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Palm Oil Modern Extraction Technology Effect on Income Generation of Selected Rural Areas in Cameroon

Dissertation Thesis

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Declaration:

I hereby declare that the work presented in this thesis is, to the best of my knowledge and belief, original and wholly my own work with original data collected directly from the field unless otherwise referenced.

In Prague, 23rd June 2014

Ing. Bassel El Khatib …………………

Acknowledgement

On top of all I want to thank God for giving me the ability to finalize my PhD studies and PhD thesis.

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ABSTRACT

Agriculture and forestry remain the leading sectors in Cameroon, accounting for some 36% of the merchandise exports and for more than 40% of GDP in 2011/12. Agriculture alone accounts for more than 30% of GDP and provides employment for about 68% of the active population.

Cameroon's oil palm industry still plays a significant role in the national economy, providing oil for house hold consumption, industrial use as well as employment for thousands of Cameroonians who are engaged in production, processing and marketing. This project aims at bringing clarity on to what extent the up to date oil extraction processing technology installed in a concrete rural district, and under a clear management and regulatory structure and environment, outperforms in terms of productivity (tons of palm oil produced) and quality (price of the crude palm oil) the existing artisan manual processing palm oil producing system.

The methodology applied within this study consists of comparing key indicators across populations of small scale palm oil processors in interaction with traditional non sophisticated technology with different work environment, production capacity, socio-economic status and income levels (cross-sectional statistical analysis). Results showed that modern mills produce a total of 0.22 tons of palm oil per worker and year, a staggering over 100% more as compared to the traditional mills production which stands at only 0.10 tons per worker and year.

Results also showed the value added chain in palm oil process, particularly relations between new technology and productivity, efficiency, quality of product and impact on income.

Keywords: Cameroon, edible oil extraction technology, palm oil, value added chain.

ABSTRAKT

Zemědělství a lesní hospodářství zůstávají hlavními ekonomickými sektory v Kamerunu. Komodity z těchto sektorů pokrývaly kolem 36% exportu a představovaly více než 40% HDP Kamerunu v roce 2011/12. Samotné zemědělství tvoří více než 30% HDP Kamerunu a zaměstnává kolem 68% ekonomicky aktivního obyvatelstva. Pěstování palmového oleje a jeho zpracování stále hraje významnou roli v národním hospodářství Kamerunu. Zabezpečuje olej pro domácí spotřebu, průmyslové využití a přitom dává práci tisícům Kamerunců, kteří se podílejí na produkci, zpracování a obchodu s touto komoditou.

Tato práce si klade za cíl pomocí vědecké analýzy zjistit závislost na tom, do jaké míry nová technologie pro zpracování palmového oleje použitá v konkrétním venkovském regionu Kamerunu při zavedení nových řídících prvků a při zachování environmentální udržitelnosti, zvýší, pokud jde o produktivitu (tun palmového oleje), kvalitu a cenu (cena surového palmového oleje), efektivnost nové technologie oproti ruční technologii, kterou používají doposud dělníci na farmách při zpracování palmového oleje. Metodika použitá v této studii se skládá z porovnávání klíčových ukazatelů drobných zpracovatelů palmového oleje tradiční technologií a moderní technologií v interakci na odlišné pracovní prostředí, výrobní kapacity, socio-ekonomické podmínky a úroveň příjmů (statistická analýza). Výsledky ukázaly, že moderní technologie produkují celkem 0,22 tun palmového oleje na pracovníka a rok, což je o více než 100% vyšší úroveň, ve srovnání s výrobou tradičních provozů, které produkují pouhých 0,10 t na pracovníka a rok.

Výsledky také ukázaly vyšší tvorbu přidané hodnoty v oblasti zpracování palmového oleje, plynoucí zejména ze vztahů mezi novou technologií a produktivitou, efektivitou, kvalitou výrobku i příjmy.

Klíčová slova: Kamerun, technologie zpracování jedlého oleje, palmový olej, tvorba přidané hodnoty

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1. Introduction

Palm oil in Cameroon has been chosen for the purpose of this study due to the following:

Agriculture and forestry remain the leading sectors in Cameroon, accounting for some 36% of the merchandise exports and for more than 40% of GDP. Agriculture alone accounts for more than 30% of GDP and provides employment for about 68% of the active population.

As in most parts of Africa, the farm culture in Cameroon is basically subsistence. Plantation farming is a new phenomenon to Cameroon. Families cultivate a small plot for their food needs and interplant tree crops. After three years or more the tree crop takes over the plot and the farmer moves to another. Farm-holdings are generally small and scattered since the land tenure system does not permit large-scale farming unless the government steps in to acquire the land for public use.

Palm oil is today the most produced vegetable oil in the world with 46 million metric tons produced in 2011 (FAO-Stat, 2012). Palm oil fresh fruit bunches have an oil content of more than 20 percent and provide a higher yield of oil per hectare than most other crops (MPOB, 2012). Malaysia and Indonesia are the largest producers of palm oil, accounting for more than 85 percent of global production, along with a fairly rapid expansion of oil palm growing in other areas around the world such as West Africa.

In addition, palm oil has been the key supplier to global edible oils market. It has helped to feed the world's growing population. Strong demand for this relatively cheap and versatile oil, including from countries like China and India (plus the prospect of bio-fuels), has driven up palm oil prices, alongside other commodities.

Today, palm oil is so versatile that we don't realize its omnipresence in our everyday lives, which is intensively used in the production of food products (cooking oil, shortening, margarine, milk fat replacer and cocoa butter substitute). Also palm kernel oil used in the oleo chemical industry (soaps, detergents, toiletries or cosmetics).

Palm oil is widely known and credited for its ability to supply millions of families in Cameroon today with finances and food. Many families depend on the yields they make from the oil palm sector to cater for their basic needs in terms of hospital bills, school fees, house rents, etc. The ever increasing demand of the palm oil cannot be ignored but unfortunately many farmers and palm oil producers are still to discover some of the countless benefits that can be derived from the numerous by- products of the oil palm.

Industrial exploitation of the oil palm tree began in Cameroon in 1907, under the German administration. Today, the oil palm industry still plays a significant role in the national economy, providing oil for house hold consumption, industrial use as well as employment for thousands of Cameroonians who are engaged in production, processing and marketing.

Oil palm was enthusiastically cultivated in Cameroon mainly because of its large number of uses; which are deeply embedded in local cultures. Demand from international markets, however, has also played a great part in convincing Cameroonians to cultivate oil palm.

Nowadays, in Cameroon, palm oil is gradually being transformed from a famine-reserve subsistence commodity and rural food to a cash crop for urban consumption. For the oil palm transformation to advance, access to technology, labor-saving quality production, harvesting and new processing technologies are needed to reduce costs, improve productivity and make oil palm of higher competitive quality.

Hence the major problems of the cooperative group are production capacity, product quality, hygiene conditions and limited management skills.

Studies show that increasing the quality and quantity of Crude Palm Oil (CPO) production and other by-products could generate recurrent revenue and will attract investment in service related activities. In a broader sense, the local community as a whole could benefit from new employment opportunities, which ultimately would lead to improve the poverty and food security levels. The new technology will also support the competitiveness of the local industry by developing quality products that comply with required standards. Product diversification and market participation will thus drag and enhance local production and will generate earnings, investment and tax income at state and country levels.

In this PhD study, I am introducing a modern palm oil processing technology in 2 different regions of Cameroon as a treatment.

I will measure the effect of the treatment on the income of the livelihoods around the treatment before and after application.

2. Objective of the PhD Thesis

The objective of this PhD Thesis is to measure the impact of palm oil technology on the revenue generation capacity of rural processors in Cameroon. More specifically, this study aims to quantify the effect of the establishment of a modern palm oil processing technique on the income levels of selected rural Cameroonian communities and compare these income levels with the ones of existing manual or semi-manual processing units

In summary, this Thesis will assess the following aspects:

- To determine whether an improved palm oil processing technology has a positive effect on productivity (FFB processed and crude palm oil per worker), efficiency (oil extraction rate), and profitability (output price) of crude palm oil processing units and whether this ultimately improves the income of its related workers. Results are compared against traditional processing centers.
- To quantify the impact in terms of income of processing capacity, productivity and efficiency with respect to traditional centers.
- To determine which processing equipment is more determinant in increasing the income of the workers
- To Issue recommendations regarding the adoption of a particular technology / processing equipment, in order to maximize income for processor workers.

Even though the economic literature suggests a positive correlation between labor productivity and wages, there is still considerable missing evidence as to be able to define under which concrete circumstances positive technological changes directly translate into replicable and widespread pro-poor income gains. It is therefore the aim of this study to bridge the gap between theory and practice by looking at the impact of a standard and concrete technological improvement’s contribution on income variables in Cameroonian rural selected communities. In other words, this PhD aims at bringing clarity on to what extend a more advanced mechanical palm oil extraction equipment (Advanced being 0.7 to 5 ton-per hour. Traditional being less than 0.7 ton-per hour) installed in a concrete rural district, and under a clear management and regulatory structure and environment, outperforms existing artesian manual processing palm oil producing system in terms of productivity (tons of palm oil produced), quality (price of the crude palm oil) and income generation capacity. Income in this case indicates salaries of the workers within the installed modern hour palm oil mills.

The literature on the determinants of household income and poverty is well established, dating back from the literature on human capital development, economic growth, and poverty reduction (e.g., Schultz 1961; Welch 1970) to more recent analyses of household data (e.g. Hassan and Babu 1991; Lanjouw and Ravallion 1995; Simler et al. 2004; Otsuka and Yamano 2006). The main determinants include household size, the age and gender composition of the household, education, health, social capital, assets and endowments, and employment, among others.

If proven successful that a new technology increases production and marketability through better quality and productivity, assisting in alleviating poverty within the rural areas of Cameroon, then, this result could be used in the design of better development policies, and favor economic growth creation, poverty reduction and youth employment. Hence, if the treatment results are positive by enhancing the economic status of livelihoods within the selected areas for the intervention, then this treatment could be recommended to the Government of Cameroon as an effective tool towards pro-poor income generation, tax revenue, economic structural change and job creation in these rural areas.

If the study fails to conclude that Palm Oil Modern Extraction Technology has a positive impact on income generation, then a plausible explanation on the determinants and causal chain will be explored. In such case the study will provide recommendations and alternatives along these lines that will be ultimately forwarded to the Government.

The study acknowledges its limitations in flawlessly predicting results in other contexts and environments. Therefore, it is not the aim of the Thesis to advocate for this particular palm oil technology as the only way to get out of poverty in oil palm producing areas or to appear as a panacea for rural development, but rather to demonstrate how under certain controlled circumstances technology directly contributes to its users to generate additional revenues.

3. Literature review

3.1 General aspects of the Oil Palm

3.1.1 Origin and distribution

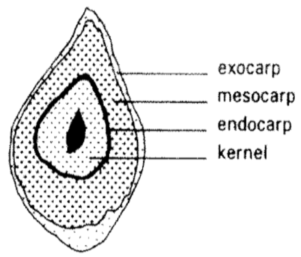
African oil palm originated in the tropical rainforest region of West Africa along the coastal strip between Liberia an Angola, from where it spread North, South and east to Senegal, Zanzibar (Tanzania) and Madagascar. Since its domestication, oil palm has been introduced and cultivated throughout the humid tropics (16°N to 16° S) elsewhere in the world.

3.1.2 Botany and ecology

The oil palm, *Elaeis guineensis* Jacq., belongs to the subfamily Cocoidae of Palmae, which also includes the coconut (Classification H.A.J. Moll, 1985). The fruits of oil palm vary widely.

The following classification is based on variations of the internal structure of the fruit:

- Dura: shell 2-8mm thick
- Pisifera: shell-less
- Tenera: shell 0.5-4mm thick.



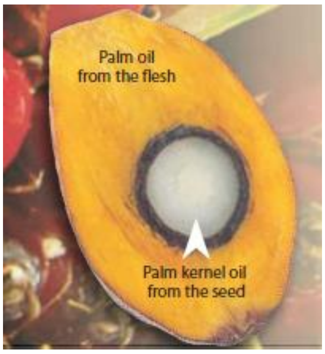
Most commercially planted palms are tenera and the fruit type nigrescens is predominant (unripe fruits deep violet to black, ripe fruits with brown or black cap).
Africa has a wider range of oil palm varieties than other regions. Most modern varieties are from the Tenera group, with thin shell and thick mesocarp, which was developed by crossing the wild –type Dura (thick shell, thin mesocarp) and shell-less Pisifera. Tenera varieties have high oil content, are easier to process than wild oil palm (Poku 2002) and are widely cultivated in Asia (Wahid et al. 2005).
The native habitat of the oil palm is tropical rainforest with 1780-2280m annual rainfall and a temperature of 24-30°C (minimum and maximum), seedlings not growing below 15°C. It

does not generally do well under closed canopies. Oil palm can be tolerant to a wide range of soil types; as long as it is well watered. African oil palm stands out to be amongst the best studied tropical rainforest plants.

3.2 Agricultural considerations

Typically, oil palm plantations are planted at a 9 m by 7.5 m spacing and the resulting 148 palms per hectare produce one new frond every three weeks, each new leaf adds 4.5 cm to the trunk height i.e. (80 cm per year, 20 m in 25 years) and goes on to form one bunch either male or female; typically under well managed conditions 10-15 bunches can be harvested per palm in a year weighing 15 – 20 kg each, total yields are thus 15- 30 tons of fresh fruit bunches (FFB) per hectare per year.

The sex determination of flowered bunches depends on the level of resources in the plant and the level of water and nutritive conditions. Under very good conditions, the majority bunches are female and can lead to high fruit yields, drought stress, increases the proportion of male flowers. Once the female flowers are pollinated, the plum shaped fruits develop in clusters of 200-300 on short stems close to the trunk. Each fruit is about 3.5 cm long and 2 cm wide and weighs about 3.5 g. The fruit comprises outer oily flesh or pericarp (made up of exo – meso and endocarp) and an oil-rich seed or kernel.



Oil palm seedlings are typically raised in a nursery for one year before planting out. Planting densities range from 110 to 150 stems per hectare. Ground cover crops are used to reduce weed growth and prevent soil erosion (Basiron 2007). Fruit production responds well to soil nutrients and trees produce more fruit when fertilized. Mulching also boost yields; for example, empty fruit bunches used as a mulch can reduce the need for fertilizers by over 50 per cent in immature stands and by 5 per cent in mature stands (Tailliez 1998).

Natural Oil palm produces fruit after 4-5 years. Yield continues to grow thanks to the successful process of breeding in some countries, especially in Malaysia, Indonesia and Australia. For not-breed African oily varieties yield reaches 0.6 t/ha, with breed varieties reaches 6 t/ha. Average yields in Malaysia can reach 7 t/ha mesocarp oil and 1.25 t/ha core oil (Espig, et al. 1991).

High performance palm varieties mature rapidly and can be harvested as soon as 2-3 years after planting (Basiron 2007), although trees aged 9-15 years are the most productive (Bisinfocus 2006). After 25-30 ears trees become too tall to harvest and are advised to be replaced. Some long –established plantations in south east Asia an even Cameroon have already been replanted for the third time (Basiron 2007)

With appropriate management plantations can be productive on a wide range of soils , including problem soils such as acid sulphate soils, deep peat and acidic high aluminium soils, where few other crops are successful (Auxtero and Shamshudin 1991).
Seasonal droughts at higher tropical latitudes can greatly reduce yields (Basiron 2007) water-stressed palms produce fewer female flowers and abort unripe fruits. Palm productivity benefits from direct sunshine; the lower incidence of cloud cover over much of Southeast Asia is thought to be one reason why oil palm yields are higher there than in most areas of west Africa (Dufrene et al.1990).

The primary unit of production of the palm oil industry is the farm where the oil palm tree is cultivated to produce palm fruits. There are also wild groves of oil palm. The farm units are of different sizes and may be classified as small, medium, and large-scale estates.
The wild groves, as the name implies, grow untended in the forest. They are found in clusters and are mainly the result of natural seed dispersal. Dura, the main variety found in the groves, for decades has been the source of palm oil – well before modern methods of oil palm cultivation were introduced to Africa in the second quarter of the 20th century.
The other varieties are Pisifera and Tenera, which is a hybrid variety obtained by crossing Dura and Pisifera. The Dura has a large nut with a thick shell and thin mesocarp. The Pisifera is a small fruit with no shell. By crossing the Dura with Pisifera a fruit is obtained with a thick mesocarp containing much more oil and fat (chemically saturated oil) than either of its parents. The Tenera nut is small and is easily shelled to release the palm kernel. The Tenera palm kernel is smaller than the Dura kernel although the Tenera bunch is much larger than Dura. In all, the Tenera is a much better variety for industrial and economic purposes.

3.3 Uses, products and by-products

Palm oil is today the most produced vegetable oil in the world in terms of production - 37 million metric tones (Oil World, 2006).

Today, palm oil is so versatile that we do not realize its omnipresence in our everyday lives. The oil palm fruit produces two oils - palm oil from the fleshy mesocarp and palm kernel oil from the seed or kernel. Palm oil is used primarily in food products: cooking oil, shortening, margarine, milk fat replace agent and cocoa butter substitute. Palm kernel oil is mostly used in the oleo chemical industry for making soap, detergent, toiletries and cosmetics.

New uses for palm oil have emerged in recent years. For example, unstable and at times soaring petroleum prices and increasing concern about global warming have increased the demand for palm oil as a feedstock for biodiesel, a renewable and green substitute for diesel. In addition, nutritional studies have found palm oil to be one of the richest and most potent natural sources of Vitamin E, and it is now being encapsulated and sold as a dietary supplement. Apart from the oil, every part of the palm can be utilized. Palm kernel residue is used in animal feed. The shell, after cracking and removing the kernels, is used as a fuel in many industrial burners and to produce activated charcoal. The fronds, trunks and empty fruit bunches have been used to make fiber boards and chipboards for furniture and even fiber mats to fight erosion and desertification.

Palm oil is widely known and credited for its ability to supply millions of families in Cameroon today with finances and food. Many families depend on the yields they make from the palm oil sector to cater for their basic needs in terms of hospital bills, school fees, house rents, to name a few, the ever increasing demand of the palm oil cannot be ignored but unfortunately many farmers and palm oil producers are still to discover some of the countless benefits that can be derived from the numerous by-products of the oil palm.

Oil palm by-products include empty fruit bunches, mill effluent, sterilizer condensate, palm fiber, palm kernel and shell. The first two are widely used as mulch and soil improvers in palm plantations, fiber and shell are increasingly used as fuels in the oil mill. Ash can be mixed with concrete and shells to surface plantation roads, while methane from mill effluent fermentation can also provide energy for mils (Yacob et al. 2006).

Treated palm trunks can be made into furniture (cited in Simorangkir 2007).

Other experimental items made from by-products include paper fiber board and fillers, fish food, compost for growing mushrooms and enzymes, vitamins and anti-biotic (Wanrosli et al. 2007).

Palm fiber is already used in the composite body of Malaysia’s national car. Commercial research goes on: for example, vanilla flavoring can be generated from empty fruit bunches, while fiber is being proposed as a means to filter heavy metal pollutants from other industrial processes. Even pest may find commercial use for example the oryctes rhinoceros beetles caught in phenomenal traps in oil palm plantations are used in a nutritional supplement for ornamental fish feed (Kamarudin et al 2007).

Cameroonians still have a long way to go, talking about by-products, apart from the squeezed chaffs and kernel shells which are used for fuel, palm oil used in cooking and kernel oil used for cosmetics and detergents, they are yet to discover what a wonderful and miraculous plant, that the oil palm can be as afore mentioned. The use of by-products can thus increase the financial viability of oil palm and reduce waste. Uptake in Malaysia is in advance and varies from company to company.

3.3.1 By-products

The main by-product and wastes produced from the processing of palm oil are the empty fruit bunches (EFB), palm oil mill effluent (POME), sterilizer condensate, palm fiber and palm shell. EFB and POME are used extensively as mulch and organic fertilizer in oil palm areas while palm fiber and shell are used as fuel, making the palm oil mill self-sufficient in energy. The shells of oil palm fruits are normally used to cover the surface of the roads in the plantation area (Yusoff, 2006).

The most common utilization is confirming waste palm oil biomass with fossil fuel. Countries of South East Asia are developing a policy for reduction of consumption of fossil fuels by supporting bio-fuels production. Confirming of palm oil waste with fossil fuels has big potential in countries of growing. In Malaysia can be easily accomplished 5% share of total electricity demand of the country (Harimi, et al. 2005).

A study by Malaysian Palm Oil Board (MPOB) to convert (EFB) into paper-making pulp was successfully carried out because EFB is categorized as fibrous crop residues known as lignocelluloses residues. There was performed method to produce the pulp which is suitable for paper production (Gurmit, et al. 1999).

Empty fruit brunches are successfully used for so called medium density fiber boards (MDFB), which are widely used in constructions. For example Malaysia is the third world's largest exporter of MDFB, after Germany and France (Sulaimana, et al. 2011).

Palm oil fibers are used as thermoplastics and thermoset filing components which are widely used in car industry. Malaysian car company Proton has reached commercialization stage with these materials (Shuit, et al. 2009).

As a promising technology of using of waste from palm oil production is the production of carbon molecular sieve (CMS) from lignocelluloses materials. A CMS is a material containing tiny pores of a precise and uniform size. It is used to separate nitrogen from the other gases contained in the air (Ahmad, et al. 2007) and (Tan, et al. 2004).
Other very promising technology based on utilization palm waste, which is so called environmentally friendly, is production of biochar. Biochar is commonly defined as charred organic matter, produced to reduce the greenhouse effect by sequestering carbon in soils and to improve soil properties. Biochar is a stable carbon that can be kept in the soil for a long time. Biochar is created when biomass is heated to temperatures between 300 and 1000 °C, without oxygen. In Malaysia in cooperation of University Putra Malaysia and Nasmech Technology there was successfully built a plant producing biochar from EFB. It is the first large-scale biochar production plant in the region (Sulaimana, et al. 2011).
Palm oil shells are also successfully used as an additive to concrete to reduce weight. Study shows that concrete made with mixture of palm shells is up to 19% lighter than normal weight concrete (Shafigh, et al. 2013)

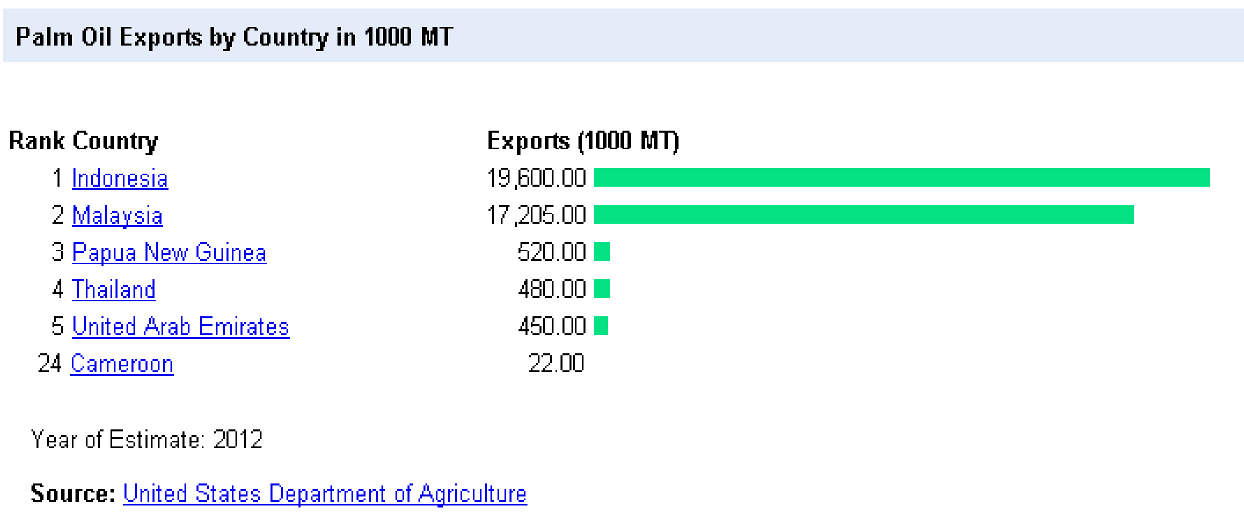
3.4 Palm oil in the world

Palm oil fresh fruit bunches have an oil content of more than 20 percent and provide a higher yield of oil per hectare than most other crops (MPOB, 2012). Malaysia and Indonesia were the largest producers of palm oil, accounting for more than 85 percent of global production (Figure 1). Production in these countries has been steadily increasing for the past 20 years (Cushion et al. 2009).

Table 1: Palm oil and Palm kernel oil top producing countries (2011). Source: FAO-STAT

Rank	Country	Palm Oil production (tons, '000)	World share	Rank		Palm Kernel Oil production (tons, '000)	World share
1	Indonesia	21,449	46%	1	Indonesia	25,810	44%
2	Malaysia	18,912	40%	2	Malaysia	20,149	34%
3	Thailand	1,530	3%	3	Nigeria	4,512	8%
4	Nigeria	1,350	3%	4	Thailand	1,287	2%
5	Colombia	941	2%	5	Brazil	1,170	2%
6	Germany	555	1%	6	Colombia	954	2%
7	P. N. Guinea	520	1%	7	Guatemala	744	1%
8	Côte d'Ivoire	400	1%	8	Côte d'Ivoire	405	1%
9	Honduras	320	1%	9	P. N. Guinea	392	1%
10	Ecuador	289	1%	10	Ecuador	353	1%
12	Cameroon	254	1%	12	Cameroon	279	0%
	Total world	**46,791**				**58,615**	

Figure 1: Palm oil exports by country



Unlike competing oils, oil palm offers a good tree cover. This golden oil has generated fat gross profit margins of some 40% or more, for efficient growers. Indonesia and Malaysia produce 85% of global output. It is key sector for these countries, accounting for over 5% of GDP (gross domestic product) in each. The large corporate growers are the dominant players, small holders supply up to 40% of the market. An estimated 4.5 million people earn their living from it in developing countries and many more indirect benefits. Continued oil palm development should be a good thing, because it is the most effective supplier to the edible oils market, and it brings much needed development to poor tropical developing regions. The round table for sustainable palm oil (RSPO) notes that one hectare planted with oil palm yields about three tones of oil per year on average, with the most efficient plantations able to produce that much oil from rapeseed (canola), sunflower or soy, up to ten times more land would be required .The total area used for palm oil production has grown to more than 12 million hectares, most of which is in Indonesia and Malaysia (www.rspo.eu/press:faq.html, 2011).

The leading palm oil producing countries in the world are Indonesia and Malaysia. Malaysia has been leading the world for a couple of decades with Indonesia taking over a few years ago. In these countries the impact of the oil palm sector is instrumental in the level of their development. While Cameroon is classified as a poor and under developed country, Malaysia on the other hand is one of the south-east emerging economic giants in the world.

Figure 2: Palm oil domestic consumption by country

Palm Oil Domestic Consumption by Country in 1000 MT

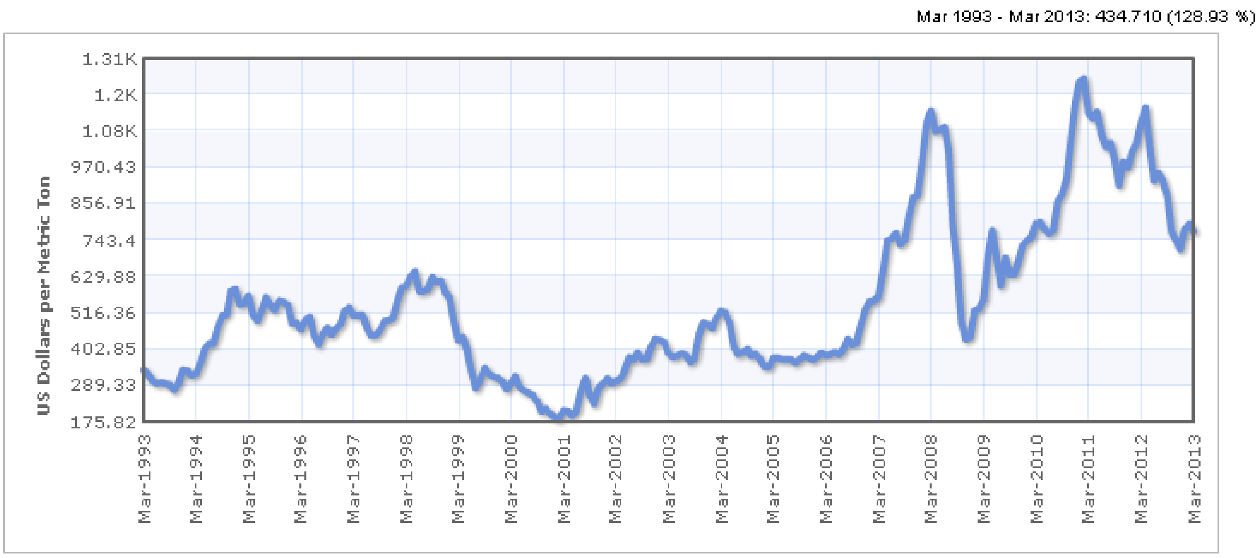
Rank	Country	Domestic Consumption (1000 MT)
1	India	8,125.00
2	Indonesia	7,870.00
3	China	6,300.00
4	EU-27	5,425.00
5	Malaysia	3,323.00
6	Pakistan	2,195.00
7	Other	1,425.00
8	Nigeria	1,315.00
9	Thailand	1,245.00
10	Egypt	1,240.00
31	Cameroon	223.00

Year of Estimate: 2012

Source: United States Department of Agriculture

Figure 3: Palm oil monthly price – USD

Palm oil Monthly Price - US Dollars per Metric Ton



Description: Palm oil, Malaysia Palm Oil Futures (first contract forward) 4-5 percent FFA, US Dollars per Metric Ton

Unit: US Dollars per Metric Ton

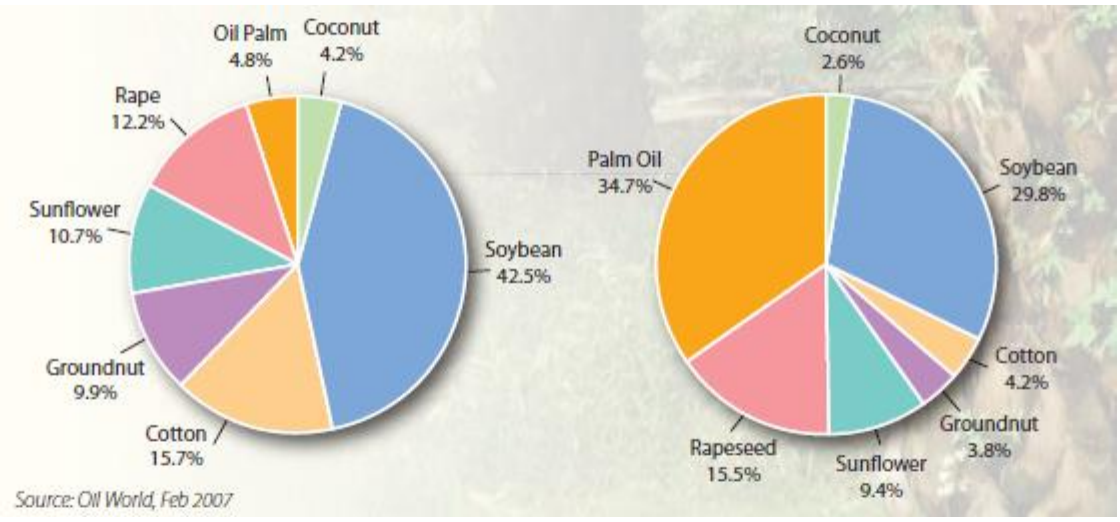
Source: World Bank

Marketing of agricultural commodities such as oil palm has become more complex over the last decades. The rise of globalization, electronic market information and exchange, and international trade policies, and the strategies pursued by the different exporting countries have translated into commodity price fluctuations well beyond the supply and demand price logic.

The price of Palm oil, along with other oilseed commodities, is therefore not only affected by international supply and demand conditions, but also by listed future prices in international markets (the only stock exchange dealing with palm oil future contracts is the Kuala Lumpur Commodity Exchange – KLCE), rules and regulations imposed by importing countries or economic protectionism. Additionally, roughly 80% of global supply is concentrated in two countries, (Malaysia and Indonesia) whereas global demand is more scattered across several countries (top 10 importers accumulate 60% of global imports). According to KLCE professionals, palm oil international prices are mainly determined by a combination of underlying supply and demand factors (overall consumption figures, expected production and export quantities, closing stocks) and CPO future prices. These factors combined directly or indirectly affect the global price of palm oil, and justify its volatility.

Palm oil is the lowest-cost feedstock for producing biodiesel today, but future demand will influence the prices. Price of palm oil correlate with the prices of others crude oils (Cushion, et al. 2010). Its average price fluctuated widely in 2007 and 2008, increasing by 68 percent in 2007 and dropping sharply in the second half of 2008, from more than \$1,000/MT to \$425/ MT. Past 2 years the prices fluctuate between \$1,000 and \$1,250/MT with correlation to others crude oils (MPOB, 2012).

Figure 4: Planted Crops Area (left) and Production of Major Vegetable Oil (right)



Oil Pam has the highest oil productivity among Major Oil Crops/seeds, Source: Oil World Annual 2006.

3.5 Cameroon brief

3.5.1 Cameroon country

The area of present-day Cameroon was integrated to French Equatorial Africa (AEF) during the "Scramble for Africa" at the end of the 19th century. However, in 1911 France ceded parts of the territory to German Cameroon, known as Neukamerun ("New Kamerun") as a result of the Agadir Crisis, and it became a German protectorate. During World War I, it was occupied by British and French troops, and later mandated to each country by the League of Nations in 1922. The British mandate was known as Cameroon and the French as Cameroon.[dubious – discuss] Following World War II each of the mandate territories was made a United Nations Trust Territory. An insurrection headed by Ruben Um Nyobé and the Union of the Peoples of Cameroon (UPC) erupted in 1955, strongly repressed by the French Fourth Republic. Cameroon became independent as the Republic of Cameroon in January, 1960 and in October, 1961 the southern part of British Cameroon joined to form the Federal Republic of Cameroon. The Muslim northern part of Cameroon had opted for union with Nigeria in May the same year. The conflict with the UPC lasted until the 1970s.

3.5.2 Economy

Cameroon's per-capita GDP (Purchasing power parity) was estimated as US$2,300 in 2008 one of the ten highest in sub-Saharan Africa. Major export markets include France, Italy, South Korea, Spain, and the United Kingdom. Cameroon has enjoyed a decade of strong economic performance, with GDP growing at an average of 4 percent per year. During the 2004–2008 period, public debt was reduced from over 60 percent of GDP to 10 percent and official reserves quadrupled to over USD 3 billion. Cameroon is part of the Bank of Central African States (of which it is the dominant economy), the Customs and Economic Union of Central Africa (UDEAC) and the Organization for the Harmonization of Business Law in Africa (OHADA).

Its currency is the CFA franc. Red tape, high taxes, and endemic corruption have impeded growth of the private sector. Unemployment was estimated at 30% in 2001, and about a third of the population was living below the international poverty threshold of US$1.25 a day in 2009. Since the late 1980s, Cameroon has been following programmes advocated by the World Bank and International Monetary Fund (IMF) to reduce poverty, privatise industries, and increase economic growth. The government has taken measures to encourage tourism in the country.

Cameroon's natural resources are very well suited to agriculture and arboriculture. An estimated 70% of the population farms, and agriculture comprised an estimated 19.8% of GDP in 2009. Most agriculture is done at the subsistence scale by local farmers using simple tools. They sell their surplus produce, and some maintain separate fields for commercial use. Urban centres are particularly reliant on peasant agriculture for their foodstuffs. Soils and climate on the coast encourage extensive commercial cultivation of bananas, cocoa, oil palms, rubber, and tea. Inland on the South Cameroon Plateau, cash crops include coffee, sugar, and tobacco. Coffee is a major cash crop in the western highlands, and in the north, natural conditions favour crops such as cotton, groundnuts, and rice. Reliance on agricultural exports makes Cameroon vulnerable to shifts in their prices.

Livestock are raised throughout the country. Fishing employs some 5,000 people and provides 20,000 tons of seafood each year. Bushmeat, long a staple food for rural Cameroonians, is today a delicacy in the country's urban centres. The commercial bushmeat trade has now surpassed deforestation as the main threat to wildlife in Cameroon.

The southern rainforest has vast timber reserves, estimated to cover 37% of Cameroon's total land area. However, large areas of the forest are difficult to reach. Logging, largely handled by foreign-owned firms, provides the government US$60 million a year, and laws mandate the safe and sustainable exploitation of timber. Nevertheless, in practice, the industry is one of the least regulated in Cameroon.

Factory-based industry accounted for an estimated 29.7% of GDP in 2009. More than 75% of Cameroon's industrial strength is located in Douala and Bonabéri. Cameroon possesses substantial mineral resources, but these are not extensively mined. Petroleum exploitation has fallen since 1985, but this is still a substantial sector such that dips in prices have a strong effect on the economy. Rapids and waterfalls obstruct the southern rivers, but these sites offer opportunities for hydroelectric development and supply most of Cameroon's energy. The Sanaga River powers the largest hydroelectric station, located at Edéa. The rest of Cameroon's energy comes from oil-powered thermal engines. Much of the country remains without reliable power supplies.

Transport in Cameroon is often difficult. Except for the several relatively good toll roads which connect major cities (all of them one-lane) roads are poorly maintained and subject to inclement weather, since only 10% of the roadways are tarred. Roadblocks often serve little other purpose than to allow police and gendarmes to collect bribes from travellers. Road banditry has long hampered transport along the eastern and western borders, and since 2005, the problem has intensified in the east as the Central African Republic has further destabilized.

International airports are located in Douala and Yaoundé. The airport at Bamenda is now closed. The Wouri estuary provides a harbour for Douala, the country's principal seaport. In the north, the Bénoué River is seasonally navigable from Garoua across into Nigeria.

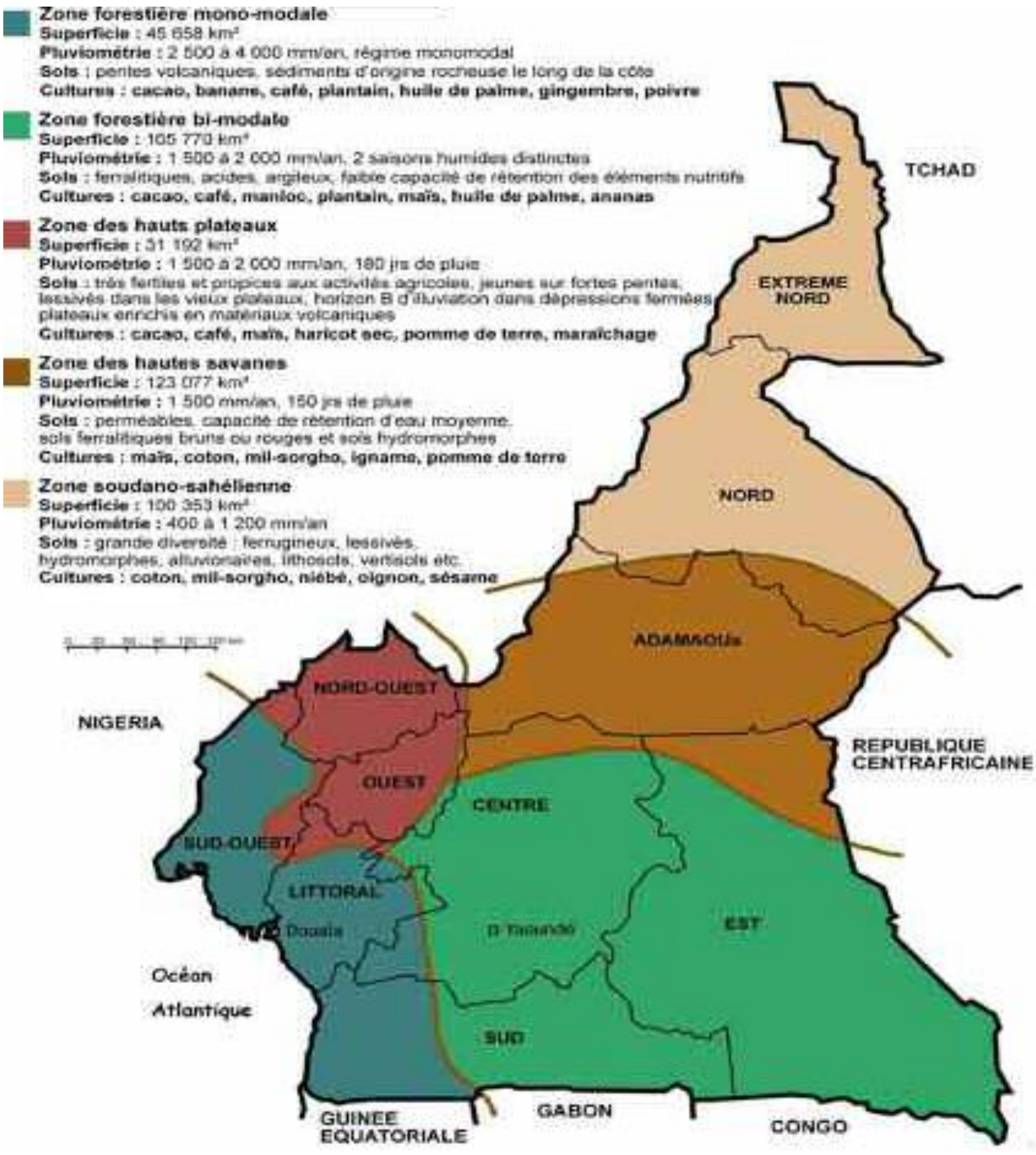
Table 2: Key selected economic indicators for the Republic of Cameroon

1. GDP: $47,3 billion
2. GDP per capita: $2,300
3. Economic Growth rate (latest 2011): 4.2%
4. Population: 20,129,000
5. Income category: Lower middle income
6. Doing Business Rank 2013: 161 (156 in 2012)
7. Industry, value added (% of GDP): 31%
8. Competitive Industrial Performance Index: 0.08
9. FDI: $360.0 million
10. Natural resources: oil, high value timber species, coffee, cotton, cocoa, gas, iron, bauxite, and cobalt.
11. Economic sector analysis:
    1. Agriculture: 19.9%
    2. Industry: 30.6%
    3. Services: 49.5%
12. Cameroon faces a stagnant per capita income and a relatively inequitable distribution of income
13. A top-heavy civil service
14. UN HDI rank : 150/187
15. The agricultural sector occupies 70% of the population but has a weak added value.
16. The poverty rate is 59% in 2010 (MDG rate of 31.3% in 2015 horizon)
17. The informal sector represents 51% of GDP

3.5.3 Agriculture and oil palm in Cameroon

Agriculture and forestry remain the leading sectors in the country, accounting for some 36% of the merchandise exports and for more than 40% of GDP in 1998/99. Agriculture alone accounts for more than 30% of GDP and provides employment for about 68% of the active population. In recognizance of this importance agriculture plays in the economy, the government promoted the use of farm inputs (fertilizers, pesticides, etc.) in the 80s by providing them to farmers at subsidized rates. The agricultural sector has, however, undergone thorough reforms since 1994 to present day following the Structural Adjustment Program (SAP) by IMF. As a result, Cameroon did not only disengage from input marketing, but liberalized the economy. The trade liberalization has resulted in massive food imports and this is affecting the livelihoods of the farmers, industries, traders, and service providers of the imported foods. The Cameroon government and industry stakeholders have expressed continuing concern about the impact of these rising food imports on the local industries and the rural communities especially as vegetable oils has a vital role to play not only as nutritional source for the Cameroon population, but for their contribution to rural incomes and employment opportunities.

Figure 5: Biogeographical regions of Cameroon (Source: IRAD and Cameroon Statistics)



Cameroon's oil palm industry still plays a significant role in the national economy, providing oil for house hold consumption, industrial use as well as employment for thousands of Cameroonians who are engaged in production, processing and marketing. Major Agro –industries in Cameroon involved in palm oil production are: SOCAPALM (25,000 ha), C.D.C (15,000 ha), PAMOL (10,000 ha), SPFS (7,000 ha) and SAFACAM

(4,000 ha). These companies are characterized by the use of organized labour force, best agronomic practice for best yields and corporate financing, organization and management. Of all the oil bearing plants in the nation, oil palm is the highest yielding and it grows in the main forest belt of the country. It contributes up to 80% of the total edible oil needs. Following the drop in the early nineties of the prices of cocoa and coffee which were the major commercial farming crops in Cameroon, many smallholders turned out planting oil palm. This fact is clearly illustrated by the amount of germinated oil palm seeds purchased by small and medium size farmers at the centre for oil palm research of La Dibamba (Cameroon) which rises up from 20% of the total production in 1996 to an average of 60% during the past ten years. From this data it is estimated that about 5 ha of oil palm were planted by small and medium size farmers each year during the last decade, making a total of about 90,000 ha palm area in Cameroon at present.

In mid 2008, the price of crude palm oil (CPO) was higher than the selling price of petroleum-derived diesel, given that its cost, on average about 10 US cents per litter to convert crude palm oil into biodiesel.

Oil palm was enthusiastically cultivated in Cameroon mainly because of its large number of uses; which are deeply embedded in local cultures. Demand from international markets, however, has also played a great part in convincing Cameroonians to cultivate oil palm.

Industrial exploitation of the tree began back in 1907, under the German administration. In fact, the first industrial plants established, in Edéa were promoted by German settlers. More were then set up on the coastal plains and around Mount Cameroon. The crop was further developed under the French–British regime until, by the 1960’s national annual production had reached 42,500 tonnes of palm oil and 37,200 tonnes of palm kernel oil. Seventy per cent of this production came from palm groves in village communities and the remaining 30 per cent from the industrial plantation of the Cameroon development corporation (CDC) and Pamol plantations limited, two firms under majority state control. Up until the beginning of the 1990’s, the main oil palm plantations were to be found in southern Cameroon and these did not affect the country’s forest areas. However, today new plantations are increasingly replacing native forests.

Figure 6: Palm oil production, net exports and domestic consumption in Cameroon (Source: self-compiled with FAO data)

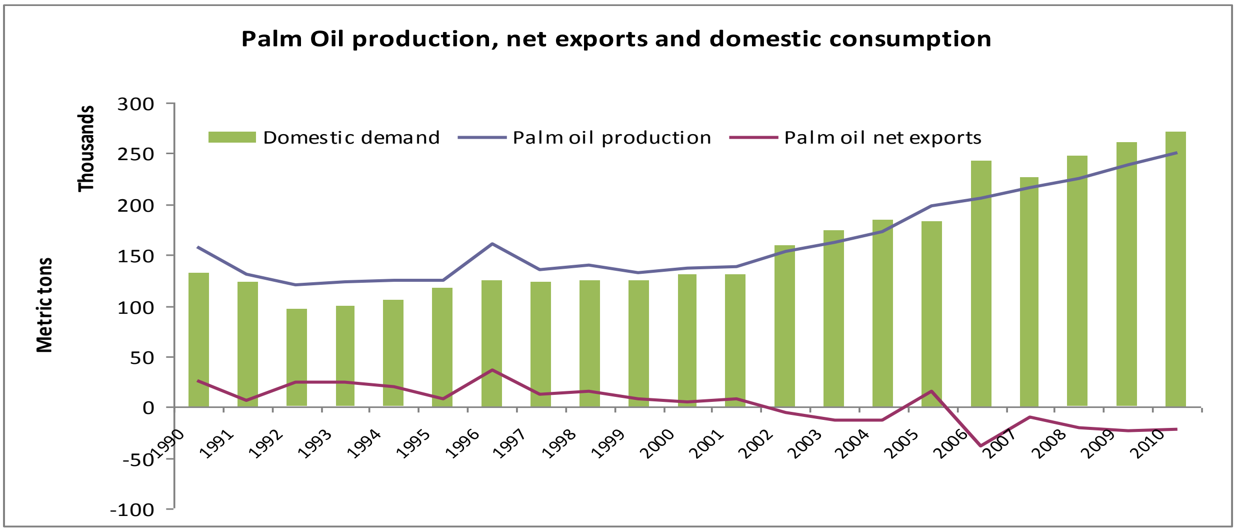


Figure 7: Palm oil and palm kernel oil production levels in Cameroon (Source: self-compiled with FAO data)

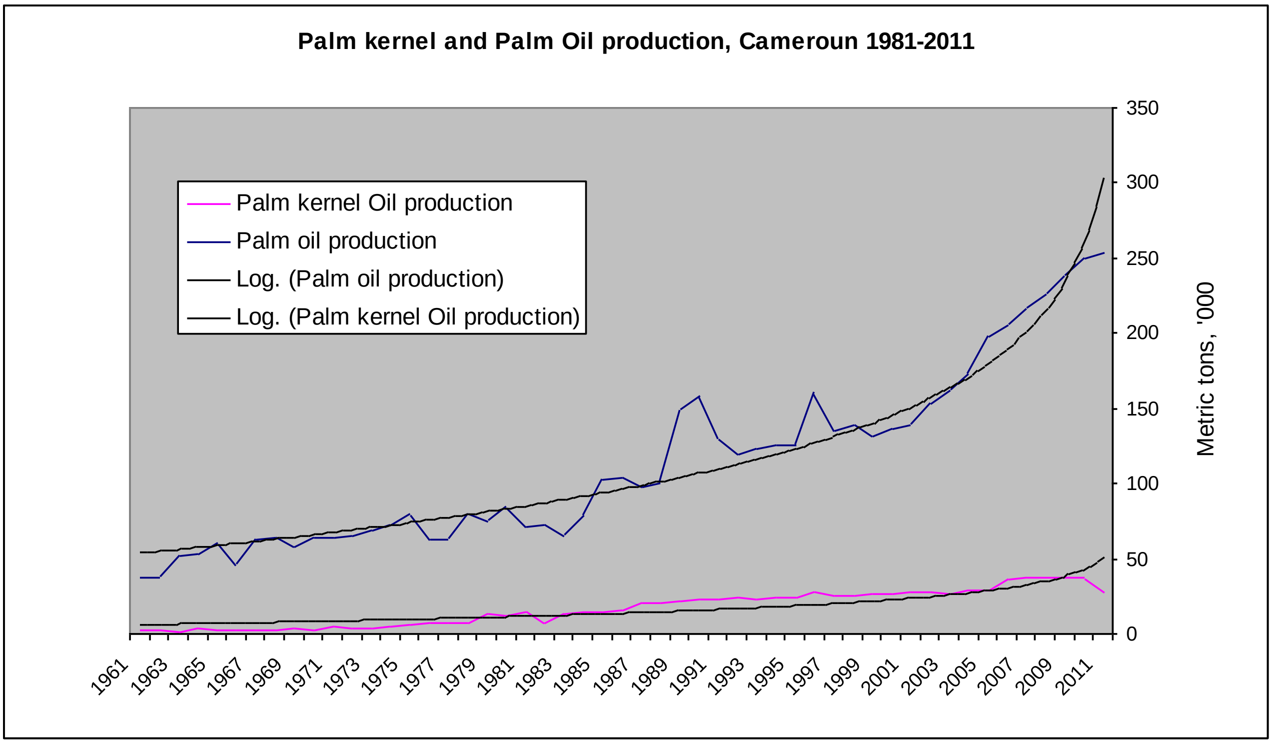
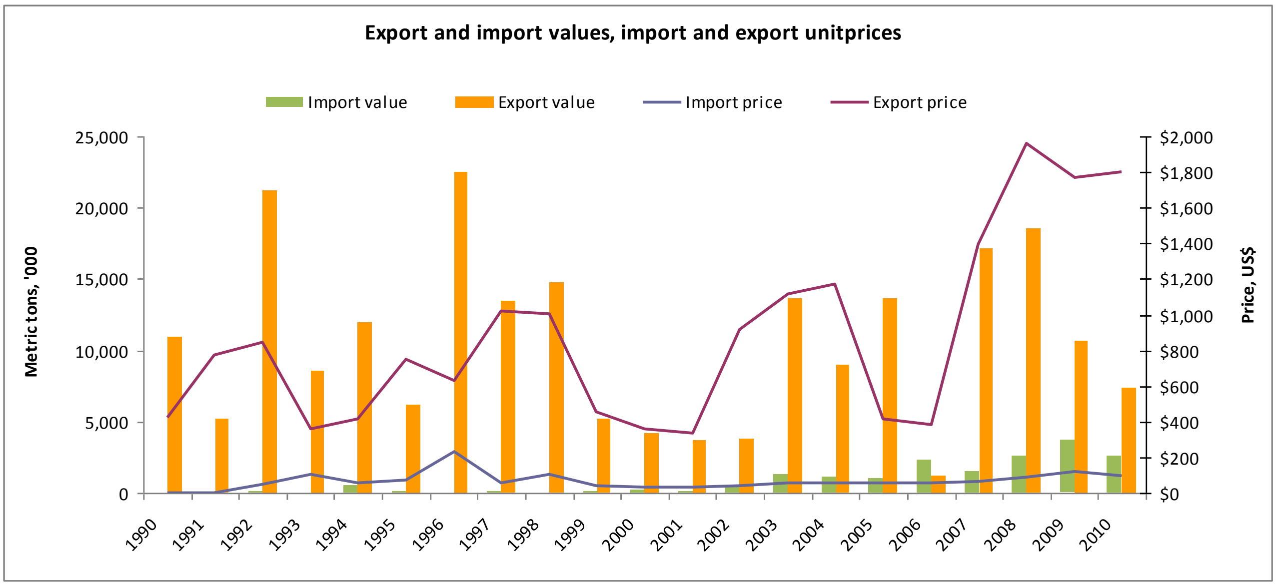


Figure 8: Palm OilExport and Import Values in Cameroon (Source: self-compiled with FAO data)



Source: FAOSTAT, 2013. Authors

3.5.4 Major challenges to value chain development in Cameroon

Table 3: Major challenges of the agro-allied sector in Cameroon as well as in developing countries and economies in transition

	Challenge	Way to address it
A. General		
1.	Not sufficient competitiveness for quality production	• Technologies appropriate to local conditions are adapted or developed.
2.	Lack of energy	• Product processing, preservation and packaging methods are improved. Decentralized/off grid energy supply systems are installed.
3.	Unavailability of affordable funding sources	• Funds are mobilized to ensure project completion and sustainability
4.	Insufficient qualified individuals	• Capacity building centre and facilities to upgrade knowledge and skills are established.
B. Processing		
5.	High agricultural waste	• Post harvest waste is minimized • Products are consistent in quality • Minimized drudgery in raw materials conversion/processing
6.	Significant post-harvest waste	• More valued added by-products are developed and recycled

7.	Low productivity	• Higher efficiency of service and widespread of manufacturing best practises.
C. Technology		
8.	Lack of adequate tools and machinery	• Imported up-to-date production technology is mastered
9.	Lack of processing technologies.	• Technologies appropriate to local conditions are developed and adapted
10.	Lack of technical know-how	• Individuals are qualified and encouraged to become self-employed
11.	Lack of services and maintenance workshops	• Staff of the maintenance and reparation services are qualified to provide proper industrial maintenance services

3.6 Palm oil small scale processing technology

Extracted from FAO (Small scale palm oil processing in Africa, FAO agricultural services bulletin, 2007)

Modern processing of oil palm fruit bunches into edible oil is practiced using various methods, which may be grouped into four categories according to their throughput and degree of complexity. These are the traditional methods, small-scale mechanical units, medium-scale mills and large industrial mills. Generally, processing units handling up to modernnes of "Fresh Fruit Bunches" (FFB) per hour are considered to be small-scale. Installations that process between 3 and 8 tonnes FFB per hour are termed medium-scale, while large-scale refers to mills that process more than 10 tonnes per hour. Much has been written about traditional technologies and medium- and large-scale mills, but information on small-scale processing units is scarce. The historical reason for the ready availability of information on medium- to large-scale operations and machinery is that most development work was undertaken in Europe, based on the observation of the traditional methods practiced in West Africa.

Plantation farming is a new phenomenon to West African culture. In most parts of Africa the farm culture is basically subsistence. The family cultivates a small plot for their food needs and interplant tree crops. After three years or more the tree crop takes over the plot and the farmer moves to another. The new plot may be acquired from the Chief in a location far removed from the old plot. Farm-holdings are therefore small and scattered. The land tenure system does not permit large-scale farming unless the government steps in to acquire the land for public use Thus it is difficult to think of one family owning a large contiguous estate suitable for plantation farming.

A small-scale palm oil farm may cover 7.5 hectares. The farm's production of fruits may be processed by the farmer, using the traditional method of palm oil extraction, or sold to other processors. During the lean season the farmer sells to the small-scale processors at prices higher than those offered to the larger mills. The small-scale farms are normally well maintained even though they may not adopt modern agronomic practices such as application of fertilizer, cover cropping, etc. to improve soil fertility and yields.

The oil winning process, in summary, involves the reception of fresh fruit bunches from the plantations, sterilizing and threshing of the bunch to free the palm fruit, mashing the fruit and pressing out the crude palm oil. The crude oil is further treated to purify and dry it for storage and export.

Large-scale plants, featuring all stages required to produce palm oil to international standards, are generally handling from 3 to 60 tonnes of FFB (Fresh Fruit Bunches)/hr. The large installations have mechanical handling systems (bucket and screw conveyers, pumps and pipelines) and operate continuously, depending on the availability of FFB. Boilers, fuelled by fibre and shell, produce superheated steam, used to generate electricity through turbine generators. The lower pressure steam from the turbine is used for heating purposes throughout the factory. Most processing operations are automatically controlled and routine sampling and analysis by process control laboratories ensure smooth, efficient operation. Although such large installations are capital intensive, extraction rates of 23 - 24 percent palm oil per bunch can be achieved from good quality Tenera.
Extraction of oil from the palm kernels is generally separate from palm oil extraction, and will often be carried out in mills that process other oilseeds (such as groundnuts, rapeseed, cottonseed, shear nuts or copra). The stages in this process comprise grinding the kernels into small particles, heating (cooking), and extracting the oil using an oilseed expeller or petroleum-derived solvent. The oil then requires clarification in a filter press or by sedimentation. Extraction is a well-established industry, with large numbers of international manufacturers able to offer equipment that can process from 10 kg to several tonnes per hour.

Alongside the development of these large-scale fully mechanised oil palm mills and their installation in plantations supplying the international edible oil refining industry, small-scale village and artisan processing has continued in Africa. Ventures range in throughput from a few hundred kilograms up to 8 tonnes FFB per day and supply crude oil to the domestic market. Efforts to mechanise and improve traditional manual procedures have been undertaken by research bodies, development agencies, and private sector engineering companies, but these activities have been piecemeal and uncoordinated. They have generally concentrated on removing the tedium and drudgery from the mashing or pounding stage (digestion), and improving the efficiency of oil extraction. Small mechanical, motorised digesters (mainly scaled-down but unheated versions of the large-scale units described above), have been developed in most oil palm cultivating African countries. Palm oil processors of all sizes go through these unit operational stages. They differ in the level of mechanisation of each unit operation and the interconnecting materials transfer mechanisms that make the system batch or continuous. The scale of operations differs at the level of process and product quality control that may be achieved by the method of mechanisation adopted. The technical terms referred to in the diagram above will be described later.

The general flow diagram is as follows:

Figure 9: Palm Oil Processing Flow Diagram (Source: FAO, 2002)

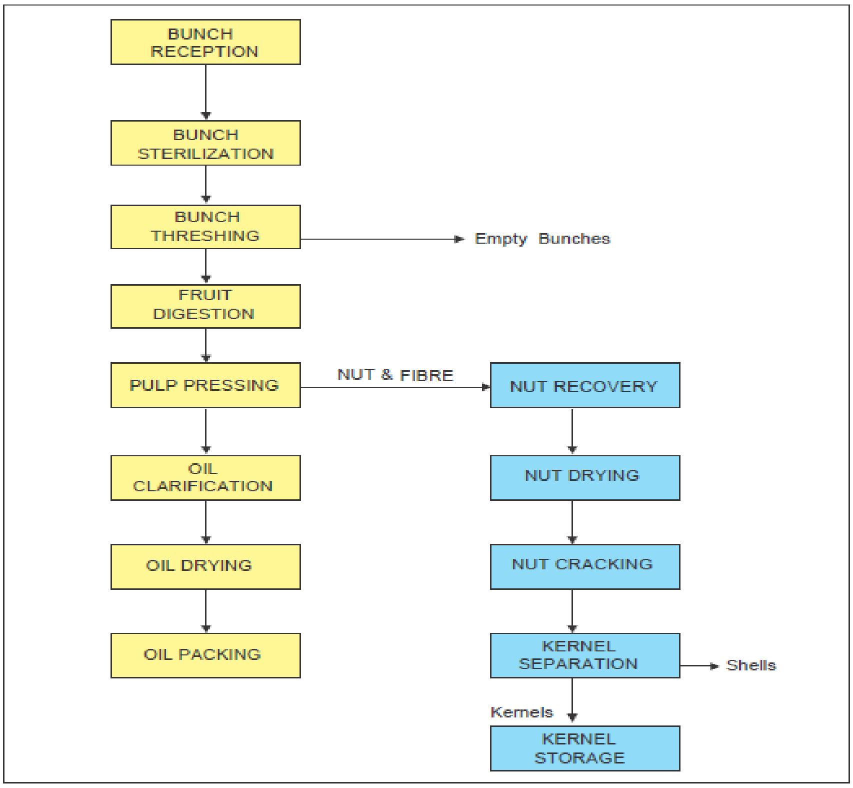


Figure 10: Modern Press Station Design

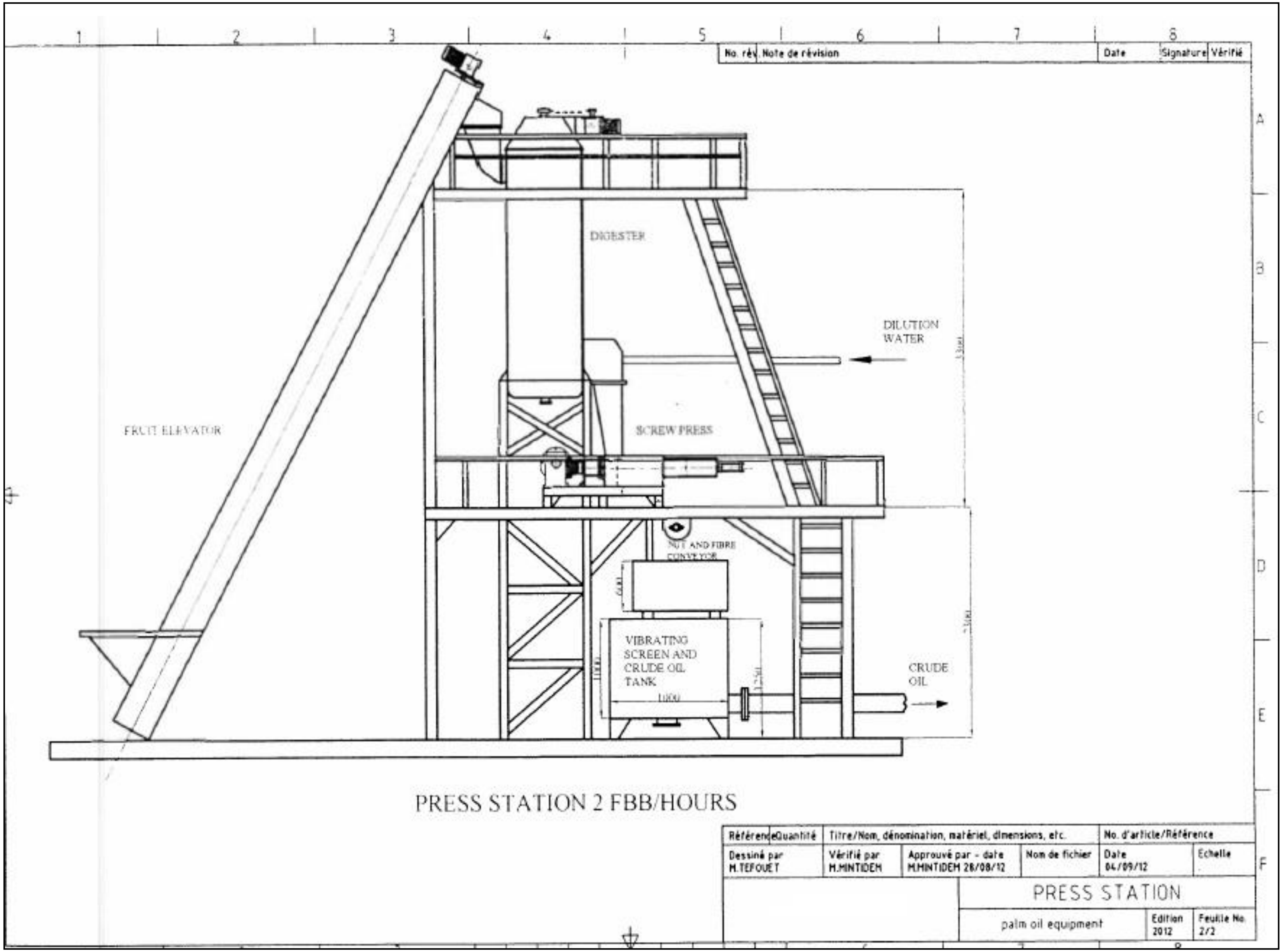
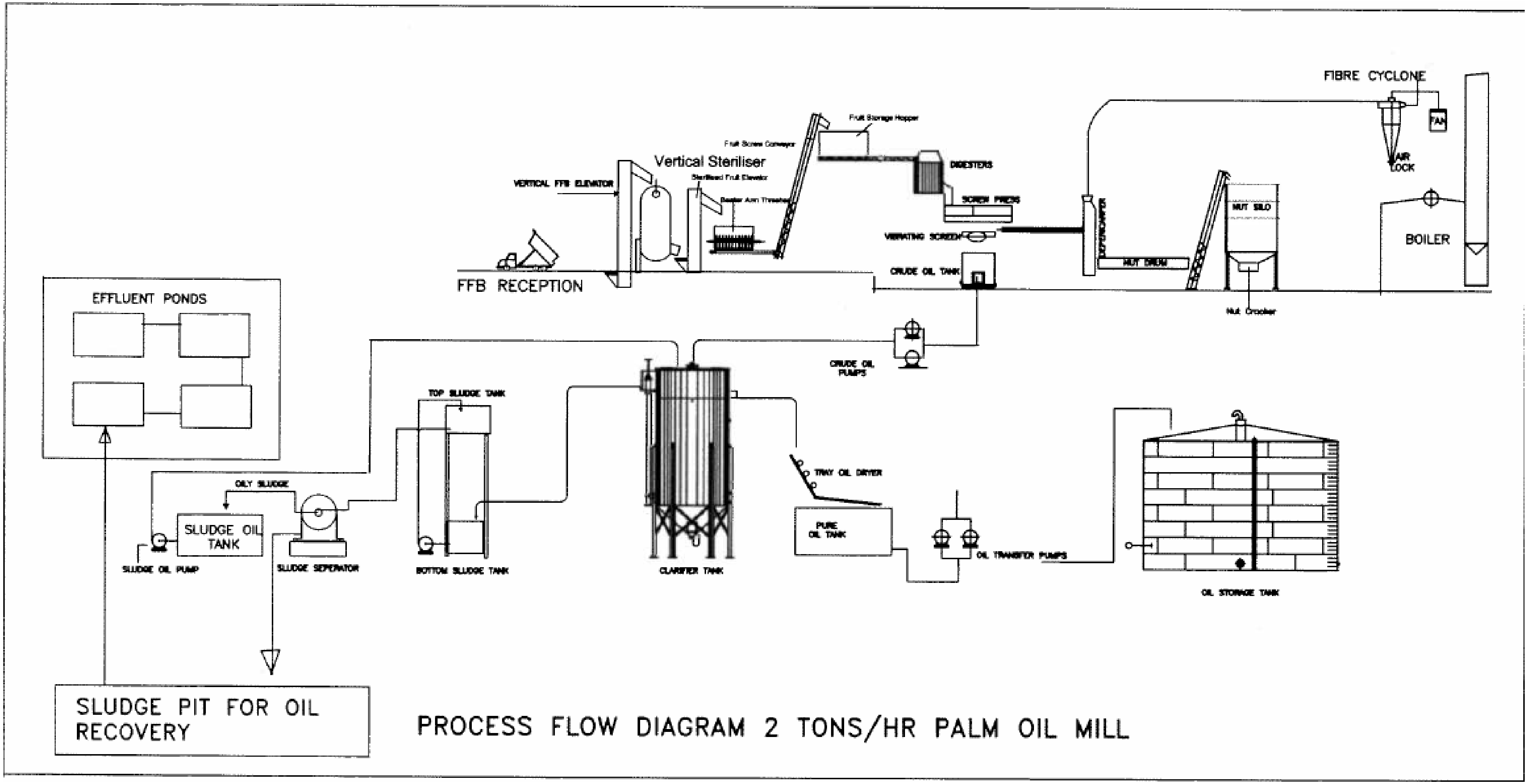


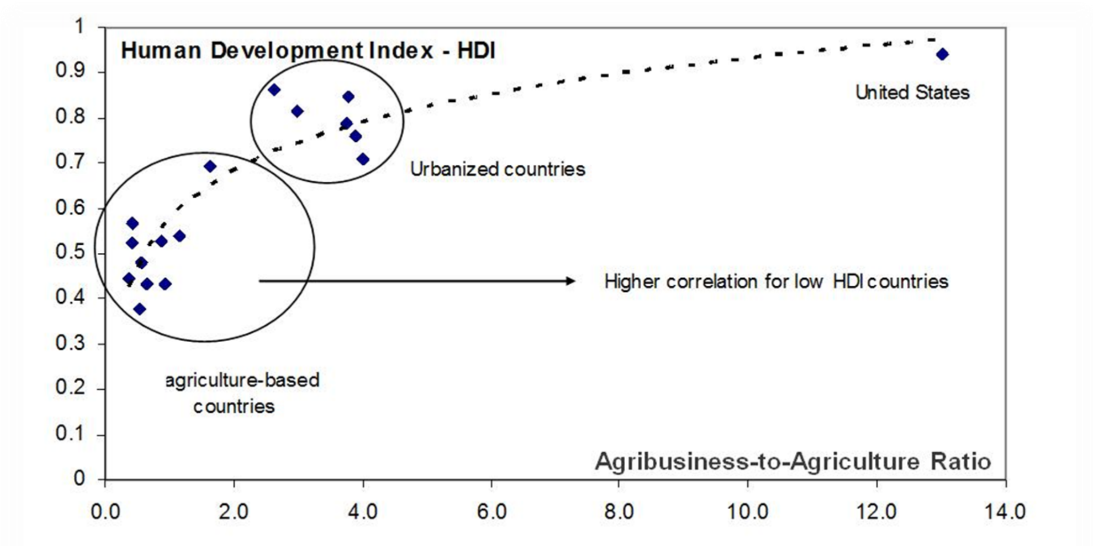
Figure 11: Process flow diagram for a modern palm oil mill



3.7 Positive relationship between Agribusiness and Development

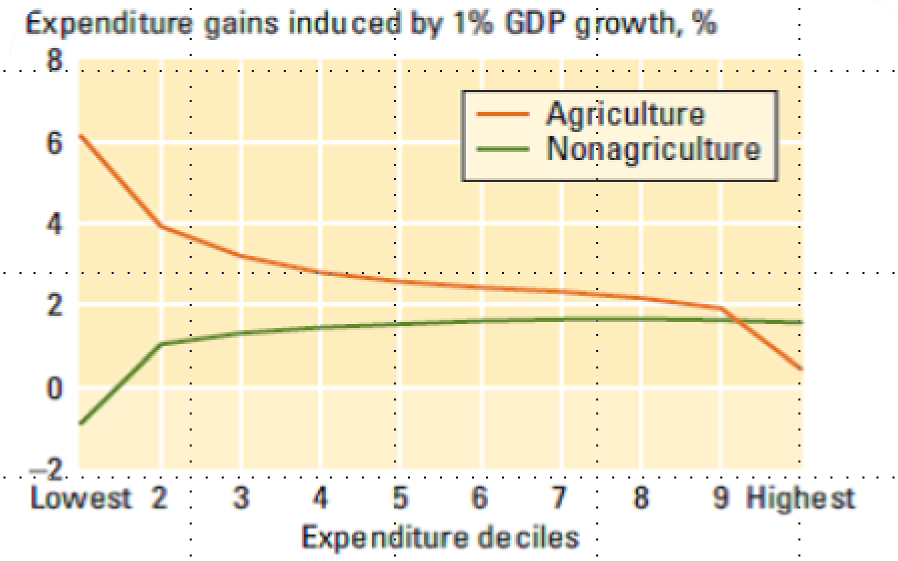
Agricultural growth has long been recognized as an important instrument for poverty reduction. Yet, measurements of this relationship are still scarce and not always reliable. Results show that rural poverty reduction has been associated with growth in yields and in agricultural labour productivity, but that this relation varies sharply across regional contexts (Janry, Sadoulet, 2009). GDP growth originating in agriculture induces income growth among the 40 percent poorest, which is on the order of three times larger than growth originating in the rest of the economy. The power of agriculture comes not only from its direct poverty reduction effect but also from its potentially strong growth linkage effects on the rest of the economy. Decomposing the aggregate decline in poverty into a rural contribution, an urban contribution, and a population shift component shows that rural areas contributed more than half the observed aggregate decline in poverty. Finally, using the example of Vietnam, the authors show that rapid growth in agriculture has opened pathways out of poverty for farming households. While the effectiveness of agricultural growth in reducing poverty is well established, the effectiveness of public investment in inducing agricultural growth is still incomplete and conditional on context. (Agricultural Growth and Poverty Reduction: Additional Evidence; Janvry and Sadoulet, 2009)

Figure 12: Correlation between Human development and Agriculture to Agribusiness ratio



Correlation between Human Development and the Agribusiness-to-Agriculture Ratio
Source: J. Wilkinson & R. Rocha (2009)

Figure 13: Expenditure gains induced by 1% GDP growth



Source: Ligon and Sadoulet 2007.
Note: Based on data from 42 countries during the period 1981–2003. Gains are significantly different for the lower half of expenditure deciles.

3.8 The problems associated with a resource-based economy

It is often suggested that natural resources are a curse rather than a benefit as a result of several unique factors:

- The finite nature of the non-renewable resources, which leaves producers vulnerable once stocks are depleted (*i.e.* natural resources are "dead end" sectors).

- The low growth potential of natural resource sectors, arising from the fact that they are "low tech" activities which do not stimulate productivity increases and a shift towards higher value-added products.

- Vulnerability to "boom and bust" cycles as a result of the volatility of commodity prices on international markets, which leaves exporters particularly vulnerable to external shocks (this applies to mineral resources, some renewable resources and a wide range of agricultural commodities).

● Vulnerability to the so-called “Dutch disease”. Revenues from natural resources exports tend to appreciate the country’s currency (via the exchange rate) and ultimately render the manufacturing sector of that given country less competitive. It’s like an economic trap in which resource-based economies can fall if they concentrate to a large extend in commodity export and which ultimately hinders other efforts towards economic diversification or industrial development.

(OECD 2008, Natural Resources And Pro-Poor Growth: The Economics And Politics)

This section has drawn on the work of Giraud and Loyer (2006) “Natural Capital and Sustainable Development in Africa”, Agence Française de Développement, Working Paper 33.

3.9 Lessons from Malaysia and Indonesia

As demonstrated by the Malaysian and Indonesian experiences, the expansion of palm oil production is an opportunity for national and local economies. When done well, it has a real potential to reduce poverty. An increase in palm oil production in Cameroon is likely to result in a series of positive impacts and benefits for the country. These include:

<u>Economic Impact:</u>

The palm oil industry is one of the key economic drivers of the agricultural sector in developing countries. Its economic potential is greatest in the oil palm growing belt, a region that encompasses 10° North and South of the equator.

- Direct effect on employment: Palm oil extraction provides direct labour oil palm farmers in the different plantations, but also and indirect labour in the related processing activities (processing, transportation, building, catering, maintenance, etc.). This contribution ultimately promotes structural economic change in this context, and helps shifting from a purely agro-based economy to a semi-industrial stage. There is little seasonality so employment and other benefits remain steady throughout the year. The economic multiplier effect of creating activities has a positive impact on the development of all sectors at local and regional level and the industry also offers a long-term and stable source of income for its smallholders.

- Impact on economic efficient and promotion of the productive sector: Oil palm is the most efficient oilseed crop in the world: one hectare of oil palm plantation is able to produce up to twelve times more oil than other leading oilseed crops. The most efficient producers may achieve yields as high as eight tons of oil per hectare. Palm oil is competitively priced against soybean, rapeseed and sunflower oil in the world‘s market for oils and fats. This means that developing the palm oil value chain in Cameroon will assure a promising development as well as a widely acknowledged industrial direction. The higher the palm oil extraction, the more competitive the process will be and therefore higher profits will be derived for its actors.

- Access to markets: Palm oil is top selling product with very favorable consumption trends in advanced economies: Palm oil is one of the 17 major oils and fats produced globally. China is the largest consumer of oils and fats, followed by the EU, India, and the United States. Among the 17 oils and fats, palm oil was the highest consumed oil in 2011, reaching three billion people in 150 countries. Global consumption for palm oil was 49.05 million tons in 2011 and has risen continuously ever since.

- Generate revenue to the State, through direct taxes, royalties and utility bills, as well as indirect taxes through the labour force. This benefit will depend on how well the State negotiates Cooperation Agreements / Conventions. Correcting the deficit in production of palm oil in Cameroon would reduce the dependence on oil imports, which would, in turn, benefit the country’s balance of payments and the country’s capacity to build infrastructure and provide social services with the derived revenue.

- Infrastructure expansion, most investors will try to locate their plantations near a sea port, however they will need to invest considerably in upgrading road infrastructure to their sites. Additionally, most reputable investors will invest in social infrastructure for their workforce – housing, water, electricity, health care and education facilities, etc. The development of the value chain will therefore stimulate national and foreign direct investment.

- Smallholder friendly: oil palm can be economic on a variety of scales, especially for smallholders. Palm oil production is very attractive to smallholders: with few pest and disease threats (so far), low input requirements, and employ of large numbers of workers all year round. In Southeast Asia, for example, 30 to 40% of palm oil by surface area is the property of smallholders, with high yields and a guaranteed purchase ensured by agro-industries. In Cameroon, smallholders control nearly three-quarters of the total area under oil palms but provide only half of the production due to very low yields.

Impact on Food security:

- Palm oil is a product with high nutritional value: Oils and fats are vital nutrients required by the human body to achieve and maintain good health. An adequate amount of fat is necessary in the human diet for proper digestion and nutrient absorption. Palm oil provides the right amounts of fat in a balanced diet. Similarly, palm oil provides Vitamins A and E, essential for the normal growth and development of the human body. Palm oil is also high in carotenoids, a rich source of vitamin A. Carotenoids can be stored in the body and be converted to vitamin A when needed. Vitamin A stimulates the immune system and controls the growth and functions of body tissues. Red palm oil, or mildly refined palm oil, has seventeen times more carotenoids than carrots. Finally, palm oil is cholesterol-free and trans fat free. It is composed mainly of triglycerides of fatty acid with a balanced composition between saturated and unsaturated fatty acids.

Clearly, the development of a local palm oil value chain will contribute to improving food security levels not only by providing additional cash resources, but also by increasing the nutritional value target populations have access to.

Impact on environment

As also demonstrated by the Malaysian and Indonesian cases, the large scale production of palm oil has, at times, several disadvantages. When new developments are carried out at the expense of forests, the impacts on the environment, biodiversity and the lives of forest dependent people can potentially be highly negative. Hence, it is important to develop palm oil in such a way to prevent or substantially mitigate such negative social and environmental impacts. The RSPO criteria aim to enhance and maintain important environmental and social values. In the Government of Cameroon's legitimate desire to expand the production of oil palm, they need to develop a best practice guide for new oil palm plantations, as well as identifying the most suitable. Several potential negative impacts of oil palm development can include:

- Loss of HCV forest and Biodiversity – Most of the areas in Cameroon suitable for oil palms happen to be covered in intact tropical rainforest, rich in biodiversity and hence important for national and global conservation. A relatively small part of this area has over recent decades been converted for human settlements as well as production (e.g. farming and logging). Palm oil investors general try to avoid developed areas where they would need to negotiate access and pay compensation to the people affected. So they prefer the least populated areas, where the forests, in most cases, are the more biodiversity. In addition to the direct damage to flora and wildlife habitats due to forest conversion, the influx of migrant workers will increase pressure on wildlife through hunting for the supply of bush meat;

- Loss of permanent forest estate – Forest Management Units (UFAs) & Protected Areas (PA) - The size of the area currently being sought by palm oil companies is not limited to private lands, degraded areas or the nonpermanent forest estate. Considering the large number of requests for land, as well as the size of the proposed investments, there is a growing pressure to convert the national forest estate, including forest management units.

Impact on livelihoods

The oil palm is a versatile and unique crop: it produces two different types of oils, palm oil and palm kernel oil. Palm oil is used in a wide variety of food products such as cooking oil, shortenings and margarine. Palm kernel oil is a raw material in the production non-food products which include soaps, detergents, toiletries, cosmetics and candles. Palm oil is increasingly being used as feedstock for biofuel although its primary use remains for food.

Negative impacts on livelihoods of local people and plantation workers - Agribusinesses currently seeking large tracts of land in Cameroon do not seem willing to involve smallholders in their projects. In the absence of such involvement, large industrial plantations often have negative social impacts on the indigenous populations as well as on the migrant populations. While the working conditions of employees of the company are usually excellent (good quality housing, clinics, schools, scholarships etc.); this does not however apply to workers hired on an ad hoc basis by subcontractors. Their working environment is characterized by poverty, extremely low wages, poor working conditions and housing, etc.

Cases of social conflict and human rights violations have been reported, such as the expropriation of land from neighbouring communities, use of migrant labour as a matter of policy, the forced displacement of indigenous people, the loss of cultural heritage and agriculture, etc. (Ricq 2009).

4. Methodology

The methodology applied within this study consists of comparing key indicators across populations of small scale palm oil processors with different work environment, production capacity, socio-economic status and income levels (cross-sectional statistical analysis). The main advantage of this methodology relies on its practical feasibility and limited cost as compared to other methods. Given the regional context (Sub-Saharan Africa) it seems a prudent and rational option.

4.1 The research method

There are a variety of ways to achieve measurable answers to any development question. Generally speaking, the methods researchers have available to them include qualitative and quantitative methodologies. These methodologies usually exhibit as focus group research methods, one-on-one interviews, written questionnaires, etc. in our study; several particularities justify the use of a questionnaire in order to gather the data. Given the nature of the target sample (rural illiterate individuals) and the rather technical and specific information that each individual is required to provide, the modality of a questionnaire accompanied by an assistant/translator was chosen.

According to Kerlinger (1973), survey research involves the studying of large and small populations selecting and studying samples chosen from the populations to discover the relative incidence, distribution and interrelations of sociological and psychological variables. It is a method of obtaining information about a population from a sample of individuals. Surveys can provide a quick, inexpensive and accurate means of obtaining information from a large group of people. If you want to know about the opinions, attitudes and perceptions of respondents, the survey is an appropriate method of collecting data. Besides, describing surveys can also be used to explain the relationship and differences between variables. The term sample survey is often used because a sample which is representative of the target population is used.

Any survey should follow a structured approach; based and adapted on the former authors, several steps were followed in order to come up with the final questionnaire:

Step 1: Defining the Objectives of the Study

The main objective of this section is to be able to answer the question “Why are we doing this survey?”

The main answer refers to overall objective of the Thesis: “to measure the impact of palm oil technology on the revenue generation capacity of rural processors in Cameroon”. The data extracted from the questionnaires is instrumental in this purpose, since the values collected will be processed. The study mainly focuses on establishing the link between palm oil industrial development and revenue generation. Therefore, questions on industrial processes such as pulp pressing capacity, oil clarifying capacity, and income are an essential part of the data collection process. What the study is really envisaging is to demonstrate a quantifiable and positive causal relationship between income and palm oil processing development.

This attempt to demonstrate, to a limited scale, that a positive technology shock promotes income generation seems to be consistent with the current understanding of economic growth reflected in the neoclassical growth model developed by Robert Solow (1956). The underling resrach question relies to a certain extend in the Solow model, whereby capital accumulation constitutes a major factor contributing to economic growth. Productivity growth results from increases in the amount of capital per worker, or capital accumulation (e.g. Fagerberg 1994). Capital deepening will continue until the economy its steady state – a point at which net investments grow at the same rate as the labor force and the capital-labor-ratio remains constant. The further the economy is below its steady state, the faster it should grow (Jones 1998). In the steady state, all per-capita income growth is due to exogenous technological change.

Technological change is thus at the very center of modern economic growth. Based on the observation that, beginning with the Industrial Revolution, technological change took place mainly in the manufacturing sectors, authors like Kaldor (1970) and Cornwall (1977) have asserted that the expansion of this sector is a driving force for economic growth (Verspagen, 2000).

Step 2. Define the population, sample size and determining the sampling technique

Unlike a census, where all members of the population are studies, survey gather information from only a portion of the population of interest – the size of the sample will depend on the purpose of the study.

The word population has is defined as all people, objects or events found in a particular group the researcher is planning to generalise to (Borg and Borg, 1983). Population of palm processors in rural Cameroon. Since the population is very large and scattered we are forced to take a sample (too expensive, time consuming and need additional resources. The important thing is that the sample has to be representative, i.e. individuals possessing similar charcteristics as the population.

As mentioned earlier, surveys rely on samples to make projections about the population. The sampling technique used to determine the sample used directly depends on the limited resources available to conduct the research and the scatteredness of the sample individuals. Given these aspects, and in order to make the data collection process feasible, the study adopted a Non-probability sampling using the technique of convenience sampling. This technique introduces the needed flexibility given the context and financially feasible. As a limitation, it provides less accuracy than more experimental mehods.
In order to compensate for the non-randomness of the sample, the study decided to collect a number of samples beyond pure necessity. The larger the sample the more likely the sample mean and standard deviation will be representative of the population mean and standard deviation. Since the total number of palm processors in Cameroon has been estimated at 300,000 rural farmers by some independent experts, and given the ressources available, the study could conduct 480 surveys.

Two categories were defined for data collection on the processing level:

A. Traditional method: This is the method used by old traditional centers using primitive manual oil processing techniques which are to be considered artisanal.
B. Modern method: This is the method used by more advanced centers with mechanized oil processing techniques.

Criteria used in order to define each group:

- Significant difference in pulp press capacity (.25 tons per hour Traditional vs. 1.25 tons per hour Modern, on average)
- Significant difference in the number of workers (6.37 workers in traditional vs. 3.76 in Modern on Average)
- Significant difference in processing capacity scale (6.7 tons of FFB per year vs. 7.8 tons of FFB per year on Average)
- Significant difference in output production (0.7 tons of Crude Palm Oil Traditional per year vs. 0.95 tons 7 tons of Crude Palm Oil Modern per year on Average).

- None of the 2 categories reported to apply quality control system nor had a digester or thresher.

Step 3: Writing the Items and Construction of the Questionnaire

Survey data was mostly obtained by means of questionnaires. Questionnaires were administered during an interview in a face-to-face session and assisted by a translator. A total of 32 closed questions per questionnaire were addressed to the interviewees. The questions were designed to be as specific and easily understandable as possible. Since most of the time the interviewees were reporting data on a different unit, the interviewer had to harmonize them for the purpose of the study (e.g. when processors report total CPO production they normally use seasonal figures as well as local measure units. The interviewer had therefore to annualize this figure and express them into comparable units, such as tons, Kilos, meters, etc.).

Each of the questions was designed in order to capture the real palm oil processing situation. Questions therefore start with a generic introduction (sex, village name, age, education level) and directly inquire on income levels and whether the processors presently use industrial techniques for processing their palm oil.

Step 4: Pilot-Testing of the Questionnaire

In order to avoid problems that may arise when the questionnaire is administered to the whole sample, the study decided to pilot-test the questionnaire in one palm oil processing group similar to the sample in the actual study. When finished, the interviewers were asked for their opinions of the interviewees and were invited to express their suggestions and remarks. (e.g. Was it too long? Which items were difficult?).

Step 5: Administering the Questionnaire

A total of 480 questionnaires with 32 questions each were administered in 4 different rural regions of Cameroon namely, the regions are: Sombo, Mkpot, Misaje and Edea. Out of the 480 a total of 240 questionnaires were collected from community-level processing units (Traditional) and 240 from more advanced processing centers (Modern). The entire process took close to two months time from October 2013 to December 2013, in which a team composed by 4 members travelled over 1000 Km throughout rural Cameroon.

Step 6: Data Entry and Analysis

Data was coded and entered using Excel files and other statistical packages. A process of harmonization, factual consistency and unification was undertaken to ensure accuracy of data entry and ensure that all codes and dummy variables were valid (for example, ‘1’ is for male, ‘2’ for female). The analysis expected a matrix of roughly 15,000 entries (32 variables asked throughout 480 individual processors).

With respect to Statistical analysis (descriptive, estimation and post-estimation), it was agreed to use Stata/IC 12.0 for Windows (32-bit), given its user friend functionality, affordable cost and strong statistical analysis potential.

4.1.1 Data collection (questionnaire[1])

Data was collected directly in the field from primary sources for a selected representative sample in four different geographical locations in Cameroon illustrated in the below figure. The centers are located in the Cameroonian oil palm producing region, providing a good mix of rural locations.

Figure 14: Map with geographical location of palm oil processing centers sampled

[1] For more details on the questionnaires distributed refer to Annex 2

Data collection method is through:

- Surveys through questionnaires which were conducted by professional surveyors.
- Interviews

- 480 questionnaires with 32 questions each were collected in 4 different rural regions of Cameroon namely, the regions are: Sombo, Mkpot, Misaje and Edea

- Out of the 480 a total of 240 questionnaires were collected from community-level processing units (Traditional) and 240 from more advanced processing centers (Modern)

- Statistical analysis (descriptive, estimation and post-estimation) was conducted with the statistical software: Stata/IC 12.0 for Windows (32-bit)

The target groups were:

- Direct workers and entrepreneurs within the processing mills

4.1.2 Indicators

The key indicators were identified and included in the surveys. Suggested indicators of reported perceptions collected in the period from October 2013 to December 2013 are as follows (to see the questionnaire distributed see Annex 2):

1. Income level per palm oil processing worker (in Central African Franc - FCFA, per year)
2. Worker productivity (tons of FFB processed per worker and year, tons of CPO processed per worker and year)
3. Total CPO production (in metric tons per year)
4. FFB pulp press capacity (CPO Pulp pressing capacity. Metric tons per hour)
5. Other 25 factors listed in the questionnaire (for a detailed description of each variable, units and labels see Table 4)

4.1.3 Data analysis and comparison

The collected data was transferred from the questionnaires and inserted into an excel spread sheet and imported to the Stata software. To do so, quantitative and qualitative (dummy variables) were created, for mutually exclusive categories (sex, education, region among others).

4.1.4 Results presentation

Data was analyzed using Stata software and is presented through descriptive, inferential and predictive statistics. Visual tools such as tables, graphs, scatter plots, or tables were used.

4.1.5 Prediction, estimation and Inference

The predictive part utilized simple and multiple regression models and parametric ordinary least squares for estimating variables. In order to avoid misleading results typical tests were performed (e.g. heteroskedasticity, endogeneity, multicollinearity or omitted variable). Additionally, the research study explored different models to attempt to find conclusive and significant relationships.

4.1.6 Limitations and assumptions

The limitations of our study are determined by

- Size of the sample (a total of 480 observations with 28 variables each were collected)
- The representativity of the sample (whether or not our sample has similar characteristics as the population in which we want to make inference for). For convenience of the purpose of the study, we assumed the data collected accurately represents the situation of palm oil processors in rural Cameroon.
- The particular socio-cultural context (education, religion, traditions), which can affect the accuracy of the data gathered.
- Problem of attribution in isolating the changing factor (was it really the technology that increased the income of the workers, or could there be other explanations?) This aspect is difficult to control for in a development study as this one, in which multiple non-quantifiable factors may interact altogether.
- Lack of treatment group and control group data (even though we will be able to collect data on a sample before and after the treatment, we will not be able to compare it with a control group who didn't suffer the treatment). This has been partly solved by using proxies for the control group, so even if the effect of technology on income has been measured across different groups, the selection of groups with large similarities (geographical, economic, socio-cultural) mitigates this deterministic (non-randomized) risk.

Assumptions:

- Data are acceptably reliable (people are not lying, etc.)
- Processing units are running and operational

5. Expected results and expected scientific contribution

5.1 Social and economic impact of palm oil production

Social and economic factors have large influence to the prospective development of palm oil production and availability of waste material. There are some critical issues which need to be mentioned. Growing demand for vegetable oil caused increasing areas where oily crops are grown, and palm oil is no exception. Currently vegetable oil made from palm oil fruit covers 35% of world consumption. Oil palm is spreading throughout the tropics, most notably in Southeast Asia. In 2008, Malaysia's Federal Land Development Authority (FELDA) announced plans to establish oil palm plantations in Kalimantan (20,000 ha), Aceh (45,000 ha), Papua New Guinea (105,000 ha), and Brazil (100,000 ha) (Wilcove et al. 2010). In May 2009, Sime Darby, the world's largest oil-palm company, also announced plans to invest 800 million US dollars in oil palm and rubber plantations in Liberia, covering around 200,000 ha (80% for oil palm) (Lopez et al. 2008). Given that large expanses of forested areas in these regions are suitable for oil palm, oil palm will likely continue to replace tropical forests (Laurance et al. 2010).

Along with employment, large oil palm plantations provide a variety of facilities for employees and their families, including housing, water, electricity, roads, medical care, and schools. In some rural areas, palm oil plantations offer the only livelihood option (Koh et al. 2007).

Large palm oil plantations have also been associated with corruption of community members, the decline of cultural traditions (the result of large inflows of immigrant workers), dependence on palm oil plantations and companies, and the loss of biodiversity. The loss of biodiversity is reducing opportunities for hunting, fishing, use of forest products, and access to clean water (Colchester et al. 2006).

In response to social concerns associated with palm oil production (as well as legal, economic, and environmental issues), the Roundtable on Sustainable Palm Oil was formed in 2004 to develop and implement global standards for sustainable production. Membership in 15 the group now includes 257 ordinary and 92 affiliate members, who represent about 35 % of palm oil production in the world (Roundtable on Sustainable Palm Oil /RSPO/, www.rspo.org, 2013).

Expansion of palm oil plantation can have a negative effect to the environment and can lead to irreversible losses of natural heritage. A report prepared by WWF shows that clearance of tropical forests for oil palm plantations has caused a lot of negatives effects (WWF, 2005). The removal or destruction of significant areas of forest has resulted in ecology instability to the natural habitat of the forests. For instance, animal species like Asian elephants, Sumatran rhinos and Sumatran tigers, which can only be found in Sumatran and Borneo Island, are facing extinctions due to the high rate of tropical forests being converted to oil palm plantations. When their natural habitats are destroyed, these animals would not be able to survive and become endangered (Tan et al. 2009).

Glastra et al. claim that most of the deforestation in South East Asia has been carried out using land burning where large scale clearance caused numerous, large and persistent fires in Sumatra. For example, it is claimed that the 1997 haze around South East Asia region is caused by this activity. Apart from that, it was also reported that from 5 million hectares of former forest in Indonesia, 3 million hectares are now covered with palm oil (Glastra et al. 2002).

5.2 Expected direct results from installing a modern palm oil processing facility

The major problems of the cooperative group are production capacity, product quality and hygiene conditions and limited management skills.

As suggested by Rist et. al (2009), the expansion of small-scale palm oil processing will likely provide higher returns to land and labour for rural communities, but must be accompanied by the correct set of friendly production public regimes in order to translate private gain into general interest.

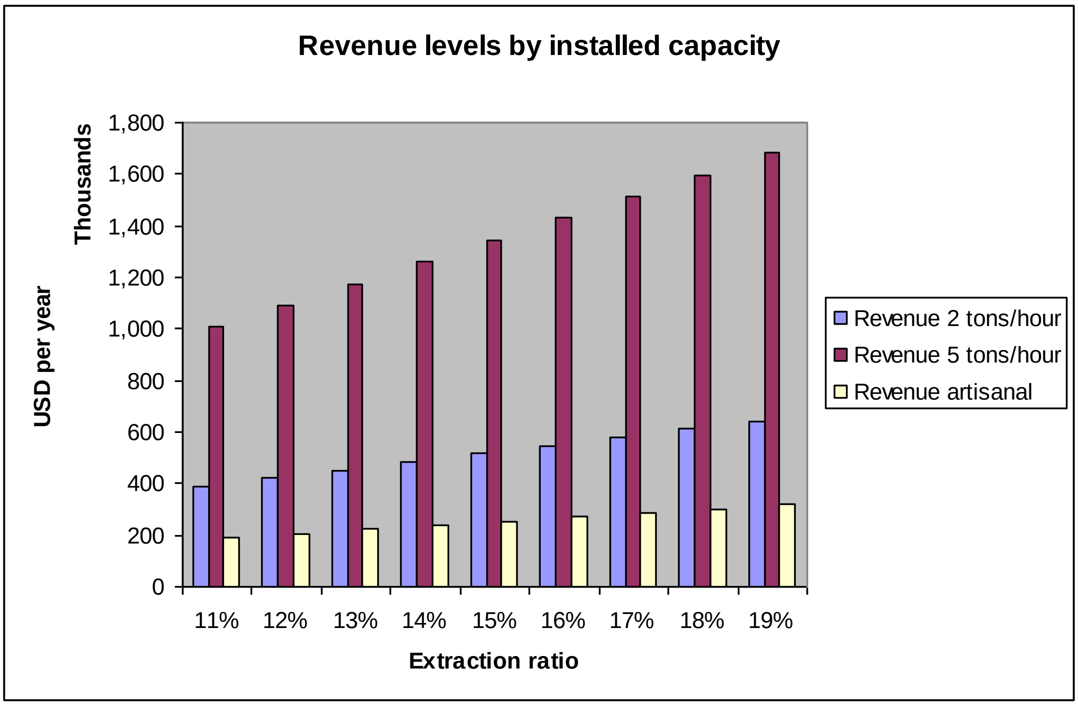
As suggested in similar experiences in the region, a direct impact will be felt in the production and processing capacity & quality (Aletor et. al 1990) of the existing palm oil production units. Increased quality and quantity of Crude Palm Oil (CPO) production and other by-products will generate recurrent revenue and will attract investment in service related activities. In a broader sense, the local community as a whole will benefit from new employment opportunities, which ultimately would lead to improve the poverty and food security levels. The new technology will also support the competitiveness of the local industry by developing quality products that comply with required standards. Product diversification and market participation will thus drag and enhance local production and will generate earnings, investment and tax income to a state and country level. These strategies have been long suggested to developing countries as a path out of poverty (Jabara 1980).

In our study a direct impact will be felt in the production and processing capacity of the existing palm oil production units. Increased quality and quantity of Crude Palm Oil (CPO) production and other by-products will generate recurrent revenue and will attract investment in service related activities. In a broader sense, the local community as a whole will benefit from new employment opportunities, which ultimately would lead to improve the poverty and food security levels. The new technology will also support the competitiveness of the local industry by developing quality products that comply with required standards. Product diversification and market participation will thus drag and enhance local production and will generate earnings, investment and tax income to a state and country level.

It is worth mentioning that the palm oil sector in which the scale of production matters and directly affects profitability.

These expected results are in line with new evidence on the capacity of agricultural growth to serve as an effective instrument for poverty reduction (The World Bank Research Observer, vol. 25, no. 1 February 2010).

Figure 15: Expected revenue levels by industrial capacity installed in Cameroon (Source: self-compiled from UNIDO and FAO).



5.3 Scientific contribution

As previously described, the neoclassical economic literature suggests that, under competitive conditions, wages are determined by the marginal revenue product and the sum of the firm's costs. More recently, economists have generally demonstrated that productivity growth is an avenue through which to raise living standards, and wage growth is expected to track increases in productivity (Cashell 2004). Additionally, experience and evidence from countries within and around the sub-Saharan African region indicates that returns to agricultural technology development could be very high and far reaching. This would transform not only the smallholder sector, but also in the entire national economies of countries in the region (Mazonde, 1993). Moreover, there is a large gap between what the smallholder farmer gets and what is feasible with the available technology in sub-Saharan Africa. In looking at what has gone wrong, a fundamental issue of concern relates to the technologies and institutional arrangements that are being promoted by governments in the region to increase agricultural productivity (Mkandawire & Matlosa, 1993). The use of agricultural technologies affects the rate of increase in agricultural output. It also determines how the increase in agricultural output impacts on

poverty levels and environmental degradation (Meinzen-Dick et al., 2002). Increased agricultural productivity, technology adoption rates, and household food security and nutrition can be
achieved through improved agricultural practices, expansion of rural financial markets, increased capital and equipment ownership by rural households, and development of research and extension linkages (von Braun, 1999). Increased technology development and adoption can raise agricultural output, hence improve household food intake. Overall, it seems safe to state that, under certain normal conditions, a positive correlation between labor productivity and wages exists, and that positive technology shocks are very likely to promote income gains.

Notwithstanding this claim, in the case at hand, several particularities make such theoretical approaches difficult to apply when trying to determine the effect of technology on incomes. The studied population is characterized by subsistence economics, repeated non-rational choices (presence of tribal and hierarchical structures and superstition), and local markets full of imperfections. Given the virtual absence of quantitative studies that accurately determine the monetary gain after the adoption of a new technology in the personal income of a specific rural processor, it has been deemed necessary in this study to attempt to ratify the classical assumptions of wage increase when positive technology shocks are present, but to bring it to a more concrete level in selected locations of rural Cameroon.

The current study looks at the impact of a standard and concrete technological improvement on the income rural communities of Sombo, Mkpot, Edea and Misaje, North-East Cameroon. In other words, this PhD aims at bringing clarity on to what extend a more advanced mechanical palm oil extraction equipment (Advanced being 0.7 to 5 ton-per hour. Traditional being less than 0.7 ton-per hour) installed in a concrete rural district, and under a clear management and regulatory structure and environment, outperforms existing artesian manual processing palm oil producing system in terms of productivity (tons of palm oil produced), quality (price of the crude palm oil) and income generation capacity. Income in this case indicates salaries of the workers within the installed modern hour palm oil mills.

This study will quantify whether the introduction of a modern mill of oil palm would be beneficial on the income increase level to the small-sized oil palm farmers and/or processors. If the treatment of this study proves successful then Cameroon could adapt this technology and strategy in order to assist in poverty alleviation and better economic state of the palm oil farmers and producers in the rural areas of the country. On the other hand this would be the solution for the small scale processors in order to adopt better production and enhanced hygienic and quality standards.

One of the main economic impacts of the introduction of a new technology is the fact that the farmer will benefit for clear market outlet not far from their farms, and therefore with reasonable transport costs. The main farmers will benefit for increased quantity and quality of demand for FFB (Fresh Fruit Bunches), which will encourage them to plan more, will strengthen the competition between farmers and induce productivity improvements (increased used of seeds, fertilizers, planting higher yielding varieties, etc.). we should keep in mind that FFB is the primary material for the processing centre and represent therefore the large part of variable costs. The FFB price (paid by the processing centres) is therefore a function of the palm oil sold & palm kernel price and the oil extraction ratio and the mill operational costs.

5.4 Results and discussion

Table 1 presents the summary descriptive statistics collected during the survey. The following list provides the abbreviations used in the forthcoming tables and graphs.
The results presented below were all extracted following the methodology suggested in previous sections. All data were obtained from the primary sources (i.e. individual palm oil processors) and analyzed in consequence.

Table 4: List of abbreviations in study

VARIABLE LABEL	VARIABLE DESCRIPTION
region	Sombo (1), Mkpot (2), Edea (3), Misaje (4)
age	Age (years)
sex	Male (1), Female (0)
edu	Education level: illiterate (1), Basic (2), Intermediate (3),

	Advanced (4)
hou siz	House hold size (number of persons)
inc	Income (Central African Franc - FCFA, per year)
land	Land: inherited (1), Purchased (0)
cult area	Total palm oil cultivated area (ha)
agrpr	Applies fertilizer (1), improved seeds (2), Both (3), None (0)
ffb pri	Price of Fresh Fruit Bunches (FFB) sold to processors (FCFA/t)
tot work	Number of workers in the processing centers (# of workers)
wor exp	Working experience (years)
equ age	Age of the equipment (years)
avr tim	Hours per day the center operates (hours)
ffb pro	Total FFB processed per year (tons)
cpo pro	Total Crude Palm Oil production per year (tons)
cpoavgpr	Crude Palm oil average selling price (FCFA)
electrc	Total cost of electrical power per month (FCFA)
ffb rec	FFB receiving area capacity (surface area, meters)
ffb thr	FFB threshing capacity (tons/year)
ffb ste	FFB sterilization capacity (tons/hr)
ffb dig	FFB fruit digestion capacity (tons/year)
pulp press	Pulp pressing capacity (tons per hour)
oil clar	Oil clarification capacity (tons per hour)
tech	Overall technology level: Traditional (0), Modern (1)
oil pack	Oil packaging capacity (CPO liters)
oer	Oil extraction rate measured as CPO (t/year) divided by FFB (t/year), expressed in percentage (%)
wastm	Waste management technique applied: manure (1), biomass (2), other (3)

Table 5: Summary descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Region	474	2.487342	1.113462	1	4
age	474	47.97468	11.312	18	78
Sex	474	.7616034	.4265531	0	1
edu	474	2.888186	.7653625	1	4
housiz	474	6.580169	2.910015	1	20
inc	474	375482	631934.4	39500	6944000
land	474	.9177215	.2750788	0	1
cultarea	474	4.839135	7.984482	.5	100
agrpr	474	1.814346	.9006252	0	3
ffbpri	474	6118.143	16259.61	0	52000
totwork	474	4.835443	2.9639	0	35
worexp	474	10.29536	7.195349	0	50
equage	474	5.300844	3.931765	0	19
ffbpro	474	6.514884	11.90232	0	124
cpopro	474	.7352595	1.599244	0	18
cpoavgpr	439	551.2779	136.8074	0	800
electr	474	2197.354	5500.254	0	30000
ffbrec	474	3.635021	6.233962	0	100
ffbthr	474	.0168776	.3674522	0	8
ffbste	474	.7805422	1.135737	0	9
ffbdig	474	1.265823	27.55891	0	600
pulppress	474	.6491561	.8284894	0	4.5
oilclar	474	.5764304	.8867035	0	8
oilpack	474	18.22785	6.119216	0	30
wastman	474	1.544304	1.228252	0	3
tech	474	.4936709	.5004882	0	1
avgtim	449	5.518374	2.4002	0	12
cpoprow	428	.1632811	.2538411	.0083333	2.17
oer	428	.1061503	.0222941	.05	.18
ffbprow	428	1.364596	1.693986	.0833333	15.5

Below is a correlation matrix for the main explanatory variables in the model. Numbers are Pearson correlation coefficients going from -1 to 1. Closer to 1 means strong correlation. A negative value indicates an inverse relationship (i.e. when one goes up the other goes down).

Table 6: Correlation matrix of the most relevant variables of the model

	inc	cpopro	ffbrec	ffbste	ffbdig	pulppr~s	oilclar
inc	1.0000						
cpopro	0.7356*	1.0000					
	0.0000						
ffbrec	-0.0280	0.0156	1.0000				
	0.5429	0.7353					
ffbste	0.4925*	0.4381*	-0.0233	1.0000			
	0.0000	0.0000	0.6136				
ffbdig	0.0014	0.0004	0.0396	-0.0073	1.0000		
	0.9754	0.9926	0.3895	0.8738			
pulppress	0.2339*	0.2625*	-0.2392*	0.2027*	-0.0250	1.0000	
	0.0000	0.0000	0.0000	0.0000	0.5879		
oilclar	0.4652*	0.4118*	-0.0540	0.8793*	-0.0092	0.1841*	1.0000
	0.0000	0.0000	0.2410	0.0000	0.8424	0.0001	

As we can observe in the Table 6, "inc" has a strong positive correlation (significant at 95%) with the total "cpopro" CPO production. This is logical, since the main source of income of the processing centres is the sale of crude palm oil to the local market. Therefore, the more CPO produced and sold, the higher the income of the workers in such processing center.

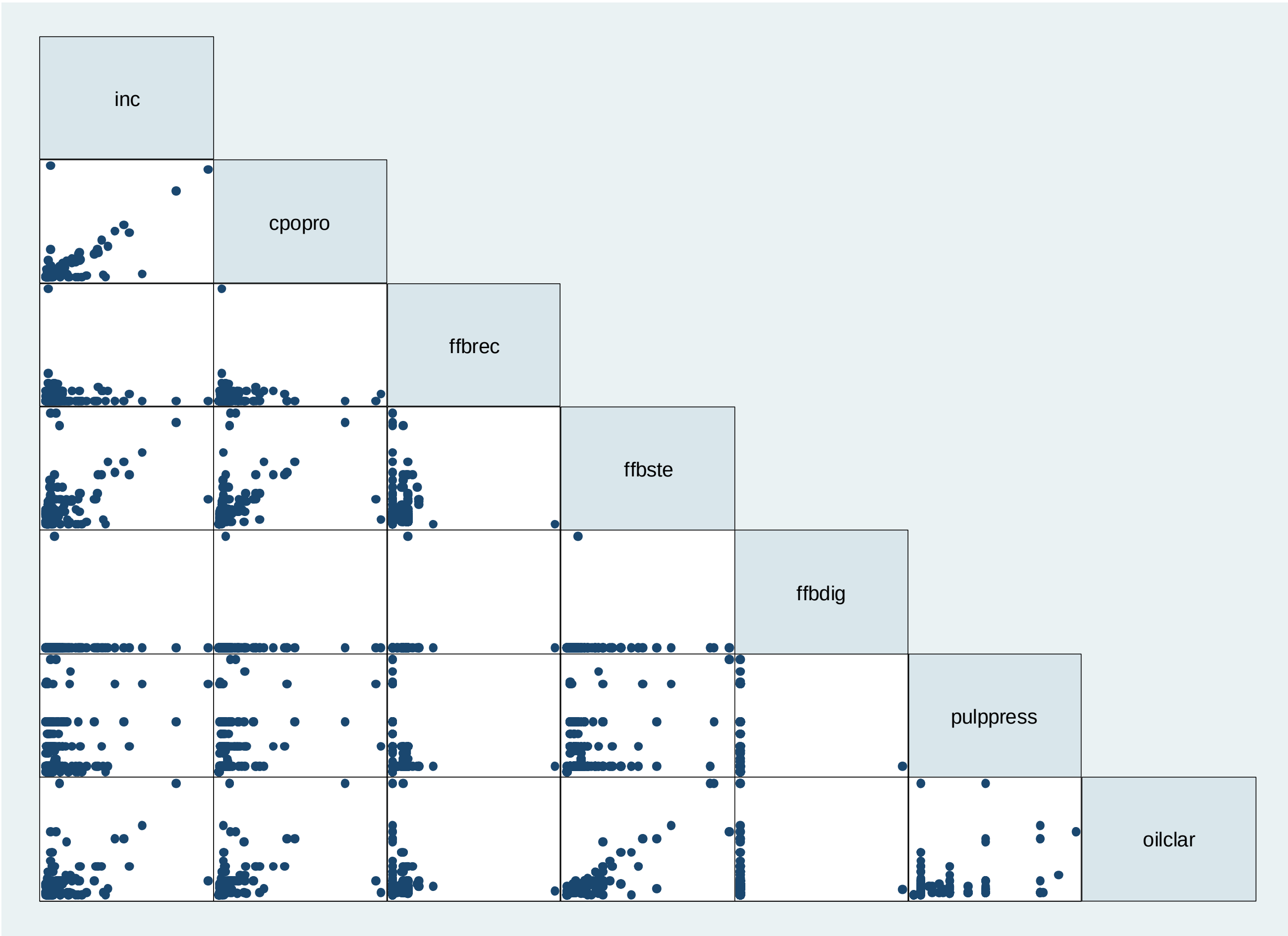
Alternatively, "inc" has positive and significant correlations with "ffbste", "pulppress" and "oilclar", suggesting that the higher pressing capacity and higher clarification capacities are generally associated with higher income levels.

"Pulppress" and "ffbrec" (FFB receiving area capacity) have a negative correlation, probably explained by the fact that an increased pressing capacity allows factories to have a smaller receiving area, since FFB are directly processed when arrive at the factory gate, and need not have to wait to be transformed.

These preliminary findings are encouraging in order to proceed to the selection of such explanatory variables for the model, since to optimize a statistical model explanatory variables should be strongly correlated with the independent variable but weakly correlated among them.

The following graph provides the same information from a graphical representation -point of view-, (scatter plots), displaying the correlation matrix of the main explanatory variables.

Figure 16: Graphical correlation matrix



It can again be seen than increased processing and quality enhancing capacity are associated with higher production and higher income levels. Also, the graph seems to suggest that the different processing stages are weakly correlated among them, highlighting that the processing structure of canters in rural Cameroon does not form a general pattern across areas, but is rather improvised.

Finally, we can observe that the variable “ffbdig” (FFB fruit digestion capacity expressed in tons per year) is virtually not correlated with variable “inc” (Income per year in Central

African Franc - FCFA), or to any other variables considered in the model (its correlation factors are all close to zero). This finding suggests that FFB digesting capacity seems not to be associated with higher income levels or other processing stages. One plausible explanation is the fact that only five units out of 480 surveyed reported having any FFB digester capacity. FFB digestion capacity (variable ffbdig) therefore provides little additional information since it does not bear any particular relationship with the other variables taken into account in the model. This observed indication from the correlation table will be further explored in the regression analysis, in order to attempt to find causal relationships with other dependant variables (mainly income and productivity).

5.4.1 Productivity

The results show that the traditional method can process less Fresh Fruit Bunches (FFB) per worker per year than the modern method. Modern mills can process a total of 1.8 tons of FFB per worker per year, compared to 0.98 tons/worker/year in traditional ones (statistically significant at 95%) (Graph 1). Controlling for the number of workers, modern mills will, on average, be able to process additional 8 tons of FFB per year than traditional mills (Table 7).

The following graph describes the relationship between the total quantity of FFB processed (t/year) in the y-axis, and the total number of workers required to do so in each of the 2 groups considered (modern and traditional centers) in the x-axis. As we can see, for a given amount of FFB processed, traditional centers require more workers.

Graph 1: Relationship between total FFB processed and number of workers

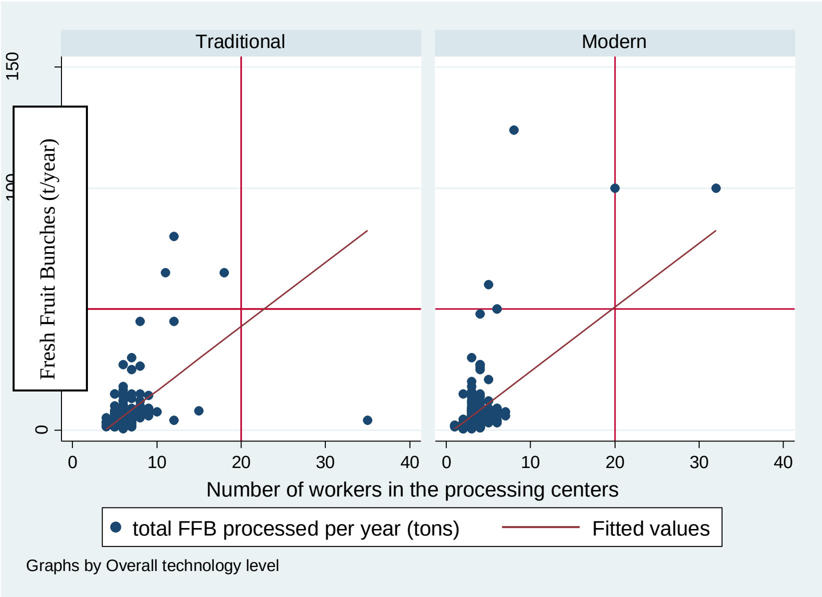


Table 7: Regression of FFB processing capacity on total workers

```
Linear regression                                      Number of obs =     428
                                                       F(  2,    425) =    5.26
                                                       Prob > F      =  0.0055
                                                       R-squared     =  0.2961
                                                       Root MSE      =  10.364
```

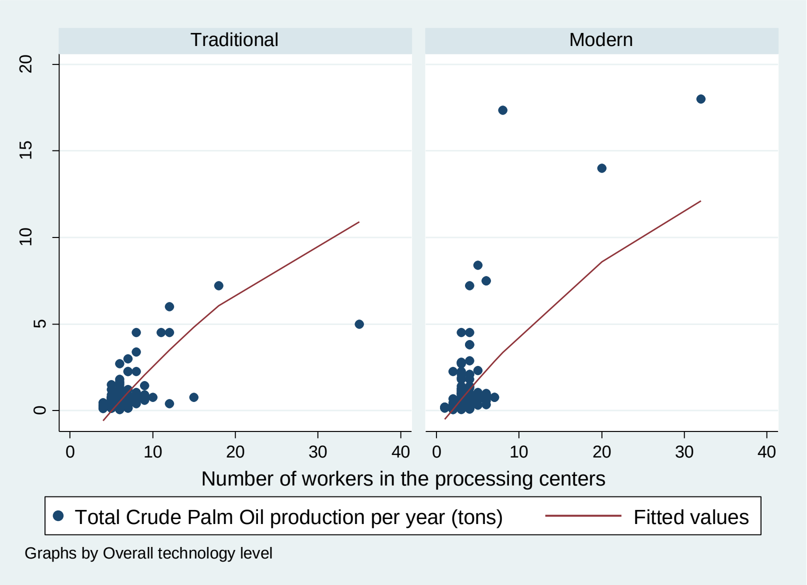
ffbpro	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
totwork	2.645754	.9372409	2.82	0.005	.8035495	4.487959
tech	8.024812	2.485227	3.23	0.001	3.139946	12.90968
_cons	-10.17098	5.610654	-1.81	0.071	-21.19906	.8571074

Results also show that modern mills produce a total of 0.22 tons of palm oil per worker and year, whereas traditional mills produce only 0.10 tons per worker and year (Table 8). Therefore, Crude Palm Oil (CPO) per worker in modern centers is on average 0.12 tons per year higher than in traditional ones (Table 8).

Given the same number of workers, modern mills will, on average, be able to process additional 1.38 tons of CPO per year than traditional mills (Table 12).

The following graph describes the relationship between the total quantity of CPO produced (t/year) in the y-axis, and the total number of workers required to do so in each of the 2 groups considered (modern and traditional centers) in the x-axis.

Graph 2: Relationship between CPO produced and number of workers



The graph shows that for any given amount of CPO produced, traditional centers require more workers. As an example, we could say that in order to produce five tons of CPO per year, traditional centers require close to 15 workers, while only 11 workers are required to produce the same amount of CPO in modern centers. This indicates that modern palm oil processing centers require 36% less labour force in order to achieve the same output quantity.

Table 8: Hypothesis test for the difference in mean CPO produced per worker and year in traditional and modern centers

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Traditio	231	.106427	.0097867	.1487447	.087144	.12571
Modern	197	.2299476	.0232114	.3257872	.1841715	.2757237
combined	428	.1632811	.0122699	.2538411	.1391643	.187398
diff		-.1235206	.0239088		-.1705145	-.0765267

```
    diff = mean(Traditio) - mean(Modern)                      t =  -5.1663
Ho: diff = 0                                     degrees of freedom =      426

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Table 9: Effect of an additional worker on total CPO production

```
Linear regression                                      Number of obs =     428
                                                       F(  1,    426) =    5.05
                                                       Prob > F      =  0.0251
                                                       R-squared     =  0.1955
                                                       Root MSE      =  1.4942
```

cpopro	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
totwork	.2588851	.1151695	2.25	0.025	.0325138	.4852563
_cons	-.525508	.5584511	-0.94	0.347	-1.623171	.5721546

Table 9 above shows that on average, an additional worker increases the CPO production by 0.25 tons per year. This represents approximately a 30% increase with respect to the mean estimation for the CPO production for both groups.

Additionally, in traditional centers, the effect on CPO production of an additional worker is 0.11 tons per year (an increase representing 17% of the mean CPO production for this group), compared to 0.63 tons in modern centers (an increase representing 60% of the mean CPO production for this group). For more details on the regression, see Table 10 below.

Table 10: Effect of an additional worker on total CPO production sorted by the different centers technology

-> tech = Traditional

Source	SS	df	MS
Model	18.812202	1	18.812202
Residual	107.894881	229	.471156687
Total	126.707083	230	.550900362

Number of obs	231
F(1, 229)	39.93
Prob > F	0.0000
R-squared	0.1485
Adj R-squared	0.1448
Root MSE	.68641

cpopro	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
totwork	.1163258	.0184094	6.32	0.000	.0800524	.1525992
_cons	-.1200989	.1257774	-0.95	0.341	-.3679278	.12773

-> tech = Modern

Source	SS	df	MS
Model	538.105267	1	538.105267
Residual	498.762759	195	2.55775774
Total	1036.86803	196	5.29014299

Number of obs	197
F(1, 195)	210.38
Prob > F	0.0000
R-squared	0.5190
Adj R-squared	0.5165
Root MSE	1.5993

cpopro	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
totwork	.6352964	.0437998	14.50	0.000	.5489142	.7216786
_cons	-1.3527	.2004976	-6.75	0.000	-1.748122	-.9572779

Even though modern mills have a smaller average number of workers (3.76 vs. 6.37), modern mills are more productive because they have on average more experienced workers (9.9 vs. 11.5 years of experience), and more capital (higher pulp press capacity on average).

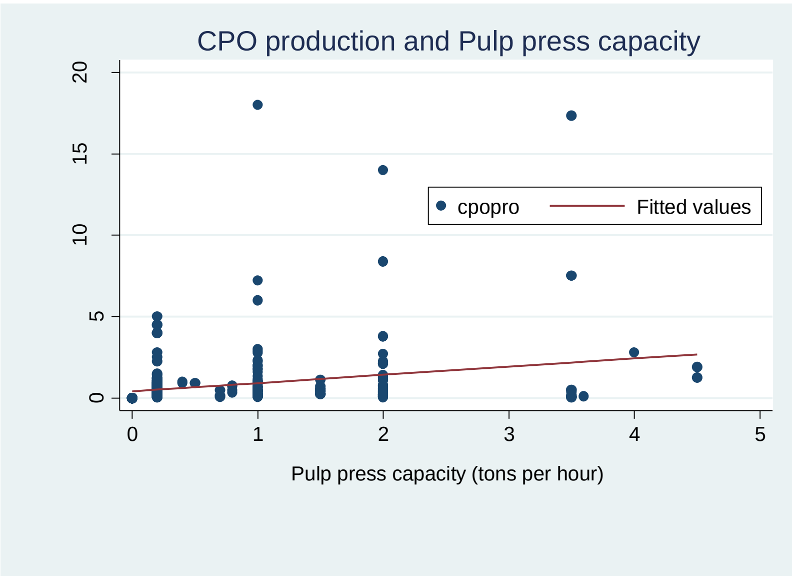
Table 11: Simple linear regression on CPO total production (cpopro) given pulp press capacity (pulppress)

```
Linear regression                                      Number of obs =      474
                                                       F(  1,    472) =     8.27
                                                       Prob > F      =   0.0042
                                                       R-squared     =   0.0689
                                                       Root MSE      =   1.5448
```

cpopro	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
pulppress	.5066734	.1761844	2.88	0.004	.1604706	.8528762
_cons	.4063493	.080046	5.08	0.000	.2490587	.56364

Given the above regression we can see that for each 1 ton per hour increase in pulp press capacity, the production of CPO is likely to increase by 0.5 tons per year. Even though the R-square is low, the t-statistic shows significance at 95%. The following graph provides the scatter-plot for these two variables, and draws the line for the predicted values of CPO production.

Graph 3: Scatter plot between CPO production and pulp press capacity



As it can be observed, there is a linear relationship between pulp press and CPO production.

Since there seem to be other factors affecting the CPO production levels, other explanatory variables such as total number of workers in the processing centers (totwork) and the total cultivated area (cultarea) have been included in the model.

Table 12: Simple linear regression on CPO total production (cpopro) given pulp press capacity (pulppress), total workers (totwork) and cultivated area (cultarea).

```
Linear regression                                      Number of obs =     474
                                                       F(  3,   470) =    5.76
                                                       Prob > F      =  0.0007
                                                       R-squared     =  0.4844
                                                       Root MSE      =   1.152
```

cpopro	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
pulppress	.4189207	.1178802	3.55	0.000	.1872832	.6505582
totwork	.2231744	.1000353	2.23	0.026	.0266027	.4197462
cultarea	.087127	.0390481	2.23	0.026	.0103966	.1638574
_cons	-1.037452	.4875322	-2.13	0.034	-1.995465	-.0794395

Given the above regression, we can infer that “pulppress”, “totwork” and “cultarea” are significant at 95% and positively affect “cpopro”. The model improves dramatically, with an R-squared up to 0.48.

cpopro= -1.03 + 0.41*pulppress + 0.22*totwork + 0.08*cultarea

For each one-point increase in the number of workers, the total production of CPO increases by 0.2 tons per year. This result is presumably higher in the case of modern centers, since the worker productivity is higher.

5.4.2 Efficiency

Palm oil efficiency is the capacity of the oilseed to provide an output given a fixed amount of input. At primary stage, it can be defined as the tons per year of CPO that can be produced out of a hectare of palm oil plantation. At processing stage –which is our focus- palm oil efficiency is defined as the tons of CPO that can be produced out of a ton of FFB in a given period of time (one year in our case). The higher the ratio, the higher the efficiency would be. The average OER for all the 480 individual processors inquired was approximately 10%.

A standard and widely used method to measure efficiency is through the Oil Extraction Rate (OER); the ratio between the output (CPO) and the input (FFB). This ratio allows to compare modern and traditional centers among them, and permits to observe the different degrees of efficiency across the different types of centers. A higher oil extraction rate allows processors to obtain a greater quantity of processed product given an amount of FFB to process.

Both FFB and CPO data for each processor were collected during the surveys. The study harmonized this data in terms of quantities (tons) and period of time (year) and combined them to develop a new indicator designated “oer” (Oil extraction rate, measured as CPO (t/year) divided by FFB (t/year) and expressed in percentage).

The following table presents hypothesis test for the difference in mean OER in traditional and modern centers. This test aims at determining whether there is statistically significant difference in the mean of OER in traditional centers as compared to modern centers.

Table 13: Hypothesis test for the difference in mean OER in traditional and modern centers

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Traditio	231	.0955355	.001149	.0174626	.0932717	.0977993
Modern	197	.1185972	.0014885	.0208915	.1156617	.1215326
combined	428	.1061503	.0010776	.0222941	.1040322	.1082685
diff		-.0230617	.0018539		-.0267057	-.0194177

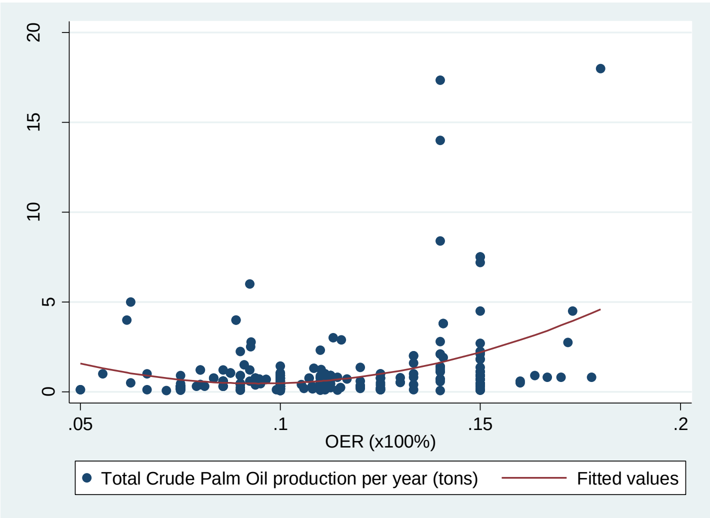
```
    diff = mean(Traditio) - mean(Modern)                      t = -12.4392
Ho: diff = 0                                  degrees of freedom =      426

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

The Table 13 above shows that OER is on absolute average terms 2.3% higher in modern than in traditional centers. This means that modern centers have an OER which is 22% higher than traditional centers.

The following graph describes the relationship between the total quantity of CPO produced (t/year) in the y-axis, and the oil extraction rate in the x-axis. As we can see, for an OER above 10% the total amount of CPO produced increases more than proportionally.

Graph 4: Relationship between OER and CPO produced



Graph 4 indicates that the quadratic relationship determines that the CPO produced increases more than proportionally when OER increases.

Table 14 below shows that an increase of 1% in OER will provide additional 4.6 tons of CPO per year on average.

Table 14: Effect on CPO production of an increase in OER

Source	SS	df	MS
Model	186.280378	2	93.1401888
Residual	995.914507	425	2.34332825
Total	1182.19488	427	2.76860629

Number of obs	= 428
F(2, 425)	= 39.75
Prob > F	= 0.0000
R-squared	= 0.1576
Adj R-squared	= 0.1536
Root MSE	= 1.5308

cpopro	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
oer	-106.2272	24.52391	-4.33	0.000	-154.4305	-58.02393
oer2	562.8658	105.2568	5.35	0.000	355.977	769.7545
_cons	5.468918	1.388585	3.94	0.000	2.739569	8.198266

5.4.3 Impact on income

Agricultural productivity in Sub-Saharan Africa is among the lowest in the world (Savadogo et al., 1998; Fulginiti et al., 2004). The agricultural low productivity is linked to weak access to input materials, poor farmer health during the late dry season and the beginning of the cropping season (Abellana et al., 2008); the failure of agricultural commodity and credit markets (Mather, 2009); and the very limited use of improved agricultural technologies (Mather et al., 2008). To increase productivity, the Government of Cameroon together with UN Organizations and other development partners are promoting the use of agriculture technologies and food processing techniques. The goal of disseminating technology is to increase farm and off-farm productivity to increase a marketable surplus that will increase household income and therefore food insecurity. This approach has been summarized as the agricultural productivity pathway out of poverty and subsistence agriculture (Barrett, 2008).

In Cameroon, income is determined by a multitude of factors including household size, the age and gender composition of the household, education, health, social capital, assets and endowments, or employment. This study, however, enquired particularly on the monetary revenue from working in a palm oil processing center or the revenue derived from selling palm oil to the local market. In this survey subjects reporting their income were either employees of palm oil mills or entrepreneurs in the palm oil processing business. This is why the income can be seen either as a wage or as revenue.

The empirical model

The literature on causal inference contains numerous approaches that can be used to evaluate the effect of a processor's exposure to a treatment (processing technology) on some outcome (processor's income). The economic approach used in the current study involves regression analysis with income as the dependent variable (inc) and pulp press capacity (pulppress), FFB sterilizing capacity (ffbste), FFB receiving area capacity (ffbrec), FFB processing capacity (ffbpro) and oil clarifying capacity as explanatory variables.

The following table presents the different models to explain changes in income attributable to differences in processing technologies. More concretely, the models are:

Model (1): inc = 230,742.95 + 195,362.5pulppress

This simple regression model shows relationships between income and pulp press capacity. The coefficient of pulp press indicates that one additional ton of installed press capacity is significantly increases expected income by 195,362 FCFA (US$411). The coefficient is significant at 95%, although the R square seems to indicate the model's ability to explain the variance of the independent variable is rather weak.

Model (2): inc = -15,695.8 + 154,036.3pulppress + 198,760.2ffbste + 114.865oilclar + 7,702.1ffbrec

This multiple regression model shows the relationship between income and pulp press capacity, FFB sterilization capacity, oil clarification capacity and FFB receiving area capacity. All coefficients indicate a positive relationship with income, i.e. as we increase each of these variables, the income will also increase. Pulp press capacity is statistically significant at 95% and shows that 1 ton per hour increase in pulp press capacity increases income by 154,06FCFA (US$324). The model improves dramatically as the R square is now at an acceptable 0.3 level.

Model (3): inc = -52,341.7 + 84,371.5pulppress + 6,076.2ffbste + 117,047.1oilclar + 1,773.4ffbrec + 38,220.8ffbpro

This last multiple regression model shows the relationship between income and pulp press capacity, FFB sterilization capacity, oil clarification capacity, FFB receiving area capacity and FFB processing capacity. All coefficients indicate a positive relationship with income. It is worth noting that pulp press capacity is still statistically significant at 95% and shows that 1 ton per hour increase in pulp press capacity increases income by 84,371FCFA (US$178). Additionally, FFB processing capacity seems to be very determinant in income since it is statistically significant at 99%. This aspect indicates that a unit with a FFB processing capacity of an additional 1 ton per year provides an additional income of FCFA 38200 (US$80). This later fact suggests that larger processing units tend to be more productive and distribute more revenues among its members. Once again, by including more explanatory variables, the model improves substantially beyond an R square of 0.7.

Table 15: Different models of income on processing stages

	(1) inc	(2) inc	(3) inc
pulppress	195362.6*	154036.3*	84371.5*
	(79022.4)	(75470.4)	(38045.3)
ffbste		198760.2	6076.2
		(125794.7)	(63436.2)
oilclar		114865.0	117047.1
		(158627.4)	(67875.6)
ffbrec		7702.1	1773.4
		(4533.5)	(1887.1)
ffbpro			38220.8***
			(8669.3)
_cons	230742.5***	-15695.8	-52341.7
	(41272.1)	(89555.2)	(47721.5)
N	428	428	428
R-sq	0.066	0.323	0.726
adj. R-sq	0.064	0.316	0.723
rmse	620299.6	530087.7	337351.0

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table15 above indicates that an increase of 1 ton per hour in pulp press capacity significantly provides a positive effect on income of approximately 84,371 FCFA per year (US$ 177), which represents an increase of 22.7% with respect to the mean income for both groups.

After detecting the presence of heteroskedasticity, robust indicators were used (see annex for scatter of residuals).The independent variable oilclar would have been significant at 95% if indicators wouldn't have been robust.

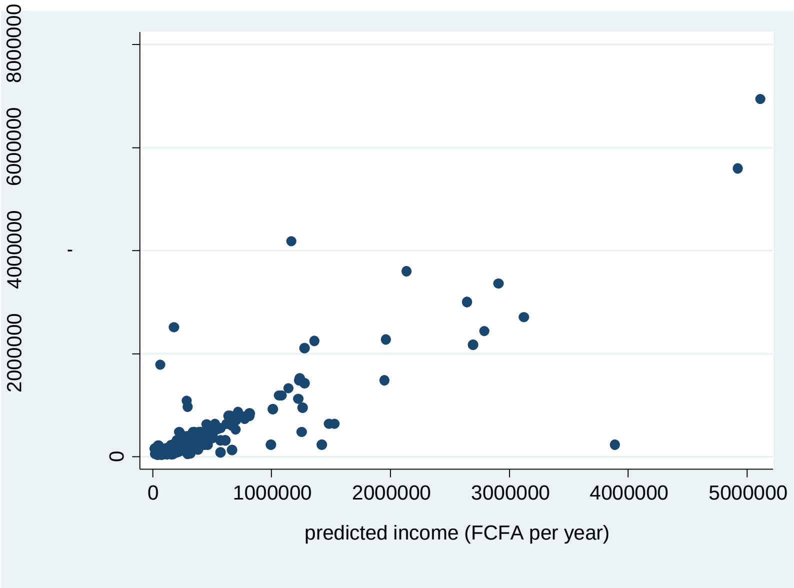
Processing technology might increase the quantity and qualities of palm oil produced, and ultimately increase the income of its operators. In the model below, we observe a significant relationship between the pulp press installed capacity (pulppress) and income (inc). Other variables such as the FFB sterilization capacity, the Oil Clarifying capacity, or the FFB receiving area capacity, even if positive in their coefficient (positively affect income) are not representative at 95%. However, and since the difficulty of obtaining reliable data in this context, we may accept significance levels of 90%, a level from which the Oil clarification capacity would become significant (a presenting a strong coefficient).

Even though indirect, the relationship between technology and income is still significant to some degree.

The model also shows that an increase of 1 additional ton in FFB processing capacity increases the income of operators by 38,220 FCFA per year (US$ 80), which represents an increase of 10.2% with respect to the mean income (FCFA 371,193.6)
In addition, that an increase of 1 additional ton in Oil clarification capacity increases the income of operators by 117,047 FCFA (US$ 245) a year.

Assessment of the model: below is the scatterplot of predicted values for income and the observed (collected values in the surveys).

Graph 5: Observed vs predicted income given the model in Table 14



We gladly expected a certain 45 degree pattern in the data (Graph 5). Y-axis is the observed data and x-axis the predicted data. In this case the model seems to be doing a good job in predicting inc.

The following table describes the same information as the models in Table 15, but provides more statistical detail.

Table 16: Regression details of income on processing stages

```
Linear regression                                      Number of obs =     428
                                                       F(  5,   422) =   20.50
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7263
                                                       Root MSE      =  3.4e+05
```

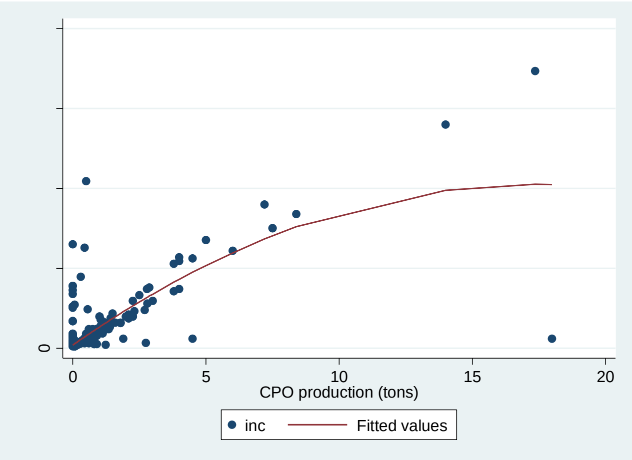
inc	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
pulppress	84371.52	38045.3	2.22	0.027	9589.632	159153.4
ffbste	6076.181	63436.17	0.10	0.924	-118614	130766.4
oilclar	117047.1	67875.63	1.72	0.085	-16369.38	250463.5
ffbrec	1773.437	1887.079	0.94	0.348	-1935.808	5482.681
ffbpro	38220.75	8669.328	4.41	0.000	21180.31	55261.19
_cons	-52341.66	47721.53	-1.10	0.273	-146143.2	41459.84

As determined by the model in Table 16, pulppress is significant at 95%, and therefore has a strong explanatory and positive power in determining income levels.

Also, Oilclar is significant at 92%, so it is also likely a positive contributor to the income level. An additional ton in oil clarifying capacity would result in an additional 117,047 FCFA.

Besides, the installed processing capacity (ffbpro) significantly determines income. An additional ton of FFB processing capacity increases income by 38,220 FCFA on average (US$ 80).

Graph 6: Predicted income for different CPO production levels given the joint production functions



Graph 6 indicates that traditional centers produce on average 0.7 tons of CPO per year while modern centers produce on average 0.95 tons of CPO per year. Therefore, modern centers can produce 35% more CPO per year than traditional centers.

Table 17: Regression of income on CPO production

Source	SS	df	MS
Model	1.1018e+14	2	5.5091e+13
Residual	7.8705e+13	471	1.6710e+11
Total	1.8889e+14	473	3.9934e+11

Number of obs	= 474
F(2, 471)	= 329.69
Prob > F	= 0.0000
R-squared	= 0.5833
Adj R-squared	= 0.5816
Root MSE	= 4.1e+05

inc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
cpopro	466099	27984.1	16.66	0.000	411109.9	521088.1
cpopro2	-13491.07	1953.072	-6.91	0.000	-17328.88	-9653.257
_cons	74503.36	24223.81	3.08	0.002	26903.26	122103.5

Table 17 shows that the CPO production is a very relevant factor in determining the income of the palm oil processors. This is also clear in graph 4.

5.4.4 CPO Quality

The quality of the Crude Palm Oil (CPO) can be a relevant factor to account for. Under normal conditions, a better quality product is paid at a higher price. However, if buyers are not able to differentiate a good and an average product, or there are other parameters to account for in determining the price (e.g. distance to markets, competitive position), this quality difference will not directly translate into a higher price being charged by palm oil processors.

The study intends to find the relationship between internal quality factors (i.e. whether the center is able to further refine and clarify its oil), and the price it charges for its oil.

Table 18: Hypothesis test for the difference in mean CPO price in traditional and modern centers

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Traditio	240	549.275	9.546085	147.8873	530.4698	568.0802
Modern	199	553.6935	8.679809	122.4438	536.5767	570.8102
combined	439	551.2779	6.52946	136.8074	538.4449	564.1109
diff		-4.418467	13.12955		-30.22337	21.38644

```
    diff = mean(Traditio) - mean(Modern)                      t =  -0.3365
Ho: diff = 0                                   degrees of freedom =      437

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3683         Pr(|T| > |t|) = 0.7366          Pr(T > t) = 0.6317
```

Table 19 shows that the average selling price for all processors is 551.3 FCFA (US$1.16) per liter of CPO produced. Selling prices across the different centers are not significantly different.

Palm oil quality can be approximated at factory level measuring the center’s oil clarifying capacity. The oil clarifier’s main function is to recover a maximum amount of Crude Palm Oil (CPO) and produce a finished CPO that is both clean and dry. An increased clarifying capacity should therefore increase the price of the CPO and therefore the income of the processors.

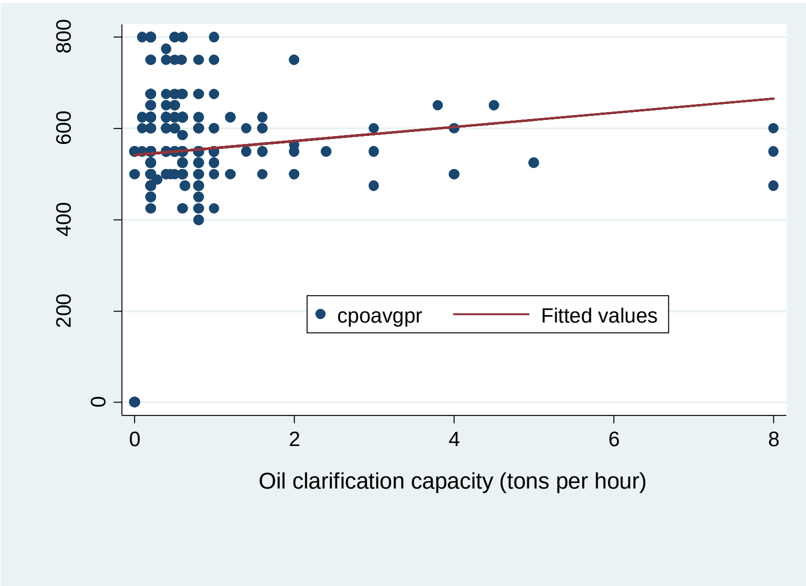
Table 19 below indicates that the CPO average selling price seems to be poorly determined by the processing quality factors, and rather suggests that other off-factory external factors such as geographical proximity to demand markets could be more determinant in establishing price levels.

Table 19: Regression of CPO average price on the different processing stages

```
Linear regression                                      Number of obs =     439
                                                       F(  4,   434) =    2.13
                                                       Prob > F      =  0.0764
                                                       R-squared     =  0.0250
                                                       Root MSE      =  135.71
```

cpoavgpr	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
pulppress	10.259	6.27423	1.64	0.103	-2.072651	22.59066
oilclar	2.17644	10.33795	0.21	0.833	-18.14223	22.49511
ffbste	4.845321	6.845908	0.71	0.479	-8.609934	18.30058
ffbpro	1.081257	.5682007	1.90	0.058	-.0355102	2.198024
_cons	531.4219	12.29164	43.23	0.000	507.2633	555.5804

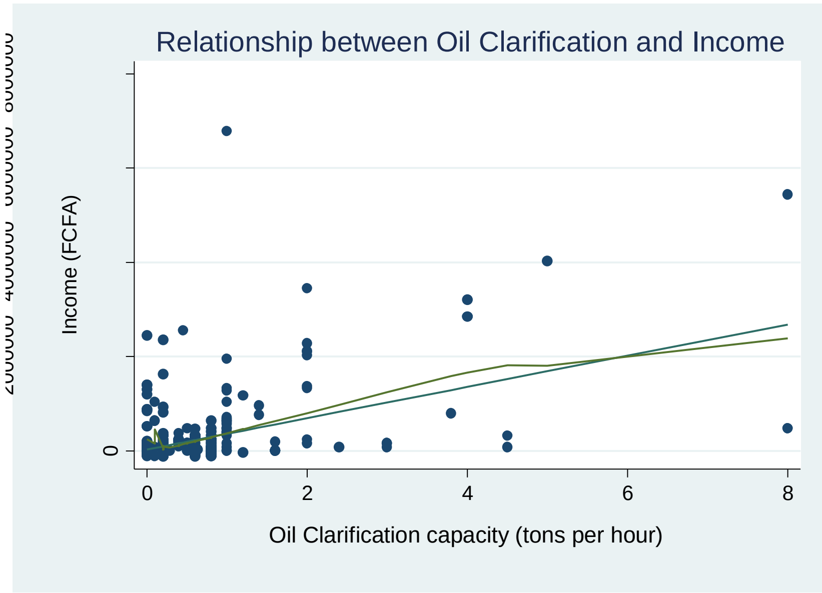
Graph 7: Scatter plot and predicted values for CPO selling price and Oil clarification capacity



The results indicate a positive relationship between the clarification capacity and the average price of the CPO sold, suggesting that increased levels of clarification improve the oil quality and ultimately allow processors to sell the production at a slightly higher price.

We could finally try to explore the relationship between the clarification capacity and income levels, by plotting both variables in the same graph and observe the relationship.

Graph 8: Relationship between Oil clarification capacity and income



We can observe a quasi linear relationship between the oil clarification capacity and the income, indicating a proportional increase in the oil clarifying capacity is associated with increased income levels.

The analysis therefore suggests that increasing the clarifying capacity within the processing centers could be a possible way to increase palm oil average price and income of workers within these palm oil factories.

5.4.5 Results summary

- Traditional and modern mills tend to have a similar FFB processing capacity (6.64 and 6.38 tons of FFB processed per year respectively). Traditional mills can process on average 4% more FFB per year than modern centers.

- Modern mills have a higher productivity per worker than traditional ones (0.23 tons per year and 0.10 tons respectively). Therefore, productivity in modern centers is 103% higher than in traditional centers.

- Modern mills have on average better extraction efficiency (11.8% and 9.5%)

- The average income in modern mills is on average FCFA106,142 (US$219) superior to the income of workers in traditional mills (428,000 FCFA vs. 322,000 FCFA). This means modern-mill workers have an income 32.9% higher on average than traditional-mill workers.

- The most determinant processing stage is the FFB pulp press. An increase of 1 ton per hour increased capacity significantly results in additional 84 000 FCFA (US$ 176) per worker and year, on average, which represents an increase of 22,7% of the mean income of both groups.

- An increase of 1 ton per hour in pulp press capacity will, in the short run, increase by 22% the income of the subjects on average. This represents a 26% increase in the case of traditional processors and a 19.8% in the case of modern processors.

- The size of the palm oil processing center, measured as the FFB processing capacity, seems to be a significant factor in determining the income/wage level of subjects

- Other processing equipment such a CPO oil clarifier, FFB sterilizer and receiving area affect positively, but with different degrees of significance.

- CPO average price across the different categories of processing centers (traditional and modern) is not significantly different (553 FCFA per litter and 549 FCFA). The model fails to statistically attribute a higher average price to internal processing factors (internal quality processes), suggesting that other external factors uncontrolled by the model - such as local market demand and supply- are more determinant that quality (which is this context is difficult to verify) in determining the average CPO selling price. Several conjectures could be provided to explain this: 1) labeled technology difference is not such (modern and traditional centers, overall, produce similar quality oil), 2) the CPO buyers are not able to distinguish the quality and hence they are not willing to pay a premium for a product whose quality they cannot perceive, or 3) the price of some of the centers' CPO is determined by the proximity to a larger number of buyers (one source in the survey indicated Sombo's CPO to be more expensive given its proximity to Nigeria).

5.4.6 Discussion and Recommendations

Agricultural growth is widely considered as the most effective means of addressing poverty in the developing world (OECD, 2006). Similarly, the role of agro-industry in contributing to structural change, rural employment and value addition has been repeatedly stressed (FAO 1997, UNIDO 1999). Studies such as of (Janry, Sadoulet 2009) showed that rural poverty reduction is associated to growth in yields and growth in agricultural labour productivity, but that this relation varies across different regions. Other studies support the idea that palm oil businesses have improved the lives of people working and living within and around the palm oil businesses (Koh et al. 2007). Product diversification and market participation will thus drag and enhance local production and will generate earnings, investment and tax income to a state and country level. These strategies have been long suggested to developing countries as a path out of poverty (Jabara, 1980).

Moreover, Rist et. al 2009 study, suggests that expanding the small-scale palm oil processing business will provide higher returns to labour of rural communities. In addition, Aletor et. al 1990 suggested that increased production and quality of the palm oil produced generates recurrent revenues and attracts investment.

However, few studies have estimated the impact of the adoption of a new extraction technology on the income of its utilizers (rural palm oil processors).

This study supports the suggestions that a new technology insures better levels of production and of quality of the palm oil produced, which ultimately positively affect the income and consequently the lives on the families working in the palm oil centers and living around them.

After analyzing the results of the study, several recommendations can be issued:

- An additional ton per hour in processing capacity yields 0.46 more tons (460 Liters) of crude palm oil per year. This, multiplied by the average price results in a revenue of 253,000 FCFA (approximately 523US$). Hence, traditional centers could increase the amount of oil they produce and therefore their income by increasing the capacity the processing methods they currently use. Only increasing the FFB pulp press capacity by 1 ton per hour will likely increase the revenue of operators by a 25%.

- Provided that an additional 1 ton of CPO produced per year generates approximately additional 300,000 FCFA (US$630), palm oil processing centers have an opportunity to increase their revenue/income by increasing the amount of CPO produced. Shall the Government want to expand the revenue basis of its palm oil small scale processors; it should motivate the expansion of CPO production.

- As demonstrated by the findings, increasing the pulp pressing capacity directly affects the income level of the beneficiaries. Also, traditional processors benefit to a larger extend than more advanced ones, since their production levels are further away from average levels. In consequence, initiatives to facilitate access to processing equipment such as mechanical oil palm presses, oil clarifiers, industrial boilers and palm oil clarifiers will likely result in an increase in the CPO production and ultimately in the income levels of its processors.

- All other productivity, efficiency and quality enhancing measures are likely to have a positive impact on income. Still, given the model's findings, there seem to be other non-industrial external factors affecting income (e.g. market prices, wage policy, etc.). It is therefore important to conceive market access policies and implement interventions such as transport and logistics infrastructure development to facilitate palm oil commercialization.

- If buyers would be further capable to distinguish among different quality oils, the price for quality oil would be further increased and traditional mills could have an incentive to increase their quality and sell at a premium. Therefore, awareness raising campaigns targeted to consumers and dealing with palm oil product quality aspects will be ultimately beneficial for small-scale processors, which could differentiate themselves by providing a better quality product. This differentiation will also provide an incentive to processors to increase the quality of their product since this higher quality results in a higher selling price.

- At this processing scale, the proximity to selling markets seems to be determinant for increasing the CPO price. New palm oil micro-entrepreneurs would therefore be advised to locate their factories as close to its buyers as possible.

- The results suggest that palm oil processing scale directly affect factory profitability. A 5-ton per hour is more profitable than a modern mill. This can be explain by the fact that economies of scale are present in this sector given the need for infrastructure development (size would therefore decrease average costs substantially). Therefore, the Government with the different Development partners should encourage processors to increase their processing scale by any means: creating collective processing associations, facilitating linkages within the value chain (e.g. contractual arrangements between farmers and processors).

6. Conclusion and Discussion

This study examined the effect of the utilization of modern palm oil technology (mechanized presses, clarifiers, digesters, etc.) on processor's income by comparing results of 480 palm oil processors in four Cameroonian rural regions. The study did so by comparing income levels across comparable processors using new technology and processors using the old traditional technology.

It is worth mentioning that such empirical analyses are very scarce in the scientific world given the complexities of the context (population very scattered, language barriers, financial costs to gather such sample, etc.). Therefore, the monetary effect of introducing new oil extraction technology in the income generated through this new technology has never been accurately calculated.

This study successfully identified a positive effect of adopting a new oil extraction technology on the income of the interviewed individuals. It has been proven that an additional ton per hour in palm oil pulp pressing capacity increases the income of processors by 22%. Similarly, the study has shown that modern factories need 36% less workers to produce a given amount of CPO, as well as 23% less FFB to produce a ton of CPO.

The study also attempted to demonstrate that the introduction of the new technology would affect the final quality of the palm oil produced. Since there was no way to measure the quality via testing the physical characteristics of the product (% of free fatty acids, nutrition facts, etc.), the study decided to look at the selling prices per ton of CPO as a proxy for determining the quality of the produced palm oil, and compare it across modern and traditional centers. However, after performing such statistical analysis, the results propose that the prices per ton of CPO are not significantly different across modern and traditional centers. The study concludes that this is caused by some market problems such as access to information from consumers, and inefficient marketing infrastructure.

These results of this study are in line with other research on the capacity of agricultural growth to serve as an effective instrument for poverty reduction (The World Bank Research Observer, vol. 25, no. 1 February 2010).

Therefore, for the oil palm sector industrial development to take place, access to technology and labor-saving quality production, harvesting and processing technologies are needed to reduce costs, improve productivity and make the oil palm sector more competitive.

Since the major problems of the cooperative groups are production capacity, product quality and hygiene conditions and limited management skills, actions promoting production capacity expansion, mechanization and technical skills transfer will result in a positive effect for small-scale rural palm oil processors.

The expansion of small-scale palm oil processing will likely provide higher returns to land and labor for rural communities, but must be accompanied by the correct set of friendly production public regimes in order to translate private gain into general interest.

Increased quality and quantity of Crude Palm Oil (CPO) production and other by-products will generate recurrent revenue and will attract investment in service related activities. In a broader sense, the local community as a whole will benefit from new employment opportunities, which ultimately would lead to improve the poverty and food security levels.

The new technology will also support the competitiveness of the local industry by developing quality products that comply with required standards. Product diversification and market participation will thus drag and enhance local production and will generate earnings, investment and tax income to a state and country level.

Increased quality and quantity of Crude Palm Oil (CPO) production and other by-products will generate recurrent revenue and will attract investment in service related activities. In a broader sense, the local community as a whole will benefit from new employment opportunities, which ultimately would lead to improve the poverty and food security levels.

The new technology will also support the competitiveness of the local industry by developing quality products that comply with required standards.

This study supports the suggestions that a new technology insures better levels of production and of quality of the palm oil produced, which ultimately positively affect the income and consequently the lives on the families working in the palm oil centers and living around them.

The results of this study can therefore be presented to the Cameroonian Government for their adoption, replication and up-scaling in other rural regions of the country.

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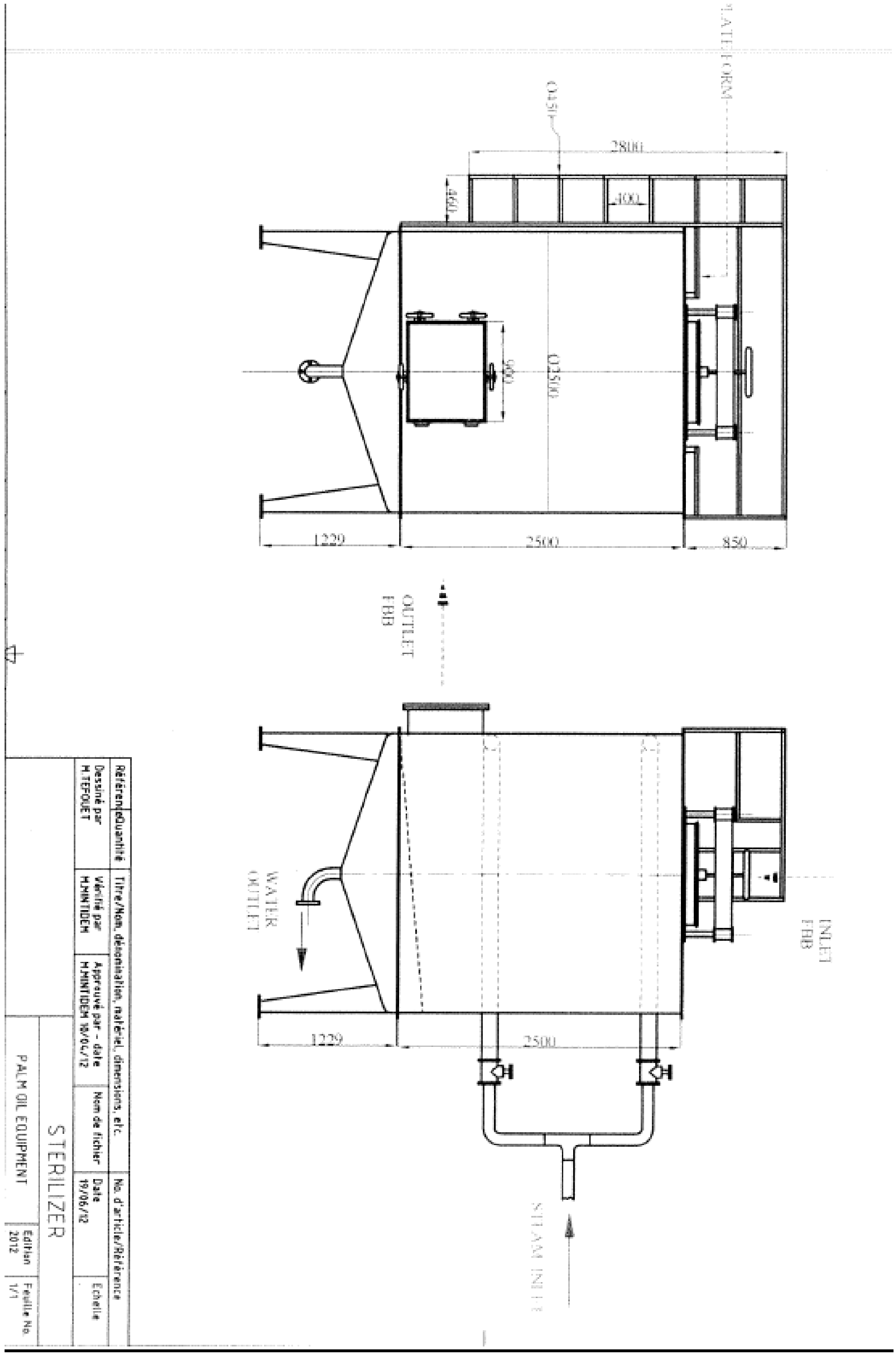
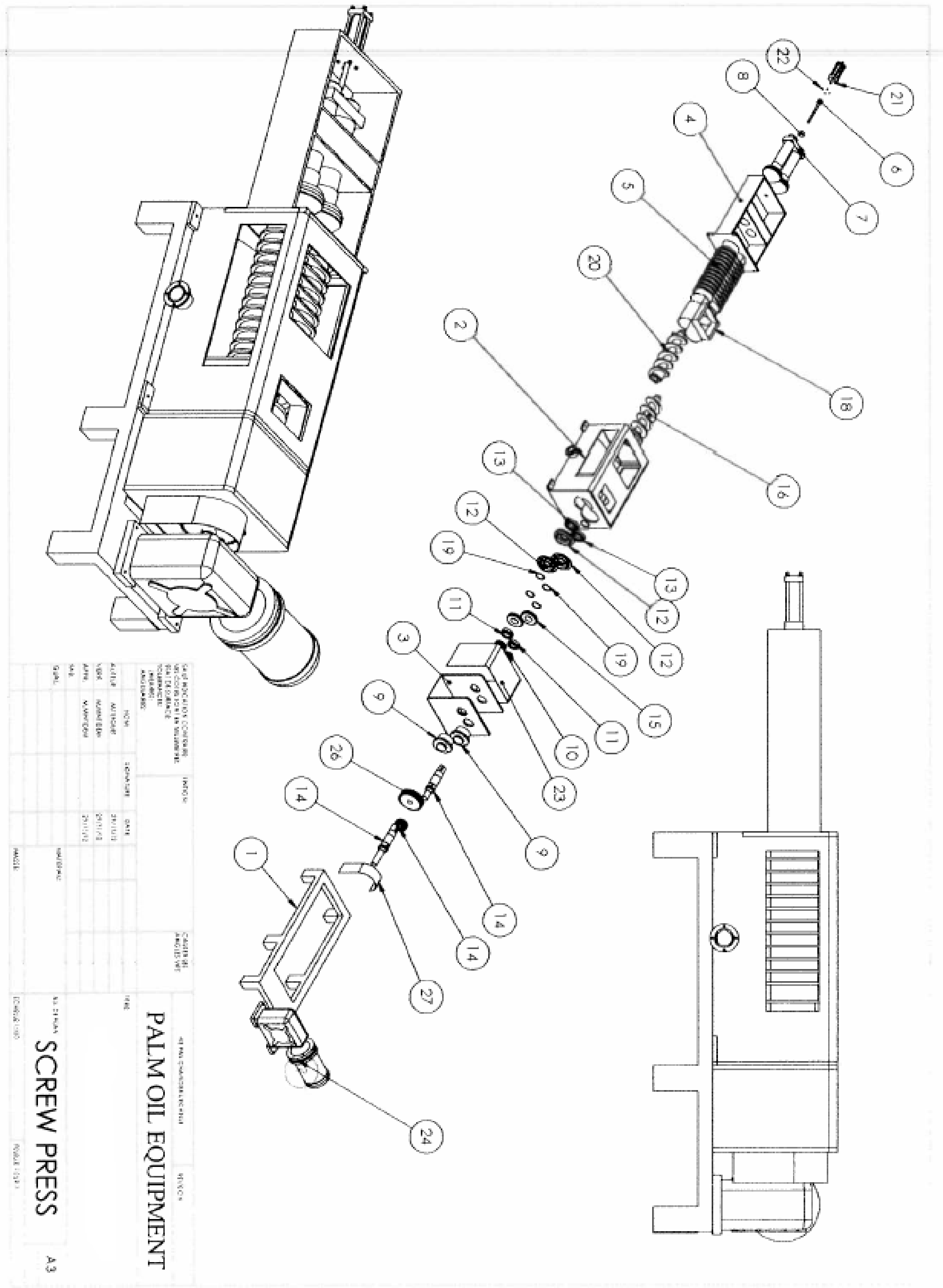
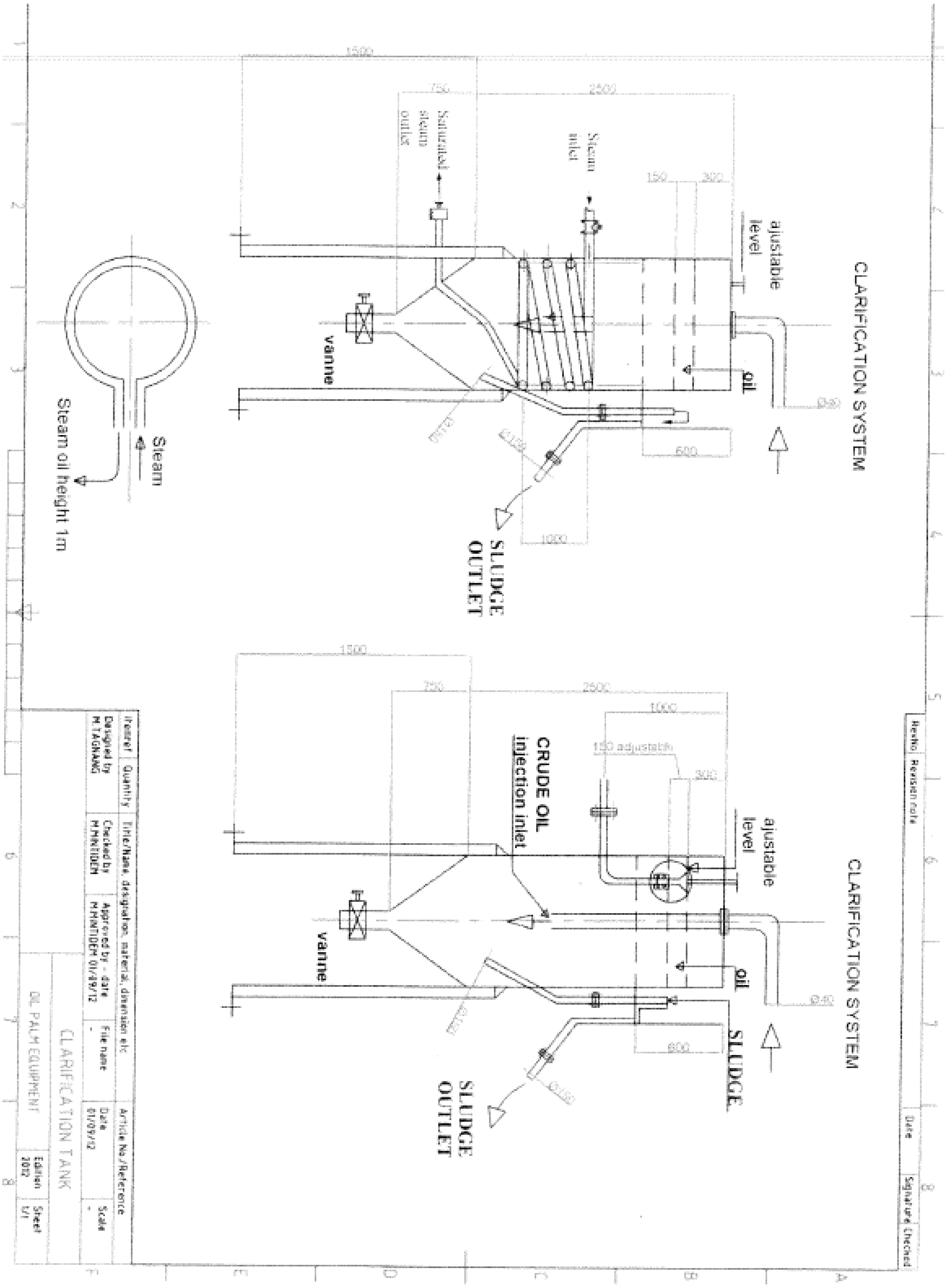
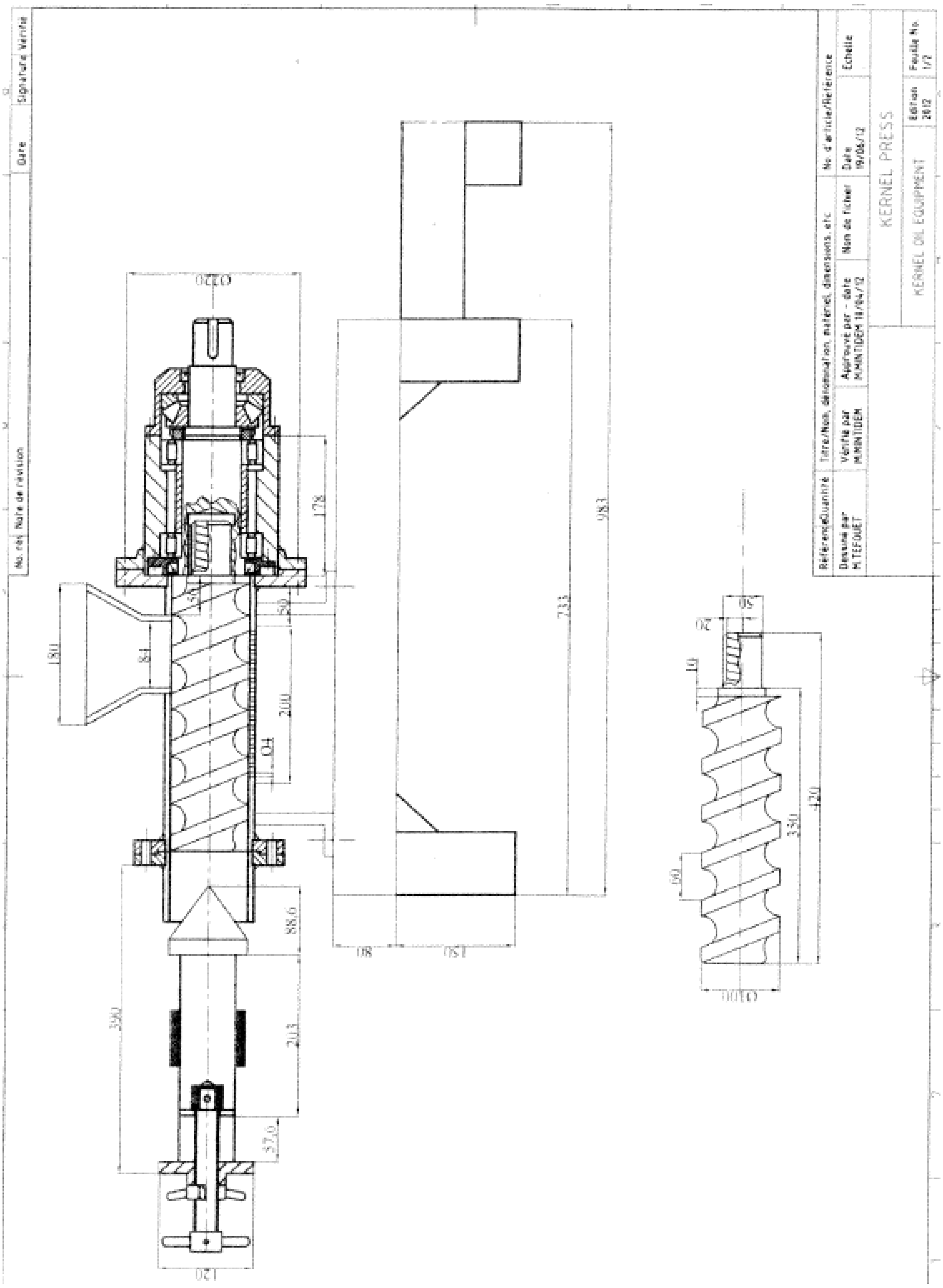
8. Annexes

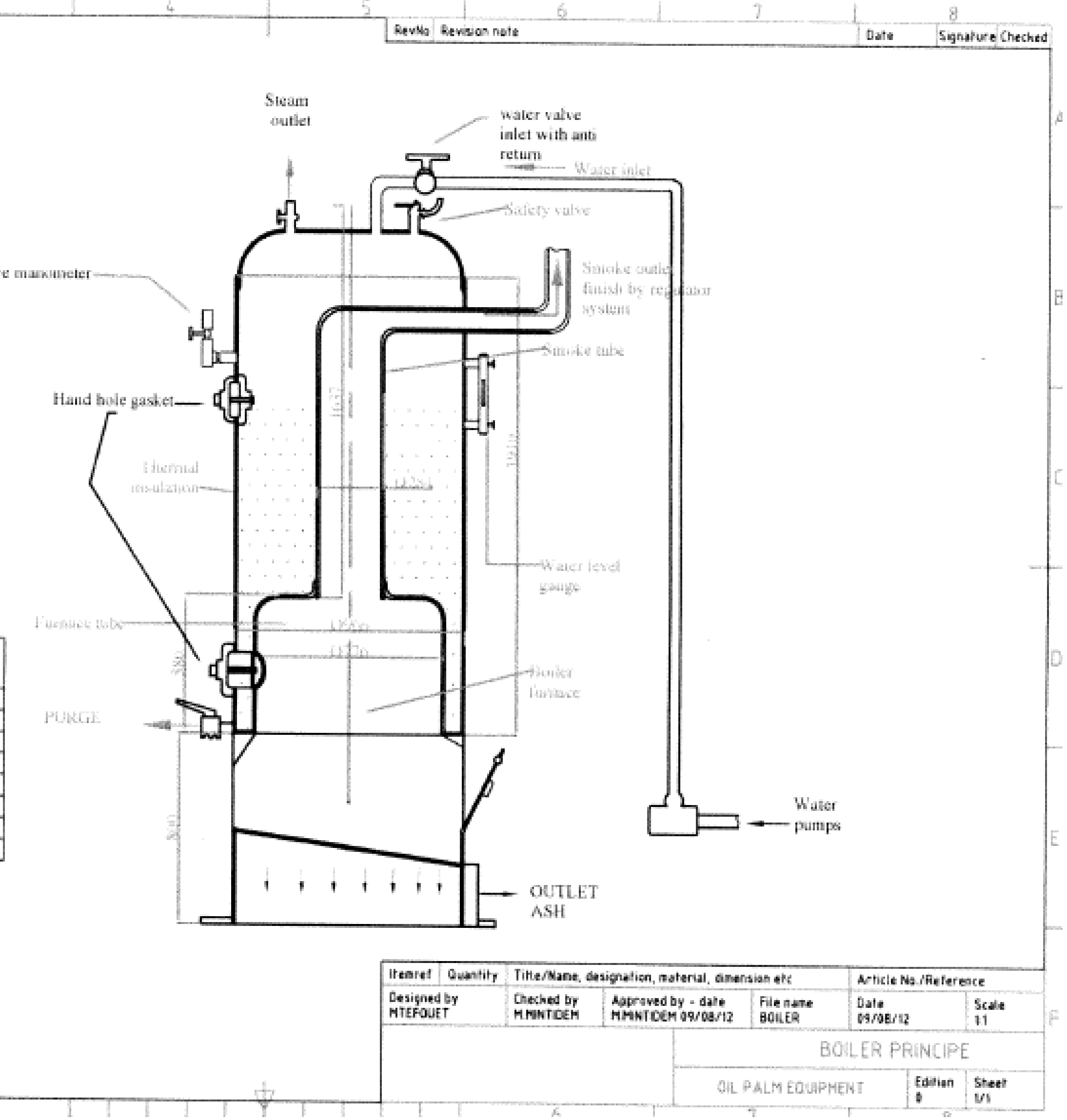
Annex 1. Drawings and technical specifications of modern palm oil processing equipment




PALM OIL EQUIPMENT
SCREW PRESS
A3

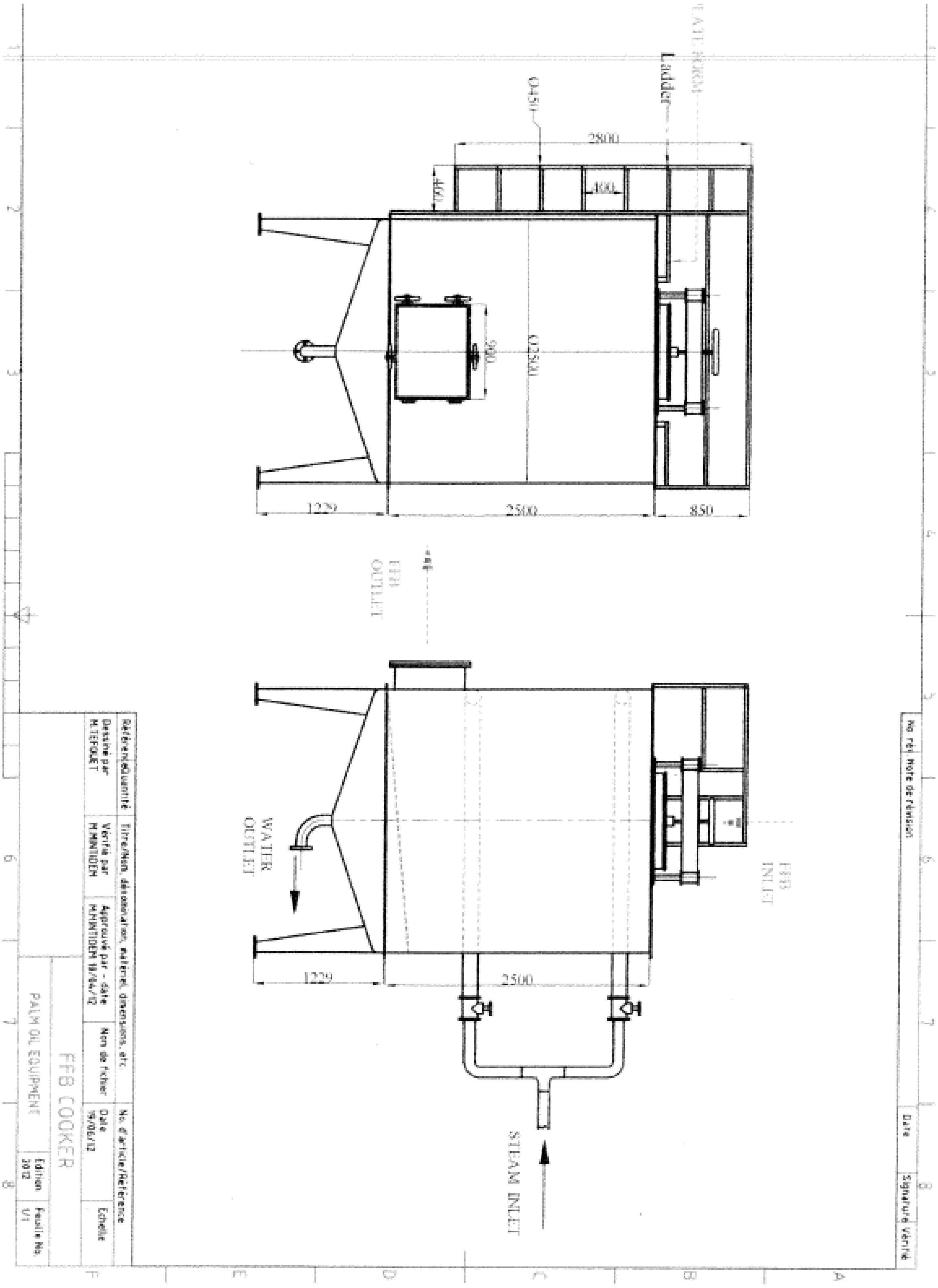

CLARIFICATION SYSTEM
ajustable level
oil
Steam inlet
Saturated steam outlet
vanne
SLUDGE OUTLET
Steam
Steam oil height 1m
CLARIFICATION SYSTEM
ajustable level
CRUDE OIL injection inlet
oil
vanne
SLUDGE
SLUDGE OUTLET
1500
750
2500
150
300
600
1000
Designed by M.TAGNANG
Checked by M.MNTIDEM
Approved by - date M.MNTIDEM 01/09/12
Date 01/09/12
CLARIFICATION TANK
OIL PALM EQUIPMENT
Edition 2012
Sheet 1/1


KERNEL PRESS
KERNEL OIL EQUIPMENT

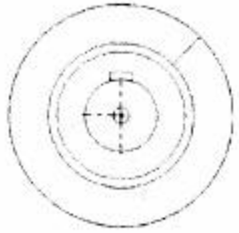


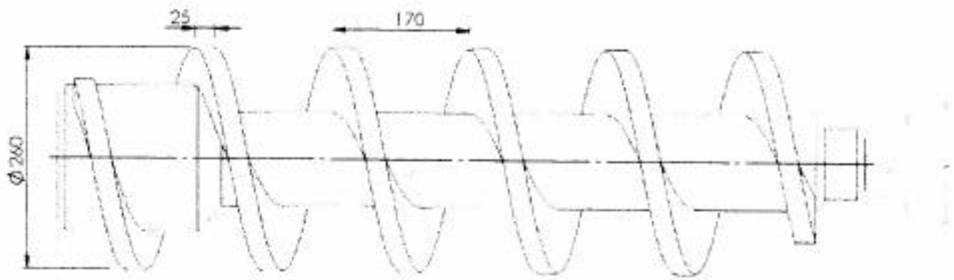
components of boiler: power 5bars , capacity 2tons steam/hours and temperature=152°C

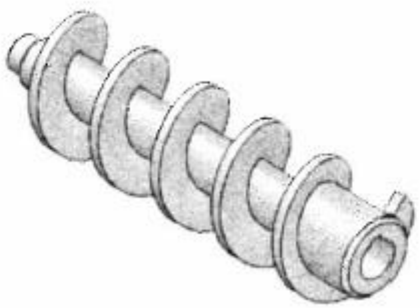
Designation	Quantity	
water pump	01	
water valve	03	
Purge	02	
level water gauge	01	
safety valve	02	
hand hole gasket	02	
presure manometer	02	



FFB COOKER
PALM OIL EQUIPMENT
STEAM INLET
WATER OUTLET
FFB INLET
FFB OUTLET
Ladder
2800
2500
1229
850







Names	caracteristiques	Quantity
TPN 250/10	3x1.5	01
Pipe Ø96x66	lenght=800mm	01
Pipe Ø160/110	Lenght=200mm	01
Pipe Ø65x35	lenght=100mm	01

PALM OIL EQUIPMENT

SHEET METAL
PIPING dia 96

SCREW PRESS

A3

Annex 2: Questionnaires distributed to conduct the data collection

Questionnaire for palm oil mill operators

PERSONAL INFORMATION:

1. Name of Village: ....
2. Name of Region: Region 1 ☐ Region 2 ☐ Region 3 ☐
3. Age: ☐ years old
4. Sex: Male ☐ Female ☐
5. Education: Illiterate (can't read or write) ☐ Basic (can read) ☐ Intermediate (can read & write) ☐ advanced (certified) ☐
6. Household size: ☐ people living in the same house
7. Your income per month or year for working in the palm oil processing center is ☐ FCFA.

ECONOMIC ENVIRONMENT:

Agriculture level (in the case where you are also a farmer)

8. Your land is: inherited ☐ purchased ☐ rented ☐
9. Cultivated area? ☐ Hectares
10. Do you apply fertilizers ☐ improved seeds ☐ irrigation techniques other techniques ☐
11. You harvest ☐ Kg of fresh palm fruit nuts per month / season
12. The season lasts ☐ months

13 The FFB you produce is sold to the processors at ☐ FCFA per Kg

Processing

General

14. How many workers work in this processing center? ☐
15. On average, the workers have ☐ years of experience in processing
16. The processing equipment is on average ☐ years old
17. The palm oil processing center operates on average ☐ hours per day
18. How much can you process? ☐ Kg/t of FFB per day / month
19. What is the total production of palm oil? ☐ Kg per day / month
20. What is the highest Crude Palm Oil (CPO) selling price? ☐ FCFA
21. What is the lowest CPO selling price? ☐ FCFA
22. Is the output sold in bulk or packaged? Bulk ☐ Packaged ☐

Specific

23. Does the processing center where you work have a FFB receiving area? Y ☐ N ☐
    If so, what is its FFB reception area total capacity ☐ Kg/t of FFB
    If not, what is the FFB reception area capacity? ☐ Kg/t of FFB
24. Does the processing center where you work have a FFB thresher? Y ☐ N ☐
    If so, what is the total threshing capacity of the center? ☐ Kg of FFB / hour
    If not, what is the center threshing capacity? ☐ Kg of FFB / hour
25. Does the processing center where you work have a FFB sterilization/cooker? Y ☐ N ☐
    If so, what is its capacity? ☐ Kg of FFB / hour
    If not, what is the center sterilization/cooking capacity? ☐ Kg/hour of FFB
26. Does the processing center where you work have a fruit digester? Y ☐ N ☐
    If so, what is its capacity? ☐ Kg of Fruit per hour / day
    If not, what is the center fruit digestion capacity? ☐ Kg per hour / day
27. Does the processing center where you work have a mechanical pulp press? Y ☐ N ☐
    If so, what is its capacity? ☐ Kg / t of pulp per hour / day
    If not, what is the center pressing capacity? ☐ Kg / t of pulp per hour / day
28. Does the processing center where you work have an oil clarifier? Y ☐ N ☐
    If so, what is its capacity? ☐ Kg / t of oil per hour / day
    If not, what is the center clarifying capacity? ☐ Kg / t of oil per hour / day
29. Does the processing center where you work have an oil storing place? Y ☐ N ☐
    If so, what is its capacity? ☐ m^3 of storage tank capacity
    If not, what is the center storing and capacity? ☐ m^3
30. Does the processing center have an oil packing unit (bottler)? Y ☐ N ☐
    If so, what is its capacity? ☐ Kg / Liters of packaged palm oil per hour / day
    If not, what is the center bulk container capacity? ☐ Kg / Liters
31. What is the oil extraction ratio/rate (Kg of CPO / Kg of FFB) of the processing unit wher you work? ☐ %
32. Does the processing center where you work have a quality control system? Y ☐ N ☐
    If so, what is the average % FFA in the oil that you produce? ☐

Annex 3: Other relevant empirical findings

Below is a correlation matrix for all variables in the model. Numbers are Pearson correlation coefficients; go from -1 to 1. Closer to 1 means strong correlation. A negative value indicates an inverse relationship (roughly, when one goes up the other goes down). Star (*) indicates significance at 95% confidence level.

Table 20: Correlation matrix for all variables in the model

	inc	edu	housiz	totwork	ffbpro	cpopro	cpoavgpr
inc	1.0000						
edu	0.0937	1.0000					
	0.0527						
housiz	0.1804*	0.0397	1.0000				
	0.0002	0.4123					
totwork	0.2414*	0.1959*	0.1712*	1.0000			
	0.0000	0.0000	0.0004				
ffbpro	0.8295*	0.1056*	0.1661*	0.4611*	1.0000		
	0.0000	0.0289	0.0006	0.0000			
cpopro	0.7753*	0.0740	0.1481*	0.4421*	0.9532*	1.0000	
	0.0000	0.1263	0.0021	0.0000	0.0000		
cpoavgpr	0.1219*	-0.0520	-0.0289	-0.2954*	0.0652	0.1292*	1.0000
	0.0116	0.2833	0.5511	0.0000	0.1782	0.0074	
electrc	0.3521*	-0.0133	0.0332	0.0074	0.2958*	0.3446*	0.2006*
	0.0000	0.7843	0.4939	0.8794	0.0000	0.0000	0.0000
ffbrec	-0.0254	0.0006	0.1191*	0.2078*	0.0105	-0.0137	-0.1375*
	0.5999	0.9893	0.0137	0.0000	0.8287	0.7773	0.0044
ffbste	0.5295*	0.1499*	0.0795	0.1934*	0.4862*	0.4195*	-0.0417
	0.0000	0.0019	0.1005	0.0001	0.0000	0.0000	0.3894
ffbdig	0.0018	0.0079	0.0222	0.0141	0.0011	-0.0019	-0.0167
	0.9704	0.8712	0.6465	0.7717	0.9816	0.9692	0.7310
pulppress	0.2568*	-0.1444*	-0.0224	-0.2691*	0.1726*	0.2341*	0.3442*
	0.0000	0.0028	0.6437	0.0000	0.0003	0.0000	0.0000
oilclar	0.4987*	0.1323*	0.0581	0.1596*	0.4209*	0.3930*	-0.0609
	0.0000	0.0061	0.2306	0.0009	0.0000	0.0000	0.2086
cpoprow	0.7632*	0.0418	0.1279*	0.0289	0.7566*	0.7305*	0.3070*
	0.0000	0.3878	0.0081	0.5506	0.0000	0.0000	0.0000

	electrc	ffbrec	ffbste	ffbdig	pulppr~s	oilclar	cpoprow
electrc	1.0000						
ffbrec	-0.0556	1.0000					
	0.2508						
ffbste	0.2283*	-0.0695	1.0000				
	0.0000	0.1515					
ffbdig	-0.0205	0.0374	-0.0110	1.0000			
	0.6717	0.4400	0.8205				
pulppress	0.5841*	-0.3041*	0.1537*	-0.0298	1.0000		
	0.0000	0.0000	0.0014	0.5382			
oilclar	0.1758*	-0.0988*	0.8733*	-0.0127	0.1368*	1.0000	
	0.0003	0.0410	0.0000	0.7939	0.0046		
cpoprow	0.4280*	-0.0610	0.4529*	-0.0073	0.3289*	0.3789*	1.0000
	0.0000	0.2076	0.0000	0.8802	0.0000	0.0000	

Table 21: Detail description of variable „age“

	Percentiles	Smallest		
		age		
1%	22	0		
5%	30	18		
10%	32	20	Obs	474
25%	40	22	Sum of Wgt.	474
50%	49		Mean	47.91139
		Largest	Std. Dev.	11.49522
75%	55	73		
90%	63	74	Variance	132.1401
95%	69	75	Skewness	-.1232559
99%	72	78	Kurtosis	3.072679

The median is 49 years old and the average is 47.9 years old. The sample is slightly skewed towards younger subjects (since the mininum age is 22), although distributed quite uniformely across the sample.

We can infer that palm oil processing is performed by rather old strata of the national population, since the national life expectancy is close to 52 years old. One possible explanation could come from the fact that the cost of investment in technology is only discouraging younger cohorts with little accumulated wealth. The figures seem to indicate that Palm oil processing does not necessary require younger subjects, and that perhaps it is not such a physical activity as others (e.g. farming).

Table 22: Detail description of variable „Region“

Region	Freq.	Percent	Cum.
Sombo	119	25.11	25.11
Mkpot	120	25.32	50.42
Edea	120	25.32	75.74
Misaje	115	24.26	100.00
Total	474	100.00	

Data has been collected uniformely accross four different Regions, each of them providing approximately 25% of the total sample. Misaje has the highest number of invalid data (5).

Table 23: Detail description of variable "sex"

Sex	Freq.	Percent	Cum.
Female	113	23.84	23.84
Male	361	76.16	100.00
Total	474	100.00	

76% of the population surveyed are males. In Cameroon, culturally, palm oil processing has always been an activity undertaken mainly by men, and as such are reflected in the table.

Table 24: Detail description of variable „edu“

edu	Freq.	Percent	Cum.
Illiterate	27	5.70	5.70
Basic	87	18.35	24.05
Intermediate	272	57.38	81.43
Advanced	88	18.57	100.00
Total	474	100.00	

Almost 60% of the population in the palm oil processing surveyed sector has intermediate education, only 5.7% being illiterate. Clearly, palm oil processing is an activity that requires above-average skills to be performed effectively.

Table 25: Detail description of variables „Edu and center technology”

Key
frequency *row percentage*

edu	tech Tradition	Modern	Total
Illiterate	10 37.04	17 62.96	27 100.00
Basic	15 17.24	72 82.76	87 100.00
Intermediate	176 64.71	96 35.29	272 100.00
Advanced	39 44.32	49 55.68	88 100.00
Total	240 50.63	234 49.37	474 100.00

There seems to be no clear pattern on the distribution of educational levels across center technology. Illiterate, Basic and Advanced subjects are a majority in „Modern“ centers while „intermediate“ are a majority in traditional centers.

Table 26: Detail description of variables “Edu and region”

Key
frequency *row percentage*

edu	Region Sombo	 Mkpot	 Edea	 Misaje	 Total
Illiterate	7 25.93	10 37.04	8 29.63	2 7.41	27 100.00
Basic	7 8.05	9 10.34	38 43.68	33 37.93	87 100.00
Intermediate	65 23.90	89 32.72	55 20.22	63 23.16	272 100.00
Advanced	40 45.45	12 13.64	19 21.59	17 19.32	88 100.00
Total	119 25.11	120 25.32	120 25.32	115 24.26	474 100.00

Sombo is the center with the most skilled people (69% declare themselves as to have either intermediate or advanced education), followed by Mkpot (56%). Edea is the center with the lowest average education level (42% of the workers have at least intermediate education).

Sombo and Edea are the centers with the highest difference in education levels across workers (Advanced : Illiterate = 8.5 for Edea; and 5.7 for Sombo).

Table 27: Detail of variable “Land”

land	Freq.	Percent	Cum.
Purchased	39	8.23	8.23
Inherited	435	91.77	100.00
Total	474	100.00	

92% of the population surveyed own and inherited their land from their families. Purchasing was only an option for 8% of the sample.

Table 28: Detail of "land" and "region"

Key
frequency
row percentage

land	Region				
	Sombo	Mkpot	Edea	Misaje	Total
Purchased	5 12.82	2 5.13	21 53.85	11 28.21	39 100.00
Inherited	114 26.21	118 27.13	99 22.76	104 23.91	435 100.00
Total	119 25.11	120 25.32	120 25.32	115 24.26	474 100.00

Purchased land percentages were substantially higher in „modern“ centers than in „traditional“ones. One plausible reason is that agriculture productivity is substantially higher in Edea and Misaje, and this surplus has allowed the owners to invest in new land.

Table 29: Detail of "Cultivated Area"

```
cultarea
--------------------------------------------------------------------------------

                  type:  numeric (double)

                 range:  [.5,100]                     units:  .01
         unique values:  33                       missing .:  1/475

                  mean:   4.83914
              std. dev:   7.98448

           percentiles:        10%       25%       50%       75%       90%
                                 1         2         3         5         8
```

On average terms, the subjects have a cultivated area of 4.8 Ha. However, this seems to be skewed by large landowners in the sample (the median area is 3 Ha). The sample seems to be very scatter, as indicated by the significant standard deviation (7.9 Ha), and the wide range.

Table 30: Detail of agriculture productivity techniques employed by Region

Region	Agriculture productivy technique None	Fertilize	Improved	Both	Total
Sombo	12	3	97	8	120
Mkpot	2	0	118	0	120
Edea	5	1	54	60	120
Misaje	64	0	47	8	119
Total	83	4	316	76	479

Almost 66% of the surveyed population utilized improved seeds, whereas up to 17% does not use any soil productivity measure. Mkpot and Sombo were the two location with the highest use of agriculture productivity techniques.

Table 31: Detail of agriculture productivity techniques employed by frequency

Agriculture productivy technique	Freq.	Percent	Cum.
None	83	17.33	17.33
Fertilizer	4	0.84	18.16
Improved seeds	316	65.97	84.13
Both	76	15.87	100.00
Total	479	100.00	

The following table presents the detail distribution of income per year derived from palm oil business activities across the 4 centers surveyed. The variable ranges from FCFA 39,500 (US$81) to FCFA 6,944,000 (US$14,369). The average obvserved income is FCFA 375482 (US$776), and the median is FCFA 200,000 (US$413). The sample is therefore skewed towards higher values and it seems data a very spread across the sample (high standard deviation).

Table 32: Detail of income across the sample

```
inc

                type:  numeric (long)

               range:  [39500,6944000]              units:  10
       unique values:  156                      missing .:  1/475

                mean:    375482
            std. dev:    631934

         percentiles:        10%       25%       50%       75%       90%
                           79200    118800    200000    375000    675000
```

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Table 33: Deatil of income levels across the different processing centers

Region	Summary of inc Mean	Std. Dev.	Freq.
Sombo	278067.23	340288.52	119
Mkpot	363951.67	418149.18	120
Edea	484283.33	1002395.2	120
Misaje	374785.04	532132.72	115
Total	375482.03	631934.43	474

The observations show how Edea (FCFA 484,282) and Misaje (FCFA 374,785) have on average higher wages than Mkpot (FCFA 363,951) and Sombo (FCFA 278,067). Thus, it can be said that on average, wages/incomes in traditional centers are on average lower than in modern centers.

Table 34: Detail of income across the different processing centers

-> Region = Sombo

Variable	Obs	Mean	Std. Dev.	Min	Max
inc	119	278067.2	340288.5	39600	2276000

-> Region = Mkpot

Variable	Obs	Mean	Std. Dev.	Min	Max
inc	120	363951.7	418149.2	39500	2708000

-> Region = Edea

Variable	Obs	Mean	Std. Dev.	Min	Max
inc	120	484283.3	1002395	46550	6944000

-> Region = Misaje

Variable	Obs	Mean	Std. Dev.	Min	Max
inc	115	374785	532132.7	46400	3600000

In terms of income inequality across the different centers, Edea seems to be the center with highest income inequality (total range of FCFA 6,897,450), and Sombo the most egalitarian one (range of FCFA 2,236,400). Even though traditional centers have lower incomes, its distribution seems to be more homogeneous.

The following table presents the detail distribution of total FFB harvest per year across the 4 centers surveyed.

Table 35: Detail of „totharv" across the sample

```
totharv                                                              Total harvest (t

              type:  numeric (double)

             range:  [.5,124]                    units:  .001
     unique values:  54                      missing .:  0/479

              mean:    7.1512
          std. dev:   11.2327

       percentiles:        10%       25%       50%       75%       90%
                           1.5      2.25         4       7.5        14
```

The variable ranges from 0.5 tons of FFB per year to 124 tons per year. The average observation is 7.1 tons per year, and the median is 4 tons per year. The sample is therefore skewed towards higher values and it seems data a very spread across the sample (high standard deviation).

Table 36: Summary of years of working experience across the different processing centers

Region	Summary of Working experience (years) Mean	Std. Dev.	Freq.
Sombo	10.608333	6.1498047	120
Mkpot	9.1833333	5.6449328	120
Edea	8.175	4.6230379	120
Misaje	13.235294	10.057214	119
Total	10.294363	7.159202	479

The observations show how Misaje (13.2 years) and Sombo (10.6 years) have on average more years of experience in processing than Mkpot (9.1 years) and Edea (8.1).

Table 37: Summary of age of the processing equipment across the different processing centers

Region	Summary of Age of the equipment (years) Mean	Std. Dev.	Freq.
Sombo	5.6666667	4.8321983	120
Mkpot	5.15	2.3821818	120
Edea	5.8416667	5.2994305	120
Misaje	4.3907563	2.3399258	119
Total	5.2640919	3.9858123	479

The observations show that Edea and Sombo have the oldest equipment among the 4 surveyed centers. Modern centers therefore have a slightly newer equipment base (5.1 years) than traditional centers (5.37years).

Table 38: Summary of FFB product per year across the different processing centers

Region	Summary of ffbpro Mean	Std. Dev.	Freq.
Sombo	5.3857143	8.0579079	119
Mkpot	7.5566667	10.085685	120
Edea	5.4254583	15.944328	120
Misaje	7.7330435	11.99187	115
Total	6.514884	11.902325	474

Table 39: Summary of CPO produced per year across the different processing centers

Region	Summary of cpopro Mean	Std. Dev.	Freq.
Sombo	.47252101	.61738441	119
Mkpot	.728125	.82408316	120
Edea	.70026667	2.2430433	120
Misaje	1.0510957	2.0204796	115
Total	.73525949	1.5992437	474

Table 40: Summary of CPO average selling price across the different processing centers

Region	Summary of cpoavgpr Mean	Std. Dev.	Freq.
Sombo	547.59649	106.96145	114
Mkpot	620	76.325816	120
Edea	442.60204	204.30954	98
Misaje	577.66355	58.476401	107
Total	551.2779	136.80738	439

Table 41: Summary of electrical cost across the different processing centers

Region	Summary of electr Mean	Std. Dev.	Freq.
Sombo	0	0	119
Mkpot	2125	5252.5504	120
Edea	3912.8833	7771.4413	120
Misaje	2756.5217	5021.9541	115
Total	2197.3544	5500.2544	474

Table 42: Summary of FFB receiveing area capacity across the different processing centers

Region	Summary of ffbrec Mean	Std. Dev.	Freq.
Sombo	2.4705882	9.9896756	119
Mkpot	9	0	120
Edea	1.25	2.8291698	120
Misaje	1.7304348	2.869445	115
Total	3.6350211	6.2339619	474

Table 43: Summary of FFB threshing capacity across the different processing centers

Region	Summary of ffbthr Mean	Std. Dev.	Freq.
Sombo	0	0	119
Mkpot	0	0	120
Edea	0	0	120
Misaje	0	0	115
Total	0	0	474

Table 44: Summary of FFB sterilization capacity across the different processing centers

Region	Summary of ffbste Mean	Std. Dev.	Freq.
Sombo	1.2302689	1.1923396	119
Mkpot	.57791667	.63135162	120
Edea	.58291667	1.1989929	120
Misaje	.73282609	1.2907029	115
Total	.78054219	1.1357368	474

Table 45: Summary of FFB digesting capacity across the different processing centers

Region	Summary of ffbdig Mean	Std. Dev.	Freq.
Sombo	0	0	119
Mkpot	5	54.772256	120
Edea	0	0	120
Misaje	0	0	115
Total	1.2658228	27.558913	474

Table 46: Summary of oil clarification capacity across the different processing centers

Region	Summary of oilclar Mean	Std. Dev.	Freq.
Sombo	.93847059	1.0831955	119
Mkpot	.37958333	.30462098	120
Edea	.45583333	1.041637	120
Misaje	.53304348	.7895948	115
Total	.57643038	.8867035	474

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Table 47: Summary of pulp press capacity across the different processing centers

Region	Summary of pulppress Mean	Std. Dev.	Freq.
Sombo	.18655462	.05029467	119
Mkpot	.31333333	.28013602	120
Edea	.93	1.1236645	120
Misaje	1.1852174	.85463068	115
Total	.64915612	.82848937	474

Table 48: Summary of oil packaging capacity across the different processing centers

Region	Summary of oilpack Mean	Std. Dev.	Freq.
Sombo	18.655462	5.0294674	119
Mkpot	20	0	120
Edea	13.666667	9.3425325	120
Misaje	20.695652	2.5552626	115
Total	18.227848	6.119216	474

Table 49: Detail of waste management technique used across the different processing centers

Key
frequency   *row percentage*

Region	wastman None	Manure	Biomass	Other	Total
Sombo	22 18.49	20 16.81	0 0.00	77 64.71	119 100.00
Mkpot	72 60.00	3 2.50	4 3.33	41 34.17	120 100.00
Edea	48 40.00	2 1.67	69 57.50	1 0.83	120 100.00
Misaje	21 18.26	0 0.00	78 67.83	16 13.91	115 100.00
Total	163 34.39	25 5.27	151 31.86	135 28.48	474 100.00

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Table 50: Detail of overall technological lecvel across the different processing centers

Key
frequency   *row percentage*

Region	tech Tradition	Modern	Total
Sombo	119 100.00	0 0.00	119 100.00
Mkpot	120 100.00	0 0.00	120 100.00
Edea	0 0.00	120 100.00	120 100.00
Misaje	0 0.00	115 100.00	115 100.00
Total	239 50.42	235 49.58	474 100.00

Table 51: Detail of CPO per worker across the different regions

-> Region = Sombo

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	111	.0854515	.0942922	.0083333	.6

-> Region = Mkpot

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	120	.1258294	.1837225	.0125	1.44

-> Region = Edea

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	82	.2068598	.3315901	.0233333	2.17

-> Region = Misaje

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	115	.2464103	.3220265	.0140625	1.8

Table 52: Detail of CPO per worker across the different centers category (modern and traditional)

-> tech = Traditional

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	231	.106427	.1487447	.0083333	1.44

-> tech = Modern

Variable	Obs	Mean	Std. Dev.	Min	Max
cpoprow	197	.2299476	.3257872	.0140625	2.17

Table 53: Summary of OER of the processing equipment across the different processing centers

-> Region = Sombo

Variable	Obs	Mean	Std. Dev.	Min	Max
oer	111	.0915528	.0112173	.05	.1

-> Region = Mkpot

Variable	Obs	Mean	Std. Dev.	Min	Max
oer	120	.0992195	.0210854	.05	.15

-> Region = Edea

Variable	Obs	Mean	Std. Dev.	Min	Max
oer	82	.1170442	.0210678	.0625	.1777778

-> Region = Misaje

Variable	Obs	Mean	Std. Dev.	Min	Max
oer	115	.1197046	.020786	.0833333	.18

Table 54: Detail of FFB per worker across the different Regions

-> Region = Sombo

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	111	.9045607	.9248244	.0833333	5.909091

-> Region = Mkpot

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	120	1.059423	.9125751	.1142857	6.666667

-> Region = Edea

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	82	1.677215	2.334692	.1666667	15.5

-> Region = Misaje

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	115	1.904161	2.124326	.25	12

Table 55: Detail of FFB per worker across the different center category

-> tech = Traditional

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	231	.9850086	.9197549	.0833333	6.666667

-> tech = Modern

Variable	Obs	Mean	Std. Dev.	Min	Max
ffbprow	197	1.809697	2.211327	.1666667	15.5

Table 56: Different models of income on processing stages and Region (dummy)

	(1) inc	(2) inc	(3) inc	(4) inc
pulppress	178380.3*	191466.9*	88343.8	80088.0
	(76246.9)	(85086.3)	(78939.6)	(83208.8)
_Itech_1		-44560.5	91164.8	
		(56432.7)	(63606.8)	
oilclar			321136.8***	349384.3***
			(94974.5)	(96410.1)
ffbrec				-413.0
				(2389.5)
_IRegion_2				273694.0***
				(66188.9)
_IRegion_3				314796.8***
				(88932.5)
_IRegion_4				158081.1
				(101336.2)
_cons	259685.4***	273282.3***	87822.4	-63740.1
	(37126.7)	(32154.5)	(59584.7)	(78900.8)
N	474	474	474	474
R-sq	0.055	0.056	0.243	0.272
adj. R-sq	0.053	0.052	0.238	0.263
rmse	615061.1	615403.8	551576.9	542476.7

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

The sequence of models above provides robust indicators for income, based on factors such as pulp press capacity (pulppress), center technology level (dummy variable tech), oil clarification (oilclar), FFB receiving area capacity (ffbrec), and evaluates its differences across regions (dummy „Region". 0=Sombo, Region 2=Mkpot, Region 3=Edea and Region 4=Misaje).

It can be osbserved that given the same pulp press and oil clarification capacity the income of Edea would be FCFA 273,694 (US$566) higher that Sombo; 41,102 FCFA (US$85) higher that Mkpot; and FCFA 156,715 (US$324) higher than the one of Edea.

Table 57: Linear regression on CPO average price on its different determinants

```
Linear regression                                      Number of obs =     439
                                                       F(  7,   431) =    2.06
                                                       Prob > F      =  0.0465
                                                       R-squared     =  0.0588
                                                       Root MSE      =   133.8
```

cpoavgpr	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
pulppress	6.404502	6.214915	1.03	0.303	-5.81081	18.61981
oilclar	4.453504	5.855541	0.76	0.447	-7.055466	15.96247
cpopro	7.411674	4.226374	1.75	0.080	-.8951932	15.71854
worexp	.6919989	.9458072	0.73	0.465	-1.166969	2.550967
agrpr	8.87191	7.872907	1.13	0.260	-6.602158	24.34598
edu	-1.525399	9.900283	-0.15	0.878	-20.98424	17.93344
equage	6.057235	2.050757	2.95	0.003	2.026505	10.08796
_cons	485.6794	40.58346	11.97	0.000	405.9132	565.4455

The model above describes robust indicators for CPO average selling price. Even though the model only explains 6% of the variation in cpoavgpr, we can observe that equipment age is significant at 99%. The model predicts an increase of FCFA 6 for every additional age of the equipment.

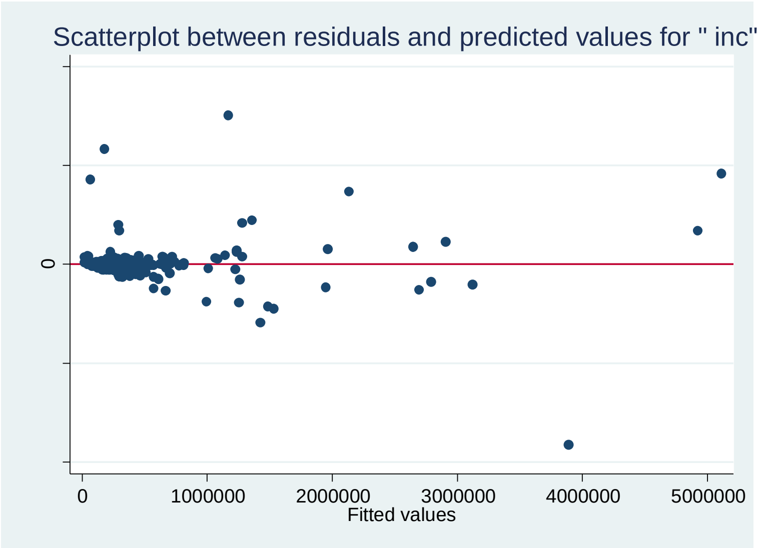
Table 58: Linear regression on CPO production on its different determinants

```
Linear regression                                      Number of obs =     474
                                                       F( 12,   461) =   73.26
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9289
                                                       Root MSE      =  .43184
```

cpopro	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
ffbpro	.133005	.0108952	12.21	0.000	.1115946	.1544154
edu	.0074634	.0309069	0.24	0.809	-.0532726	.0681993
cultarea	-.0156702	.0090099	-1.74	0.083	-.0333757	.0020354
agrpr	.0266173	.0226812	1.17	0.241	-.017954	.0711886
totwork	.0251283	.029278	0.86	0.391	-.0324066	.0826632
worexp	.0015434	.002992	0.52	0.606	-.0043362	.007423
equage	-.0065911	.0049253	-1.34	0.181	-.0162699	.0030878
ffbrec	.0014007	.0029735	0.47	0.638	-.0044426	.007244
ffbste	-.2250832	.126388	-1.78	0.076	-.4734512	.0232849
pulppress	.1047796	.0410642	2.55	0.011	.0240834	.1854758
oilclar	.2431071	.159469	1.52	0.128	-.0702692	.5564834
tech	.2601874	.105509	2.47	0.014	.0528492	.4675256
_cons	-.394282	.2419817	-1.63	0.104	-.8698058	.0812419

The model above describes the robust determinants for CPO production per year. As it can be seen, the amount of FFB per year, the pulppress capacity and the oil clarification capacity are relevant factors in explaining CPO production. The dummy variable „tech“ indicates that modern centers significantly produce additional 0.26 tons of CPO per year when compared with traditional centers, all rest held constant. Similarly, one additional ton of FFB processed provides 0.13 tons of CPO per year; one additional pulp press capacity per hour yields .1 tons of CPO per year; and one additional oil clarification capacity per hour increases CPO production by .24 tons annually.

Graph 9: Scatterplot between residuals and predicted values of inc in model inc=pulppress, oilclar, ffbste, ffbrec, ffbpro



When plotting residuals vs. predicted values (Yhat) we observe a certain pattern that indicates the presence of heteroskedasticity. The problem with heteroskedasticity is that we may have the wrong estimates of the standard errors for the coefficients and therefore their t-values. As we can observe, the distribution of the residuals between observed and predicted values are not constant, the residuals seem to slightly expand at higher levels of Yhat.

Table 59: Hypothesis test for the difference in income across different pulp press capacity (threshold at 0.7 tons per hour)

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
< 0.7 to	315	322030.6	22318.77	396118.9	278117.4	365943.9
>= 0.7 t	159	481376.3	73829.7	930957.1	335555.8	627196.8
combined	474	375482	29025.71	631934.4	318446.7	432517.3
diff		-159345.7	61102.71		-279412.6	-39278.66

```
    diff = mean(< 0.7 to) - mean(>= 0.7 t)                      t =  -2.6078
Ho: diff = 0                                     degrees of freedom =      472

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0047         Pr(|T| > |t|) = 0.0094          Pr(T > t) = 0.9953
```

The income level of palm oil workers in mills with a capacity of less than 0.7 tons per hour is significantly different from the ones working in centers with a capacity greater than 0.7 tons per hour.

Table 60: Hypothesis test for the difference in income across different oil clarification capacity (threshold at 0.2 tons per hour)

Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
<= 0.2	243	233579.4	21757.83	339171	190720.5	276438.3
> 0.2	231	524756.2	53312.79	810284.3	419712.3	629800.1
combined	474	375482	29025.71	631934.4	318446.7	432517.3
diff		-291176.8	56565.41		-402328	-180025.6

```
    diff = mean(<= 0.2) - mean(> 0.2)                          t =  -5.1476
Ho: diff = 0                                  degrees of freedom =      472

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

The income level of palm oil workers in mills with a clarifying capacity of less than 0.2 tons per hour is significantly different from the ones working in centres with a capacity greater than 0.2 tons per hour.