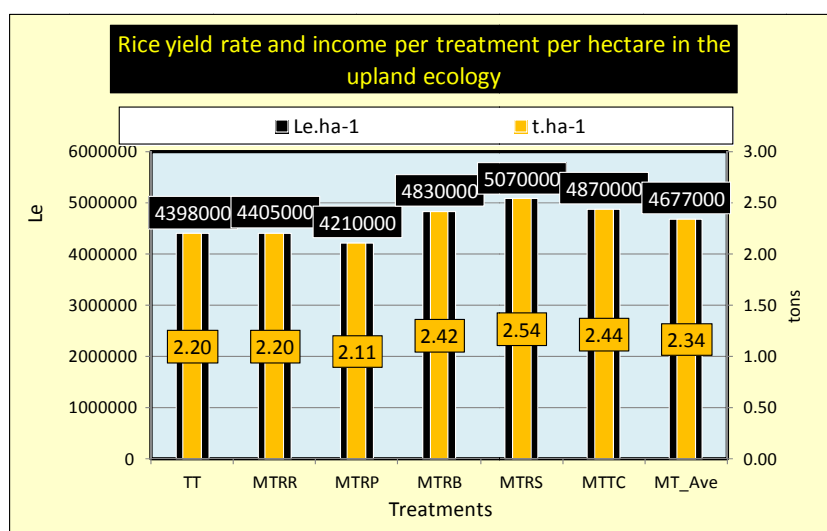
**Figure 2.33.** shows the cost threshing and winnowing in the traditional and modern treatments of the experiment.



**Figure 2.34.** The yield rate of rice per kilograms per hectare in the respective treatments.

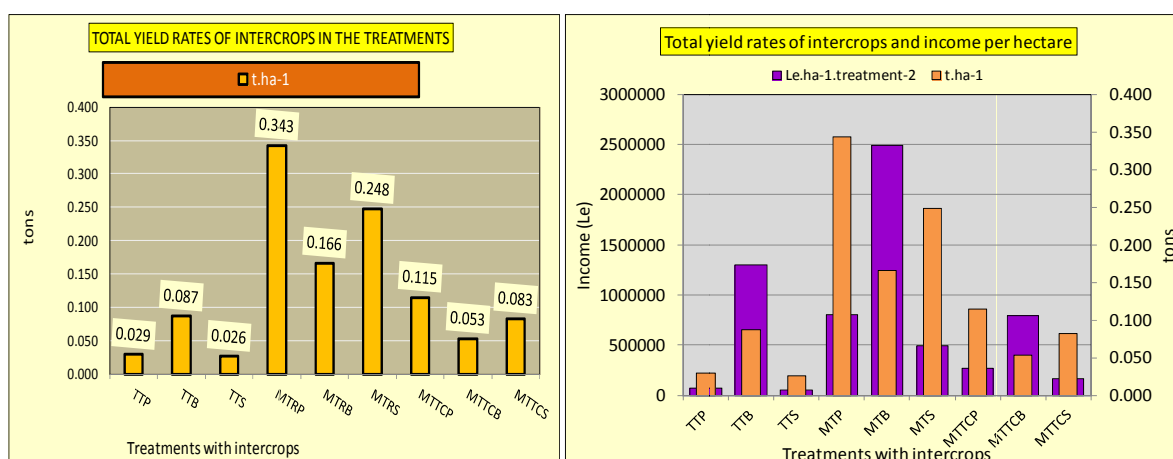
TT=Traditional treatment, MTRR=Modern treatment with rice only, MTRP=Modern treatment of rice intercropped with pigeon peas only, MTRRB=Modern treatment of rice intercropped with beni-seeds only, MTRS=Modern treatment of rice intercropped with sorghum only, MTTC=Modern treatment of rice intercropped with all the 3 intercrops, MT\_Ave=Average of all modern treatments.







**Figure 2.35.** The yield rates and income of rice yields in the respective treatments in the traditional and modern methods per hectare.

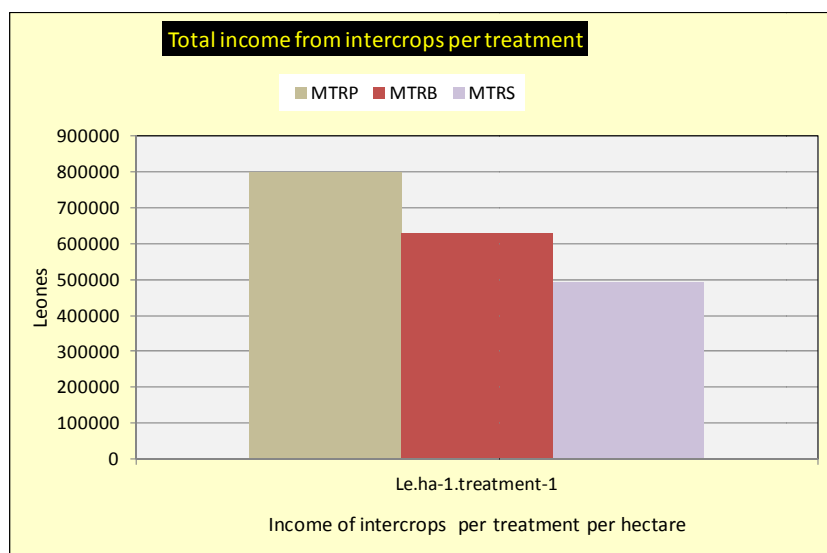
*TT=Traditional treatment with rice mixed with all the 3 alien crops of pigeon peas, beni-seeds and sorghum, MTRR=Modern treatment with rice only, MTRP=Modern treatment with rice and pigeon peas only, MTRB=Modern treatment with rice and beni-seeds only, MTRS=Modern treatment with rice and sorghum only, MTTC=Modern treatment with rice and the 3 intercrops combined and MT\_Ave=Average results for modern treatments.*



**Figure 2.36.** Shows the yield rates and the income of the intercrops in the respective treatments.

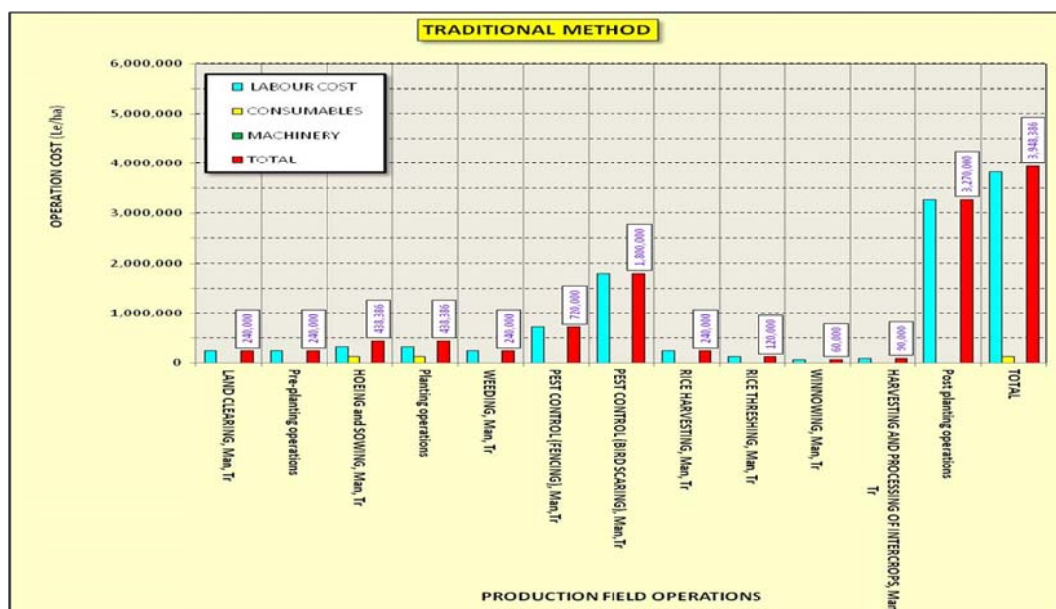
*TTP-Traditional treatment with pigeon peas, TTB-Traditional treatment with beni-seeds, TTS-Traditional treatment with sorghum, MTRP-Modern treatment with pigeon peas, MTRB-Modern treatment with beni-seeds, MTRS-Modern treatment with sorghum, MTTCP-Pigeon peas with all 3 intercrops combined, MTTCB-Beni-seeds with all 3 intercrops combined and MTTCS-Sorghum with all 3 intercrops combined.*

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**Figure 2.37.** Showing the total income obtained from the intercroops in the respective treatments per hectare.

TT Traditional treatment with pigeon peas, beni-seeds and sorghum, MTRP-Modern treatment with pigeon peas, MTRB-Modern treatment with beni-seeds, MTRS-Modern treatment with sorghum, MTTC-Pigeon peas, beni –seed and sorghum.



**Figure 2.38.** Total production cost of rice cultivation in the upland ecology using traditional method.



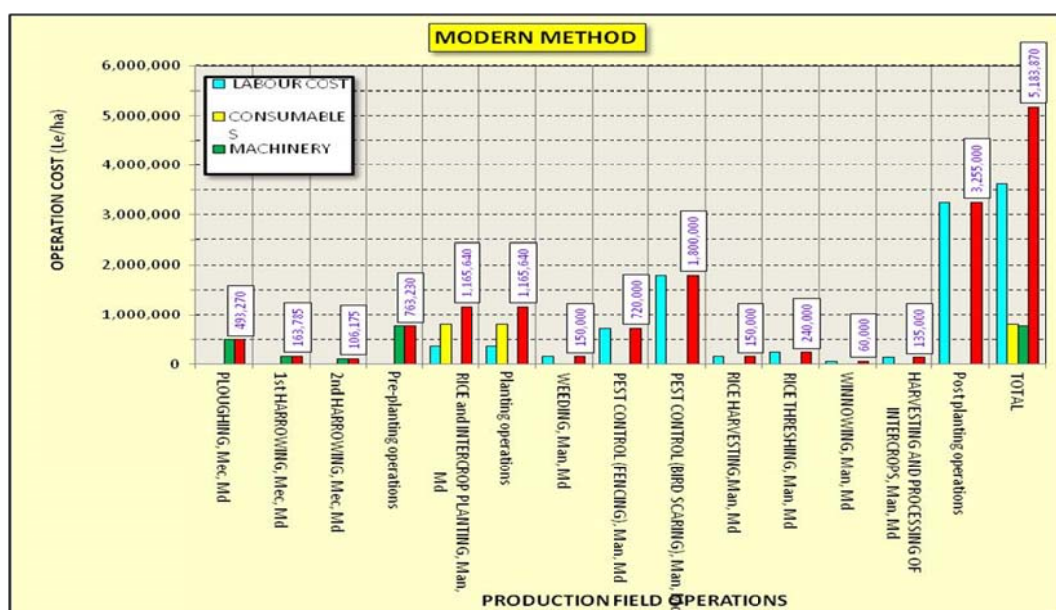


Figure 2.39. Total production cost of rice cultivation in the upland ecology using modern method.

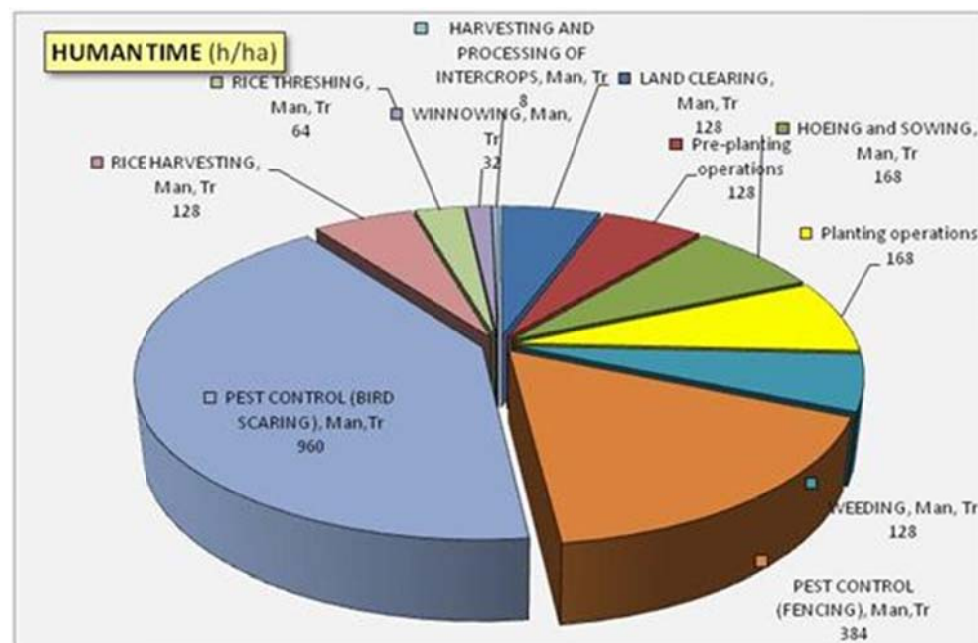


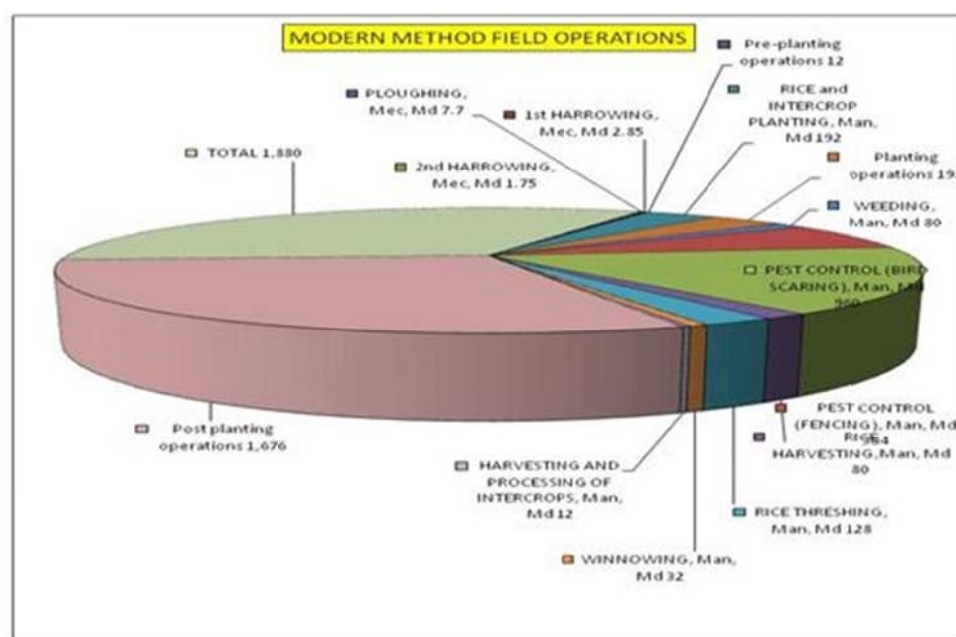
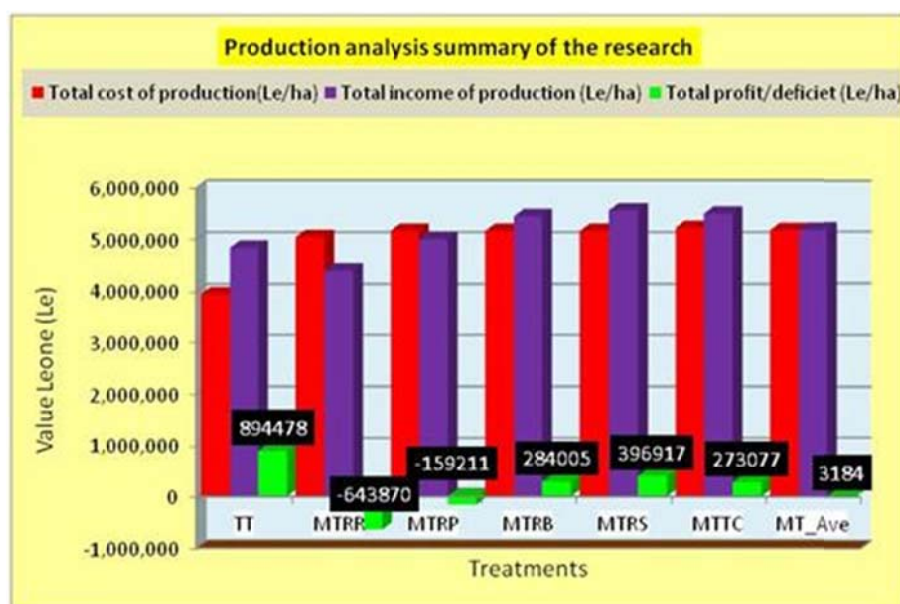


Figure 2.40. Shows the time taken to carry out the field operations in the production process in the traditional method.



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**Figure 2.41.** Shows the time taken to carry out the field operations in the production process in the modern method





**Figure 2.42.** Production total cost-benefit analysis for the traditional and modern methods of rice cultivation in the upland with intercrops or mix crops.

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## Tables



**Table 2.1.** Soil sample collection pattern after harvesting of the rice and ground from the jatropha plants in the treatments.

Rice research site soil sample collection after the harvesting of rice in November, 2-2013.							
Location: Rotebainko							
Plot Number	MTRR treatment (g)	MTRP treatment (g)	MTRB treatment (g)	MTRS treatment (g)	MTTC treatment (g)	TT treatment (g)	Comment(s)
1	1=100	1=100	1=100	1=100	1=100	1=100	
2	2=100	2=100	2=100	2=100	2=100	2=100	
3	3=100	3=100	3=100	3=100	3=100	3=100	
4	4=100	4=100	4=100	4=100	4=100	4=100	
Total	400	400	400	400	400	400	
Quantity (g) needed for lab analysis	100	100	100	100	100	100	
Sub total	600 g=0.6 kg						
Jatropha research site soil sample collection after the harvesting of the ground nut October, 2013.							
Location: Bumbang							
Plot number	JIG (g)	JSC (g)		Comment(s)			
1	1=100	1=100					
2	2=100	2=100					
3	3=100	3=100					
4	4=100	4=100					
Total	400	400					
Quantity (g) needed for lab analysis	100	100					
Sub total	200 g=0.2 Kg						
Grand total	800=0.8 Kg						

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**Table 2.2.** Traditional land clearing data analysis.

TRADITIONAL APPROACH							
OP_01	LAND CLEARING (Type of operation: <b>MANUAL</b> )						
	Plot	Unit	<b>P1</b>	<b>P2</b>	<b>P3</b>	<b>P4</b>	<b>P_Ave</b>
	Area	ha	0.25	0.25	0.25	0.25	0.25
<b>LABOUR</b>	Number of day	nr	1.0	1.0	1.0	1.00	1.0
	Employed (men/women)	nr	4	4	5	4.00	4
	Human total time	h	32	32.0	40.0	32.0	32.0
	<b>(A) Labour cost</b>	Le	60,000	60,000	75,000	60,000	60,000
		€	11.32	11.32	14.15	11.32	11.32
<b>CONSUMABLES</b>	<i>Lunches (plate of rice)</i>		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<i>Consumable_02</i>		0	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<i>Consumable_03</i>		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<i>Consumable_04</i>		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<i>Consumable_05</i>		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<i>Consumable_06</i>		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	<b>(B) Consumables costs</b>	Le	0	0	0	0	0
		€	0	0.00	0.00	0.00	0.00
<b>MACHINES</b>	Total fuel consumption	dm <sup>3</sup>	0.00	0.0	0	0	0.0
	Machines total time	min	0.00	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0
	Operator total time	min	0.00	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0
	<b>(C) Machinery costs</b>	Le	0	0	0	0	0
		€	0	0.00	0.00	0.00	0.00
<b>COSTS</b>	<b>Operation cost (A+B+C)</b>	Le	60,000	60,000	75,000	60,000	60,000
		€	11.32	11.32	14.15	11.32	11.32
		Le·ha <sup>-1</sup>	<b>240,000</b>	<b>240,000</b>	<b>300,000</b>	<b>240,000</b>	<b>240,000</b>
		€·ha <sup>-1</sup>	<b>45.3</b>	<b>45.3</b>	<b>56.6</b>	<b>45.3</b>	<b>45.3</b>
	Work capacity (area/time)	ha·h <sup>-1</sup>	<b>0.008</b>	<b>0.008</b>	<b>0.006</b>	<b>0.008</b>	<b>0.008</b>
		m <sup>2</sup> ·h <sup>-1</sup>	78	78	63	78	78
		m <sup>2</sup> ·day <sup>-1</sup>	625	625	500	625	625

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**Table 2.3.** Detailed information about the tractor used in soil tillage.

FIAT 780		Transmission	8+2/12+3	PTO Speed	540	
Technical information		Synchronised gears	04-Jun	Dimensions and weights		
Years	1975-1978	Quick -change gear	x			
Engine model	FIAT 8045	Reverser	x		Weight kg 2WD	2940
Cyl/Turbo/Intercooler	4	Speeds in km/h	1.4-26.2		Weight kg 4WD (DT Model)	3200
Displacement	3670	Max. Speed km/h	x		Height wcab (cm)	255
Bore x stroke mm	103X110	Hydraulic system			Length (cm)	349
Rated power hp DIN/rpm	X	Hydr. Flow l/min	25.8		Wheelbase (cm)	227
Max. Power hp DIN/rpm	78/2440	Hydr. Pressure bar	x		Fuel tank (l)	80
Torque Nm DIN/rpm	262/1400	Lift capacity (kg)	2400		Turning circle M2wd	7.5
Cab noise level Db	89.5/82.5				Turning circle m 4WD (mod DT)	11.4
Steering	hydrost				Front tyres 2WD	7.5-18
					Front tyres 4WD (DT Model)	11.2-28
					Rear tyres 2WD	16.9-34
					Rear tyres 4WD (DT Model)	16.9-34

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**Table 2. 4.** Mechanical soil tillage (on ploughing) data analysis.

MODERN APPROACH							
OP_01	PLOUGHING (Type of operation: <u>MECHANICAL</u> )						
	Plot	Unit	P1	P2	P3	P4	P_Ave
	Area	ha	0.25	0.25	0.25	0.25	0.25
LABOUR	Number of day	nr	0.0	0.0	0.0	0.0	0.0
	Employed (men/women)	nr	0	0	0	0	0
	Human total time	h	0.0	0.0	0.0	0.0	0.0
	(A) Labour cost	Le	0	0	0	0	0
		€	0.00	0.00	0.00	0.00	0.00
CONSUMABLES	Consumable_01		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	Consumable_02		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	Consumable_03		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	Consumable_04		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	Consumable_05		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	Consumable_06		0.00	0.00	0.00	0.00	0.00
			0	0	0	0	0
	(B) Consumables costs	Le	0	0	0	0	0
		€	0.00	0.00	0.00	0.00	0.00
MACHINES	Total fuel consumption	dm <sup>3</sup>	9.0	9.0	11.5	11.5	10.3
	Machines total time	min	110	148	100	104	116
		h	1.8	2.5	1.7	1.7	1.9
	Operator total time	min	110	148	100	104	116
		h	1.8	2.5	1.7	1.7	1.9
	(C) Machinery costs	Le	114,017	139,413	118,583	121,257	123,318
		€	21.51	26.30	22.37	22.88	23.27
COSTS	Operation cost (A+B+C)	Le	114,017	139,413	118,583	121,257	123,318
		€	21.51	26.30	22.37	22.88	23.27
		Le·ha <sup>-1</sup>	456,067	557,653	474,333	485,027	493,270
		€·ha <sup>-1</sup>	86.1	105.2	89.5	91.5	93.1
	Work capacity (area/time)	ha·h <sup>-1</sup>	0.14	0.10	0.15	0.14	0.13
		m <sup>2</sup> ·h <sup>-1</sup>	1364	1014	1500	1442	1330
		m <sup>2</sup> ·day <sup>-1</sup>	10909	8108	1200	11538	

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**Table 2.5.** Seed rice rate quantity analysis and cost.

Rice seed quantity analysis								
		SURFACE AREA (ha)						
		0.25	0.05	0.05	0.05	0.05	0.05	0.05
PLOT	Unit	TREATMENTS						Ave.
		TT	MTRR	MTRP	MTRB	MTRS	MTTC	MT_Ave
P 1	kg	14.99	4.52	2.75	2.75	2.75	2.75	2.75
P2	kg	14.97	4.51	2.75	2.75	2.75	2.75	
P3	kg	14.96	4.53	2.75	2.75	2.75	2.75	
P4	kg	14.98	4.53	2.75	2.75	2.75	2.75	
Average	kg	14.98	4.52	2.75	2.75	2.75	2.75	
sd		0.01	0.01	0.00	0.00	0.00	0.00	
Seed rate	kg·ha <sup>-1</sup>	60	90	55	55	55	55	55
Total cost	Le·ha <sup>-1</sup>	119800	180900	110100	110080	110070	110050	110060
Total cost	€·ha <sup>-1</sup>	22.60	34.13	20.77	20.77	20.77	20.76	

**Table 2.6.** Intercrop seed rate quantity analysis.



Intercrops seeds rate analysis										
		SURFACE AREA (ha)								
		TREATMENTS								
PLOT	Unit	TT			MT		MTTC			
		P	B	S	RP	RB	RS	P	B	S
P 1	kg	0.23	0.02	0.03	0.09	0.01	0.02	0.03	0.00	0.01
P2	kg	0.23	0.02	0.03	0.09	0.01	0.02	0.03	0.00	0.01
P3	kg	0.23	0.02	0.03	0.09	0.01	0.02	0.03	0.00	0.01
P4	kg	0.23	0.02	0.03	0.09	0.01	0.02	0.03	0.00	0.01
Average	kg	0.23	0.02	0.03	0.09	0.01	0.02	0.03	0.004	0.01
Seed rate	kg·ha <sup>-1</sup>	0.91	0.07	0.11	1.89	0.25	0.39	0.64	0.08	0.13
sd		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total cost of intercrop seeds	Le·ha <sup>-1</sup>	2121	1004	212	4412	3810	781	1481	1253	250
Total	€·ha <sup>-1</sup>	0.40	0.19	0.04	0.83	0.72	0.15	0.28	0.24	0.05



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**Table 2.7.** Cost of rice harvesting in the traditional and modern methods.

MODERN APPROACH									
OP_04	RICE and INTERCROPS PLANTING (Type of operation: <u>MANU</u> )								
	Treatments	Unit	TT	MTRR	MTRP	MTRB	MTRS	MTTC	P_Ave
LABOUR	Number of day	nr	0.0	0.2	0.2	0.2	0.2	0.2	0.2
	Employed (men/women)	nr	0	6	6	6	6	6	6
	Human total time	h	0.0	9.6	9.6	9.6	9.6	9.6	9.6
	(A) Labour cost	Le	0	18,000	18,000	18,000	18,000	18,000	18,000
		€	0.00	3.40	3.40	3.40	3.40	3.40	3.40
CONSUMABLES	Rice seeds	kg	0.00	4.52	2.75	2.75	2.75	2.75	3.10
		Le	0	9,040	5,500	5,500	5,500	5,500	6,208
	Sesame seeds	kg	0.00			0.01		0.004	0.01
		Le	0	0	0	150	0	60	42
	Pigeon pea seeds	kg	0.00		0.09			0.03	0.06
		Le	0	0	210	0	0	70	56
	Sorghum seeds	kg	0.00				0.02	0.01	0.02
		Le	0	0	0	0	40	20	12
	Furrow maker	h		200.00	200.00	200.00	200.00	200.00	200.00
		Le			40,000	40,000	40,000	40,000	
	Tape measure and garden lines	h		80.00	80.00	80.00	80.00	80.00	80.00
		Le			80	80	80	80	
	(B) Consumables costs	Le	80	9,040	45,790	45,730	45,620	45,730	
		€	0.02	1.71	8.64	8.63	8.61	8.63	
MACHINES	Total fuel consumption	dm <sup>3</sup>	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Machines total time	min	0	0	0	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Operator total time	min	0	0	0	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(C) Machinery costs	Le	0	0	0	0	0	0	0
		€	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COSTS	Operation cost (A+B+C)	Le	80	27,040	63,790	63,730	63,620	63,730	56,382
		€	0.02	5.10	12.04	12.02	12.00	12.02	10.64
		Le.ha <sup>-1</sup>		540,800	1,275,799	1,274,600	1,272,400	1,274,600	1,127,640
		€ha <sup>-1</sup>		102.0	240.7	240.5	240.1	240.5	212.8
	Work capacity (area/time)	ha.h <sup>-1</sup>		0.005	0.005	0.005	0.005	0.005	0.01
		m <sup>2</sup> .h <sup>-1</sup>		52	52	52	52	52	52
		m <sup>2</sup> /day	0	417	417	417	417	417	417

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**Table 2.8.** Rice harvest yield rate analysis and income.

	Rice harvest yield rate analysis							
	Plot	TREATMENT						
	Unit	TT	MTRR	MTRP	MTRB	MTRS	MTTC	MT_Ave
P1	g	240	200	290	200	180	190	212
	g	210	150	200	290	210	150	200
	g	200	240	170	200	300	200	222
	g	240	165	120	300	200	200	197
	g	190	250	290	220	150	130	208
P2	g	200	290	210	210	200	260	234
	g	180	250	200	220	200	280	230
	g	210	110	210	310	450	250	266
	g	150	220	290	290	400	400	320
	g	250	210	250	290	210	210	234
P3	g	200	300	190	300	290	390	294
	g	240	220	200	110	200	300	206
	g	250	190	150	240	310	200	218
	g	200	340	250	150	400	250	278
	g	200	200	120	220	300	300	228
P4	g	200	220	220	290	240	280	250
	g	278	200	200	230	200	200	206
	g	300	200	250	290	230	190	232
	g	270	250	200	180	200	290	224
	g	190	200	200	290	200	200	218
Average yield of rice	g·m <sup>-2</sup>	220	220	211	242	254	244	234
sd		35	50	47	54	79	67	59
Average yield of rice	kg·m <sup>-2</sup>	0	0	0	0	0	0	0
Total rice yield	t·ha <sup>-1</sup>	2.20	2.20	2.11	2.42	2.54	2.44	2.34
Total Cost	Le·ha <sup>-1</sup>	4398000	4405000	4210000	4830000	5070000	4870000.0	4677000.0
Total cost	€·ha <sup>-1</sup>	829.8	831.1	794.3	911.3	956.6	918.9	882.5





*Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone*



*Assessment of the traditional mix cropping method using local tools and the modern method of rice cultivation using machinery with minimum tillage and row planting with intercrops in the upland ecology*



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**Table 2.10.** Total field operations summary for the rice cultivation in the upland.

FIELD OPERATIONS SUMMARY						
	OPERATION COST				HUMAN TIME	WORK CAPACITY
	LABOUR COST	CONSUMABLES	MACHINERY	TOTAL	TOTAL	TOTAL
	Le'ha <sup>-1</sup>	Le'ha <sup>-1</sup>	Le'ha <sup>-1</sup>	Le'ha <sup>-1</sup>	h'ha <sup>-1</sup>	ha'h <sup>-1</sup>
LAND CLEARING, Man, Tr	240,000	0	0	240,000	128	0.008
HOEING and SOWING, Man, Tr	315,000	123,386	0	438,386	168	0.006
PLOUGHING, Mec, Md	0	0	493,270	493,270	8	0.133
1st HARROWING, Mec, Md	0	0	163,785	163,785	3	0.371
2nd HARROWING, Mec, Md	0	0	106,175	106,175	2	0.574
RICE and INTERCROP PLANTING, Man, Md	360,000	805,640	0	1,165,640	192	0.005
WEEDING, Man, Md	150,000	0	0	150,000	80	0.013
WEEDING, Man, Tr	240,000	0	0	240,000	128	0.008
PEST CONTROL (FENCING), Man, Md	720,000	0	0	720,000	384	0.003
PEST CONTROL (FENCING), Man,Tr	720,000	0	0	720,000	384	0.003
PEST CONTROL (BIRD SCARING), Man, Md	1,800,000	0	0	1,800,000	960	0.001
PEST CONTROL (BIRD SCARING), Man,Tr	1,800,000	0	0	1,800,000	960	0.001
RICE HARVESTING,Man, Md	150,000	0	0	150,000	80	0.013
RICE HARVESTING, Man, Tr	240,000	0	0	240,000	128	0.008
RICE THRESHING, Man, Md	240,000	0	0	240,000	128	0.008
RICE THRESHING, Man, Tr	120,000	0	0	120,000	64	0.016
WINNOWING, Man, Md			0	60,000	32	0.031
WINNOWING, Man, Tr	60,000	0	0	60,000	32	0.031
HARVESTING AND PROCESSING OF INTERCROPS, Man, Md	60,000	0	0	60,000	12	0.023
HARVESTING AND PROCESSING OF INTERCROPS, Man, Tr	135,000	0	0	135,000	8	0.063

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**Table 2. 11.** Production activities cost summary for the traditional method.



TRADITIONAL METHOD PRODUCTION COST SUMMARY							
	OPERATION COST Le'ha <sup>-1</sup>	CONSUMA- BLES	MACHI- NERY	TOTAL	HUMAN TIME		WORK CAPACITY
	labour cost				h'ha <sup>-1</sup>	%	
LAND CLEARING, Man, Tr	240,000	0	0	240,000	128	6.4%	0.008
Pre-planting operations	240,000	0	0	240,000	128	6.4%	0.008
HOEING and SOWING, Man, Tr	315,000	123,386	0	438,386	168	8.4%	0.006
Planting operations	315,000	123,386	0	438,386	168	8.4%	0.006
WEEDING, Man, Tr	240,000	0	0	240,000	128	6.4%	0.008
PEST CONTROL (FENCING), Man,Tr	720,000	0	0	720,000	384	19.2%	0.003
PEST CONTROL (BIRD SCARING), Man,Tr	1,800,000	0	0	1,800,000	960	48.0%	0.001
RICE HARVESTING, Man, Tr	240,000	0	0	240,000	128	6.4%	0.008
RICE THRESHING, Man, Tr	120,000	0	0	120,000	64	3.2%	0.016
WINNOWING, Man, Tr	60,000	0	0	60,000	32	1.6%	0.031
HARVESTING AND PROCESSING OF INTERCROPS, Man, Tr	90,000			90,000	8	0.4%	0.063
Post planting operations	3,270,000	0	0	3,270,000	1,704	85.2%	0.129
<b>TOTAL</b>	<b>3,825,000</b>	<b>123,386</b>	<b>0</b>	<b>3,948,386</b>	<b>2,000</b>	<b>100%</b>	<b>0.142</b>
	100%	100%	0	100%	100%	100%	100%

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**Table 2.12.** Production activities cost summary for the modern method.



MODERN METHOD PRODUCTION COST SUMMARY							
	LABOUR COST	CONSUMABLES	MACHINERY	TOTAL	h'ha <sup>-1</sup>	%	ha'h <sup>-1</sup>
PLOUGHING, Mec, Md	0	0	493,270	493,270	7.7	0.4%	0.133
1st HARROWING, Mec, Md	0	0	163,785	163,785	2.85	0.1%	0.371
2nd HARROWING, Mec, Md	0	0	106,175	106,175	1.75	0.1%	0.574
Pre-planting operations	0	0	763,230	763,230	49	107.8%	0.000
RICE and INTERCROP PLANTING, Man, Md	360,000	805,640	0	1,165,640	192	10.0%	0.005
Planting operations	360,000	805,640	0	1,165,640	192	10.0%	0.005
WEEDING, Man, Md	150,000	0	0	150,000	80	4.2%	0.013
PEST CONTROL (FENCING), Man, Md	720,000	0	0	720,000	384	20.0%	0.003
PEST CONTROL (BIRD SCARING), Man, Md	1,800,000	0	0	1,800,000	960	50.1%	0.001
RICE HARVESTING, Man, Md	150,000	0	0	150,000	80	4.2%	0.013
RICE THRESHING, Man, Md	240,000	0	0	240,000	128	6.7%	0.008
WINNOWING, Man, Md	60,000	0	0	60,000	32	1.7%	0.031
HARVESTING AND PROCESSING OF INTERCROPS, Man, Md	135,000	0	0	135,000	12	0.6%	0.023
Post planting operations	3,255,000	0	0	3,255,000	1,676	86.8%	0.091
<b>TOTAL</b>	<b>3,615,000</b>	<b>805,640</b>	<b>763,230</b>	<b>5,183,870</b>	<b>1,960</b>	<b>97%</b>	<b>1.175</b>
	95%	653%		131%	96%	100%	825%



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**Table 2.13.** Production cost-benefit analysis for rice cultivation in the upland ecology.

PRODUCTION COST-BENEFIT ANALYSIS FOR RICE AND ITS ALLIED INTERCROPS																
Unit			TT Leone	Euro	MTRR Leone	Euro	MTRP Leone	Euro	MTRB Leone	Euro	MTRS Leone	Euro	MTTC Leone	Euro	MT_Ave Leone	MT_Ave(Euro)
Total cost of production	Le'ha <sup>-1</sup>	-	3,948,386	744.98	5,048,870	952.62	5,168,870	975.26	5,168,870	975.26	5,168,870	975.26	5,228,870	986.58	5,183,870	978.09
Income generated				0.00												
		Rice	4398000	829.81	4405000	831.13	4210000	794.34	4830000	911.32	5070000	956.60	4870000	918.87	4,677,000	882.45
		Pigeon peas	68024	12.83	0		799659	150.88	0	0.00	0	0.00	267922	50.55	213,516	40.29
		Beni-seeds	324520	61.23		0.00		0.00	622875	117.52	0	0.00	198825	37.51	164,340	31.01
		Sorghum	52320	9.87	0		0	0.00	0	0.00	495787	93.54	165200	31.17	132,197	24.94
		Total Intercrops	444864	83.94	0		799659	150.88	622875	117.52	495787	93.54	631947	119.24	510,054	96.24
Total income of production	Le'ha <sup>-1</sup>		4842864	913.75	4405000	831.13	5009659	945.22	5452875	1028.84	5565787	1050.15	5501947	1038.10	5,187,054	978.69
Total Profit/deficit			894478	169	-643870	-121	-159211	-30	284005	54	396917	75	273077	52	3184	0.6
Total profit/deficit	€			169		-121		-30		54		75		52		0.60



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**Table 2.14.** Traditional Method compared with Modern Method: main results obtained in the field tests The index values (%) shows that Modern Method assures better results for each parameters, except for the total cost of production (€·t<sup>-1</sup>).

PRODUCTIO PARAMETERS	UNIT OF MEASURE	TRADITIONAL METHOD	MODERN METHOD
SEED-LAND PREPARATION TIME	h·ha <sup>-1</sup>	396 (100%)	48 (12%)
SEED-LAND PREPARATION WORK CAPACITY	ha·h <sup>-1</sup>	0.008 machete 0.006 hoe	1.078
PLANT POPULATION DENSITY	plants·m <sup>-2</sup>	150 (100%)	178 (125%)
SEED RATE	kg·ha <sup>-1</sup>	60 (100%)	55 (92%)
WEED POPULATION DENSITY	weeds·m <sup>-2</sup>	60 (100%)	51 (85%)
AVERAGE HEIGHT	m	1.08 (100%)	1.16 (107%)
TILLE RING	n.	5 (100%)	6 (120%)
PANICLE BEARING	n.	4 (100%)	5 (125%)
YIELD RATE OF RICE	t·ha <sup>-1</sup>	2.20 (100%)	2.34 (106%)
YIELD RATE OF ALL INTERCROPS		0.082 (100%)	0.422 (515%)
<b>TOTAL</b>		<b>2.282 (100%)</b>	<b>2.762 (121%)</b>
TOTAL COST OF PRODUCTION (rice and intercrops)	€·ha <sup>-1</sup> €·t <sup>-1</sup>	745 (100%) 326 (100%)	978 (131%) 354 (108%)
TOTAL INCOME OF PRODUCTION (rice and intercrops)	€·ha <sup>-1</sup>	914 (100%)	979 (107%)
<b>TOTAL PROFIT OF PRODUCTION</b> (rice and intercrops)	€·ha <sup>-1</sup>	<b>169 (100%)</b>	<b>1 (0.6%)</b>
TIME IN ENTIRE PROCESS OF PRODUCTION	h·ha <sup>-1</sup>	2000 (100%)	1960 (96%)



**Table 2.15.** Leaf colour chat (LCC) showing the nitrogen content in the soil through the response of rice growth.

Treatment	TT	MTRR	MTRP	MTRB	MTRS	MTTC
Level of nitrogen in the soil	3	2	4	3	3	3



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## CHAPTER 3-The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers

### Abstract

Across the continent of Africa, only 10% of individuals have access to the electrical grid, and of those, 75% come from the richest two quintiles in overall income. Electrical provisioning in Africa has generally only reached wealthy, urban middle class, and commercial sectors, bypassing the region's large rural populations and urban poor. According to the forum of Energy Ministers of Africa, most agriculture still relies primarily on humans and animals for energy input [[http://en.wikipedia.org/wiki/Energy\\_in\\_Africa#Current\\_Energy\\_Usage\\_in\\_Africa](http://en.wikipedia.org/wiki/Energy_in_Africa#Current_Energy_Usage_in_Africa)]. This acute shortage of energy has led to the tremendous snail pace rate of development of the countries in the continent whilst the rest of the developed world is taking advantage of the deficiency to exploit the natural wealth through the importation of most of the resources in their raw or crude form to the developed countries for processing and later returned to Africa at higher costs at the expense of the impoverished people; rendering them poorer and poorer and hence branded as underdeveloped.

One of the ways to avert this unpleasant situation is to explore a more sustainable means of generating energy which can be produced, processed and used in the African continent by local people. Renewable energy in the form of plant products could be one of the answers to achieve this objective. This research is geared towards exploring means of animating farmers to produce energy through the cultivation of jatropha crop locally in their rural communities, which can produce vegetable oil that can be used as bio-fuel in specific electricity generating machines to provide energy. Jatropha is an introduced crop from the Western and Asiatic world which has been observed to grow well in diverse tropical soils in Africa. This crop's product (seeds) used as source of energy was scarcely known in the continent of Africa until late in the 20<sup>th</sup> century. The crop was mainly known in Sierra Leone as an ornamental plant around houses in urban and rural settlements.



The growing of jatropha as a crop for energy production is a completely new phenomenon in Sierra Leone which this research is investigating to know what agronomic, socio-economic and technical impacts such a venture could have in the rural communities in relation to energy and food production.

On the aspect of agronomy, the research is to investigate the growth and reproductive effects of the plant when cultivated solely as a mono-crop and as an intercrop with another crop that can be eaten by the farmers.

The research is aimed at investigating the effects of pests, weeds and other agronomic managements in relation to the growth and reproductive pattern of the crop in the field using traditional and modern method approaches with local farmers. In addition, the aspect of the varieties involved into the research shall also be investigated to know which of the varieties could best suit the production process in terms of management, life cycle to reproduce and yield ratio per hectare.

On the economic sphere, the research is investigating the cost of production of the crop when it is cultivated as a sole crop and as an intercrop with another edible crop by the farmers in the community.



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On the social sphere, the research will investigate how much time and energy that maybe needed to produce the needed seeds for the production of bio-fuel that can be used to generate energy for the consumption of the village community. The challenges or positive effects the production of jatropha shall have on the farming activities of the farmers that will be involved into the research in the community. The research will also investigate the mutual benefits that will be shared by the farmers working together in groups to produce the jatropha seeds in the sole and intercrop methods in the field. The research will be directed also towards discovering what modern agricultural skills that could be beneficial to the farmers from the research activities during and after the field exercises in jatropha cultivation. The research will investigate the interactive impacts of the production of the jatropha (as fuel to generate electricity); ground nut (as food for the farmers) and the other food cultivation activities in the lives of the rural community people.



It is eminent that the national electricity grid of Sierra Leone will hardly reach the rural poor communities; therefore one of the means of acquiring sustainable energy is by the rural poor is to involve in an activity that can enable them get a readily available source of energy that can be produced and used locally through the use of local resources such as land, traditional tools and crops they can be cultivated. This may not only be readily available but also sustainable thus positively influencing their social lives to improve their socio-economic status.

### 3.1 Objectives of the study

1. To investigate how bio fuel in the form of Pure Vegetable Oil (PVO) can be locally produced and used to generate electricity by farmers through the growing of the energy producing crop called jatropha.
2. To investigate the impacts of such production in relation to food production and processing activities at local community level.
3. How jatropha can be grown to produce seeds for the production of bio fuel in the form of (PVO) for the use of farmers in a specially designed diesel engine at local community level to generate electricity for domestic consumption.
4. To investigate the varieties of jatropha that can be cultivated in Sierra Leone, that has the potentials to reproduce seeds for bio-fuel.
5. How the cultivation of jatropha may impact the social, economic and agronomic status of the farmers involved in the crop's production in Sierra Leone.

### 3.2 Introduction of the study

Bio fuel resource technology involves the exploitation of natural substances and/or biotechnological approaches in production processes. The utilization of various parts of Jatropha, revealed for the first time the combined targets of the crop, thus potentially improving the economic situation of various tropical countries [G.M. Giibitz]. Jatropha, a multipurpose small tree belonging to the family of Euphorbiaceae, is a native of tropical America, but now thrives in many parts of the tropics and sub-tropics in Africa or Asia. The crop has been used for diverse purposes such as medicine, pesticide, firewood, fencing, latex, erosion control and ornamental plant. Despite all various purposes, the

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application as fuel is probably the most interesting from both economical and ecological point of view [Bredeson, 2007].

Jatropha is a promising crop with many applications (Figure 3.1).

The technology is in its infancy and on the verge of commercialisation. Expectations are high. The first developments are underway, but not much has been realised so far. Researchers are trying to gain experience in several pilot projects and has encountered many initial obstacles and problems. Since this crop is not edible, it is seen by a lot of food advocates as a threat to edible food stuffs especially in Africa where the level of food production is incredibly low.

However, looking at the critical situation of the world's fuel consumption level and the threat it is posing through climate change and the downturn of crude oil reserves, there is an urgent need to look for appropriate alternatives to these fossil fuels; of which jatropha is one of the answers.

### Varieties of jatropha cultivars

Jatropha exists in different varieties that are grown all over the world today in the five continents. The most common varieties mostly seen cultivated are *jatropha curcas* (*J. Curcas* L.) and *jatropha gossypifolia* (*J.gossypifolia* L.) (Figures 3. 2. a and b). This study shall look into these two varieties carefully to investigate their respective field performances in Sierra Leone in the upland ecology using mostly the traditional method of crop cultivation, interspersed with modern agronomic practices.

The two varieties commonly grown in Sierra Leone serve as hedges around houses and ornamentals especially in urban communities. *Jatropha curcas* is also known as a medicine used to cure malaria and as a purgative in most communities in Sierra Leone. The plant is commonly called "Fig nut" in one of the local tribal dialects (Creole) in Sierra Leone.



Jatropha is a tall bush or shrub that can grow up to 6m tall, (*J. curcas*), while (*J. gossypifolia*) can maintain a height of about 3 m in very good soils.

*J. curcas* lifespan is in the range of 50 years. These trees are deciduous wood type with leaves falling off under conditions of water stress. This makes it to be able to survive in adverse climatic conditions and soils, especially in the tropics.

They show different plant architecture, ranging from a main stem with no or few branches to a plant that is branched from below. The branches of the jatropha plant contain white, sticky latex that leaves brown stains, which are hard to wash out.

The root system from natural jatropha plants is well developed, with roots growing both laterally and vertically into deeper soil layers.

The plant is monoecious, with male and female flowers on the same plant. Fruits form at the end of branches in bunches. *Jatropha curcas* can have 5 – 20 fruits, with a shape resembling an "American football" and are about 40 mm long. Each fruit contains 3 seeds, though occasionally one may have 4 or 5. *Jatropha gossypifolia*, however have fewer seeds with smaller size but can be more numerous than *jatropha curcas* in every branch. Jatropha seeds look like black beans with an average of 18 mm long and 12 mm wide and 10 mm thick. These dimensions vary within seeds from the same plant or provenance and between seeds from different provenances. Seed weigh between 0.5 and 0.8 gram, with an average of 1333 seeds per kilogram. The weight of *jatropha gossypifolia* is known to be 7500 seeds per kilogram.

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Seeds contain various toxic compounds (phorbol esters, curcun, trypsin inhibitors, lectins and phytates) and are non-edible. Seeds consist of a hard shell that makes up around 37% by weight on average and soft white kernel that makes up 63% by weight. The dry seeds have a moisture content of around 7% and contain between 32 and 40% of oil, with an average of 34% [Azam M.M, 2005]. Virtually all the oil is present in the kernel. This oil can easily be converted into bio-diesel, meeting the standards of US, Germany and European Standard Organization through the process called trans-esterification.

In normal conditions the plant will fruit once a year, yielding 2–5 tons of dry seed per hectare per year after 5 years. This largely, depends on the genetic variety, agro-climatic conditions and the management input. The age of jatropha has tremendous effects on its reproduction process. The yield per plant progresses as the plant becomes more mature in age (Figure 3.3).

### Soil and climatic conditions

Like any other crop, jatropha needs very good soils in order to be able to grow and reproduce at an early age, especially with *J. Gossypifolia*. The most suitable soils are loam, sandy clay loam and silt loam. Heavy soils (clay, sandy clay, clay loam, silty clay loam, and silt) are only suitable under relatively dry conditions when frequent periods of heavy rainfall are absent. In that case jatropha can be quite productive because these soils usually have a good nutrient supply. Jatropha cannot tolerate permanent wetness (it becomes waterlogged). Heavy soils, therefore, are only suitable when they are not saturated with moisture for long periods (maximum one week, which will already have a negative impact on production). These conditions occur when there are no periods of high rainfall that lead to water logging and when the ground water table is out of reach. Heavy soils are not suitable under conditions where very dry and wet periods quickly follow each other because they shrink and swell and root formation is impaired [Y. Jan Franken and F. Nielsen 2010].

Regardless of the soil, a good pH for jatropha lies between 5.5 and 8.5. Under more acidic or alkaline conditions jatropha growth is limited. Soil depth should be at least 45 centimetres and soil slope should not exceed 30°. Jatropha can survive low soil nutrient contents, but in that case growth and production are limited. Higher nutrient levels in the soil translate into increased production. Soil organic matter is also favourable to jatropha growth, especially in coarse soils.



Jatropha needs an average rainfall of 600-1500mm of rain per year [Position Paper on Jatropha Large Scale Project Development, FACT 2007]. Since artificial irrigation is hardly practiced in Africa, especially in Sierra Leone, adequate rain fed support of the plant will largely affect its field performance in growth and reproduction (Figure 3.4).

### 3.3 Methods and materials

The location of the research is 8°48'36" N; 11°57'27" W. It is 12.3 Km by air and 14 Km on road in a community called Bumbang. It is found in the Paki Masabong chiefdom, in the Bombali district, North of Sierra Leone. The community has a population of 1700 inhabitants who are predominantly farmers, heavily relying on upland farm cultivation activities.

This research on jatropha crop production is characterised by the three main phases of the crop production; namely pre-planting, planting and post planting.

The operations in each of these phases were essential in accomplishing the management and production of the crop. Although jatropha was perceived to be an ornamental crop in Sierra Leone, the

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sensitization and clear explanation of this research shed vivid convincing responses by the farmers and the entire community people that its cultivation as a crop must be embraced as an integral part of their agriculture activities in the village. Key emphasizes were laid on the relevance of jatropha as a crop instead of perceiving it to be a mere ornamental plant as the case was before the research.

The materials used in this research were purely local with a few that cannot be obtained around in the village, such as the 50 m tape measure and spring balance. All the tools and planting materials were obtained locally either in the village or around the Northern region where the research project was carried out.

### **3.3.1. Pre-planting phase**

#### **3.3.1.1. Community sensitization and mobilization**

As described in chapter two, community sensitization was carried out through the three level meetings. This was to explain the objectives of the research, strategies to be used to get the farmers accept to cultivate jatropha as a crop, the offering of their land for the research work and the general organization of the work schedule and work ethics within, between and amongst the farmers in the community through the formulation of simple rules and regulations by the farmers themselves. These formed a solid foundation for the commencement of the research activities which were seen to go through amicably and successfully over the period of the field research work.

#### **3.3.1.2. Research site identification and selection**



The acceptance of the village authorities together with the land owners for the jatropha cultivation research to be done in the community land through the offering of a small money token was accomplished in one of the village meetings. The land owners agreed to release their land of 2.5 ha to be used for the research activities for a period to be determined by the researcher and the farmers since jatropha is a relatively permanent crop.

The researcher and the farmers together with the land owners went to identify the research site in a location 100 m from the village and close to the motor road towards Makeni.

Using a 50 m tape measure the 2.5 ha land was demarcated together with the farmers of the selected by the community for the research project. The farmers used cutlasses to create the path way through which the pegs were used to indicate 0.5 ha for each of the 5 groups that were to participate in the research; making a total of 2.5 ha for the entire research work. A meeting was immediately held in the research site together with the farmers and their leaders as to when the work of clearing the natural vegetation (brushing) was to be started. It was agreed that all the field operations of the research project must be carried out in one of the days of the week until the research activities were accomplished.

#### **3.3.1.3. Traditional method of land preparation of the plots (brushing/slashing and burning)**

As scheduled by the two heads of the community farmers together with the farmers themselves, the preparation of the land for planted was started with the clearing of the natural vegetation by brushing or cutting down of the trees and grasses (slashing) using cutlasses by both women and women. Every member of the project was required to be present or send a representative that was capable to do the job like the regular member of the project. The work normally starts at 9: am after some of the members have come from tapping their morning 'palm wine' around the community bushes. Palm wine

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is an essential local beverage from the palm tree that is used by most of the people in this community. The leaders usually take the lead by asking a member of the entire group to share portions amongst the members into small groups of four or five; depending on the number of farmers that were present. Each of these groups will brush their portion from start to finish and then move to another during the scheduled period of the work. The work normally ends at about 1:00 pm each day. This is because the entire group does not provide food during the work period; hence their working potential lasts for only 4 hours for each day, i.e. half man-day.

Before the beginning of the field work, a regulation was instituted by the entire group through the 2 leaders that if any member of the project absents him or herself three times for the work which has been scheduled to take place on a generally agreed day, without giving any approved valid reason(s) to the group, the member automatically loses his or her membership with the project.

For every field activity carried out by the group, registration of members present was done by the appointed secretary of the entire group and names of those present were called at the end of the working period. This helped a lot in controlling absenteeism during the field operations. The exercise of registering members during and after work was strictly adhered to by the group leaders to enable fair treatment of every member in terms of equal contribution to the work force of the field activities.

This bush clearing operation was carried out for three consecutive times in three weeks to complete the brushing of the 2.5 ha for the entire project (**Figure 3.5**).



The tools and materials used were cutlasses, sharpening stones and water. At some intervals of slashing the fresh bushes, farmers were seen sharpening the cutlasses on special stone using water to enabled them continue with the exercise.

The brushed vegetation was allowed to dry for a week and then burning was carried out by one or two members of the group. The remaining debris and some stumps were cleared off the surface using cutlasses to allow easy access for further field activities such as ploughing using small hoes.

#### **3.3.1.4 Traditional method of land preparation in the plots (ploughing)**

After burning and clearing of the debris and stumps, ploughing was the next activity that was carried out by the farmers. Ploughing was done by both men and women in the cleared area.

Ploughing involved the use of small hoes as being done for the planting of the rice in the upland farms. Like in the cultivation of rice women used the short handle hoes while the men used the long ones. The depth of plough was about 10 to 15cm depending on the strength and skill of the farmer. The area to be ploughed was subdivided into smaller pieces amongst the number of farmers present for the day's operation and each smaller group will engage in its portion until it was completed. There was a keen competition amongst the farmers as to who should complete their portion first and rest. This accelerated the day's work to be able to complete a large portion of the field intended to be ploughed. Every smaller group that completed its portion will report to the leader responsible for the sharing of these portions for further allotment until the time of recess from the work was reached. Registration of all members present was done and those absent were noted with their excuses of why they were absent. This operation was consecutively carried out until every part of the field intended for the project was ploughed.

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### **3.3.1.5. Plot design and treatment lay-outing**

After ploughing, the whole surface area was divided into 5 plots of 0.5 ha (5000 m<sup>2</sup>) each. Each plot was assigned to a group of farmers. Each group was made of 10 to 11 farmers including the 2 heads (a male and female) of that group.

The entire 0.5 ha (5000 m<sup>2</sup> i.e. 50 m x 100 m) of each group was again subdivided into two parts; 0.2 ha (1000 m<sup>2</sup> i.e. 50 m x 20 m) and 0.8 ha (4000 m<sup>2</sup> i.e. 50 m x 80 m). The 4000 m<sup>2</sup> was to be planted with jatropha and intercropped with ground nut while the 1000 m<sup>2</sup> was to be planted purely with jatropha (Figure 3.6).

The lay-outing was done together with the farmers who were totally involved together with the researcher to know the simple design of the treatments and the entire plot. The 0.5 ha plots were laid out parallel to each other measuring 100 m x 50 m each.

The use of materials such as the 50 m tape measure, pegs, garden lines, and hoes was done by the farmers and researcher. The farmers, who cannot read and write, therefore used long sticks or garden lines that have been calibrated into meters to participate in the measuring process during the lay-out and spacing for the planting of jatropha in the treatments. Eventually most of the farmers were able to use the 50 m tape measure during the lay-outing and planting exercises (Figure 3.7).

### **3.3.1.6. Seed collection and processing for planting**

#### **1. Ground nut seeds**

Ground nut is the fifth most important crop widely grown in Sierra Leone. It is cultivated in friable dry soils with only field capacity water; predominantly in the upland. It can be also cultivated in lowland such as the inland valley swamps during the dry season. It is highly tolerant to droughts and can grow in wide range of soils; from gravel stone loam to sandy clay or loamy. The most prominent edaphic factor for the growth of ground nut is the soil being well drained since it does not grow in any water logged condition.

The color of the seeds of the local ground nut mostly cultivated in Sierra Leone can be brown or red (Figure 3.8). The seeds used in this experiment were obtained from the farmers' stock. These two varieties are normally used in this mixed manner with little or no concerns about their differences by the farmers in terms of production and quality. The ground nut pods were shelled manually and the seeds removed, winnowed and weighed for planting. For each group, the seeds were weighed using a spring balance and the weight recorded before planting (Figure 3.9). After the planting of each plot, the remaining seeds are again weighed to know the amount of seeds used in each treatment plot.



This was to determine the exact quantities that were used in each treatment of the plot.

#### **2. Jatropha seeds**

The jatropha seeds were collected from different sources by different people in and out of Bombali district from jatropha trees that could be found around houses and along hedges in both rural and urban settlements.

Reports from people bringing or selling these seeds to the researcher are that the seeds were collected from the ground under the jatropha plant, the epicarp removed and the dried seeds placed in either plastic bags or open plastic containers before collecting them. The seed collection was mainly done on request by the researcher as these seeds were completely useless to the people who owned the trees before this research intervention. Since these seeds were collected



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from different people and at different times, it was difficult to assess their viability due to the different treatments given to them during harvesting, processing and storage before collecting them from the owners (**Figure 3.10**). The seeds collected were counted, weighed and placed in plastic bags ready for planting.

The process was the same for the seeds of *jatropha gossypifolia* which was another common variety planted in Sierra Leone. The seed collection was a very big challenge for this research because the jatropha plants were found in irregular points as either purely ornamental plants or growing wild in the environments; predominantly near old community settlements. There were no known agronomic practices to handle the harvesting, processing and storage of these seeds by the people who supplied the stock planted in the research site. On the other hand, there was no enough time to test the germination rate of these seeds before the planting into the field as there was very little time left for the planting season to expire after the early rains of May in Sierra Leone. This prompted the direct sowing of seeds into the field of research as they were obtained from the suppliers from the different locations around Makeni.

### 3.3.2. Planting phase

#### 3.3.2.1. Modern method of row planting of jatropha seeds

##### Spacing for the planting of jatropha seeds

The planting of jatropha was done using a modern method of row planting with definite spacing together with the farmers in the field of research. The farmers were taught on the use of the 50 m tape measure to measure distances of 2 x 2 m in the already demarcated plots of the two treatments of jatropha intercropped with ground (JIG) and jatropha as sole crop (JSC).



Materials such as the 50 m tape measure, pegs, garden lines and long slender sticks were used by the farmers to carry out the 2 x 2 m spacing for the jatropha (*jatropha curcas* and *jatropha gossypifolia* varieties) plants in the research plots (**Figure 3.11**).

The planting was commenced by dropping a single seed of jatropha in each spot marked by the farmers; making a spacing of 2 x 2 m apart in each treatment.

##### Planting of the jatropha seeds

Planting of the jatropha seeds is done manually by the researcher, who demonstrated to the farmers the number of seeds per hole and the depth of planting. Each demarcated point was planted with a seed of jatropha at a depth of 2-4 cm deep and seed was covered with fine soil tilth. All large stones and debris were removed from the spot of the planted seed to allow easy or undisturbed emergence of the seedling. The two varieties of jatropha (*jatropha curcas* and *jatropha gossypifolia*) were planted in the ratio of 4:1 plots respectively. Four plots were used to plant *J. Curcas* and 1 plot for *J. Gossypifolia* using the same 4 m<sup>2</sup> spacing. This planting was done in holes already demarcated by the farmers during the spacing process in which either the 50 m tape measure was used or the 2 m long stick that has been designed to do the spacing by these farmers in the plots (**Figure 3.12**).

The planting of the jatropha seeds was done using either the cutlasses or the small hoes by the farmers within the same day when the ground nut was planted in the treatments. For each plot of the 5 groups, 1250 seeds were planted making a total of 6250 jatropha seeds for the 5 plots. Plots 1-3 and 5 were

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planted with *J. Curcas* while plot 4 was planted with *J. gossypifolia*, making the ratio of *J. Curcas* to *J. gossypifolia* 4:1 respectively.

### **3.3.2.2. Planting of ground nut seeds**

Ground nut was planted as an intercrop amongst the jatropha in 0.8 ha of the entire 0.5 ha of each experimental plot. The already processed and weighed seeds of ground nut were planted by the farmers in the described area of the research plot. The seeds were planted using small hoes in the already ploughed area of the experimental plot. The spacing of ground nut seeds was done in an estimated manner as the planting was done manually; mostly by the women of the research farmers. The hoe was handled with one hand about 30cm from its blade by the planter and a hole was created by scratching the soil with the blade where the ground nut seed was dropped with the other hand and then covered with fine soil tilth (Figure 3.13). This process was repeated by all the planters making rough dimensions of 15 cm x 30 cm or 15 x 25 cm, depending on the skill and experience of the planters.

The depth of planting ranges from 2-3 cm deep. During the planting process all weeds germinating in the ploughed soil surface were removed together with any big stone or stick debris. This was to give ample space for the easy emergence of the young ground nut seedlings with little or no obstructions by these objects. The ground nut seeds were properly covered with the soil to prevent or minimise the incidence of pests from eating the seeds.

Scaring of pests from the planted ground nut was not possible because all the farmers were busy with their other respective farm operations which cannot allow them to stay in the research site within the 7 days when germination was expected to be complete. It was however observed that no eminent destruction was done to the planted ground nut seeds in the research plots by these pests above the threshold levels.

### **3.3.3 Post planting phase**

#### **3.3.3.1. Population densities of Jatropha and ground**

##### **Jatropha population density assessment**



The population density of the jatropha was assessed by head counting of the germinated plants in each plot and the total number recorded. This was done in the two different treatments of jatropha sole and intercrop in each plot and results recorded.

##### **Ground nut plant population density assessment**

The population density of the ground nut crop was assessed by using the 1 m<sup>2</sup> quadrat method in each of the 5 plots of the experiment 1 month after planting. Five different quadrates were taken in each plot and number of ground nut plants in these quadrates was recorded. This was to get the average population density of the ground nut crop in the treatments of jatropha intercropped with ground (JIG).

#### **3.3.3.2. Jatropha growth assessment**

The growth assessment of the different varieties of jatropha plants was carried out at an interval of 1 month after planting until the 6<sup>th</sup> month when the dry season eminently affected the growth rate due to lack of adequate field capacity water that can support visible physiological activities.

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Twenty plants were selected randomly in the central part of each treatment (JIG and JSC) in the 4 experimental plots. For each assessment period the growth rate was measured using the following plant parameters: the vertical height (in cm), number of leaves, number of branches and number of flowers or fruits (when available) (Figure 3.14).

With the use of a tape measure or meter ruler, the vertical height of the jatropha plants which were selected at random in the centrally located region of the treatment were measured in centimeters and such measurements recorded. The number of leaves, branches and fruits (when available) of the same plants was counted and record. This exercise was repeated every 1 month since June, in all the treatments of the 4 plots until January when the visible growth of the crops came to a standstill due to the souring dry season when there was little or no additional water to support the active physiological activities in the plants.

### **3.3.3.3. Weeds and weed prevalence assessment**

#### **Weeding**

Weeds were noticed in all the two different treatments of JIG and JSC two weeks after the planting of the jatropha and ground nuts in the plots. Weeding was scheduled to take place a month and half after planting of the crops by the farmers of the research project.



Weeding was done manually using cutlasses and hand pulling of the weeds from the crops i.e. amongst jatropha and ground nut plants (Figure 3.15). The number of farmers present for this farm operation was recorded by the farmers' group leaders. The weeding progressed with the dates of planting in the different plots; weeding the first planted plots followed by the second and so on. The plots were weeded by all the farmers involved into the research like was accomplished with the other activities, were each member was either present or sent a representative (Figure 3.16).

#### **Weed assessments in the treatments**

Weeds assessment was carried out in two stages in the treatments of the plots. The prevalence was assessed a month after planting of ground and jatropha in the treatments and one month after the harvesting of ground nut in the treatments. The process used to assess the population density of weeds in the field was the 1 m<sup>2</sup> quadrat method. Five different locations were selected within the 2 treatments of each plot and with the use of the meter square quadrat the number of weeds present were counted and recorded. This was done in plots 1 and 2, 3 and 4 in each of the treatments of JIG and JSC. The method was repeated in the same treatments a month after the ground was harvested to find out how much weeds have re-emerged from the two treatments (JIG and JSC) in the 4 plots and data recorded.

### **3.3.3.4. Pest identification and control**

Pests are major agents that have been known to have adverse effects on crop production in Sierra Leone and Africa at large. They range from micro (invisible organisms) to macro (easily visible organisms) in the fields of cultivation. In this research pests have been identified from the time of sowing of the ground nut seeds in the field to its harvest. Also pests have been identified with the jatropha plants in the field with the naked eyes as there was no device used to verify the damages caused by some of these pests. The pests included birds, rodents and insects (Figure 3.17). There was no special device used to identify these pests. Instead, they were identified through series of visits and

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physical observations on the damages they caused in the field. It was observed that the pests seen destroying ground nut at the germination stage included guinea hens, bush fowls and squirrels, which were active during the day while the crickets and ants were more active at night; all eating the seeds directly as they try to germinate or emerge from the soil or when uncovered by the planters.

During the growth process of ground nut plants the rodent pests called cane rats and porcupines invaded the plots. Cane rats and porcupine (Figure 3.18) feed on the young ground nut pods by uprooting the entire plant from the soil. These are small mammals that live in groups of 4-6 in any given ecology at a time. They are mostly active at night while they rest in quiet cold bushes during the day. Their feeding activities can destroy a whole farm if no proper and timely control interventions are taken. Some protective measures were taken by the researcher and farmers to control their activities to threshold. However, the damage caused ended up destroying one of the plots of the experiment which was plot 5. They eat all the ground nut plants which led to the aggressive growth of weeds in the plot, which was consequently abandoned by the research team. This led to the entire research to end up with 4 plots. Plots 1-3 were planted with *J. curcas* while plot 4 was with *J. Gossypifolia*.

Prominent amongst the insect pests also were the grasshoppers. They attacked both the leaves and even the stems of the jatropha plant. They were however seen to be more active with *jatropha gossypifolia* than *jatropha curcas* in the experimental field. There was no device used to measure the effects of these insect pests damage in the field during this research; only visual observations were carried out in the respective treatments and plots.

### **3.3.3.5. Harvesting and crop yields assessment of ground nut and jatropha**

#### **Ground nut harvesting**

The harvesting of ground nut took place 90 days after planting. This was done immediately by the farmers to avoid the ground nut pods remaining in the soil or re-germinating.



The harvesting was done manually by uprooting the entire plants with the hands together with the pods (Figure 3.19). The uprooted plants were placed in a single place, spreading the straws with the ground pods exposed enough into the sunlight to get dry. The spread ground plants were left in the field for a week to allow the pods to dry and the stalks attaching the pods to the stem of the plant shrink to allow easy plugging of these pods from the stems.

The spread ground nut stems are left in the field for a week before the farmers went back to plug the ground nut pods from the stems (Figure 3.20). The plugging is again done manually by removing the ground nut pods from the straw. Small containers were used to collect the ground nut pods which were emptied into bigger plastic bags and carried to the village from final drying. The harvesting and plugging of the ground nut were done by both men and women of the research team (Figure 3.21).

#### **Assessment of ground nut yield**

The yield of ground nut was assessed by both the farmers and the researcher from the field's harvest. The process involved the use of the 1 m<sup>2</sup> quadrat by the farmers and the researcher in the treatment containing ground nut plants (JIG) in each plot.

The 1 m<sup>2</sup> quadrat was used with 5 randomly selected points in each of the four plots. This was done at the centre of the treatment. Every 1 m<sup>2</sup> space of the ground nut plants was harvested and the stems

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tied together to be plugged later (**Figure 3.22**). The 5 different samples from the 4 plots were taken to the village and dried for 5 days. The dried quantities were winnowed and weighed to get the weight of each 1 m<sup>2</sup> ground nut pods from the ground nut treatments. The process was the same as the normal situation used by the farmers to ensure there were no variations in the quantity harvested by the farmers and the one harvested for the assessment purpose.

### Assessment of jatropha reproduction

The reproduction of jatropha crop has been the major focus of this research during the period under review. It has been observed that the two varieties of jatropha can reproduce within one cropping year. However, the two varieties show different periods of reproduction during the growth and reproduction cycles.

*Jatropha gossypifolia* which tends to grow very fast when compared to *jatropha curcas* was observed to set on its flowers and fruits 4 months after planting, while *jatropha curcas* started flowering 6 months after planting. The reproduction process of these crops however came to a halt in January when there were no more rains to provide adequate water that could support the physiological activities of the plants. Since the entire production process was a rain-fed system, its recession brought the entire active growth rate of the crops to a standstill.

The yields of these two jatropha varieties were not calculated due to these factors:



1. the research period was completed from the field after 6 months, hence was unable to collect the fruits of the crops from the field after that period;
2. the dry season interrupted the reproductive life cycle of the jatropha plants as there were no more rains to support the growth and reproduction of the crops. In fact, it was reported that the crops dropped all their leaves to avoid excess evapo-transpiration of the limited water from the soil through the leaves (**Figure 3.23**) and
3. attack of the jatropha crops by insect pests (grasshoppers) in the field which ate the remaining leaves of the plants.

The entire cultivation system was totally dependent on the natural rain cycle (rain-fed) which implies the plants must adapt a system of surviving the 6 months long dry season by dropping most of its leaves to conserve the water in the soil for its survival during the dry period.

The reproduction of the fruits by the two jatropha varieties: *J. Curcas* (**Figure 3.25**) and *J. Gossypifolia* (**Figure 3.24**) was interrupted by the dry season period from January, due to the tremendous loss of most of its leaves as a means of conserving the soil's limited amount of water for its survival during the dry spell of the season.

#### 3.3.3.6. Mulching of jatropha plants

Mulching is the spreading of any suitable materials (soil, plant remains, or plastic) around a plant to protect it from adverse conditions and add to the soil's nutritional value for the use of the intended plant. The dry ground nut straws were used to mulch the jatropha crops in the treatment planted with ground nut only. The mulching involved the spreading of the already dry ground straws that have been plugged off the ground nut pods, which the farmers use as food and the remains were used as organic mulch which will eventually become fertilizer for the growth and reproduction of jatropha. The straws

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which were already dry were spread around the jatropha plants by the farmers with their hands (**Figure 3.26**).

### **3.3.3.7. Rural chain to transform jatropha seeds into Pure Vegetable Oil (PVO) and electricity**

Whilst the jatropha seed production has been carefully examined using the traditional and some modern agronomic practices, the chain of the entire process to generate electricity at community level will not be complete without the proper transformation of these seeds into PVO which can be used into an internal combustion (i.c) engine. Seeds can be transformed into two major ways: a) for further propagation to new plants and b) for PVO to generate electricity and other by-products.

This literature review carefully examines how seeds can be transformed into electric energy to be used in rural communities in Sierra Leone (**Figure 3.28**).

Harvested seeds need to be stored before being processed as either for planting or oil production. The storage method is therefore very crucial in this case.

Some publications have confirmed that the storage method is very important to determine the seed viability for further planting or the production of oil [**J. Moncaleano-Escandon et al., 2013**]. Seeds must be stored in dry places with low humidity. The preferred containers (bags) should be jute or other local suitable fibers.

The period of storage of the seeds must be precise to maintain the viability of the seeds for either oil production or propagation.

The extraction of PVO from seeds can be done in two different ways. It could be chemical or mechanical. The mechanical method is further divided into motorized and manual. For the purpose of this study, the manual mechanical means is highly recommended since it can be used in the rural community with less cost and does not need any other electrical or mechanical energy to carry out the extraction (**Figures 3. 28 and 3.29**).

The purification of the Crude Vegetable Oil (CVO) to PVO can be done in three ways:

1. sedimentation;
2. filtration and
3. flotation in water.



Sedimentation involves the passing of the CVO into three different tanks to separate the oil from its impurities to get PVO which can be used in a specially designed i.c. engine to generate electricity (**Figure 3.30**).

This method is seen to be most suitable for rural communities since it does not involve the addition of any other chemicals, costs or the use of energy to get the purity of the oil. However, this method could be slow since it involves 2-4 days in order to get the desired quality of the PVO.

Filtration is the process of passing the CVO through series of filters to obtain the desired purity of the PVO. This involves careful monitoring, cleaning and changing of filters. This method is not suitable for rural communities since it involves the high cost of the filters and the technical aspect of monitoring the quality of the oil by the illiterate farmers.

Flotation in water is a very good method of purifying CVO since it can remove most of the impurities but involves other auxiliary activities such as pre-heating, continuous mixing and final separation of the PVO.



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This will create additional use of energy, cost and high technical skills which cannot be met by the farmers, thus it is not suitable for rural purposes to generate electricity [W. Rijssenbeek, 2010].

Storage of the oil is a key factor to enable the efficient performance of the engine into which the PVO is used. The most appropriate method of storing the oil is in plastic containers in ambient temperatures to ensure little or no further reaction of the oil with its environment. [F.O. Abulude, 2007]. The period of the PVO storage must be carefully determined to avoid exceeding its useful quality with the i.c. engine to be used.

The PVO can be used directly into special diesel engine Cycle, without going through the trans-esterification reaction [K. Nahar, S.A. Sunny, 2011], industrial process developed to produce a bio-fuel (called bio-diesel) very similar to the gasoil. Of course, the trans-esterification process is not suitable for rural community use.

Consequently, the use of a specially designed engine (like, for example, Lister engine) -that can carry out effective combustion of the PVO- is necessary in this case for the local rural communities.

### 3.4 Results and discussions

#### 3.4.1 Pre-planting phase

Pre-planting activities which included the brushing, clearing of debris after burning and ploughing (with small hand hoes) has a total cost of 555,000 Le·ha<sup>-1</sup>. The total time involved in carrying all these operations was 148 h·ha<sup>-1</sup>, while the work capacity of the human labor involved has an average of 0.035 ha·h<sup>-1</sup> (Figure 3.31).

#### 3.4.2 Planting operations



##### 3.4.2.1 Planting of ground nut and jatropha

The planting operation included the sowing of ground nut and jatropha seeds. This was achieved at a cost of 680,500 Le·ha<sup>-1</sup>. The cost of labor was (300,000 Le·ha<sup>-1</sup>) and the cost of the jatropha and ground nut seeds (380,500 Le·ha<sup>-1</sup>), (Table 3.1). The total time spent on these operations is 80 h·ha<sup>-1</sup>, with a work capacity of 0.026 ha·h<sup>-1</sup>.

#### 3.4.3 Post planting operations

Post planting operations or activities involved weeding, pest observation and control, harvesting, plugging and drying of ground nuts. This phase of the field work had the highest cost of 1,320,000 Le·ha<sup>-1</sup> per hectare. The total human time spent in all these field activities is 352 h·ha<sup>-1</sup> while the work capacity is 0.047 ha·h<sup>-1</sup>.

The total cost of production is 2, 555,500 Le·ha<sup>-1</sup> using a total time of 580 h·ha<sup>-1</sup> and an average work capacity of 0.107 ha·h<sup>-1</sup> (Table 3.2). All these activities were carried out within a period of 7 months of the experiment.

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### 3.4.3.1 Population densities of crops

#### 1. Ground nut

The ground nut germinated 5 days after planting in the field. Its germination percentage was excellent with 95%. The average stands of ground nut plants per meter square were 26, which makes up for a spacing of 15 cm x 25 cm. The total ground nut plant population density per hectare was therefore estimated to be 26,666,667 plants·ha<sup>-1</sup>.

#### 2. Jatropha

Germination of jatropha was at 5 to 7 days after planting. The jatropha seeds planted had very poor germination rate of 10% in this experiment; hence its population density which was expected to be 2,500 stands·ha<sup>-1</sup> was rather 250 stands·ha<sup>-1</sup>. This was mainly due to the undefined source of the seeds and the poor management before reaching the researcher for planting.

### 3.4.3.2 Growth assessment of jatropha

The two varieties of jatropha (*J. Curcas* and *J. Gossypifolia*) used for the experiment have different growth responses in the field of cultivation. *Jatropha gossypifolia* can grow more rapidly in the field and can reproduce seeds at the age of 4 months after planting, while *jatropha curcas* grows slower and can reproduce seeds only after 6 months of planting (Figures 3.34 and 3.35).

In terms of the two treatments of jatropha intercropped with ground nut (JIG) and jatropha as sole crop (JSC), different performances in terms of growth of the 2 varieties were noticed.

#### 1. The vertical growth rate

In all the two varieties planted, the jatropha realised better vertical growth rate in the treatment with ground (JIG) than the ones as sole crops (JSC). With *jatropha curcas* variety, at the 6th month after planting, it was able to attain a vertical growth height of 61 cm in JIG while with JSC it was 35 cm. With *J. gossypifolia*, which tends to grow faster than *J. curcas*, it attained a vertical height of 97 cm with JIG while with JSC was only 43 cm in 5 months;

#### 2. The number of leaves



In all the two varieties in the experiment, the leaf production rate of the plants was higher in JIG when compared with the JSC. An average of 16 leaves was obtained by *J. Curcas* with the JIG treatment while there were only 9 leaves with the treatment JSC at the 5th month. With *J. Gossypifolia*, an average of 11 leaves was realised with JIG while there was only 6 with JSC at the same period i.e. 5th month (Figure 3.35);

#### 3. The branching and canopy spread

The branching and canopy spread of the two varieties showed much difference between the two treatments of JIG and JSC. Although *Jatropha Curcas* is a very poor branching variety, it however showed a better canopy spread with JIG when compared with JSC at the 5th month after planting. With the *J. Gossypifolia* which has a better branching ability, the data showed that there is better branching and eventually better canopy spread in the treatment with ground (JIG) when compared with jatropha sole cropping (JSC) at the 4th month;

#### 4. Fruit reproduction

With the *jatropha gossypifolia* which was able to reproduce fruits at the 4th month after planting. The data shows that more fruits were produced with the JIG treatment, while there was nothing realised from the JSC at that age (Figures 3.33 and 3.34).

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In summary, it can be observed that the general performance of the jatropha crop (*J. Curcas* and *J. Gossypifolia*) is better in the treatment with ground nut than when cultivated as a single or sole crop in the upland ecology.

#### **3.4.3.3 Weed prevalence and weeding**

Weed prevalence was observed to be higher in the JSC than in the JIG (Figures 3.37 and 3.38). The inclusion of ground nut as an intercrop in the cultivation of jatropha might have contributed to the suppression of the weeds in the JIG treatment when compared with the JSC. In all the two sets of weed prevalence assessments, it was observed that weeds dominated more in the treatments without ground nut in the jatropha experimental plots. This higher weed prevalence in the JSC might be one of the reasons why the rate of jatropha performance in the field of cultivation was less than in the JIG. Also, it can be seen that the cost of weed control is high with a total amount of 652,500 Le·ha<sup>-1</sup> (for 1st and 2nd weeding) during the single production season. This farm operation consumes a lot of the farmers time (174 h·ha<sup>-1</sup>) during the production process.

Therefore, the inclusion of ground nut as an intercrop will not only help in enhancing the addition of nutrients in the form of nitrogen to the soil but also acts as weed suppressor for the jatropha crops, hence reducing the time and energy spent in controlling these weeds and also averting the incidence of pests using the weeds as secondary hosts to attack the jatropha plants.



#### **3.4.3.4 Ground nut yield rate and income assessment**

The average yield of ground nut per hectare in this research is 0.820 t·ha<sup>-1</sup>. The cost of this quantity in Leones per hectare is 6,150,000 Le·ha<sup>-1</sup> (≈1160 €) (Table 3.7 and Figure 3.38). According to the data, the total cost of production is 2,555,500 Le·ha<sup>-1</sup>; therefore the production analysis will definitely yield some positive returns to the farmers with a profit of 3,594,500 Le·ha<sup>-1</sup>. The cost of ground in Sierra Leone is 7,500,000 Le·t<sup>-1</sup> (≈1415 €·t<sup>-1</sup>).

This makes the cultivation of jatropha even more acceptable to the farmers because there is an immediate benefit of the exercise even before the harvesting of the jatropha for the extraction of bio-fuel for the generation of electricity for the rural people. In addition to ground nut being useful as nutrient provider, weed suppressant and source of food for the people, it also creates a ready source of income for the rural poor farmers. Therefore, it psychologically creates a room of hope for the farmers to accept the growing of jatropha which does not seem to be much beneficial to them during the first one or two years for generating electricity for their domestic use.

#### **3.4.3.5 Mulching of the jatropha**

The use of the ground nut straw to mulch the jatropha plant in this experiment showed some tremendous benefits after the harvesting of the ground nut in the plots. The spreading of ground nut straw as mulch, 3 months after harvest; has valuably contributed to the additional provision of organic manure to the jatropha plants, suppressing the weeds, reducing the rate of water lose into the atmosphere around the jatropha, especially when it was approaching the dry season in October and November and encouraging the activities of the macro and micro-organisms in the soil. This can be attributed to the increased growth of jatropha (*J. Curcas* and *J. Gossypifolia*) in the treatments with ground as intercrops when compared with jatropha as sole crop (Figures 3.33 and 3.34).

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### 3.3.3.6 Pest effects and control

No numerical data or estimates on the effects of pests were carried out in this experiment. However, the effects of pests can be clearly shown from the physical damages caused to both the ground nut and the jatropha during the production process. The 5th plot of the experiment was damaged by bush fowls, Guinea hens, cane rats and porcupines. The leaves of *J. Gossypifolia* were almost eaten by grasshoppers, while the rats were identified to eat a lot of the ground pods uprooted and packed in the field for plugging by the farmers. It is therefore very eminent that the pests must be controlled by the farmers to ensure maximum realisation of the production level of both the intercrop and jatropha plants. However, in Africa generally Flea beetles (*Aphthona spp.*) eat the leaves and their larvae penetrate the roots [Nielsen 2007, Gagnaux 2008]. The yellow flea beetle (*Aphthona dilutipes*) appears to cause more severe damage than the golden flea beetle, sometimes resulting in 100% mortality. The yellow flea beetle has been known in Manica Province in Mozambique and also noticed in another farm in Malawi where it also causes severe damage. These were not experienced in this research since not much time was available to investigate their availability and damages with the jatropha crop in the field.

### 3.4.3.7 Jatropha reproduction state

From the data collected, results show that *J. Gossypifolia* was able to produce its first fruit at the age of 4 months after planting, while *J. Curcas* was at 6 months after planting. This result confirmed that jatropha can reproduce its seeds in one cultivation season (6 months) of the year but further showed that the production level was very low due to the height and age of the crops.



The eventual change of season; from the rainy season (May-October) to the dry season (November-April) can vehemently interrupt the growth and reproduction activities of jatropha in the field. As mentioned above, the jatropha, being a broad leaf crop, drops almost all its leaves during the dry season, hence becoming virtually dormant in terms of active growth and reproduction of fruits during this period.

The cultivation of this crop therefore must be time bound with great care in managing the crop well during the rainy season to maximise its growth and reproduction performance. The use of chemical fertiliser might be possible if the farmers cannot continue with the cultivation of ground nut every year to augment the nutrient content of the soil for the plant.

### 3.4.3.8. Harvesting and dehulling (shelling) of jatropha fruits

Although this research did not carry out any harvesting due to the limited period on the field activities; studies have however shown that harvesting of the jatropha seeds is a difficult process due to the ripening characteristics of the jatropha fruit. Due to these ripening issues, the harvesting of jatropha is mainly done by hand. The harvesting process becomes a very labour-intensive process, and has a high impact on the production costs of jatropha oil. Harvesting, therefore, is an important aspect to consider in the entire production process. In Tanzania and Congo, data have shown that 50 to 60 kg of jatropha fruits can be harvested by day depending on the population density of the plants. The manual harvesting of the crop takes about 30% of the total cost of production in some farms in Africa and other places [W. Rijssenbeek, 2010].

There have been many attempts to improve this process by mechanisation. These mechanical improvements are still under development, however, and have been applied only in pilot projects.

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The dehulling principle is based on provoking slight pressure and friction on the fruits within the dehuller that results in the opening and coming loose of the fruit shells (Figure 3.48). There are different types of dehullers; from manual to motor driven. Most of the existing dehullers are designed for industrial uses and large volumes. Similar dehullers are used for coffee and peanuts. There are also small, locally made types in use, which are made of local available materials, using manpower.

Dehulling can be done with fresh (yellow) fruits or with dry (brown) fruits. The shell of a fresh jatropha fruit is approximately 5 mm thick, while the shell of the dried fruit is approximately 1 mm thick. Dehulling the larger sized fresh fruit has the advantage of provoking more friction, which results in a higher dehulling efficiency than of dry fruit. The fruit shells come out of the dehuller mixed with the seeds and they need to be separated [T. Galema, 2010].

#### **3.4.3.8 Rural transformation of jatropha seeds into PVO and electricity**

##### **Seed drying and storage**

###### Drying

When the seeds are separated from the fruit shells they have to be stored for use. It is best to transport the seeds from the field to the processing area. Transport modes are tractor carts, donkey carts, bikes or manual. The seeds require drying to 6% moisture content (ideally) before pressing.

The drying process takes place for the individual seeds, while storage takes place in sacks. The yield per hectare, period of harvesting and the duration of drying determine the size of the drying area needed for drying. If one looks at the area needed, it is estimated that one seed requires about 2 cm<sup>2</sup>, so 1000 seeds, which can weigh 550 to 800 grams, require 0.2 m<sup>2</sup> (average would be 1400 seeds/kg<sup>-1</sup>). Per kilogram of seed, this would be around 0.25 m<sup>2</sup>. After drying the seeds can be placed into woven sacks (aeration) and or jute or other locally available fibre containers for further storage.

###### Storage



The bulk density of jatropha seed is estimated at a cubic area of 400 kg·m<sup>-3</sup>. This is for air-dry seed of 0.8 grams per seed.

The design of a storage shed needs to have a large roof and an open or semi-open wall structure. It can be similar as one used to store maize. It should be well aerated and the containers should be open bins, just like those for maize. Yet jatropha seed is not eaten, so fumigation is not needed. Since 400 kg per cubic meter can be stored, the net volume for the storage shed for 665 kg·ha<sup>-1</sup> estimated in this study will be 1.7 m<sup>3</sup>. The shed for a hectare should be 1 x 1 x 1.7 m=1.7m<sup>3</sup>.

The storing of seeds for either further propagation or oil production is characterised by factors such as the humidity, duration, type of container and the temperature of the store.

It has been proven from research that the viability of jatropha seeds is at maximum 9 months, whilst it shows its best germination performance at 3 months after harvest [K. J Sowmya et al., 2011] (Figure 3.39).

The humidity of the storage system must be low to avert the incidence of seed moulding, especially during the rainy season in Sierra Leone. The temperature must be moderate in the store (20-25°C). This is however difficult to achieve in Sierra Leone which has an average temperature of 30 to 35°C. In the rural communities where some of their houses are made up of thatch, this could serve as ideal store

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centre during the dry season since they maintain lower temperatures of 28-32°C during the dry season. This could however be a problem during the rainy season because they are normally very humid during this period, hence may affect the quality of the seeds if not removed to corrugated iron sheet (zinc) stores.

The containers used to place the seeds should be fiber bags made up of jute or other suitable local materials [A. Kumar et al., 2010]. This will help to maintain good status of the seeds in terms of their physical and chemical contents as reported by a research in India [S. Karaj, and J. Müller, 2010] by maintaining a moisture content (m.c.) of 5-7%.

#### CVO/PVO extraction

Basically, the process of getting oil from oilseeds is as old as mankind. Although the means that were used for this purpose have evolved, it still entails the crushing of the seeds to extract the oil. There is not much practical experience with pressing of jatropha seeds to draw upon. GTZ (German Agency for Technological Co-operation) was one of the first organisations to be involved in jatropha pressing in the late 1980s and early 1990s. New studies on expelling and cleaning of jatropha started at other institutions, including the WUR (Wageningen University and Research Centre) and RUG (University Groningen) in the Netherlands. In addition to these big research institutes, smaller, practically oriented initiatives by jatropha enthusiasts have yielded interesting results [P. Beerens et al].

The extraction of CVO is a critical activity that will determine the success of the entire process of producing electricity from plants. In this process, series of other related activities must be carried out such as the removal of the epicarp from the seeds, examining the moisture content and determining which method could be used for the extraction.

The removal of the epicarp can be done mechanical or manually. The manual method is however described above (*dehulling*) for this study since it does not involve any addition cost through the use of electrical or mechanical energy in the village.

From theoretical point of view oil extraction from jatropha seeds can be carried out in two ways:

1. mechanical and
2. chemical.



The mechanical method involves the use of machine through the application of high pressure to remove the oil. This mechanical method can be manual or motorised.

The manual method involves compressing the seeds in a machine called ram press [K. Bielenberg, 1985]. The capacity of this method is limited to 2-3 kg·h<sup>-1</sup>. At a recovery rate of 70-80% and an oil density of 0.918 kg·dm<sup>3</sup>, this means < 1dm<sup>3</sup>·h<sup>-1</sup>. This implies, in order to extract a quantity of 665 kg·ha<sup>-1</sup> of dry seeds using a single manual machine and an operator, it will need 665/3 kg x 8 h = 28 days·ha<sup>-1</sup>.

Recently, the aspect of developing the supply chains for the generation of energy in developing countries has been studied through the use of manually operated mechanical methods [R.C. Pradhan et al., 2009]. Machines of this type are in India, with working capacity of 30-60 kg · h<sup>-1</sup>.

The manual mechanical method tends to show  $\eta_{EXT} = 65 \div 75\%$ , the motorized mechanical method showed  $\eta_{EXT} = 98\%$ .



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Despite the higher extraction efficiency of the motorized machined, the manual mechanical machine such as the ram press has the following advantages that makes it more suitable for rural community:

1. simple structure;
2. low maintenance and repairs;
3. meager investment and low operating costs;
4. minimal specialization of operator and
5. low production level.

At rural local community level therefore, the use of the manual mechanical method is most appropriate. This is because it does not involve the use of additional mechanical or electric energy rather than the human (farmer) effort although this may result to low oil extraction (65-75%). To press oilseeds, as in all production processes, power is needed. Small presses like the Bielenberg ram press can be powered by hand, by one or several operators. Capacity is then typically 3-5 kg seed·h<sup>-1</sup>. One hour of press operation costs 3000 kilojoules if operated by 2 persons and roughly produces 1 litre of oil per hour. This comes down to an energy consumption of **0.85 kWh·dm<sup>-3</sup>**.

Larger capacity presses, especially the expellers, are engine driven. In general, electrical engines are chosen because of their ease of installation, coupling, operation and low cost. As a rule of thumb 1-2.5% of the energy content of the produced oil is used as input power [P. Beerens, 2010]. It is, however, perfectly possible to couple the press directly to a diesel engine to be independent of grid – the diesel engine can even run on the jatropha oil that it is pressing. In case an expeller is powered by a diesel engine, the energy input will be 5-10% of the energy content of the produced oil [8]. Because of the superior oil recovery rate of the expeller this comes down to 100-200 joules·kg<sup>-1</sup> or **0.30 kWh·dm<sup>-3</sup>**. From energy efficiency point of view the expeller is preferable, although one should keep in mind that the electricity or fuel required are not available in many rural areas.



The chemical method involves the use of solvents to remove the oil with a good efficiency, but is not simple to apply. There are series of problems between the oil and the solvent such as the viscosity, temperature and miscibility.

When the two systems were compared the oil extraction efficiency was seen to be better with the mechanical ( $\eta_{\text{EXT}} = 95.9\%$ ) than the chemical ( $\eta_{\text{EXT}} = 79.3\%$ ) [C. Ofori-Boateng et al., 2012].

This however largely depends on the moisture content of the seeds in question. Studies have revealed that the higher the moisture content, the more pressure is needed to extract the oil [A. Kabutey et al, 2011].

The net quantity (Net extraction efficiency) of oil extracted from the seeds can be calculated by the amount of energy input compared with the oil output relating to its crude and pure states.

$$\eta = \frac{\sum E_{out}}{\sum E_{in}}$$

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Where  $\eta$  = Net extraction efficiency,

$$E_{out} = \text{Quantity of energy output}, E_{in} = \text{quantity of energy input}.$$

The seeds contain 30–35% oil by weight, which can easily be converted into bio-diesel meeting the standards of US, Germany and European Standard Organization [Azam et al., 2005].

#### Temperatures in CVO extraction

The quantity of oil extracted from seeds can also be influenced by the temperature during the process. Higher temperatures are known to affect the viscosity of the oil by decreasing it but in this case it has led to increasing it hence the quantity of oil extracted increases. This however can lead to increase in the impurities of the oil (Figure 3.41). Apart from the temperature, the quality and quantity of the oil can also be affected by the maturity of the seeds [Tigere TA et al].

#### Seed maturity

The more the seed are mature, the less the level of Free Fatty Acids (FFA) (Figure 3.41) hence the better the CVO could be.

The oil extraction efficiency therefore can be calculated by using the formula:



$$\eta_{ext} = \frac{m_{oil\ extracted}}{m_{oil\ extractable}} = \frac{0.2511}{0.35} = 0.72$$

If the seeds have 35% of oil and the quantity extracted is 25%, then the oil extraction efficiency will be 25/35, the extraction efficiency will be  $\approx 0.72$ .

#### CVO purification

This involves the cleaning up of the extracted crude oil from series of **impurities** that may cause damage if used into the machines or in other purposes. The crude jatropha oil leaving the expeller contains 5-15% solids by weight. This comes down to 10-30% by volume, depending on what the sediments are. In addition, the circumstances during pressing and the intended application for the oil may require further processing of the crude oil. For soap-making and lamp fuel, the quality requirements are less stringent than when applying the jatropha oil in a diesel engine. In most cases, vegetable oil produced by cold pressing does not require degumming and neutralization. Prior to use in a diesel engine the oil should be free of all particles  $> 5\ \mu\text{m}$  to prevent clogging of fuel filters. Normal diesel fuel filters have a pore size of 5-10  $\mu\text{m}$ . The cleaning process should follow shortly after the pressing process to avoid filtration problems when the oil was stored under unfavourable storage conditions.

The impurities present in jatropha oil consist of both dissolved and suspended particles that are not part of the structure of the oil. Solid particles, FFAs and phosphor need to be removed before the oil is ready to use in engines. Removal of these impurities is also required to prevent deterioration of the oil during storage. Water (both free and intermolecular) will, for example, hydrolyze the oil and stimulate the formations of FFA. Pro-oxidant metals like copper and iron will speed up oxidation. Dust or solid particles that might have not been filtered from oil will not affect the oil itself but the usage of the oil will be more difficult. It is therefore important to monitor feedstock (moisture level & freshness) and oil quality after cleaning.

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To assure good PVO quality the German DIN V 51605 was introduced in Europe in 2007. This norm is based on the earlier 'Quality standard for rapeseed oil as fuel 5 / 2000' from the German Bavarian State Institute of Agricultural Engineering, Wiehenstephan. In order to minimize the negative effects on engines, PVO from jatropha should comply with this DIN V 51605 norm for plant oil.

Three main methods are involved here:

1. sedimentation;
2. filtration and
3. flotation in water.

### Sedimentation



Sedimentation is the simplest and cheapest way of cleaning by using the earth's gravity; the solids settle at the bottom of the tank. Sedimentation is only recommended for small purification processes. For production rates of < 50 litres/hr sedimentation is a preferred since it has low cost. It requires little technology and efficiency losses are less important when producing small volumes. It is a cheap cleaning method because little hardware needs to be purchase; only storage tank large enough to keep the oil for about a week with gradual flowing. If necessary, the process can be completed in multiple stages as shown in (Figure 3.30) [[www.fact-foundation.com](http://www.fact-foundation.com)].

The tanks are placed in sequential order; and in each of them are the separation phases of the CVO where only the lighter part has access to the next stage. Sometimes it also requires a pre-filter (to eliminate rubbers) and/or a finishing filtration. The process is very slow: in each tank is provided a minimum time of sedimentation of 2-4 days, at a temperature of 20°C; for these reasons, sedimentation is not recommended in industrial supply chains. It is however ideal for local community because it has low cost, simple implementation, structural simplicity, lack of energy inputs and the certainty of a good quality of PVO. The sludge of the system as by-product can also be used as biogas.

### Filtration

This is a method widely used. It involves the passing of the oil through series of highly standardized filters at different levels to get the desired quality of oil at the end. This needs careful monitoring, cleaning and consecutive changing of filters in the system. Some of the filters are quite expensive. It is a system widely used in industries. It cannot be suitable for rural community purposes.

The easiest way of filtering is by using a cloth. However, be aware that not every textile has a suitable pore size! The capacity to absorb particles, referred to as the nominal capacity, differs between materials. A nominal capacity of 85% for a cloth with pores of, for example, 5µm means that 85% of the particles bigger than 5µm are stopped by the cloth. Special filtering cloth or bag filters can be bought at various suppliers, like Monopoel, amafilter group or local suppliers. The cloth is available in sheets or as bags, for example. Filtering is easier at lower viscosity of the oil. A temperature between 40-55°C would be optimal. Make sure the filter cloth is resistant to these temperatures. If not the mesh may widen and a 5µm filter may only filter up to 20µm. There are 5 different methods used in the process, namely: gravity filter, band filter, filter press, press leaf filter and bag filter. They are all geared to make the CVO suitable for the desired purpose but each has its own advantages and disadvantages especially in connection its suitability in the rural communities.

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### Flotation in water

This is a method that is relatively unknown but seems to be very appropriate to refine the extracted oil. The method can guarantee the removal of most impurities such solid particles and other liquids from the oil. However, this system needs auxiliary activities such pre-heating of oil to 60°C, continuous mixing and the final separation of the emulsion [W. Rijssenbeek, 2010]. It is a complex industrial system of oil purification to produce good biodiesel for the direct consumption of i.c. engines. It cannot be suitable for rural community purposes.

### PVO conservation

This is the method through which the purified oil can be conserved or kept in such a way that it will not easily change its status either physically or chemical in order to maintain the safety of engine in which it is being used. Since the PVO contains certain additional chemicals such as peroxides, FFA, iodine, phosphorus, ashes, water, and potassium oxides the container in which it should be stored must be carefully selected to avoid it being contaminated through different reactions to change its quality. It has been investigated that the container in which the PVO/CRO is put can largely determine its quality after a certain period of time because each of the above mentioned chemicals which can react with its environment (the container) (Figure 3.42). Studies have proven that the best storage system of PVO is in plastic containers [F.O. Abulude, 2007]. It has also further verified that the quality of the oil can be suitable for use within a particular period of time such as 4 months after purification. However, some industrial researchers have ascertained that PVO can be stored for 12 months with a good quality for i.c. engine [www.kimminic.com].



For a convenient storage capacity, if the community is capable of producing  $665 \text{ dm}^3 \text{ ha}^{-1}$ , they need a storage capacity of plastic containers which have been recommended as the best for PVO. If a container has a capacity of  $22.5 \text{ dm}^3$ , then they require 30 plastic containers to store the oil from one hectare. If the cost of a container is 1 Euro, this will make a total of  $30 \text{ € ha}^{-1}$ .

Vegetable oils contain enzymes that originated from metabolic activities during the plants growth. The activity coefficient of enzymes doubles with each 10 degree centigrade increase. This shortens the life of oil during storage as it promotes auto oxidation of the oil. This will result in fast colour change and an increase in free fatty acids in the oil. It is therefore important to keep the storage area cool, in order to prevent instability and an increase in FFA. Most of the enzymes in the oil become more active at a temperature above 30 degrees centigrade. If the jatropha oil is kept in a drum, IBC (International Bulk Container, 1000 litres) or other storage containers, temperature variations can cause condensation of water. This means water will be dissolved in the oil, which is not good for the quality of the oil. The temperature should therefore be kept, as much as possible, at the same level. Another way of avoiding condensation is to keep the container airtight and filled to the maximum [J. van Eijck, 2010].

### Use of PVO as fuel

By nature, PVO generally has excellent properties as fuel in diesel engines, so-called compression ignition engines. Generally any warm diesel engine will run on heated PVO. Nevertheless, for generations diesel engines have been designed and optimized for diesel fuel.

Since some fuel properties of PVO differ from diesel fuel, different conditions must be followed, and changes (conversions and modifications) must be made to the engines in order to handle some of these

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different properties. The necessary changes to the engine are typically named conversion or modification.

There are two equally important criteria to follow in order to successfully use PVO as fuel in diesel engines:

1. the PVO fuel quality should meet criteria specified in PVO fuel quality standards. Such standards already exist in Germany for rapeseed PVO, DIN V 51 605. Similar standards should be made for other kinds of PVO and
2. the diesel engine should be selected as suitable for PVO conversion, and it should be well maintained and in a well adjusted condition. In addition, when it's converted, care should be taken regarding the special challenges for that exact type of engine. And the engine should be used in a suitable way (load pattern).

Both conditions will secure efficient combustion of the PVO, minimizing the emissions and fuel consumption, and guarantee a normal, long lifetime of the engine. Under these conditions, the performance and fuel consumption when running on PVO will be comparable to that of diesel.

On the other hand, if the PVO is combusted inefficiently, problems can be expected sooner or later. Typically, this is because of deposits or other ways of accumulating unburned fuel in the engine. Or it could be the PVO damages the injection system because of aggressive properties leading to corrosion.

The PVO can be transformed through a process called trans-esterification, which can now be used into any diesel engine without resulting to mechanical damage [**M. Benge, 2006**].

Triglyceridi [fre Fatty Acids] + Alcool → Glicerine + alkyl esters



Representation of the trans-esterification of triglycerides (in the example, with methanol)



The releasing of some of the glycerol and the FFA makes the PVO now suitable to be used as diesel in any diesel i.c. engine.

It has been further observed that there a tremendous differences between PVO and the fossil fuel diesel. This accounts for some of the reasons why PVO cannot be used as direct fuel in diesel engines. Such differences can be detected in (**Table 3.3 table**).

Comparing the PVO and the diesel, it can be concluded that the viscosity, carbon residue and ash contents are lower in the latter, while the calorific energy in the diesel fuel is higher than in the PVO [**A.K. Hossain, P.A. Davis, 2012**].

The following therefore can be stated in terms of the qualities of the PVO and the fossil fuel diesel combustion:

1. the specific consumption rate is lower in the PVO than the diesel fuel;

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2. the thermal efficiency is lower in PVO than the diesel fossil fuel;
3. carbon emission is lower in the PVO than in the fossil fuel diesel and
4. the emission of the nitric oxide (No) is higher in PVO than in the diesel.

#### Criteria for the selection of i.c electric machine

Having considered the characteristics of the PVO in relation to its combustibility in an i.c. engine, the scope to select a machine that can be used in a small village community must be carefully done to ensure the following:

1. enabling a system that can be carried out completely including the energy transformation at village level;
2. the use a machine that will create a balance between the energy needed and food production in the community (lower power-less consumption);
3. to ensure continuous supply of energy that is sustainable, optimal and can improve the lives of the people in the village by maintaining a balance between the quantity of PVO and the consumption rate of the machine and
4. by creating the network of cooperation between and amongst farmers that can be replicated in other communities.

#### The generation of electricity from the selected machine

There are 3 types of machines yet discovered by this research, specially designed for the use of PVO from the jatropha which are compared here.

The **first** is a one cylinder LISTER machine with a power of 12 CV and an electric power of 6.1 kW (Figure 3.43). The speed of the machine is 1000 rpm/min. The technical details of the machine are shown in (Table 3.4). The important aspect to be considered here is the specific consumption of the machine in relation to its load.

It can be observed that a minimum consumption of  $0.346 \text{ dm}^3 \cdot \text{kWh}^{-1}$  will produce 2.89 kWh per  $\text{dm}^3$ . Eventually, if there is  $665 \text{ dm}^3 \cdot \text{ha}^{-1}$  of PVO, it will produce (with a full capacity of 315h) a corresponding electric energy of  $1922 \text{ kWh} \cdot \text{ha}^{-1}$  from the jatropha cultivated.

The cost of this machine is 3480 Euros=Le 18,444,000



The **second** alternative is another generator called LWA 10(A) that is produced by the company LISTER PETTER (England). The dimensions are similar to the last one but this is more recent and more expensive (Figure 3.44 and Table 3.5).

With this machine, with a capacity of 350 h, using the same  $665 \text{ dm}^3$  it will produce  $2135 \text{ kWh} \cdot \text{ha}^{-1}$ . It costs 9075 € (Le 48,097,500), almost twice the LISTER generator above.

This machine has some complex electronic control system and has some difficult maintenance problem since it is not common in Africa. Therefore it could not be suitable for the village community level such as Bumbang.

The **third** alternative is a machine with the model "Multifuel 3SP, which is a German product branded 'ATG'. It is a highly portable machine with less weight (106 kg) and size 720 x 480 x 630 cm), and an electric power of 2.8 kW. It has a specific consumption rate of  $0.45 \text{ dm}^3 \cdot \text{kWh}^{-1}$  with an ability to generate electrical power of  $1477 \text{ kWh} \cdot \text{ha}^{-1}$ . It costs 1937 € (Le 7,828,100) (Figure 3.45 and Table 3.6).



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In considering the socio-economic and technical aspect of the investment, the 3 machines can be evaluated technically and economically to know which one is most suitable for rural community purpose.

Therefore, we look at the  $\text{€kW}^{-1}$  of the three machines.

1<sup>st</sup> 3480 Euro/6.0 kW=570  $\text{€kW}^{-1}$

2<sup>nd</sup> 9075 Euro/6.0 kW=1488  $\text{€kW}^{-1}$

3<sup>rd</sup> 1937 Euro/2.8 kW=692  $\text{€kW}^{-1}$ .

It can be stated here that the LISTER machine is most suitable in terms of the cost (Euro) per kW. Apart from that it has better maintenance opportunities since such machines are very common in Africa especially in Sierra Leone, when compared with the Multifuel 3SP ATG brand and LISTER PETTER. It has more electric potential to be able to supply the entire village community, while the former with (2.8 kW) could be too small to achieve that.

Having examined the power of these machines and their other characteristics, the energy needs of the people at the community level was also examined. This will enable the research to determine what quantity of seeds that are needed and the subsequent amount of PVO from these seeds that can be obtained based on the consumption of the machine.

It can be observed that the use of energy varies in accordance with the day's activities and the season in the community.

The regular needs of the community were categorized into domestic, social or public occupational use.



The following have been identified as key electric power needs of the Bumbang community:

1. domestic light;
2. domestic fans;
3. domestic water supply;
4. radio station;
5. TV station;
6. agricultural irrigation;
7. agricultural refrigeration;
8. cottage industries (wood carving and polishing, tailoring, light metal welding);
9. public light (mosque and church);
10. public fans (mosque and church) and
11. community centre (light & musical set/video).

An average consumption of the electric energy can be calculated per hour of the day based on the average specific consumption of the machine. This will lead to know how much total energy will be needed, hence the quantity of PVO that can produce such energy.

The quantity of PVO can be determined by the quantity of jatropha seeds produced to satisfy the village needs sustainably, economically and environmentally friendly.

To know the hectare of the PVO needed at any given time, the following can be used:

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$$A \text{ (ha)} = \frac{V_{SVO} \cdot d_{SVO}}{\eta_{ex} \cdot \eta_p \cdot y_{ss}} = \frac{dm^3 \cdot \left(\frac{kg}{dm^3}\right)}{(\%) \cdot (\%) \cdot \left(\frac{kg}{ha}\right)}$$

Where A= Area (ha),

<sup>v</sup>SVO= Quantity of PVO (dm<sup>3</sup>),

<sup>d</sup>SVO= Density of PVO,

$\eta_{ex}$  = Extraction efficiency of CVO,  $\eta_p$  = Extraction efficiency of pure oil,

$y_{ss}$  = Total seed yield/ha

The power consumption levels are scheduled as showed in (Table 3.7). From the power schedule, it can be seen that the total power needed of the entire village is **4.6 kW**. There is a reserve power of **1.5 kW** from the machine that has a **6.1 kW**. This makes the machine safe to be able to carry additional load in the future if there is any additional energy needs from the community. It also has the advantage to work safely without energy stress or damage due to any additional load induced.

This however has its disadvantage of not using the full potential of the machine, consuming fuel that is not of importance to the lives of the community.

The needs can however, be prioritized based on their importance. For example the lighting of the houses, domestic water supply, radio station, school and health centre are amongst the key **domestic needs** that are critical and cut across in the community.

**Occupational** public needs such as cottage industries, agricultural irrigation and refrigeration were identified as another priority area.

**Social needs** such as mosque, church, community centre were branded as another set of priorities.

A simulation of the use of the 6.1 kW energy can therefore be made to be able to know the average consumption of the machine based on the load that is given to it during its 24 hours work (Figures 3.46a, b, c).



The first is domestic and social activities in the community (Figure 3.46b).

The second hypothesis is to engage all the domestic and occupational and public activities of the community during the day (Figure 3.46a).

The third hypothesis is to the provide power for all the activities to be carried out simultaneously in the community during the day and the consumption efficiency of the machine observed (Figure 3.46c).

In hypothesis 3, it can be observed from (Figure 3.46c) that the specific consumption was lowest when compared with (Figures 3.46a and 3.46b.) for hypotheses 1 and 2. This is because there is more effective engagement of the electric power (70%) produced by the machine into the activities of the community; hence its specific consumption is highly reduced.

However, the quantity of fuel (PVO) used was 82 dm<sup>3</sup> per day. Therefore this machine will need **29930 dm<sup>3</sup>** PVO for the year. Since this machine with this load can produce **77 kWh.day<sup>-1</sup>**, it t can therefore generate **28105 kWh.yr<sup>-1</sup>**.

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In hypothesis 2, the figure shows very high specific consumption rate because the power produced by the electric machine was minimally used. The quantity of PVO used was 80 dm<sup>3</sup> per day, which is much lower when compared with hypothesis 3. The total fuel needed more the year will be **29200 dm<sup>3</sup>** and **74.7 kWh** per day was produced. The amount of kWh to be produced from this hypothesis will be **27266 kWh** for the year.

In hypothesis 1, the specific consumption level is mid way between Hypothesis 1 and 3. Its fuel consumption per day was **48 dm<sup>3</sup>** and can produce **39.1 kWh** per day. The total PVO needed in this case is **17520 dm<sup>3</sup>** for the entire year. It will therefore produce **14272 kWh** for the year.

Comparing the 3 hypotheses in terms of the surface area needed to produce the quantity of PVO required in each scenario, the following calculation was done.

Hypothesis:-If the total consumption of the machine per year is 29930 dm<sup>3</sup>·yr<sup>-1</sup>, given that the PVO produced per hectare is **1754 dm<sup>3</sup>·ha<sup>-1</sup>** in this study, the total number of hectares needed to satisfy the smooth running of the machine will be:  $\sum (\text{tot. PVO dm}^3 \text{ consumed yr}^{-1}) / (\text{Tot. PVO dm}^3 \text{ ha}^{-1})$ .

Hence, 29930/1754=17.1 ha. Using the same approach for hypothesis 2 and 3 the following results were shown.

In hypothesis 1, **10 ha** are needed to support the process per year.

In hypothesis 2, **16.6 ha** are needed to support the running of the machines for per year.

In hypothesis 3, **17.1 ha** are needed to support the smooth running of the electric generator per year.



Comparing the kWh produced in each of the 3 hypothesis per hectare, in hypothesis 3, the total kWh produced was 28105 kWh·yr<sup>-1</sup>. If 17.1 ha are needed to produce this kWh, then amount of kWh·ha<sup>-1</sup> will be:

1. 14272/10=1427.2 kWh·ha<sup>-1</sup>;
2. 27266/16.6=1634 kWh·ha<sup>-1</sup> and
3. 28105/17.1=1644 kWh·ha<sup>-1</sup>

It can be clearly seen that in hypotheses 2 and 3, higher kWh production per hectare was achieved to satisfy the needs of the community. Although there are larger surface areas to be cultivated (9.4 and 8.7 ha respectively) but the output of kWh is appreciable to fulfill the needs and desires of the people. The hypothesis 1 however, the area to be cultivated was less but the kWh produced cannot adequately satisfy the needs of the people instead there is a high specific fuel consumption level that will lead to inefficient use of the power of the machine.

The cultivation of 17.1 hectares at any village level is tremendous difficult and challenging in terms of field work and general management.

In other to maintain this type of system, **the first** and most important strategy is to reduce the surface area by increasing the yield quantity per hectare. This can be done by improving the agronomic practices of the farmers.

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**The second** is to improve on the seed management in terms of storage, extraction and purification since all of these activities can lead to increase in the quantity and quality of the PVO.

**The third** is to select a machine that can consume less PVO due to its low energy production such as a 5 kW if it is available in the market. This is because in this research the amount of power needed is 4.6 kW, thus a 6 kW machine could virtually be a waste of power that is not needed by running it.

### 3.5 Conclusion

The research also shows that an average of 10 farmers can cultivate a hectare of jatropha intercropped with a consumable crop within the course of the production season (one year) without hindering the other regular crop production activities such as rice cassava, potato etc in their farms.

It further shows that jatropha can be grown in the rural communities if its cultivation is tied up with a consumable crop such as ground which the farmers can eventually use as either food or for cash.

The data results show that the cost-benefit relationship in the cultivation of jatropha and ground nut is positive for the farmers as there is a high profit generated by the ground nut per hectare, apart from the production of the jatropha seeds at the end of every production season (**Figure 3.47 and Tables 3.7 and 3.8**). This therefore can serve as a motivating factor for farmers to increase their acreage per group which will eventually lead to larger production of the jatropha seeds for more sustainable generation of electricity in the rural communities if properly managed.



The data shows that intercropping a leguminous crop such as ground nut with jatropha has positive effects on both the growth rate of jatropha (**Figures 3.33, 3.34 and 3.35**) and weed control (**Figures 3.36 and 3.37**).

The study has confirmed that jatropha seeds can be reproduced in one cultivation season; and that the rate of seed production can be increased as the life cycle period of the trees continues. The quantity of seed production for the first year was not however calculated as there was not enough time for the researcher to collect the data of the jatropha fruit production during the period under review. However, based on some bibliographies read, the seed production can range from 0.5 to 6 t<sup>ha</sup><sup>-1</sup> based on factors such as the type of soil and its fertility management, water availability, type of variety and the agronomic practices engaged.

It can be also seen from the results that the change of season has an adverse effects on the growth and reproduction of jatropha (**Figures 3.33, 3.34 and 3.35**). As the dry season (period with no rains) approaches, intensive shedding of leaves was observed which eventually affected the other physiological activities of the crop such as fruit production.

Pest infestation in the form of grasshoppers was observed to be more acute with *jatropha gossypifolia* than *jatropha curcas*. This was especially during the end of the rainy season whilst approaching the dry season through the eating of all the leaves including the stems at some level of the infestation. There was no control measures used during the period except the removal of all the pests secondary hosts such as the weeds from the jatropha crops.



In terms of the power supply from jatropha, a calculated area of 17.1 ha should be cultivated to produce the (**29930 dm<sup>3</sup>**) needed PVO for the 6.1 kW machine. This quantity of fuel can provide the power

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needed to fulfill the most desirable needs of the community for the entire year (**Figure 3.46c**). Although not all the power shall be used as there is a reserve of 1.5 kW. More activities can be added in other to achieve the efficient use of the machine but NOT overstretching its power limit of 6.1 kW.

Whilst the introduction of electric power is possible and it is an important venture to improve the lives of the rural poor, the complete traditional method of jatropha cultivation will affect the food productivity of the community if the use and maintenance of this machine's electrical power is to be sustained throughout the year. This is due to the large 17.1 ha surface area needed for the production of the needed PVO by the farmers using the hoe and cutlass (***slash and burn method***). Therefore this study will recommend the following:

1. identification of high yielding varieties of jatropha (*J. Gossypifolia* and *J. Curcas*);
2. improve the agronomic practices of the farmers;
3. improving on the intercropping system in the form of crop rotation by the farmers;
4. introduction of minimal mechanization to minimise the drudgery of the famers and
5. the minimal use of chemicals (fertilizers and pesticides-if easily available and affordable by the farmers).

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## Figures

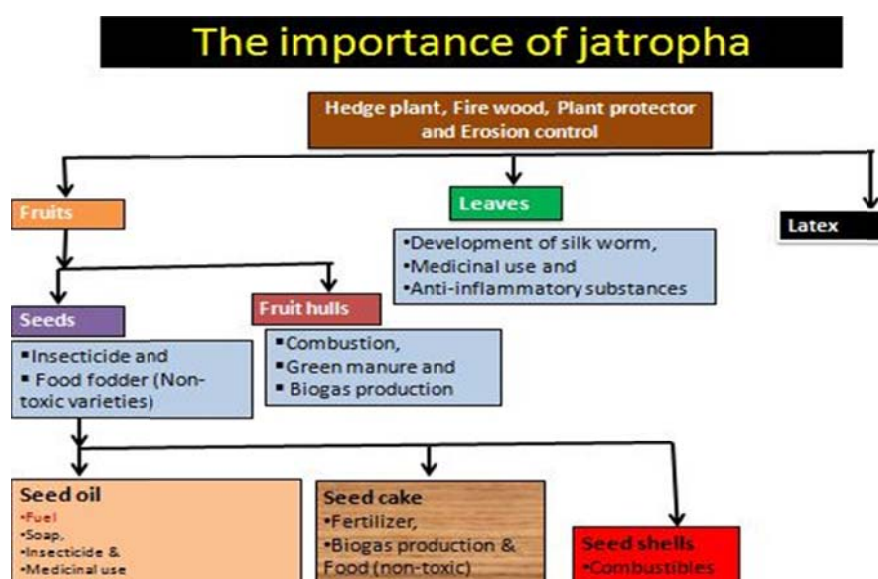
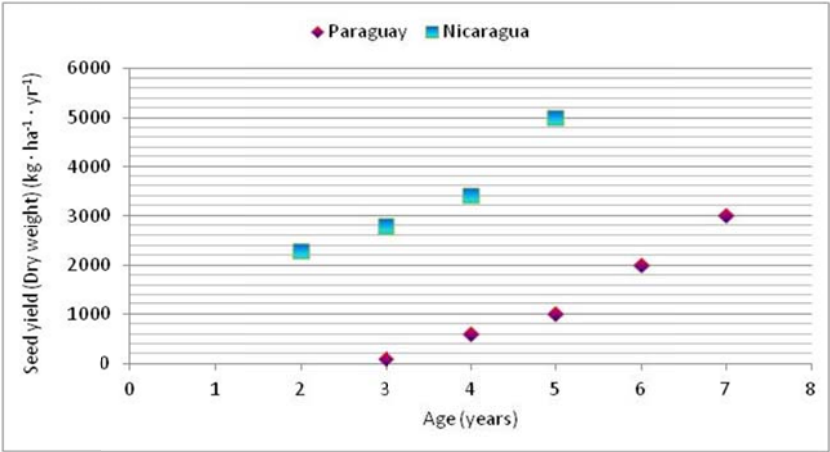


Figure 3.1. The importance of jatropha as a crop.

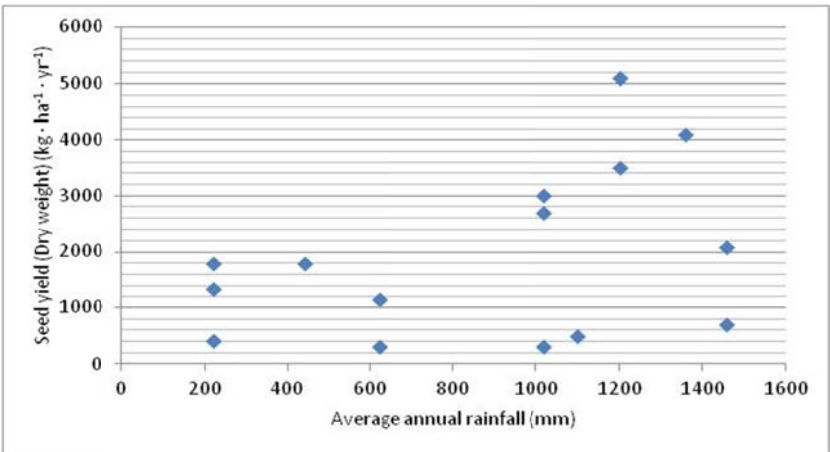


Figure 3.2. Shows typical *Jatropha gossypifolia* (left) and *Jatropha curcas* (right)







**Figure 3.3.** Shows the relationship between jatropha plant age and yield rate.

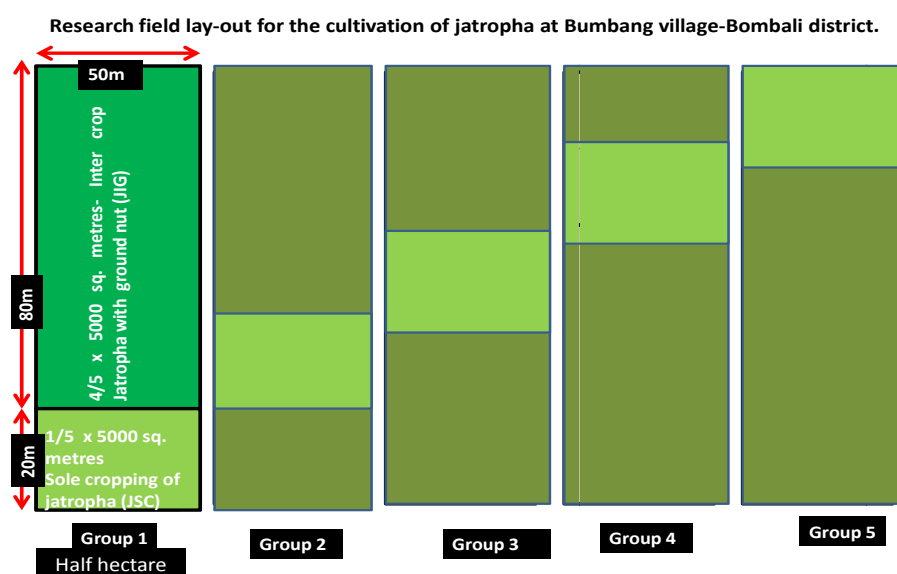


**Figure 3.4.** The relationship between annual rainfall and yield rate of jatropha plant.



**Figure 3.5.** Clearing of fresh bush by slashing of natural vegetation with cutlasses or machetes (source: C. Vigano).



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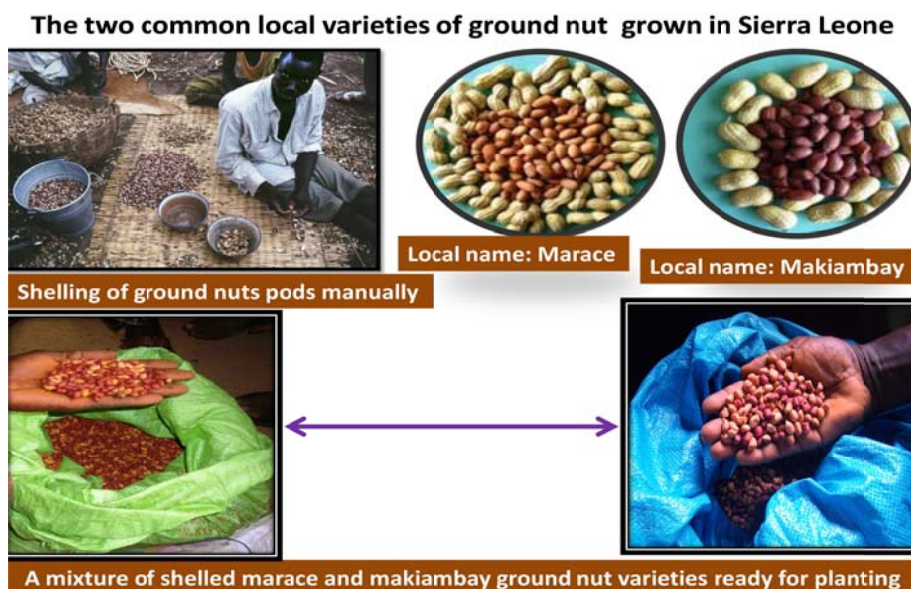


**Figure 3.6.** Treatment lay-out for the planting of jatropha.



**Figure 3.7.** Research field design by researcher and farmers [Source: C. Vigano].

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 35/64</p>





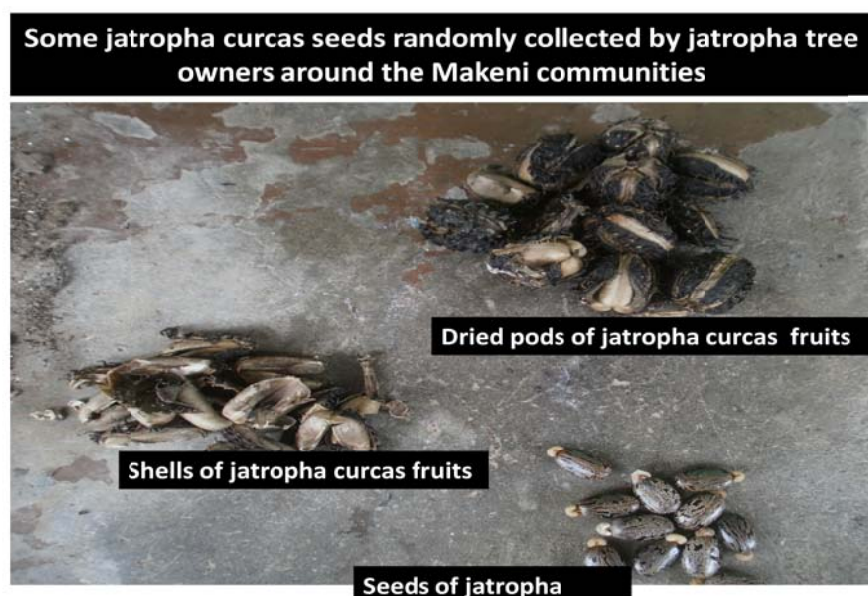
**Figure 3.8.** The two common local varieties of ground nut cultivated in Sierra Leone [Source: C. Vigano].



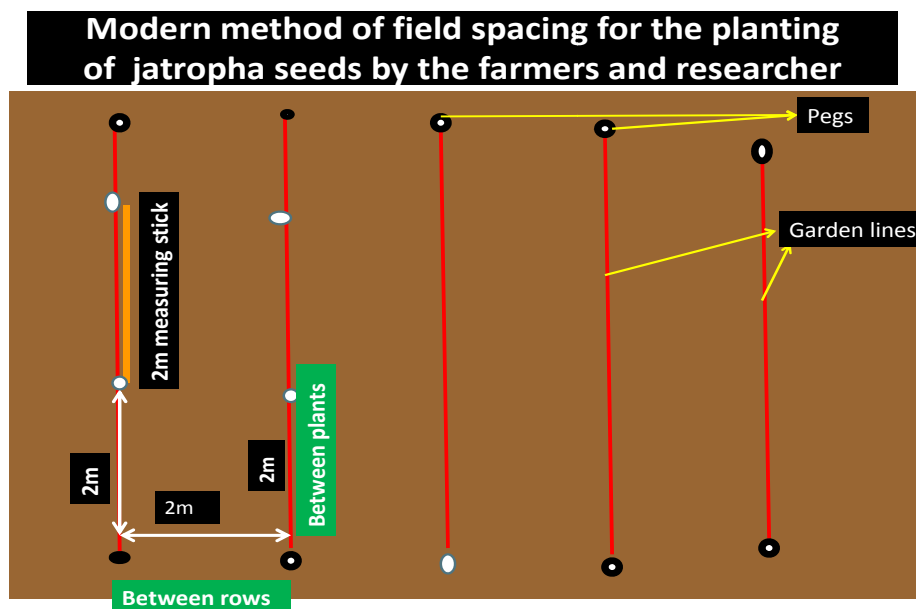
**Figure 3.9.** Weighing of the shelled ground nut seeds by farmers before planting [Source: C. Vigano].





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<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 36/64</p>



**Figure 3.10.** Samples of jatropha seeds harvested around the Makeni communities to be used for planting in the experimental farm in Bumbang.



**Figure 3.11.** Modern method spacing for the planting of jatropha seeds in the experimental plots.

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 37/64</p>

### Farmers participating in the modern method of spacing for the planting of jatropha seeds





**Figure 3.12.** Farmers participating in modern method spacing for the planting of jatropha seeds [Source: C. Vigano].

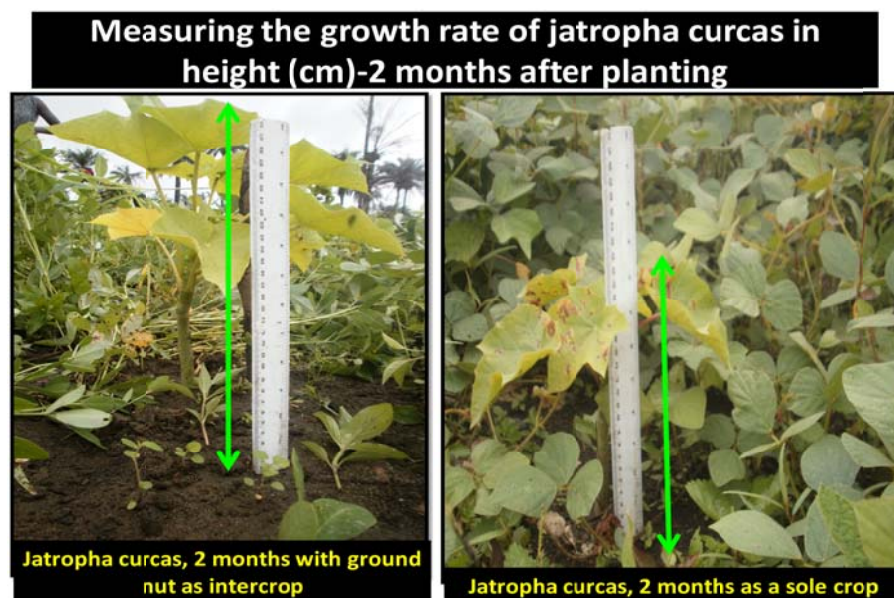
### Planting of ground nut seeds by the farmers in the research plot



**Figure 3.13.** Planting of the ground nut seeds in the treatments of jatropha with ground nut as intercrop [Source: C. Vigano].



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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 38/64</p>





**Figure 3.14.** Jatropha growth assessments in height (cm), 2 months after planting (DAP) in the different treatments (JIG and JSC).



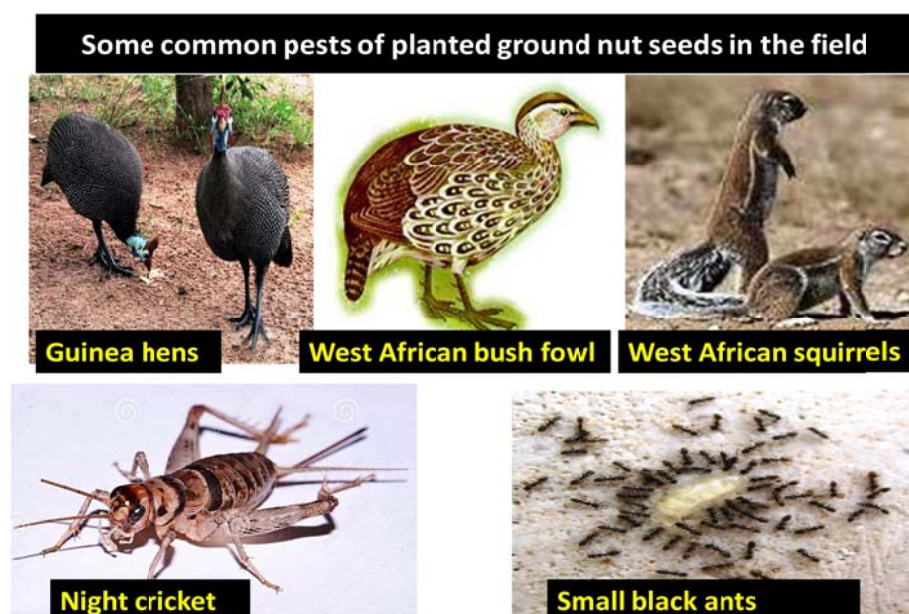
**Figure 3.15.** Weed prevalence in the different treatments in the plots of jatropha.





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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 39/64</p>

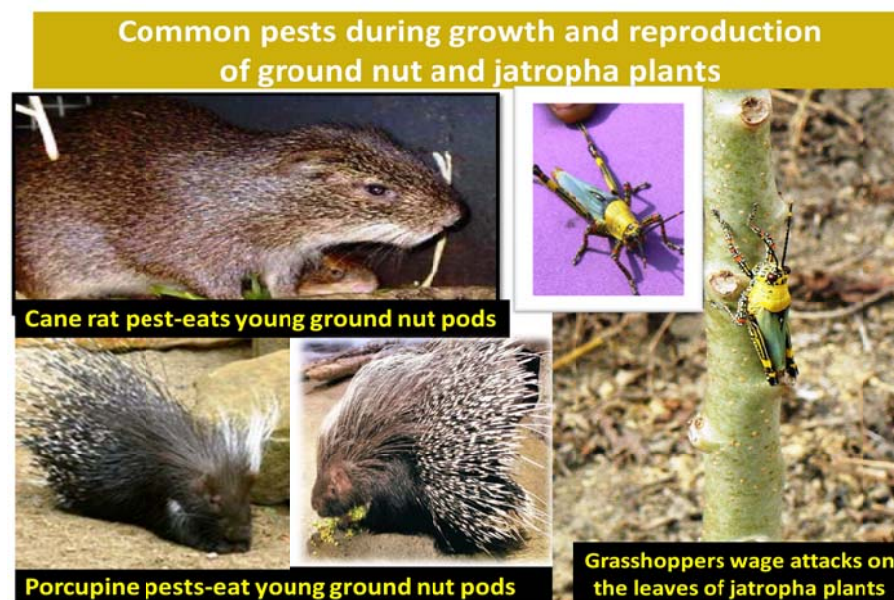


**Figure 3.16.** Manual weeding of plots by the farmers of the research.



**Figure 3.17.** Some common pests observed eating ground nut seeds in the field after planting.

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 40/64</p>





**Figure 3.18.** Some common pests of ground nut and jatropha plants during growth and reproduction.



**Figure 3.19.** Manual harvesting of ground nut crop in the field.





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	<p style="text-align: center;"><b>PhD Thesis</b></p> <p style="text-align: center;"><i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b></p> <p style="text-align: center;"><i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 41/64</p>



**Figure 3.20.** Processing of harvested ground nut stems immediately after harvesting.

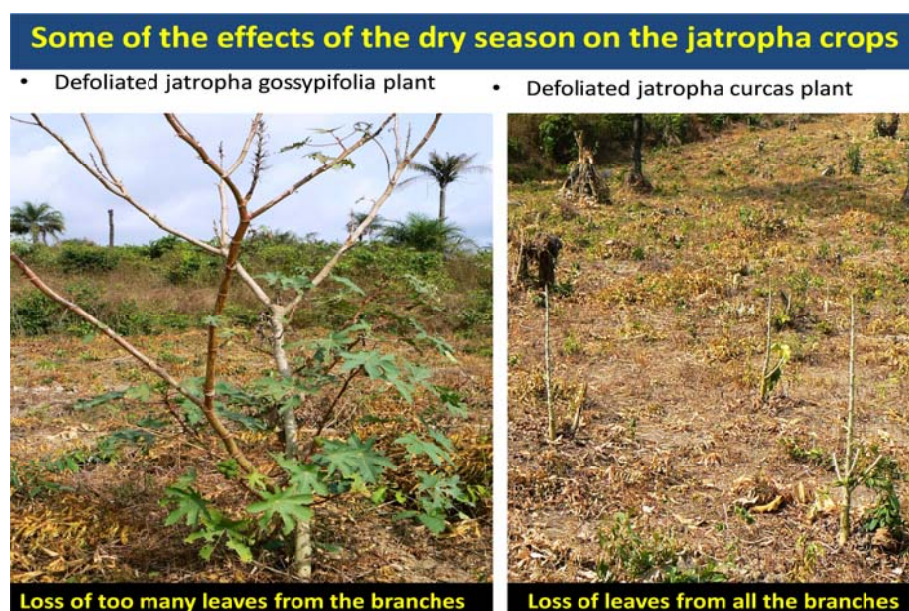


**Figure 3.21.** Framers plugging ground nut pods from dried ground nut stems.

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 42/64</p>





**Figure 3.22.** Assessment of the yield of ground nut crop in the research treatment JIG together with a farmer.



**Figure 3.23.** Some of the effects of the dry season on jatropha crops-no artificial irrigation mechanisms.



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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
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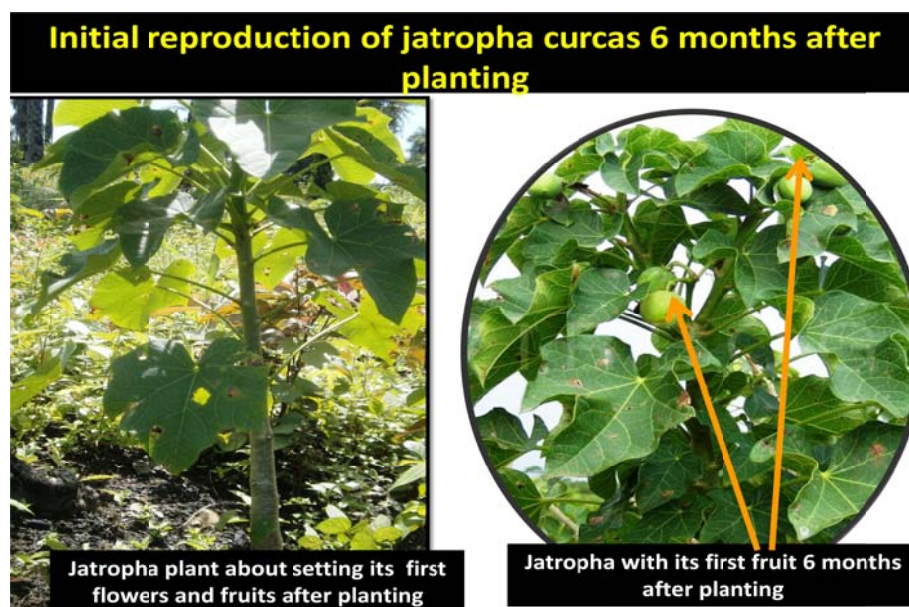


Figure 3.24. Jatropha curcas setting its first fruits at 6 months after planting.

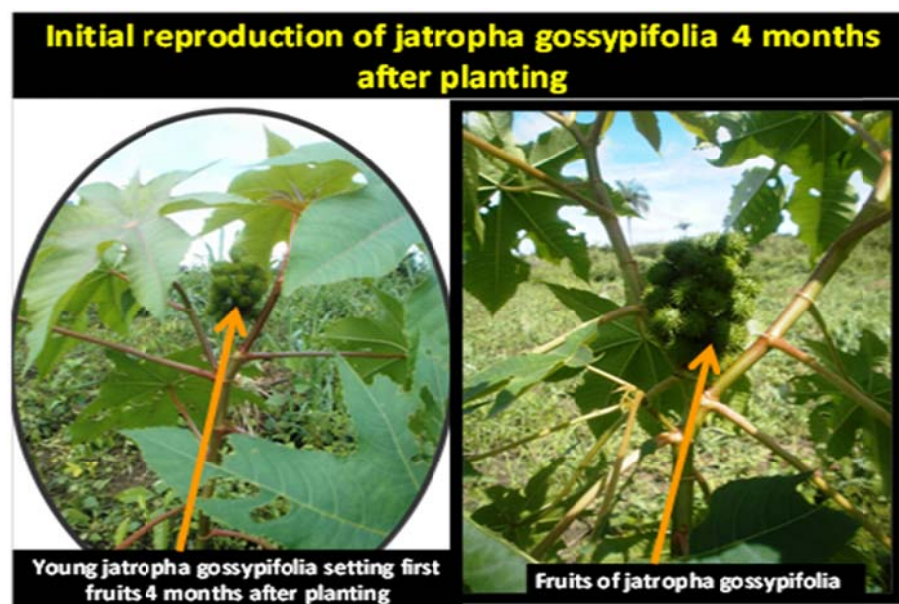




Figure 3.25. Jatropha gossypifolia setting its first fruits 4 months after planting.

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	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 44/64</p>

### Mulching of jatropha plants in the research treatment of jatropha with ground nut as intercrops (JIG)



Figure 3.26. Mulching of jatropha using dry ground nut straws in the JIG treatment only.

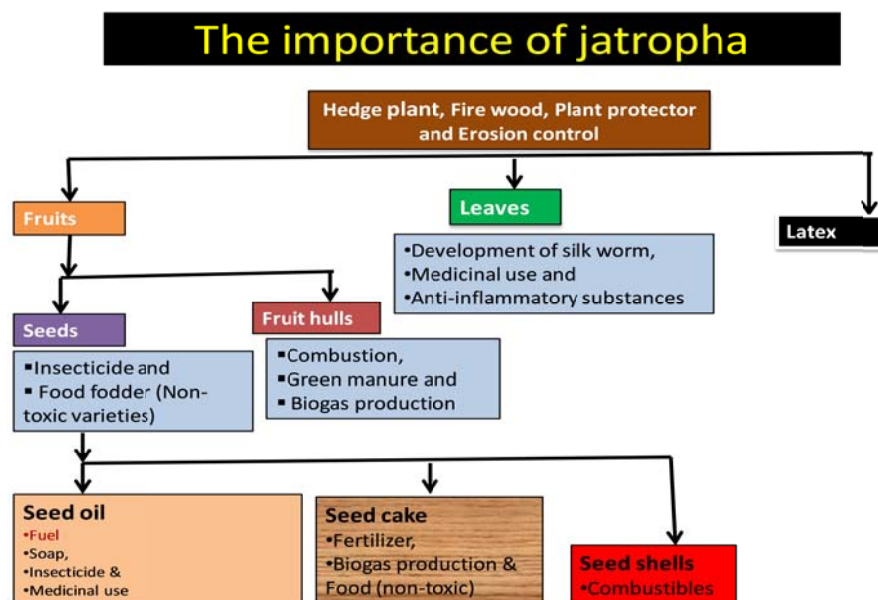




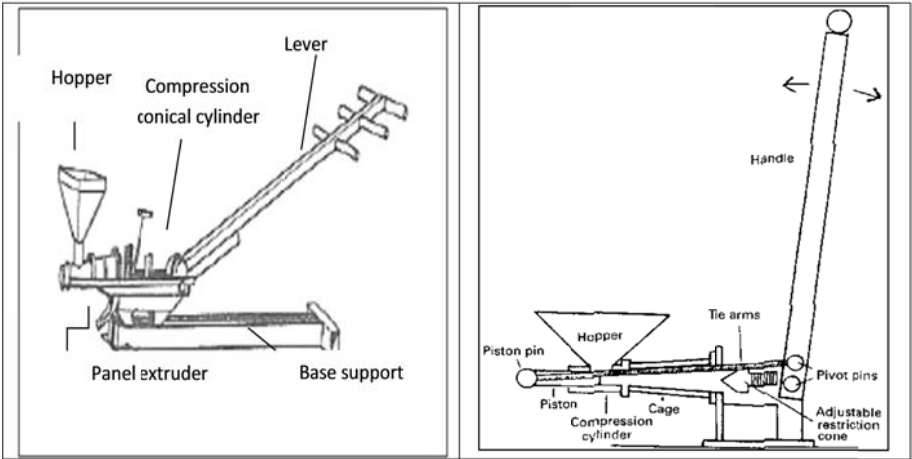
Figure 3.27. The process of Transforming jatropha seeds to rural electrification.



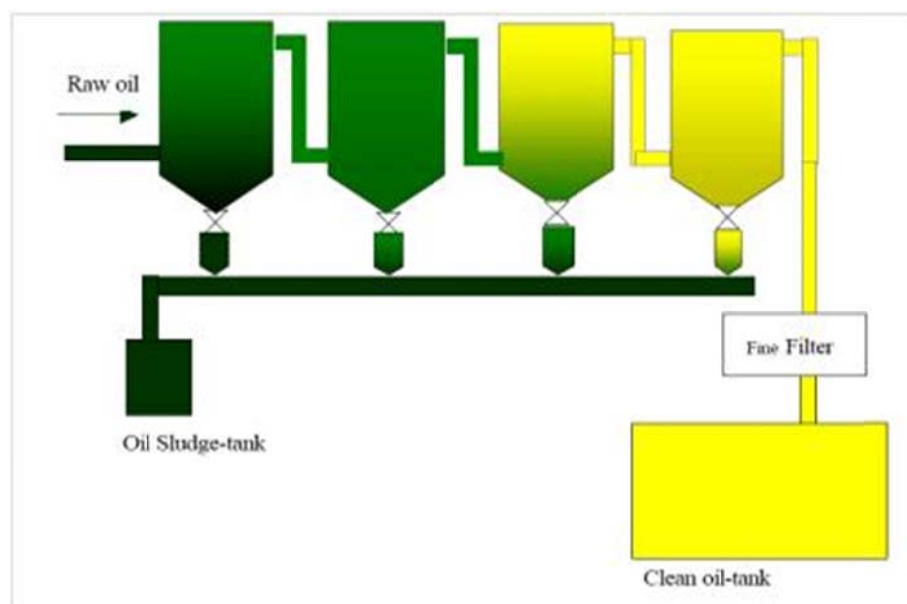
<p style="text-align: center;">School Innovative Technology for Agri-Food and Environmental Sciences Cycle XXVII</p> <p style="text-align: center;"><b>Dr. Joseph B. Tholley</b> Tutor: Prof Marco Fiala</p>		
	<p style="text-align: center;"><b>PhD Thesis</b> <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i></p>	
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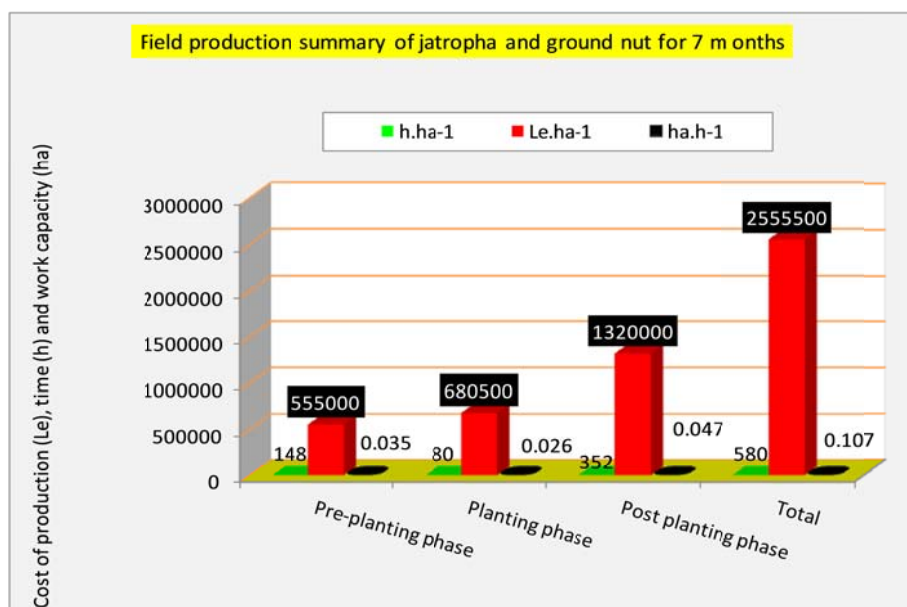
**Figure 3.28 .** Manual mechanical (ram press) method of CVO extraction from jatropha seeds.



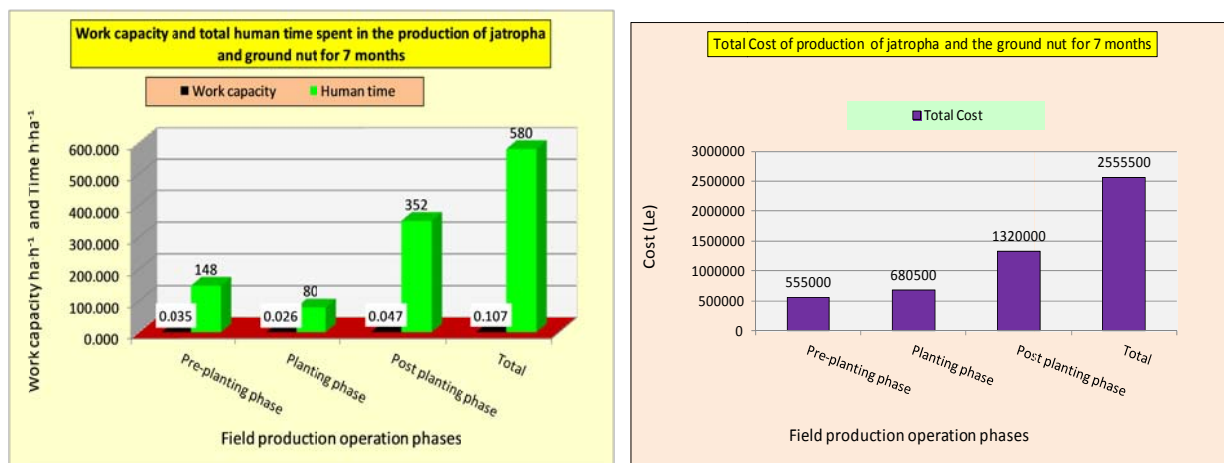
**Figure 3.29.** Different manual mechanical machines for the extraction of CVO from jatropha seeds.



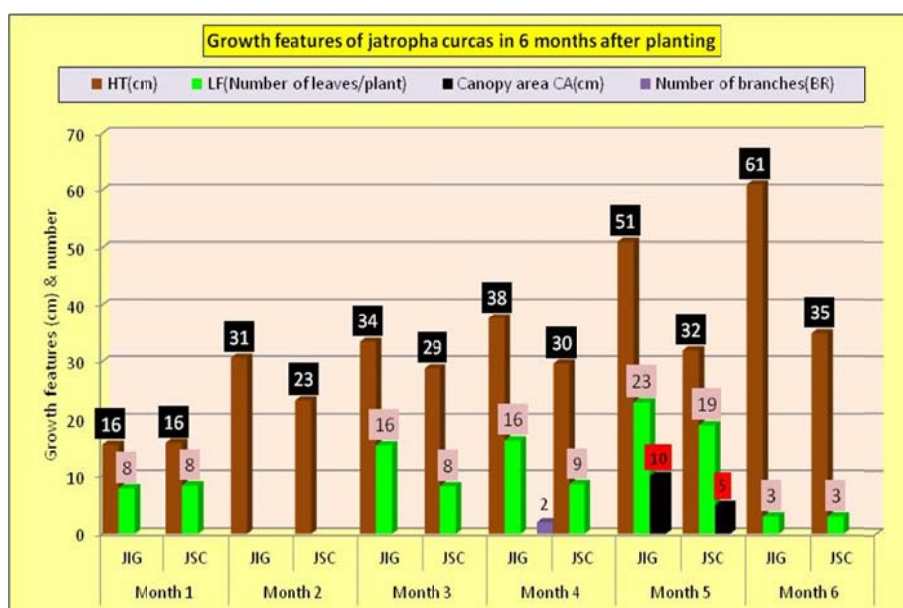
**Figure 3.30.** Sedimentation tanks for the purification of CVO to PVO for generating of electricity in the rural area with an i.c electric generator.



**Figure 3.31.** Field operations on the production of jatropha and ground nut as intercrop in 7 months.



**Figure 3.32.** Shows the total cost of field operations and the time and work capacity of the total production exercise of jatropha and ground nut in 7 months.



**Figure 3.33** Growth features of *jatropha curcase* in the two treatments of jatropha intercropped with ground nut (JIG) and jatropha as sole crop (JSC).



## PhD Thesis

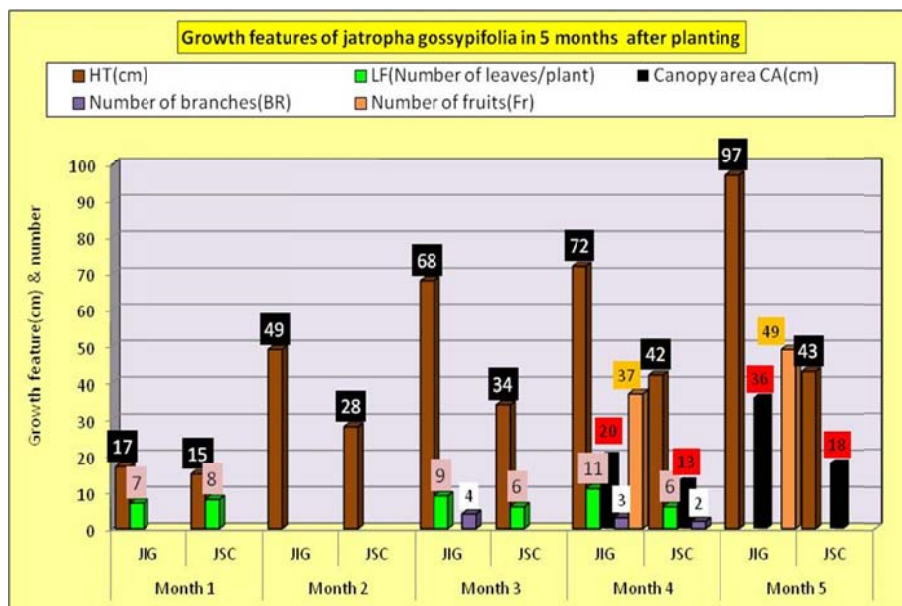
*Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone*



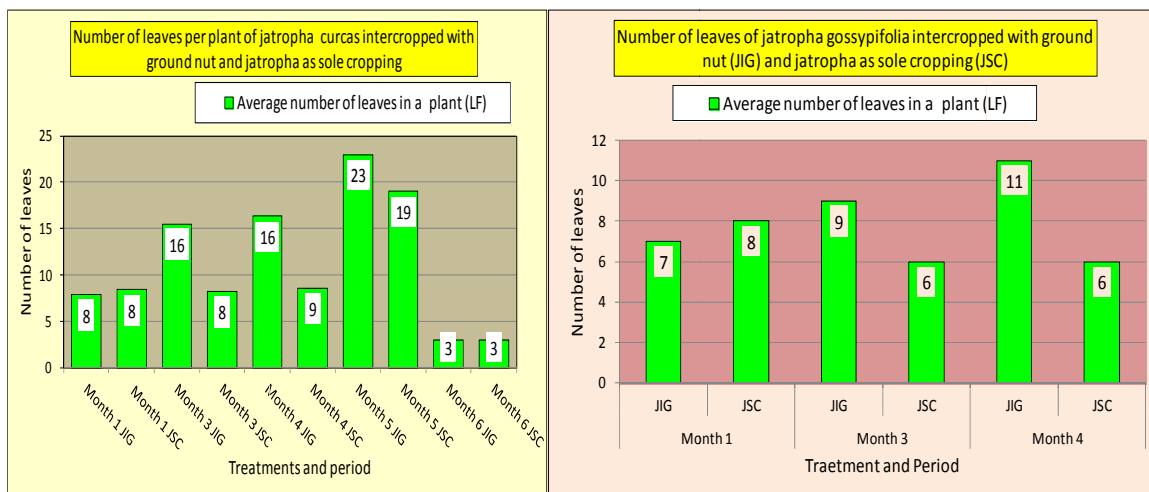
## Chapter 3

*The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers*

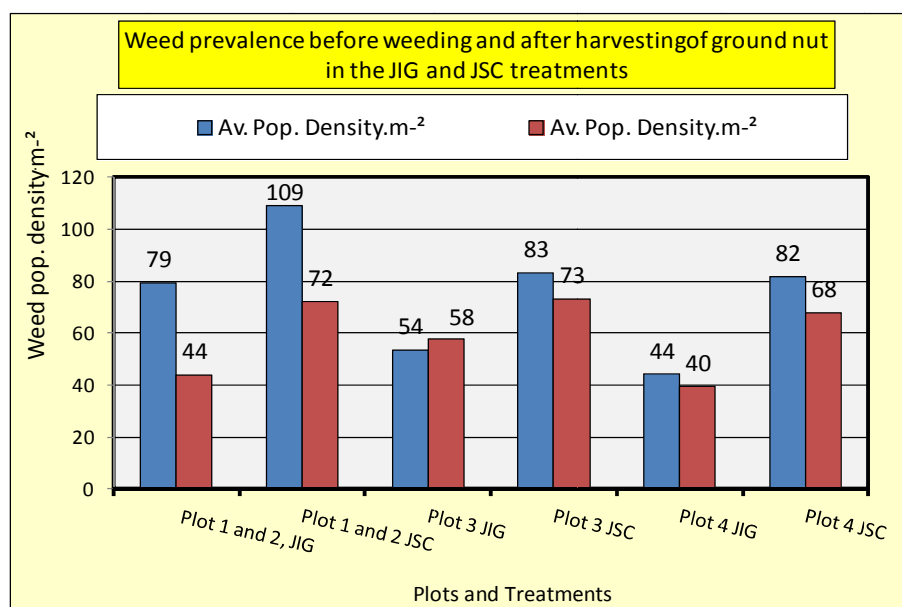
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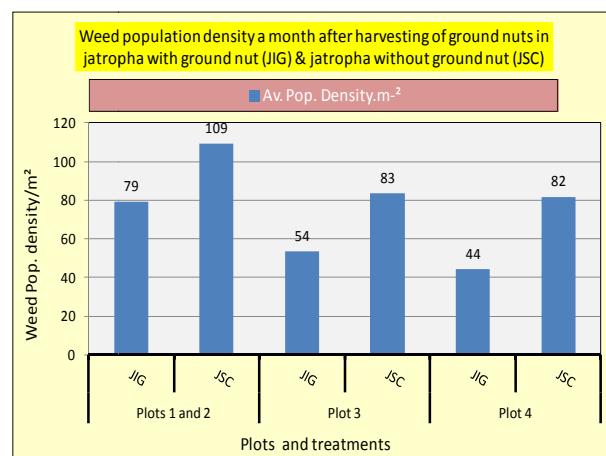
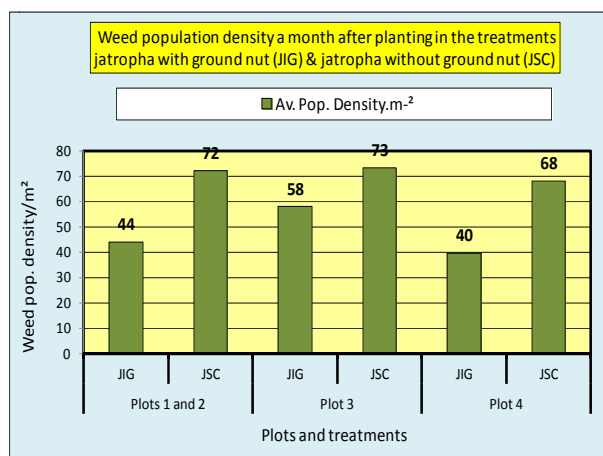
**Figure 3.34.** Growth features of jatropha gossypifolia in the two treatments of jatropha intercropped with ground nut (JIG) and jatropha as sole crop (JSC).



**Figure 3.35.** Number of leaves in the two varieties of jatropha curcas and gossypifolia in the treatments of JIG and JSC.

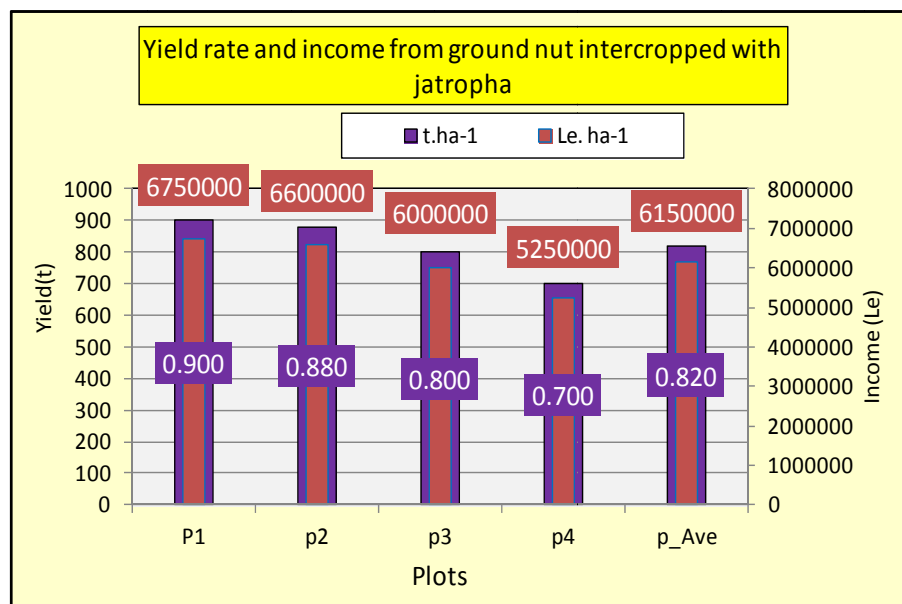


**Figure 3.36.** Average weed population density in the treatment of jatropha with ground as intercrop (JIG) and jatropha as sole crop (JSC).

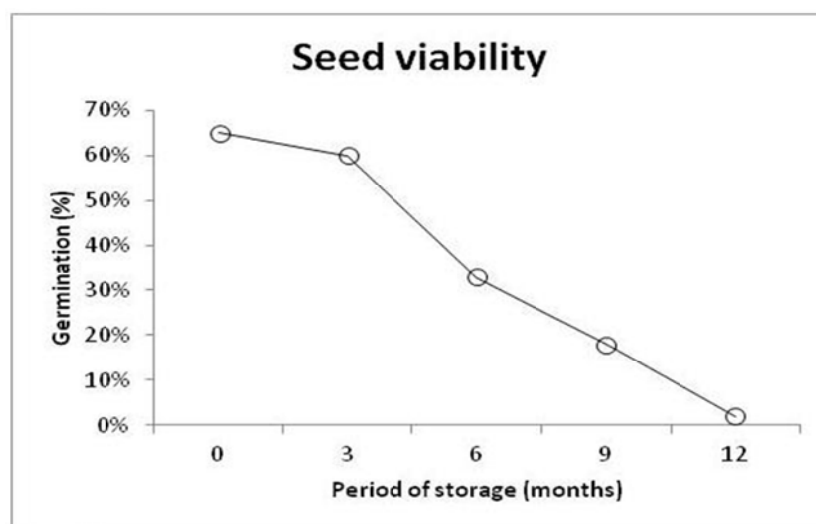


**Figure 3.37.** Weed population density in the treatments a month after planting and a month after weeding in the two treatments of JIG & JSC.





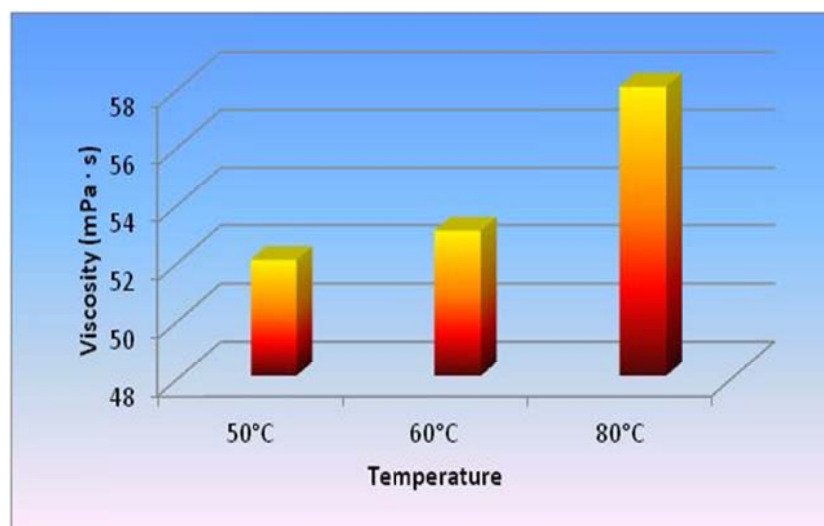


**Figure 3.38.** Ground nut yield rate and total income per hectare.

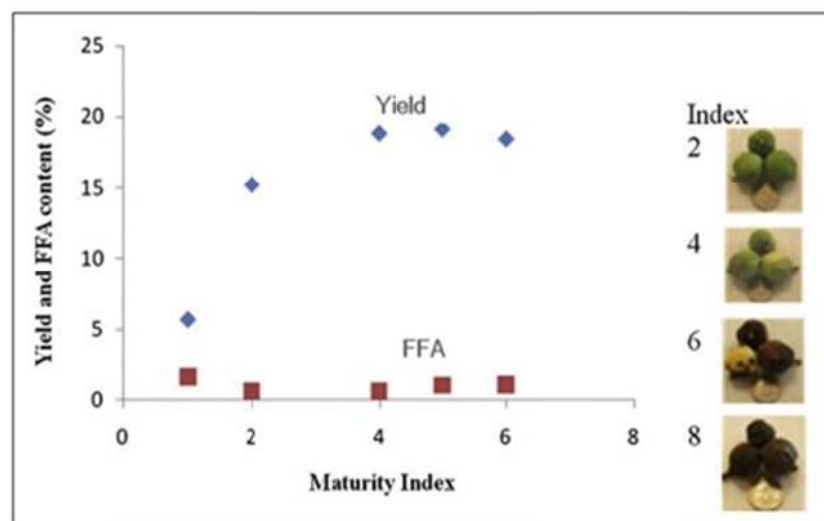


**Figure 3.39.** Jatropha seed viability and germination potential at storage period.



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<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 51/64</p>

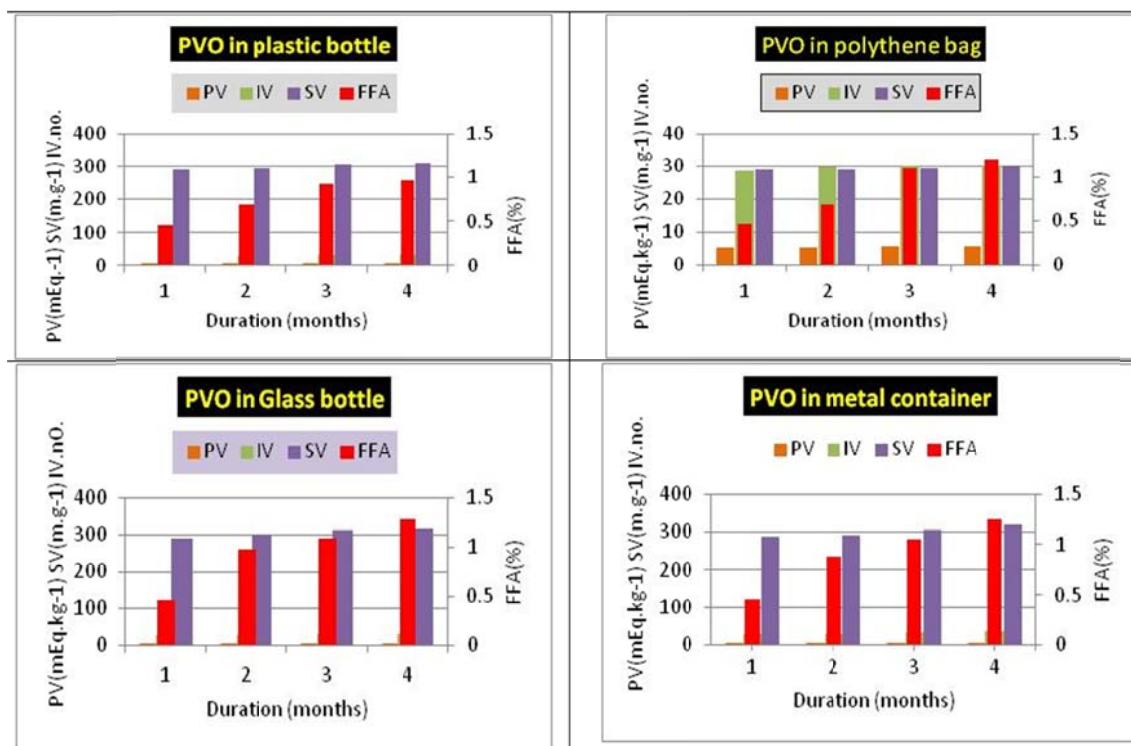


**Figure 3.40.** Viscosity of the oil product at different extraction temperatures.



**Figure 3.41.** The relationship between seed maturity, CVO yield quantity and FFA.



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<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 52/64</p>



**Figure 3.42.** The difference reactions of the mineral contents of PVO in different containers at storage.



**Figure 3.43.** Motorised LISTER electric generator with 6.1 kW electric power.

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	<p style="text-align: center;"> <b>PhD Thesis</b>  <i>Integrated agricultural technology impacts on food and energy production with small scale farmers at local community level in the upland ecology of Sierra Leone</i> </p>	
<p style="text-align: center;"> <b>Chapter 3</b>  <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i> </p>		<p style="text-align: right;">page 53/64</p>



**Figure 3.44.** Motorised LISTER PETTER electric generator with 6.1 kW electric power.



**Figure 3.45.** Motorised ATG Multifuel 3SP Generator electric generator with 2.8 kW electric power.



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Chapter 3

The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers

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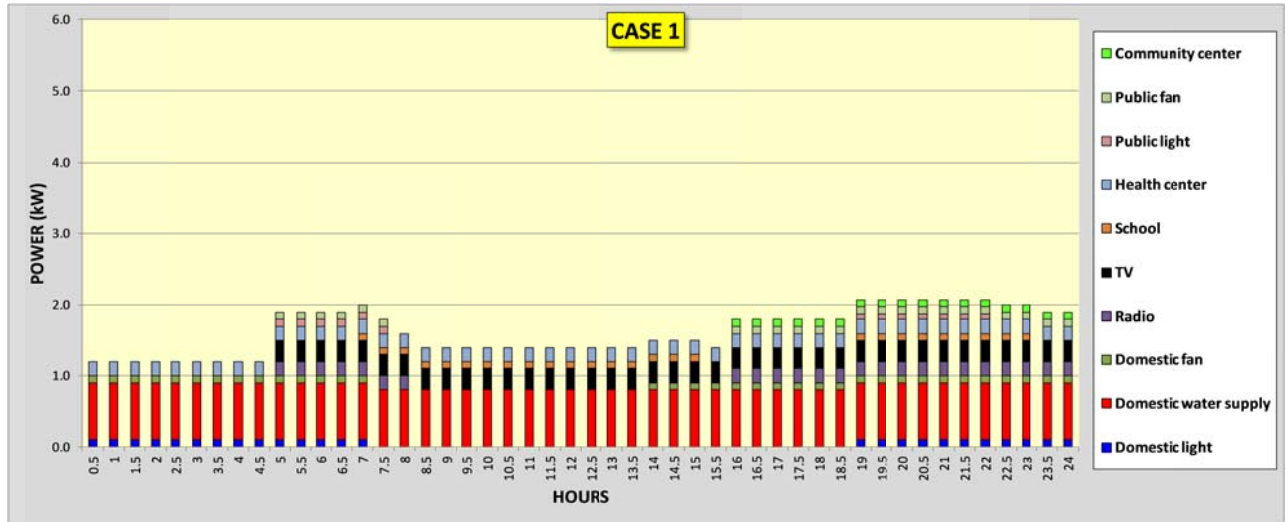


Figure 3.46 (a)

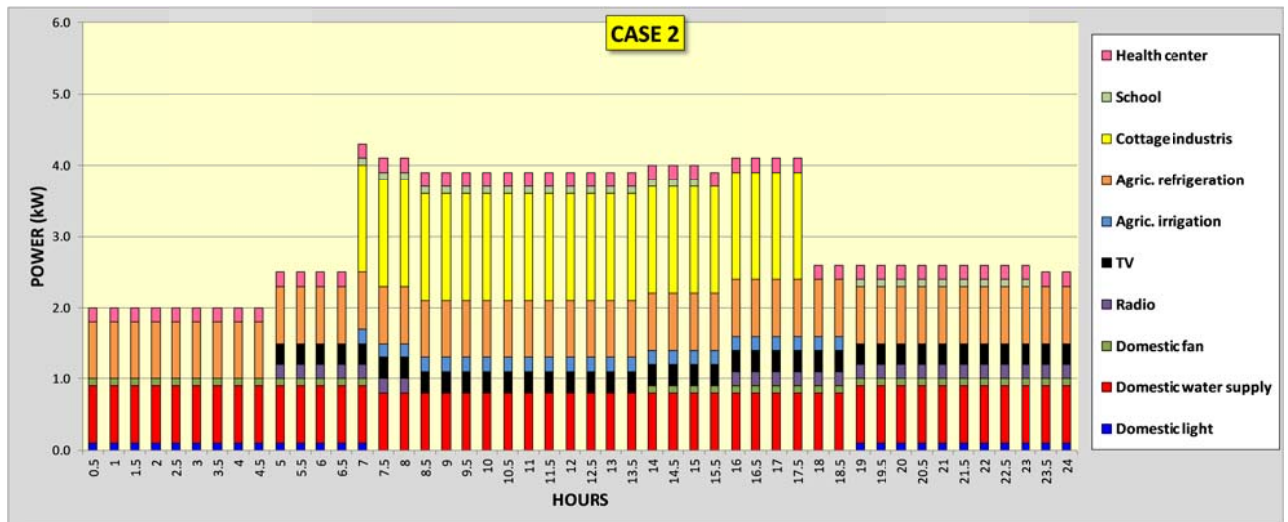


Figure 3.46 (b)



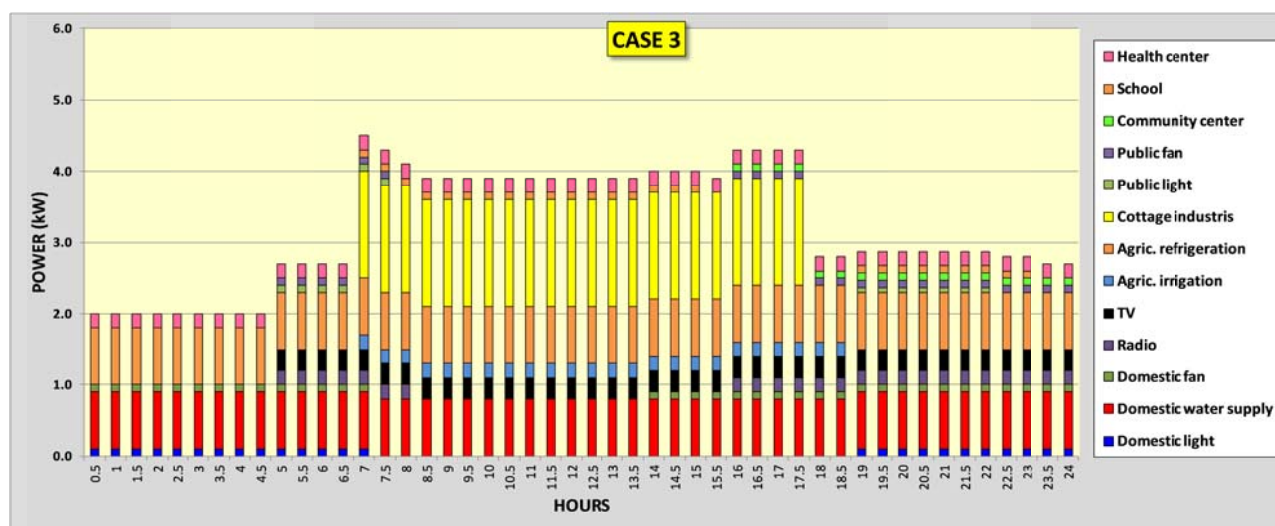


Figure 3.46 (c)

Figure 3.46 (a, b, c). Power simulation for a 6.1 kW electric machine showing different specific consumption rates due to different loads given to it at the same period.

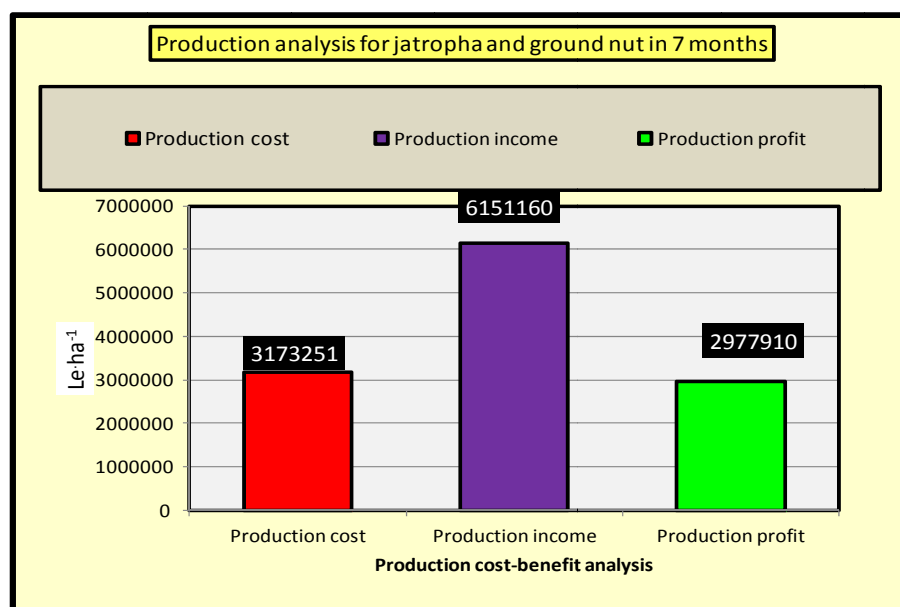


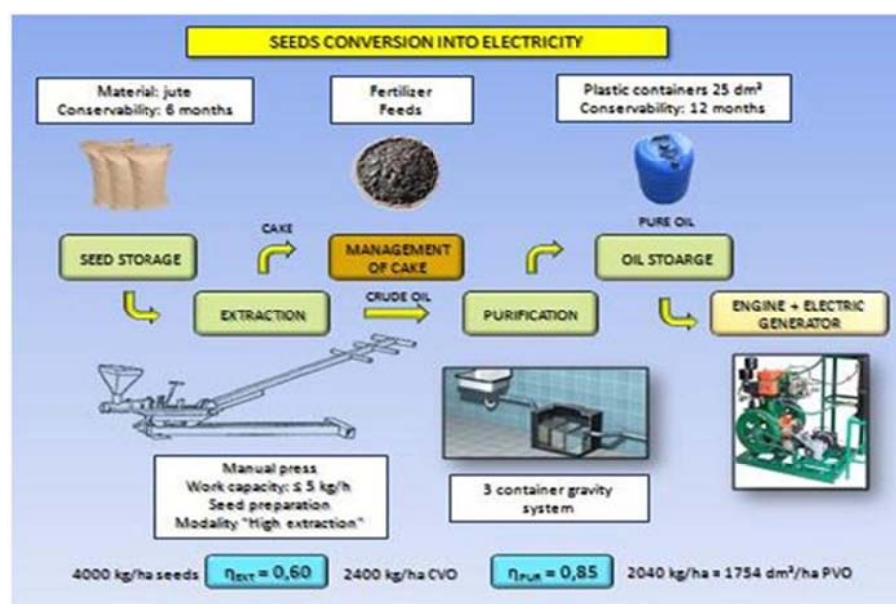


Figure 3.47. Shows the cost-benefit relationship of cultivating jatropha together with ground nut as intercrop within a period of 7 months in the upland ecology of Sierra Leone.



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<p style="text-align: center;"><b>Chapter 3</b> <i>The cultivation of jatropha in the upland ecology for the production of seeds to be used for the extraction of bio-diesel for generating electricity in the rural communities by the local farmers</i></p>		<p style="text-align: right;">page 56/64</p>



**Figure 3.48.** A schematic diagram of a dehuller (left) and a woman dehulling jatropha seeds (right).





**Figure 3.49.** Jatropha seeds transformation processes from seed to rural electrification.

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## Tables

**Table 3.1.** Data analysis on the total cost of planting of ground nut including labour and seeds as intercrop in the jatropha crop site.

Planting of ground nut							
OP_02							
	Plot	Unit	P1	P2	P3	P4	P_Ave
	Area	ha	0.50	0.50	0.50	0.50	0.50
LABOUR	Number of day	nr	1.0	1.0	1.0	1.0	1.0
	Employed (men/women)	nr	12	12	12	12	12
	Human total time	h	48.0	48.0	48.0	48.0	48.0
	(A) Labour cost	Le	90,000	90,000	90,000	90,000	90000
		€	16.98	16.98	16.98	16.98	16.98
CONSUMABLES	Ground nut seeds	kg	11	23	22	22	19.50
		Le					
	Jatropha seeds	kg					
		Le	0	0	0	0	0.0
		kg					
		Le	0	0	0	0	0.0
		kg					
		Le	0	0	0	0	0.0
	Other_consumable_05						
			0	0	0	0	0.0
MACHINES	Other_consumable_06						
			0	0	0	0	0.0
	(B) Consumables costs	Le	0	0	0	0	0
		€	0.00	0.00	0.00	0.00	0
	Total fuel consumption	dm <sup>3</sup>	0.0	0.0	0	0	0
COSTS	Mechines total time	min	0	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0
	Operator total time	min	0	0	0	0	0
		h	0.0	0.0	0.0	0.0	0.0
	(C) Machinery costs	Le	0	0	0	0	0.0
		€	0.00	0.00	0.00	0.00	0.0
	Operation cost (A+B+C)	Le	90,000	90,000	90,000	90,000	90,000
		€	16.98	16.98	16.98	16.98	17
		Le·ha <sup>-1</sup>	180,000	180,000	180,000	180,000	180,000
		€·ha <sup>-1</sup>	34.0	34.0	34.0	34.0	34
	Work capacity	ha·h <sup>-1</sup>	0.010	0.010	0.010	0.010	0.01
	(area/time)	m <sup>2</sup> ·h <sup>-1</sup>	104	104	104	104	104
		m <sup>2</sup> ·day <sup>-1</sup>	833	833	833	833	833



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**Table 3.2.** Cost analysis of all field activities in the cultivation of jatropha with ground nut as intercrop.

Field operation	TRADITIONAL METHOD OF JATROPHA CULTIVATION					
	Labour cost	Consumables	Work capacity ha·h <sup>-1</sup>	Human time h·ha <sup>-1</sup>	Total Cost Le·ha <sup>-1</sup>	€·ha <sup>-1</sup>
Pre-planting phase						
Bush clearing	150000	0	0.013	40.0	150,000	28.3
Debris clearing	120000	0	0.016	32.0	120000	22.6
Ploughing	285000	0	0.007	76.0	285000	53.8
Pre-planting phase	555000	0	0.035	148	555000	104.7
Planting phase						
Planting of G.nut	180000	292500	0.010	48.0	472500	89.2
Planting jatropha	120000	88000	0.016	32.0	208000	39.2
Planting phase	300000	380500	0.026	80	680500	128.4
Post planting phase						
First weeding	315000	0	0.006	84	315000	59.4
Second weeding	337500	0	0.006	90	337500	63.7
Harvesting ground nuts	315000	0	0.006	84	315000	59.4
Plugging of ground & mulching	262500		0.008	70	262500	49.5
Drying of ground nut	90000	0	0.021	24	90000	17.0
Post planting phase	1320000	0	0.047	352	1320000	
<b>Total</b>	<b>2175000</b>	<b>380500</b>	<b>0.107</b>	<b>580</b>	<b>2555500</b>	<b>233.1</b>

**Table 3.3.** Physical and chemical characteristics of diesel fuel and PVO of jatropha.

Property	Mineral diesel	Jatropha oil
Density	830	918
API Gravity	37.15	22.81
Kinematic viscosity at 40° C (cSt)	2.5	37
Cloud point (° C)	-12	9
Pour point (° C)	-15	4
Flash point (° C)	70	238
Calorific value (Kj/kg)	42,200	37,500
Carbon residue (%w/w)	0.05	0.8
Ash content (% w/w)	0.01	0.04
Carbon %	86.71	77.21
Hydrogen %	12.98	10.25
Nitrogen (ppm)	5	3
Oxygen ( % w/w)	0.31	12.52
Sulphur (ppm)	340	8

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**Table 3.4.** LISTER electric generator specification details.

Electric specification	
Power single phase	
Max output	6.6
Continuous output	6.1
Load ampage at 120 volts	
Maximum load	55
Continuous load	51
Load ampage at 240 volts	
Maximum load	27.5
Continuous load	25.4
Sound level at 7 m at full load	70 dB (A)

**Table 3.5.** LISTER PETTER electrical generator specification details.

Maximum power (kW)	6.3
Continuous power (kW)	6.1
Level of acoustic at 7 m (dB)	64
Number of cylinders	2
Maximum power (CV)	11
Revolution per minute (rpm)	1500
Ignition	Direct
Cooling	Water
Full load consumption per hour ( dm <sup>3</sup> ·h <sup>-1</sup> )	1.9
Full load specific consumption (dm <sup>3</sup> ·kWh <sup>-1</sup> )	0.311
Weight (kg)	314





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**Table 3.6.** Multifuel 3SP ATG electrical generator specification details.

Multifuel 3SP ATG details	
Maximum power	3
Continuous power	2.8
Type	
Number of cylinders	1
Maximum current intensity (A)	13
Revolution per minute (rpm)	3000
Ignition	Direct
Cooling	Air
Full load consumption per hour $\text{dm}^3\text{h}^{-1}$	1.6
Full load specific consumption $\text{dm}^3\text{kWh}^{-1}$	0.4

**Table 3.7.** Community power utility schedule on various activities.

Utility	Power (kW)
Domestic light	0.1
Domestic water supply	0.8
Domestic fan	0.1
Radio	0.2
TV	0.3
Agricultural irrigation	0.2
Agriculture refrigeration	0.8
Cottage industries	1.5
Public light	0.1
Public fan	0.1
Community centre	0.1
School	0.1
Health centre	0.2
<b>Total power (kW)</b>	<b>4.6</b>



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**Table 3.8.** Ground nut yield rate and income of the harvest.

Yield rate quantity and income from ground nut						
Plot		1	2	3	4	Ave_P
	Unit	0.2	0.4	0.4	0.4	
No. of plants	m <sup>2</sup>	27	25	23	23	25
Average no. of pods	Plant	10	8	7	5	8
Average quantity of pods	m <sup>2</sup>	270	200	161	115	187
Weight of dry pods	g·m <sup>-2</sup>	90	88	80	70	82
Weight of dry ground nut pods	kg·m <sup>-2</sup>	0.1	0.1	0.1	0.1	0.1
Average yield quantity of ground nut	t·ha <sup>-1</sup>	0.900	0.880	0.800	0.700	0.820
Cost	Le·ha <sup>-1</sup>	6750000	6600000	6000000	5250000	6150000
Cost	€·ha <sup>-1</sup>	1273.58	1245.28	1132.08	990.57	1160.38



**Table 3.9.** The cultivation of Jatropha as “sole crop” compared with “jatropha intercropped” with another crop: main results obtained in the field tests with index values (%) show that jatropha intercropped with ground nut assures better results for each parameter, including the total income return of production.

PARAMETER	UNIT OF MEASURE	JATROPHA CURCAS		JATROPHA GOSSYPIFOLIA	
		SOLE CROPPING (JSC)	INTERCROPPED WITH GROUND NUT (JIG)	SOLE CROPPING (JSC)	INTERCROPPED WITH GROUND NUT (JIG)
TOTAL TIME OF PRODUCTION	h·ha <sup>-1</sup>	580(100%)		580(100%)	
WORK CAPACITY	ha·h <sup>-1</sup>	0.107		0.107	
GERMINATION PERCENTAGE-JATROPHA	%	10	10	10	10
GERMINATION PERCENTAGE-GROUND NUT	%	-	95	-	95
HEIGHT AT 5 MONTHS (JATROPHA)	cm	31 (100%)	61(197%)	43 (100%)	91 (212%)
LEAVES AT 5 MONTHS	n.	9 (100%)	16(178%)	9 (100%)	11 (122%)
BRANCHING ABILITY AT 4 MONTHS (JATROPHA)	n.	0	2(100%)	3 (100%)	4 (133%)
SEED REPRODUCTION AGE (JATROPHA)	Months	6 (100%)	6(100%)	4 (100%)	4 (100%)
WEED POPULATION DENSITY	Density.m <sup>-2</sup>	62 (100%)	57(92%)	62 (100%)	57 (92%)
GROUND NUT YIELD RATE	t·ha <sup>-1</sup>	0.00	0.820(100%)	0.00	0.820 (100%)
INCOME FROM GROUND	€·ha <sup>-1</sup>	0.00	1160 (100%)	0.00	1160 (100%)
	€·t <sup>-1</sup>		1415 (100%)		1415 (100%)
TOTAL PRODUCTION PROFIT AT 7 MONTHS	€·ha <sup>-1</sup>	0.00	678 (100%)	0.00	678 (100%)

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**Table 3.10.** Jatropha yield rates at different soil conditions and rainfall.

JATROPHA SEED YIELDS FOR DIFFERENT WATER SUPPLY AND SOIL FERTILITY WITH RAINFALL (500 > 2500 mm)				
SOIL FERTILITY	WET SEED $\text{kg}^{-1} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$	DRY SEED $\text{kg} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$	OIL $\text{kg}^{-1} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$	POWER OUTPUT $\text{kWh} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$
High	4500	1500	300	2750
Medium	2250	750	150	1375
Low	750	250	50	458



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## Chapter 4 - General conclusions and recommendations of the research



### 4.1 General conclusion about the perspectives of the research in the rural communities

With regards to the research carried out in the rural communities of Rotebainkoh and Bumbang the following were identified as key issues discovered during the period of the exercise:

1. there was **high enthusiasm** from rural Small Scale Farmers (SSF) to follow and learn new innovations that are connected with their everyday's production activities to improve their socio-economic and welfare status;
2. the research **goals** were in **consonant with the activities** of the SSF, hence there was effective collaboration between the research and the farmers. This is because the objectives were **active** and had **concrete results** at the end of the production season in relation to the desires of the farmers. Being that the rural small scale farmers have an obligation to not only get new knowledge and skills but also to take food to their families at the end of every cultivation season, their efforts and commitments were observed to be productive at the end of the research project;
3. the **confidence of the famers** was won through **respect, trust and honesty**. This is because the farmers are very conscious of their social status and responsibilities they have in their communities, therefore engaging them together with their wives and children must be done with very good relationship and high esteem;
4. there was **clear chain of command and communication** during the research work. This is important to avoid misinformation between and amongst the farmers and the researcher hence fostering amicable working conditions and interpersonal relationships that led to the successful completion of the research;
5. there was an **acceptance of the farmers** as part of the research team through **participation**. The SSF were allowed to contribute what they know about the field work. They appreciated being listened to and adopted some of their suggestions as part of the research work. This created a reciprocal response for them to also accept the researcher's new ideas, skills, techniques and knowledge. This created a "**give and take**" situation during the research and
6. there was active and consistent leadership by the farmers and the researcher. There was a well designed plan of work to be followed during the research. This is because there were lots of other activities the farmers were engaged in during the time of the research. To avoid unnecessary clash of interests, the farmers must know and accept vehemently what they should do as their responsibility without forcing them to do it. The researcher avoided to be seen as the "**boss**" but rather the "**leader**".

### 4.2 Conclusion on rice research component

1. General perceptions

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‘We accepted your research proposal because we saw the tractor behind you’; is one of the comments made by the farmers at Rotebainkoh, where the rice research took place. This implies the farmers are really tired with intensive labour in their farms every year. This is a fact in Sierra Leone about all farmers, especially the SSF.

They said that they have held on to manual labour in their cultivation activities only because there is no alternative to the traditional “hoe and cutlass” method. Machines (e.g. tractors) cannot be afforded by the SSF due to their costs. If they (tractors) are made available to them through whatever means, they cannot afford to maintain and run them successfully.

## 2. Some problems of minimum mechanisation with small scale farmers in Sierra Leone

The use of machines for minimum mechanization to help relieve the farmers from their intensive field labour has myriad of challenges as identified from the research:

- a) the **cost of the tractors** is high to be able to support the 65-75% farming population of Sierra Leone amidst the realm of the donor driven budget of the country.

This can be achieved by the country **developing a national policy** that will direct the **local and international communities’ resources** towards that direction rather than working on alien or foreign designed agricultural projects that do not reflect the real needs and aspirations of the rural resource poor farmers;

- b) the **technical know-how** for the use and maintenance of machines such as the tractor was identified to be a major stumbling block to mechanisation. The inability of tractor operators and auto mechanics to adequately use and amend machines when there are problems must be appropriately and urgently addressed.



Institutions (both government, non-governmental and private) **MUST** take the responsibility of **training and equipping** the youths of the rural areas on the use and maintenance of agricultural machinery and equipment for sustainable execution of the field operations in small communities;

- c) the **general management** of the tractors and their running cost. This needs to be of great concern as there are a lot tractors being misused and abused in Sierra Leone due to ignorance and poor management ability in either the government institutions, NGOs or the private sectors.

Good **management leadership** and honesty of purpose **must** be an integral part of mechanisation in the country with special reference to the small communities;

- d) the **farming site land preparation**. It was discovered in this research that the land site to be tilled by the tractor needs to be properly prepared before the exercise. This involves levelling, removal of bigger stumps, trees, termite hills and stones to create conducive working atmosphere for the machine, equipment and operator. Tremendous time and energy was spent in the cultivation of a hectare due to the status of the land under tillage.

There should be a gradual shift from the popular “**shifting cultivation**” to a more organised sedentary crop cultivation together with a systematic method of **crop rotation and mix culture**

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approaches to avert the problem of heavy land clearing every year in a new location for crop production and

- e) the **availability of Spare parts** for the machinery. This was identified as a critical factor during the cultivation period. It became extremely difficult to obtain spare parts broken or damaged during the work from around or even within the country. This can lead to a total standstill of the entire process if appropriate measures are not taken to include the procurement of appropriate spare parts for the existing machines in the country.

Directing the **national budget and private sector enterprises** to securing **appropriate** and **authentic** spare parts for the existing machinery in agriculture should be a matter of **MUST**.

3. Some solutions to improve minimum mechanisation in Sierra Leone and Africa in general in the rural areas with the SSF
  - a) **cooperative or group farming** is what the farmers of this research suggested **MUST** be emphasised in Sierra Leone. This is where, for example, a tractor is provided for 1-3 communities, depending on their sizes, for a period of time to carry out soil tillage processes for them in their respective sites. Most of the farmers are ready to pay for the cost of the service when they are sure it will be done as and when they need it;
  - b) **training of rural youths** on the use of farm machinery was another strong suggestion that came from them. This is because they affirmed that the cost of maintaining these youths who are part of the communities is less when compared with bringing someone outside their communities to do the same work and
  - c) **availability** of sources of financial assistance either in the form of loan, grant or subsidy to the farmers.
4. Technical aspects

Mechanically, there is a huge advantage on the use of machines (e.g. tractors) in soil tillage in rural areas for the SSF.



In terms of time, the use of **49 hours** to cultivate (plough and harrow) a hectare with the tractor in the **modern method** was compared with **128 hours** spent to do the same job with the manual hoe and cutlass in the **traditional method**. There was 88% of time saved in these farm activities of the farmers.

The **work capacity** by using the tractor to do the soil tillage operations was **1.07 ha·h<sup>-1</sup>** in the modern method, while in the traditional method it was **0.006 ha·h<sup>-1</sup>**.

This clearly shows that more hectares can be cultivated by a farmer through the use of a machine within a short time during the season of soil tillage. This may lead to bigger farms and better soil preparation per farm family.

With the minimum mechanisation aspect as part of the modern method approach, the use of tractor has had some positive effects on the agronomic aspects of the research as discovered from the field results in the field:

- a) there was **better seed germination** in the area cultivated by the tractor (modern method-178 plants·m<sup>-2</sup>) than the (traditional method-150 plants·m<sup>-2</sup>) plots;

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- b) the **weed prevalence** was lower in the tractor cultivated treatments (51 weeds·m<sup>-2</sup>) area than the traditional (60 weeds·m<sup>-2</sup>) hoe and cutlass or machetes;
- c) the **crop performance**, (in terms of growth and yield rates) was seen to be better in the mechanised modern method (116 cm in height and 2.34 t·ha<sup>-1</sup>) than the traditional (108 cm in height and 2.20 t·ha<sup>-1</sup>) and
- d) some **farm activities** such as weeding and harvesting were accepted to be faster and easier in the mechanised modern plots than in the traditional ones.

#### 5. Economic aspects

- a) the cost-benefit relationship of the research was seen to be more positive with the traditional (895,700 Le·ha<sup>-1</sup>) when compared with the modern method (5,300 Le·ha<sup>-1</sup>), because the cost of production was lower in the traditional method than in the modern. This is however obvious due to the additional cost of the machinery which needs more specialisation on skills and techniques to manage and run it and
- b) some of the activities will be less expensive if they are mechanised, such as the modern method of seed planting. This has the second highest single activity cost of 1,165, 640 Le·ha<sup>-1</sup> in the entire farm operations. This could be lowered if it was mechanised. It can also save some time from 169 h·ha<sup>-1</sup> to about 4 h·ha<sup>-1</sup>. This could have saved approximately 165 h·ha<sup>-1</sup>. The farmers can use this time to rest, have adequate time with their families and engage in other socio-economic activities.

In summary, the cost of production can be reduced if mechanisation covers more than just ploughing and harrowing but also seed application with the use of the same machine.

The machine could be used for additional farm operations such as the cultivation of other crops such as cassava, potato, vegetables, maize and some other stationary functions if the equipments are made available.

In other to economically realise the effective utility of the tractor, it must be used in a **multi-faceted** manner than just for a **single type** of field operation in the production scale.

### 4.3 Conclusion on jatropha research component



The cultivation, processing and use of PVO from jatropha are seen as a break-through in searching for solutions for the provision of rural electrification in the communities of Sierra Leone.

#### 1. General perceptions

The introduction of the idea of rural electrification through the use of jatropha seeds was highly welcomed by the Bumbang community. This is because there were relevant and fundamental needs for electricity in the community before this research.

The needs highlighted before the research project began are:

- a) no electricity in their homes, hence the use of the inadequate and expensive petroleum product (kerosene) to light their hurricane lamps at night;

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- b) no electricity to charge their mobile phones;
- c) no light for children to study at night in the school or at home;
- d) no light in their community centre for social activities such as occasional dances, video or film shows and settlement of community disputes (palavers) at night;
- e) problem of the health centre to maintain the cold chain of the vaccines and other drugs received from the referral hospitals;
- f) food wastage such as meat and fish obtained from their environment and
- g) inadequate water supply for both domestic and agricultural activities, especially for vegetable production during the dry season.

*However, they were especially concerned as to how such a project could be implemented when they were aware that jatropha seeds cannot be eaten, and had no idea as to how such a plant could be cultivated or use its oil to produce electricity.*

Successful sensitisation led them to accept that the crop can be cultivated without interfering with the main food production activities.

The results show that 10 farmers can cultivate a hectare of jatropha during the year. The community of Bumbang has the potential to cultivate the 17.1 ha of jatropha needed to supply electricity throughout the year since their population is about 1,700.



The production process of jatropha seeds did not involve any mechanisation. The traditional method used was well integrated with some modern techniques which the farmers accepted and practiced during the period of the research.

## 2. Agronomic aspects

The introduction of ground nut as an intercrop to jatropha and the inclusion of modern agronomic methods yielded fruitful results as follows:

- a) averted the most feared perception of the farmers allocating all their time and energy in producing a crop that cannot be eaten as food; with ground nut as intercrop, there is a supplementary crop (ground nut) to eat or sell;
- b) impacted the reduction of weeds in the plots hence ease of weeding in those plots;
- c) positively affected the growth rate of jatropha in all the plots that had ground nut as intercrop and
- d) acquisition of new skills and knowledge as to how jatropha can be intercropped with ground nut through the simple scientific use of spacing with tape measure and pegs.

The assessment of the average production level of the jatropha was not achieved due to the time of the field research which ended within 7 months when the crops were still producing. However, the period for the reproduction of seeds by the jatropha crop was in consonant with the bibliographies read in the research.

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### 3. Technical aspects

The following were discovered as technical issues needed to be achieved for the rural electrification of the Bumbang community:

- a) the electric energy distribution pattern has been scheduled and kilo watt needed estimated to meet the needs of the community and the potential power supply of the machine recommended was 6.1 kW;
- b) the amount of PVO (**29930 dm<sup>3</sup>**) needed to run the LISTER generator with 6.1kW, for the whole year and the corresponding 17.1 hectares needed to be cultivated was achieved through this study. This implies the seed production should be 4 t·ha<sup>-1</sup> in other to achieve this goal. This might not be possible during the first year of jatropha cultivation but gradually through the first 5 years;
- c) the ability to manage the seeds and extract PVO has been observed to be possible in the community with the use of a manually operated extraction machine, preferably the ram press and
- d) the purification, storage and use of PVO can be carried out through minimal training of community members when the recommended LISTER electric generating machine is obtained.

### 4. Economic aspects

The economic aspect of the research cannot be achieved completely as there was still the issue of getting the recent costs of the manual mechanical ram press machine and the electric generator.

However, the agronomic cost of production was calculated to be 2,555,500 Le·ha<sup>-1</sup>, while the income from the ground nut yield was 6,150,000 Le·ha<sup>-1</sup>.

This makes economic returns (profit) of 3,594,500 Le·ha<sup>-1</sup>. The cost of ground nut is 7,500,000 Le·t<sup>-1</sup> ≈ 1415 €·t<sup>-1</sup>. The average yield of the ground nut was calculated to be 0.820 t·ha<sup>-1</sup> in this experiment.



The cost of extraction and purification still needs to be calculated based on the type of machines and equipments to be used and the quantity of jatropha seeds available.

## 4.4 Recommendations

### 4.4.1 General recommendations of the research

- Community based On-Farm Research (OFR) and or Farmers Participatory Research (FPR) should be emphasised in agriculture to break the unsubstantiated mythology of farmers being conservative to accept changes with modern method approach in agriculture.
- Active participation and respect for the intellectual contributions of farmers in field research should be an integral component of any successful approach to discover ways to improve agricultural productivity in Africa and Sierra Leone in particular.



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- Good leadership skills, proper time and activity management strategies in community based research should be fostered to create active field laboratory where new knowledge, skills and techniques can be consciously or unconsciously generated and learnt by the rural small scale farmers for effective acceptance and use.

#### **4.4.2 Minimum mechanisation, modern agronomic and technical approach to rice cultivation**



The study recommends the following.

- Intensification of minimum mechanisation including seed planting with SSF should be continued in order to reduce the amount of time and energy spent in field preparation and accomplishing the timely planting of crops in farm sites.
- Basic training of auto mechanics and machine operators is an essential ingredient in enhancing successful mechanisation in Sierra Leone and Africa in general.
- The redesigning or developing machines that will suit the type of agronomic activities practised by SSF; such as seeders that can intercrop rice with other seeds at the same time, should be an essential break-through for a sustainable agriculture development for rural small scale community farming.
- A continuation of this research work to further verify the inter-play of the respective combinations of the modern method of rice intercropping compared with the traditional method on the same piece of land for 2 -3 years is a dire need. This will help to modify the traditional shifting cultivation which demands huge amount of energy, time and cost from the already impoverished farmers.



#### **4.4.3 On Jatropha cultivation for the production of PVO for rural electrification**

This study recommends the following.

- Further identification of high yielding varieties of jatropha (*J. Gossypifolia* and *J. Curcas*) should be continued.
- Improving the agronomic practices of the farmers.
- Improve on the intercropping system in the form of crop rotation by the farmers.
- Introduction of minimal mechanization to minimise the drudgery of the farmers in the cultivation, processing and use of jatropha.
- The minimal use of chemicals (fertilizers and pesticides-if easily available and affordable by the farmers) should be introduced.
- The procurement of extraction machine (ramp press), purification unit and a 6.1 kW electric generator specially designed for the use of PVO is a needed component to practically realise the completion of this research in the rural community of Bumbang.



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- Training of community members on the use and maintenance of the machinery and equipment for the entire production, processing and running of the electrification system are key pre-requisites to the successful implementation and sustainability of the project.

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## Acronyms and Abbreviations

ADB	African Development Bank.
ARC	Agriculture Research Council.
c	Work Capacity.
DAP	Days After Planting.
FAO	Food and Agriculture Organization.
FFA	Free Fatty Acids.
FPR	Farmers Participatory Research.
GHG	Green House Gases.
GTZ	German Agency for Technological Co-operation.
h	hour.
ha	hectare.
i.c	internal combustion.
IVS	Inland Valley Swamp.
IRIN	Integrated Regional Information Network.
JICA	Japan International Cooperation Agency.
JIG	Jatropha Intercropped with Ground nut.
JSC	Jatropha Sole Cropping.
kW	kilo Watt.
LCC	Leaf Colour Chart.
Le	Leone (Sierra Leone currency).

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MAFFS Ministry of Agriculture Forestry and Food Security.

MTRR Modern Treatment with only Rice.

MTRP Modern Treatment with Rice and Pigeon peas as intercrop.

MTRB Modern Treatment with Rice and Beni-seeds as intercrop.

MTRS Modern Treatment with Sorghum as intercrop as intercrop.

MTTC Modern Treatment with Total Combination of rice with all intercrops (pigeon peas, beni-seeds and sorghum).

MT\_Ave Average of Modern Treatments.

NPBT Non Panicle Bearing Tiller.

OFR On-Farm Research.

PBT Panicle Bearing Tiller.

PVO Pure Vegetable Oil.

SSA Sub Saharan Africa.

SSF Small Scale Farmers.



SVO Straight Vegetable Oil.

TT Traditional Treatment.

TOT Total number Of Tillers.

UNDP United Nations Development Projects.

WHO World Health Organisation.

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## Glossary

**A mix crop** is a crop that is planted together with a major crop in an irregular spacing; mainly through random broadcasting. The mixed crop is normally harvested after the major crop.

**A ‘Treatment’** is referring to an experimental piece of plot with defined and definite design, allotted for a specific method of cultivation carried out and observed during the period the entire experiment is being conducted to collect data either qualitatively or quantitatively.

**Boliland** is a low land ecology that can become easily water logged with few rains but can also easily loose water when there are less rains during the year.

**Bush fallow** is the period in which the cultivated land surface is allowed to rest without any cultivation activities being carried out in that location for a period to be determined by the land users ranging from 2-50 years or more.

**Extension services** are activities meant to transmit information, techniques and technologies from the research point, institutions or individuals to the farmers either directly or indirectly; through formal, non-formal or informal method(s).

**Farmers Participatory Research (FPR) or Participatory Research Approach (PRA)** is a research approach that the researcher or research institution involves the farmers directly into the activities, either in the farmers own farms or elsewhere during the exercise.

**Furrow marker** is a device used to create furrows in the already tilled soil in definite spaces in which seeds are sown. It was fabricated by the researcher to be able to carry out manual planting of rice and the intercrops in definite spaces and at a faster rate.



**Intercrop** is a crop planted between major crops in a definite spacing; to be harvested after the major crop has been harvested.

**Intercropping** is the row planting together of a major crop such as seed rice and other crops (e.g. pigeon peas, beni-seeds and sorghum) in definite spacing after soil tillage (ploughing and harrowing) in which the major crop is harvested first then followed by the intercrops.

**Inland Valley Swamp (IVS)** is a flat low land ecology found between mountains with water logged condition during most time of the year especially during the wet or rainy season.

**On-Farm Research (OFR)** is the research done on the farmers own farm site in which all activities are carried out; instead of in an exclusive location created by the researcher or research institution.

**Mangrove swamps** are lowland ecology found along the ocean with intermittent water logged condition together with high salt content, especially during the dry season or when there are less rains. They are commonly called “mangrove swamps” because “mangrove trees” are the salt tolerant trees that are commonly found growing in these ecologies along the oceans.

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**Minimum mechanisation** is referring to the minimal or less use of farm machinery to accomplish most of the field activities in the farm. In this study, it is referring to the use of machine only for soil tillage activities such as ploughing and harrowing of the farmer's field.

**Mix cropping** refers to the introduction of a major crop such as rice together with other crops (e.g. pigeon peas, beni-seeds and sorghum) by randomly broadcasting them in the field by the farmer before ploughing or hoeing.

**Modern method** means the use of machinery such as tractor to carry out some farm cultivation activities such as soil tillage and the sowing of seeds in definite spacing in the farm.

**Palm wine** is a white liquid extracted from the palm tree by men in Sierra Leone. It is done by climbing and tapping the younger parts of the palm fronds with local instruments such as cutlass, chisel, bamboo cane pipe and gourd. The liquid contains alcohol which is used to drink by most people in the country. The practice is most predominantly carried out by the Limba tribe of the Northern part of the country as source of beverage and money for the families.

**Pre-planting phase** is the period in which all the field activities are carried out before the sowing of seeds or plant materials into the soil.

**Planting phase** is the period in which the introduction of seeds or other planting materials into the soil is being done by the farmer.

**Post planting phase** is the period in which all the field activities are carried out by the farmer after the emergence of the crop plants in the field.

**Pure Vegetable Oil (PVO) or Straight Vegetable Oil (SVO)** is the purified **Crude Vegetable Oil (CVO)** extracted from the seeds of vegetable plants such as Jatropha that can be used directly into an internal combustion (i.c) engine specially designed for it.

**Resource Poor Farmers (RPF)** are those small scale farmers that do not have the required modern techniques, skills, technologies and capital to engage in large production or increase their production levels in their diverse agricultural engagements. They are sometimes called subsistence farmers.

**Riverine swamp** is an ecology that sustains deep levels of water logged condition during the rainy season along the Ocean's estuarine rivers.

**Small Scale Farmer (SSF)** is a farmer that carries out his/her cultivation in a small piece of land with an average of 0.5 to 2 ha per season or year to merely feed the families and their basic social welfare needs. This farmer is sometimes referred to as subsistence.

**Traditional method** in this research means the clearing of the land by using machetes and hoe and the sowing of seeds (rice, sorghum, pigeon peas, beni-seeds -sesame) through random broadcasting in the field.

**Upland** is an ecology that does not sustain any water log condition even during the rainy season. It is an ecology that is mostly rain fed for plant growth and reproduction.

**Winnowing** is the act of separating the seeds from the chaffs through the use of a local device called winnower. It is mainly carried out by women and young girls in the rural communities.