CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

INSTITUTE OF TROPICS AND SUBTROPICS

Department: DEERDTS **Academic year:** 2007/08

SETTING M.Sc. THESIS

For Ms. Jana Klápová, B.Sc.

Course: Sustainable Rural Developement in Tropics and Subtropics

This thesis is required by the Head of Department as laid down in the rules of the Master studies at CULS

Thesis Title

Comparison of Economic and Environmental Aspects of *Jatropha Curcas L.* and *Elaeis guineensis Jacq.* Cultivation: A Case Study of Indonesia

Code for compiling this M.Sc. diploma thesis

1. **Introduction**
2. **Objective**
3. **Methodology**
4. **Study Area Description**
5. **Literature review**
6. **Results and Discussion**
7. **Conclusions**

Extent of the Thesis report: **60 – 70 pages**

Bibliography:

Heller, J. ***Physic nut. Jatropha curcas L. Promoting the conservation and use of underutilized and neglected crops.*** **Rome: Institute of Plant Genetics and Crop Plant Re-search, Gatersleben/International Plant Genetic Resources Institute, 1996. ISBN 92-9043-278-0**

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Hambali, Erliza, et al. ***Jatropha curcas as Biodiesel Feedstock*****. Bogor: Surfactant and Bioenergy Research Center, 2007. ISBN 978-979-1312-12-7**

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Date of M.Sc. thesis setting: **November 30, 2007**

Date of handing over the thesis: **April 2008**

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Acknowledgements

I sincerely thank to my thesis supervisor Ing.Vladimír Verner, Ph.D for consultations and proposals. Then I want to express my gratitude to Ing.David Herák Ph.D. for providing me with the essential data without which this diploma thesis could not be elaborated.

Declaration

I hereby declare that I have elaborated this master thesis independently. All information sources are quoted in References.

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Jana Klápová

Prague, 23^{rd} April, 2008

Abstract

The master thesis presents the results of comparative analysis of two oil bearing crops cultivated in Indonesia – *Jatropha curcas* and oil palm, and the economic and environmental impact of their production with special regards to small-holders. *Jatropha* oil is used mainly for the production of biodiesel, while palm oil is first of all a very valuable material for food industry. Nowadays both crops continue to gain the big importance. The development of *Jatropha curcas* cultivation is in outset, while oil palm cultivation has a long tradition in Indonesia. Natural and socio-economic condition of Indonesia and the basic characteristics of both these crops are reviewed. Their cultivation is given to context of the study area and the future prospects are analyzed. The cultivation practices used on *Jatropha curcas* plantation are very simple, usually only basic operations are carried out. The highest expenses are constituted by seedling purchase and the costs of labour for maintaining the plantation. Even if *Jatropha curcas* is not very demanding, the payback period of the plantation is about ten years because of the low purchasing price of seeds. Its cultivation is profitable mainly on marginal areas which can not be used for other purposes. On the contrary oil palm needs fertile soil, which together with the increasing demand of biofuels, strongly contributes to rain forest clearing. The main difficulty which has the farmer face when starting oil palm cultivation is the complicated access to appropriate piece of land. In the case of *Jatropha curcas* the main limiting factor is the lack of information and an undeveloped market (mainly the lack of procurement centres).

Keywords: *Jatropha curcas*, oil palm, biodiesel, small farmer, economic analysis, Indonesia

Abstrakt

Tato diplomová práce představuje výsledky srovnávací analýzy dvou olejnatých plodin pěstovaných v Indonésii – *Jatrophy curcas* a palmy olejné. Věnuje se především ekonomickým a enviromentálním dopadům jejich pěstování indonéskými malými farmáři. Olej *Jatrophy curcas* slouží především jako surovina pro výrobu bionafty, palmový olej je navíc ceněn v potravinářském průmyslu. V současné době obě tyto rostliny získávají na stále větším významu. Vývoj v oblasti pěstování *Jatrophy curcas* je teprve v počátcích, naopak pěstování palmy olejné má v Indonésii dlouhou historii. Nejprve jsou popsány přírodní a socioekonomické podmínky Indonésie a hlavní charakteristiky obou plodin. Jejich pěstování je zařazeno do kontextu zkoumané oblasti, popsána je současná situace a také budoucí výhledy. Kultivační techniky, používané v případě *Jatrophy curcas*, jsou velmi jednoduché, často jsou prováděny jen základní operace. Největší výdaje představuje nákup sazenic a náklady na pracovní sílu na údržbu plantáže. Přestože jde o velmi nenáročnou plodinu, pohybuje se doba návratnosti plantáže kolem deseti let, a to především kvůli nízké výkupní ceně semen. Pěstování *Jatrophy curcas* je však velmi výhodné na kritických půdách, které nemohou být využity k jiným účelům. Naopak palma olejná je náročná na kvalitu půdy, což spolu s rostoucí poptávkou po biopalivech značně přispívá ke kácení původních deštných lesů. V případě palmy olejné je největším problémem, kterému musí farmář čelit, nedostatek vhodné půdy. Při pěstování *Jatrophy curcas* je limitujícím faktorem nedostatečná informovanost farmářů a dosud nevyvinutý trh semen (nedostatek výkupních míst).

Klíčová slova: *Jatropha curcas*, palma olejná, Indonésie, bionafta, ekonomická analýza, malý farmář

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List of Abbreviations

AFTA	ASEAN Free Trade Area
ASEAN	Association of Southeast Asian Nations
CFC	Chlorofluorocarbons
CIF	Cost Insurance Freight
CPO	Crude Palm Oil
EU	European Union
FAO	Food Agricultural Organisation
FFB	Fresh Fruit Bunches
GDP	Gross Domestic Product
GHGs	Green House Gases
GTZ	Gesellschaft für Technische Zusammenarbeit (Agency for Technical Cooperation)
HDI	Human Devlopement Index
HIV	Human Immunodefficiency Virus
HPI	Human Poverty Index
IDR	Indonesian Rupiah
NES	Nucleus Estate Scheme
PKO	Palm Kernel Oil
PLN	Perusahaan Listrik Negara (State Electricity Company)
PNI	Partai Nasional Indonesia (Nacionalist party of Indonesia)
PVC	Polyvinyl Chloride
RNI	Rajawali Nusantara Indonesia
RSPO	Roundtable on Sustainable Palm Oil
SRIPHL	Society for Rural Initiatives for Promotion of Herbals
Timnas BBN	Tim Nasional Bahan Bakar Nabati (National Team for Biofuel Development)
UN	United Nations
UNDP	United Nations Developement Programme
USD	United States Dollar

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1 INTRODUCTION

Nowadays there are a huge efforts to lower the production of GHGs in order to prevent global warming. As transport is responsible for one quarter of human generated GHGs emission, the use of biofuels seems to be an efficient solution, because biofuels are promoted as carbon neutral (this presumption is examined in Discussion). Developed countries, which consume the majority of fossil fuels, do not have a sufficient potential to grow as much energetic plants as is needed. That is why the search for sources of biofuels in developing countries is running. There are better climatic conditions (more solar energy can be fixed), more unused land, and lower production costs (mainly the costs of labour). The progress in biofuels production and use is huge in last years, but the demand is still unsupplied.

The two main types of biofuels used in large scale are bioethanol and biodiesel. The main feed-stock of biodiesel is palm oil, but other resources are being explored. The disadvantage of palm oil for biofuel industry is, that it is highly valued in food industry, and this fact makes its international price very high, and so the sale of palm oil as biodiesel feed-stock is less profitable. From this point of view, the ideal plant is exactly *Jatropha curcas* (physic nut, *Euphorbiaceae*). Its seeds contain toxic oil, which can not be used in food industry, but is evaluated as a very good biodiesel feed-stock, with a quality comparable with palm oil. Aside from this, many other products, which can bring the additional income for poor farmers, can be obtained from this plant. The other advantages of *Jatropha curcas* for developing countries are described, too.

Jatropha curcas is a plant of multiple uses. Few years before, it was considered as a weed or planted only as a living fence to protect fields from grazing animals. In local conditions the oil was used in tribal medicine, for processing of soap, and as a substitute of kerosene. Today the large plantations have been established around the world in order to process the oil to biodiesel. This is done by transesterification and glycerol is obtained as an important by-product during this reaction. The plant is not demanding for climatic and soil conditions and it thrives well on marginal soils. This feature is utilised in soil rehabilitation and erosion control projects. This advantage against other energetic plants means, that it is not necessary to clear the areas of original rain forests to obtain suitable land for cultivation, as it is in the case of oil palm.

Nowadays *Jatropha curcas* pass through a big prime in many tropical countries, as India, Indonesia, China, Brazil, and many African countries. The situation in Asia is described in detail.

Some scientists are very optimistic about the contribution of *Jatropha curcas* growing for biodiesel production, but there exists a sceptic point of view, which claims unfeasibility of growing *Jatropha curcas* for this purpose. These sceptics prefer the extensive systems of cultivation, like the erosion control systems and the traditional use of *Jatropha curcas* as a hedge plant. In this case the costs are minimal, but so is the level of seed production. If it is planted for harvesting seeds and obtaining fuel, more investments are needed. In Africa it was promoted mainly to make rural areas self sufficient in fuels for cooking, lighting and motive power, because it can be used as a substitute of kerosene, diesel, and fuel wood. There systems of *Jatropha curcas* cultivation are mentioned in Discussion. Also the summary of advantages and disadvantages of each crop is mentioned in this chapter. The most important disadvantage of *Jatropha curcas* is its lower productivity. The production of oil per unit of area is approximately four times lower than the production of oil palm. For deciding about the profitability of *Jatropha curcas* cultivation in Indonesia, the production analysis of this crop was elaborated (see Results).

Other disadvantages result from the fact that cultivation of *Jatropha curcas* began not long ago. Therefore there are many issues which are necessary to clear up, especially the optimal conditions for *Jatropha curcas* cultivation, the seed yield in specific conditions, oil content and so on. Then there are not varieties adjusted for definite conditions developed yet. Also the market is not well developed in many regions, like in the case of Indonesia. The possible solutions of the main problems are outlined in the end.

2 OBJECTIVE

The main objective of this thesis is to evaluate which of these two crops is more suitable for cultivating in smallfarmer conditions in Indonesia. This task can be answered by performing of particular specific objectives mentioned below.

The first specific objective is to describe the study area, with focus on climatic conditions and agriculture. The next specific objective is to introduce two crops whose oil serves as an important biodiesel feed-stock. *Jatropha curcas* is introduced as a very promising plant, but a newcomer in this field. Its cultivation is in the early stages of development in many areas and a lot of studies have to be executed. On the contrary oil palm cultivation has a long tradition in Indonesia and the palm oil market is well developed.

The most important specific objective is the elaboration of the production analysis of *Jatropha curcas* cultivation and its comparison with oil palm cultivation. The costs of establishment of plantation, its maintenance and harvesting the seeds (seeds, fertilizers, pesticides, human labour, the costs of land, mechanization, etc.) are evaluated. Then the state of the market, purchasing prices of main product and by-products, and farmers' revenue and profit on one hectare of plantation are reviewed. The main outcome of this thesis is cash flow analysis and cost-benefit analysis.

Finally the main problems of each crop's cultivation are discussed, as well as their marketing advantages and disadvantages, and environmental impacts. Some solutions for these problems will be suggested, in the end.

3 METHODOLOGY

This thesis is composed of different parts, which are elaborated by different methods. For elaborating of chapter Literature review, the collection and analysis of secondary data was carried out. For description of study area mainly the data from international databases, such as FAO, World Bank, UNDP and World Resources Institute, are used. Basic characteristics of *Jatropha curcas* and oil palm, their uses, distribution and cultivation in Indonesia, was compiled by the help of specialised scientific organisations, such as International Plant Genetic Resources Institute (Rome), Plant Research International (Wageningen), Society for Rural Initiatives for Promotion of Herbals (Rajasthan), Indonesian Palm Oil Producers Association (Jakarta), Centre for International Forestry Research (Bogor), International Jatropha Organization (Kuala Lumpur), World Agroforestry Centre (Nairobi), and Deutsche Gesellschaft für Technische Zusammenarbeit (Eschborn). Also a lot of university research were studied and mentioned in this thesis, e.g. Purdue University (Indiana, USA), Eindhoven University of Technology (the Netherlands), and first of all Indonesian Bogor Agricultural University.

The main part of this thesis is the production analysis of *Jatropha curcas* and oil palm and evaluation of feasibility of growing each of them. For elaboration of this part the Indonesian literature sources are used (mainly the publication Jatropha Curcas as Biodiesel Feedstock, published by Surfactant and Bioenergy Research Centre of the Bogor Agricultural University). But the greatest part of data comes from the interviews with Ing.David Herák Ph.D. (Faculty of Engineering, Czech University of Life Sciences in Prague), and Satya Simanjuntag, SE (UNITA University in Tarutung, North Sumatra).

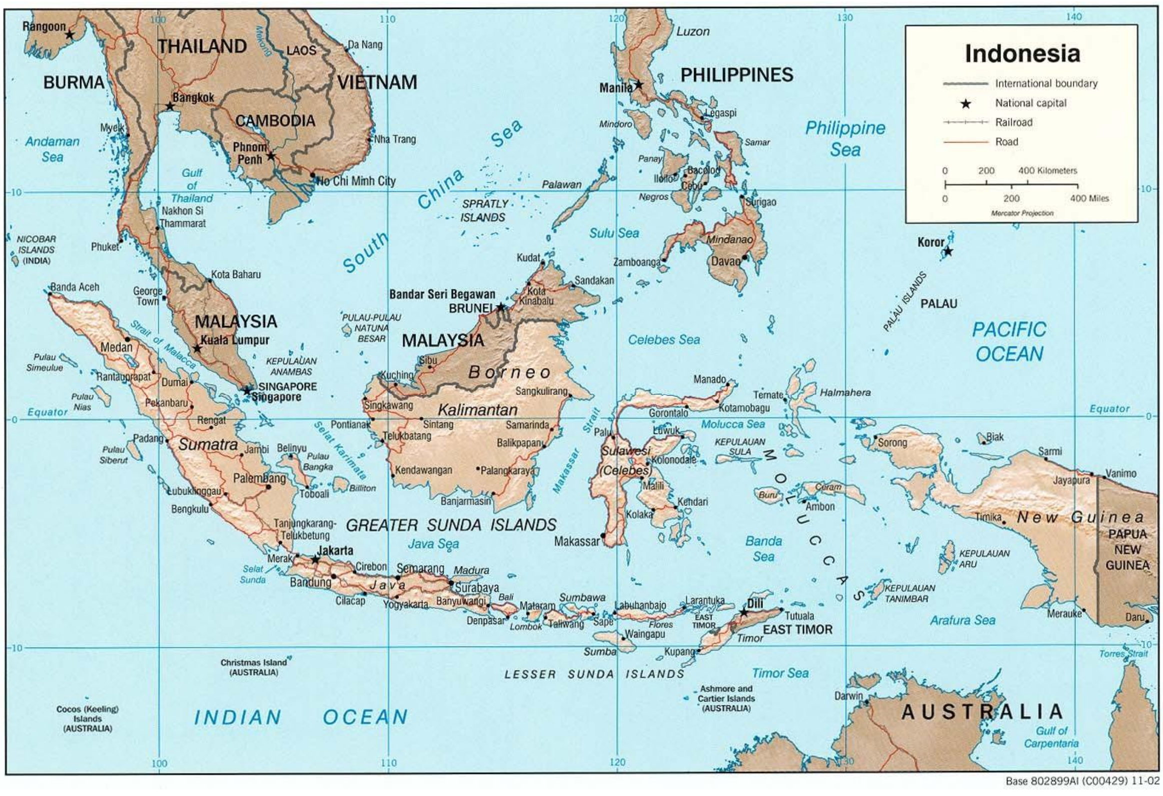
It is necessary to clear up some values used in the calculation of production analysis. The exchange rate between IDR and USD used in calculations is 0.00011 USD per one IDR (the value of April the 1st, 2008). The duration of a working day was set as twelve hours, because in Indonesian conditions it is usual, that the working day lasts about this time. As this work is focused on Indonesian small farmers, it was necessary to define this term first. The average farm size was 0.86 hectares per household in 1996 (Djojomartono and Pertiwi, 1998), therefore for simplification, the term small farmer is defined as the holder of one hectare or less.

4 STUDY AREA: INDONESIA

4.1 General overview

Indonesia lies on the world’s biggest archipelago, with total area of 1,919,440 km2 Total population was more than 220 million in 2006, which makes Indonesia the world's fourth most populous country (World Bank, 2007). At the same time, it is the most populous Muslim-majority nation, although officially it is not an Islamic state. Muslims constitute 88% of population. The other segments of the population are the Christians, the Hindus, and the Buddhists. The official name of the state is the Republic of Indonesia. The state system is parliamental republic. The official language is Bahasa Indonesia (Indonesian) and the currency is Indonesian Rupiah (IDR). The capital of the country – Jakarta – is situated on Java Island and it has about 10 million inhabitants (U.S. Department of State, 2008).

Picture 1 Map of Indonesia



Source: Yale University, 2003

The history of the country is very long and the last century was very dramatic. At the beginning of 20^{th} century, Indonesians were fighting for the independence from the Dutch, for whom they had been a colony since 1596. It was also the Dutch, who brought in 1848 the first oil palm to Bogor on Java and established the first plantations on Sumatra at the beginning of 20^{th} century. In 1942 they were defeated by Japan, who introduced *Jatropha curcas* in Indonesia in the same year. The independent republic was born after the war in 1945. The first Indonesian president became Sukarno, who led the country until a coup, organised against him in 1965. Two years later general Suharto became the second Indonesian president. During his era Indonesia became one of the founder members of ASEAN (The Association of Southeast Asian Nations) and in the eighties it joined “Asian tigers”. But the economic crisis in 1997 and corruption scandals forced Suharto to resign in 1998. From 1999 to 2001 Abdurrahman Wahid served as president. After him Megawati Sukarnoputri, the daughter of former president Sukarno, executed this function till 2004. The present president of Indonesia is Susilo Bambang Yudhoyono (Merapi, 2008).

4.2 Natural conditions

Indonesia is an island state in South East Asia, which comprises of more than 17,000 islands. The Big Sunds are composed of the biggest islands - Sumatra, Java, Kalimantan (Borneo) and Sulawesi (Celebes). On the east, there are situated the Little Sunds – Bali, Lombok, Flores, Timor, Sumbawa, etc. The western part of the second largest island of the world – New Guinea – is part of Indonesia, too. The large area together with the island structure causes problems with communication among the parts of state and some tendencies to separatism. Indonesia is surrounded by the Indian Ocean, South China Sea, and the Pacific Ocean. On land it borders with Malaysia, Brunei, and Papua New Guinea. It has common sea borders with Singapore, Thailand, Vietnam, the Philippines and Australia.

The surface differs from island to island. Large islands are composed of coastal plains with mountainous interiors. Mountains with altitude higher than 3,000 meters above sea level can be found on the islands of Sumatra, Java, Bali, Lombok, Sulawesi, and Seram. The highest peak, Puncak Jaya (5,039 meters), is located in the Sudirman Mountains in Irian Jaya. The region is noted for its tectonical instability. The volcanic ash creates very fertile soils, but it makes agricultural conditions unpredictable in some areas. The country has about 400 volcanoes, of which approximately 100 are active. The two most famous eruptions were in 1815, when a volcano at Gunung Tambora on Sumbawa created "the year without a summer" in various parts of the world. In 1883 Krakatoa between Java and Sumatra erupted and caused a great tidal wave (Frederick and Worden, 1993).

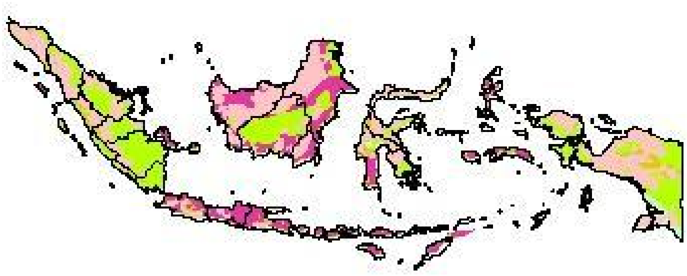
About the climate Frederick and Worden (1993) wrote: *„The main variable of Indonesia's climate is not temperature or air pressure, but rainfall. The almost uniformly warm waters that make up 81% of Indonesia's area ensure that temperatures on land remain fairly constant.“* The average temperatures in coastal plains are about 28°C, while the inland and mountain areas average is 26°C. The relative humidity ranges between 70 and 90%, according to him.

The Indonesian archipelago is traversed by Wallace’s line, which divides it at the Oriental and Australian bio geographic regions (Woodward, 1997). The line crosses between Bali and Lombok and is shown in the Picture 14 (Appendixes).

The Oriental zone is characterised by humid tropics climate with a rainy season (caused by the west monsoon), between October and March. The dry season (southeast monsoon) is between April and September. The annual rainfall is between 1,500 and 3,000 mm. The parts of Indonesia which belong to the Australian bio geographical region have a drier climate with annual rainfall of about 1,000 mm or less in the three months period between December and February (FAO, 2005). As shown in the Picture 12 *Jatropha curcas* grows in each of these two zones, while for oil palm the humid conditions of Oriental region are required.

The Indonesian environment suffers from many problems such as rising population density, soil erosion, river-bed siltation, and water pollution from agricultural pesticides and off-shore oil drilling (Frederick and Worden, 1993). Though the favourable tropical climate, the Indonesian farmers have to face up to many natural threats. The main environmental constraints are shown in the map below.

Picture 2 Map of Indonesian major environmental constraints



Legend

Low soil suitability

Erratic rainfall and cold stress risk

Steep slopes and mountains

Severe and very severe land degradation

Low to medium climatic production potential

High climatic production potential

Source: FAO, 1999b

4.3 Socio-economic overview

The economic situation is strongly influenced by the membership in ASEAN. Indonesia is the five founder members of ASEAN, which was established on 8 August 1967 in Bangkok. The aims and purposes of the Association are to accelerate economic growth, social progress and cultural development in the region, and to promote regional peace and stability. In 2002 AFTA (ASEAN Free Trade Area) was established, was a very important step towards these objectives (ASEAN, no date).

Even if the state is known as one of the *"Asian tigers"*, according to the Human Development Index (HDI), it is still placed in the second half of the chart of 177 countries. With HDI value of 0.728, it occupies 107th place of the chart. According to the Human Poverty Index (HPI), the probability of not surviving past age 40 is 8.7% and adult illiteracy rate 9.6%. There are 23% of people do not have access to an improved water source and 28% children are underweight for their age (UNDP, 2007/2008 Report). For Indonesian HDI trends from 1975 to 2005, see the Figure 4.

The last years of the 20th century and the first years of 21st century were influenced by the economic crisis in 1997, which hit all of the ASEAN countries. But today the economic results of Indonesia are very good. In 2007 the GDP achieved the growth of 6.3%, which is the same value as it was before the crisis. The proposition of the state budget for 2008 was calculated on the growth of GDP by 6.8 % (World Bank, 2008a). For Indonesian GDP trends from 2002 to 2006, see Table 21 (Appendixes).

In 2007 the investment rate growth was 7.3% and export increased by 9.4%. Unemployment decreased to 9.1%. The ratio of population living below the poverty line decreased to 16.6% (in 2006 it was 17.7%). But inflation is increasing rapidly. It was 7.4% in 2007 and it influenced mainly the food prices. The Index of household consumption decreased by 4.7 % and the costs of social services decreased by 41.8% in comparison to 2006 (World Bank, 2008a).

4.5 Indonesian agriculture

The share of agricultural sector on GDP creation declined rapidly through the progressive industrialisation. In 1970 it was 40 to 50 %, and in 2006 it was only 14 % (U.S. Department of State, 2008). But agriculture still plays a fundamental in the Indonesian economy, because it employs about 44% of its inhabitants (UNDP, 2007/2008 Report).

The most important crops grown in Indonesia are rice, oil palm (with high export potential as a consequence of the growing world prices), rubber, coffee, and cocoa. Livestock breeded in Indonesia includes cattle, goats, sheep, and the water buffalo (the most common draft animal). Also fishing and forestry are very important parts of Indonesian agriculture (Frederick, 1993).

The acreage of the farm is usually very small in Indonesia. The average acreage was 0.86 hectares per household in 1996. About 48% of farm households operated less than 0.5 hectares, and only 1.3% had more than 5 hectares (Djojomartono and Pertiwi, 1998).

Table 1 Number of households and farm size in Indonesia

Island	Number of households			
	Less than 0.5 ha		More than 0.5 ha	
	1983	1993	1983	1993
Java	8 070	7 616	3 494	2 957
Sumatera	1 384	1 446	3 080	3 095
Bali & Nusa Tenggara	557	565	766	697
Kalimantan	242	280	965	867
Sulawesi	425	467	1 240	1 115
Maluku & Papua	204	228	306	256
Total Indonesia	10 882	10 602	9 851	8 987

Source: Central Bureau of Statistics, 1999

4.6 Bioenergy and biofuels

Despite its great petroleum resources, Indonesia became a net importer of this raw material in 1995 (Hambali et al., 2007b). Moreover the world prices of petroleum are growing rapidly. In the middle of 2005 the price was slightly over 60 USD per barrel. In the middle of March 2008 it crossed the border of 111 USD per barrel (petrol.cz).

In an effort to resolve this situation the government developed the strategy to replace the part of imported petroleum by the use of renewable energy resources, such as biodiesel made from *Jatropha* oil or palm oil. One of the plans is to mix diesel with 5% of biodiesel by 2010, according to The Economic Times (2007).

5 JATROPHA CURCAS

5.1 General overview

Jatropha curcas L. is a tropical succulent plant from the *Euphorbiaceae* family, order *Malpighiales*. The *Jatropha*[1] is a very varied genus, which contains 175 species of trees, bushes and herbs. Sixty-two of them are succulents. There are two species, *J. podagrica* and *J. multifida*, which are grown as houseplants, in the Czech Republic. In Indonesia these species occur wildly in nature and two other are known - *J.gossypifolia* and *J.Integerrima* (Sudradjat, 2006).

The botanic name *Jatropha* is derived from Greek, *"Jatras"* meaning Doctor and *"trophe"*, which means nutrition (Kumar and Sharma, 2008). The Indonesian name for *Jatropha curcas* is Jarak pagar (Hambali, 2007a).

Jatropha curcas is originated in the Caribbean region. Thanks to Portuguese colonisers, it was spread throughout the tropical areas all over the world. It was used, first of all, as a hedge plant. Now it's cultivated mainly in central Africa and southern and south-eastern Asia and it has multiple uses.

The history of growing *Jatropha curcas* for commercial purposes begins in Cape Verde, the island state near the west coast of Africa. In the 15th century, it was colonized by the Portuguese. Local unfavourable climatic conditions decline possibilities of choosing plants to grow there, which is why Portuguese colonisators brought *Jatropha curcas* from Brazil and started to plant it in large quantities. According to Heller (1996), at the start of the 20th century the plantations of *Jatropha curcas* covered cca 8,000 ha. This value represents 12% of the total surface of the Cape Verde islands. *„Maximum exports from Cape Verde were 5,622 t in 1910 and 4,457 t in 1955. Exports of seed contributed in certain years for up to 60% of the total monetary value of the island's agricultural exports, "he* wrote. All obtained seeds were exported to Lisbon. The extracted oil was used for soap production and for lamps instead of kerosene. After World War II, since the 1950s, demand for the

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[1] Numerous synonyms and local names exist for *Jatropha curcas*. The most used synonyms are: Adenorhopium Rchb., Adenoropium Pohl., Castiglionia Ruiz & Pav., Collenucia Chiov., Curcas Adans., Jatropa Scop., orth. var., Loureira Cav., Mesandrinia Raf., Mesandrinia Ortega, Tempate (El Salvador; Nicaragua), Zimapania Engl. & Pax. (Porcher, 2007). The variety of local names is much higher: physic nut, purging nut (English); pourghere, pignon d'Inde (French); purgeernoot (Dutch); Purgiernuß, Brechnuß (German); purgueira (Portuguese); fagiola d'India (Italian); dand barrî, habel meluk (Arab); kanananaeranda, parvataranda (Sanskrit); bagbherenda, jangliarandi, safed arand (Hindi); kadam (Nepal); yu-lu-tzu (Chinese); sabudam (Thailand); túbang-bákod (the Philippines); jarak budeg (Indonesia); bagani (Côte d'Ivoire); kpoti (Togo); tabanani (Senegal); mupuluka (Angola); butuje (Nigeria); makaen (Tanzania); pinoncillo (Mexico); coquillo, tempate (Costa Rica); tártago (Puerto Rico); mundubi-assu (Brazil); pinol (Peru) and pinón (Guatemala) (Münch, 1986; Schultze-Motel, 1986).

Jatropha oil decreased and it seemed like the end of growing *Jatropha curcas* in Cape Verde. But in 1980 extreme droughts came and *Jatropha curcas* became important again because of its resistance against these bad conditions. It obtained a new role – reforestation of areas with vegetation destroyed by drought, and their protection against erosion.

Cultivation of *Jatropha curcas* for production of biodiesel was first practiced during World War II. It was done in Mali by the French and in Indonesia by the Japanese. But these experiments did not continue later and the plant's potential for the production of biodiesel was rediscovered only a few years ago. The nearly unknown plant, considered only as a weed, is now experiencing a big boom, supported by the increasing demand of biofuels (Wiesenhütter, 2003).

5.2 Botanical description of *Jatropha curcas*

Jatropha curcas is a perennial shrub or small tree. It is extremely fast growing, at the age of four years it can attain the height of four meters. Under favourable conditions it can be 8 or 10 m high (Kumar and Sharma, 2008), while in plantation the height is maintained about two meters to make harvesting easier (Herák, 2008). The typical sign of the family *Euphorbiaceae* is the production of latex, and *Jatropha curcas* is not an exception. The poisonous latex flows from every part of the plant, mainly from the bark.

M. Reyadh (1999) writes that the bark of *Jatropha curcas* is smooth grey, while the leaves are green to pale-green. Their position on the stem is alternate to sub-opposite, and they are about 10 cm long, 3 to 5 lobed. They are normally shed once a year, but in Indonesian conditions the plant is evergreen (Herák, 2008). The flowers are unisexual and the plant is monoecious. According to Raju and Ezradanam (2002) male and female flowers are produced in the same racemose inflorescence, formed at the end of the branch in the leaf axil. In one inflorescence there occur 1 to 5 female flowers and 25 to 93 male flowers. Male flowers are odourless and salver–shaped. There are five sepals and petals each, and ten stamens. Female flowers are usually a little bit larger, but similar in shape. There are three styles and stigmas each. The colour of flowers can be green, yellow or red.

Picture 3 *Jatropha curcas*

Source: Blanco, 1837

According to Rajendra (2007), the fruit type is an ovoid shaped capsule. At the beginning, it is green and as time goes it changes color to yellow and black at the end. Each fruit contains 3 to 4 black, oblong seeds. There are usually 1,200 to 1,500 seeds in 1 kg. The plant flowers between September and November. It is pollinated by insects. The fruit is mature after 2 to 4 months from fertilization, when it turns to yellow color, normally from October to December (see Picture 4). It can also produce several crops during the year, if the conditions are good. In Indonesia it can produce three to four crops (Herák, 2008). The production of seeds starts within two years of plantation. After 50 years of the age of the plant the production is over.

For each part of *Jatropha curcas*, see Pictures 15 to 19 (Appendixes).

Picture 4 Mature fruits of *Jatropha curcas*

Source: Hambali, 2006

5.3 Varieties of *Jatropha curcas*

Three varieties of *Jatropha curcas* exist. There is the Nicaragua variety, which is native in Latin America; the Mexican variety, whose seed is non-toxin and can be eaten after roasting; and the most important Cape Verde variety. The last one is extended everywhere, except Latin America (Rabé, 2006). This variety can be found in Indonesia, as well.

Picture 5 Seeds of Cape Verde variety (left) and Nicaragua variety

Source: Henning, 2004

5.4 Ecology of *Jatropha curcas*

Jatropha curcas is a succulent plant so it is best adapted to arid and semi-arid conditions with higher temperatures. According to Heller (1996), the optimal average annual temperature ranges between 20°C and 28°C, and the optimal average annual rainfall varies from 300 to 1,000 mm. It can even withstand years without rainfall, and it grows successfully with higher precipitations, too. It occurs mainly at lower altitudes, between 0 and 500 m. It is not sensitive to day length, but it needs well-drained soils with good aeration. In heavy soils, root formation is reduced.

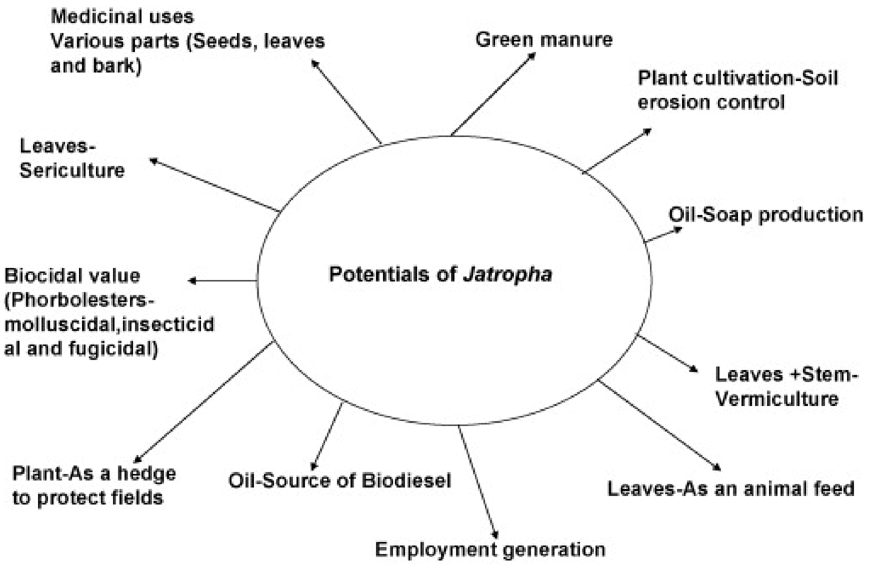
The big advantage in comparison with other energetic plants is its resistance to the pedoclimatic conditions and various types of pests. It can thrive on degraded soils with low nutrient content, where it is very difficult to grow any other plant. Kumar and Sharma (2008) wrote: *„It can grow even in the crevices of rocks.“* In Indonesia, there is about 23.24 million hectares of marginal and degraded land, according to Setyaningsih (2007), which can be replanted by *Jatropha curcas*.

This means, that it is not necessary to cut down the rain forests like in the case of oil palm. At the same time, on these infertile places *Jatropha curcas* does not provide competition for food plants. Besides that, it can protect the soil from further erosion and degradation. The growing of *Jatropha curcas* regenerates these marginal soils (Openshaw, 2000).

5.5 Uses of *Jatropha curcas*

Jatropha curcas is a plant which was used only marginally a few years before, mainly as a living fence, in tribal medicine and for processing of soap and candles. But nowadays it's very famous for its high quality oil obtained from seeds, which is used for the processing of biodiesel. It is also important for its medicinal uses, pesticidal uses, and for dying and tanning. The seeds or seed cake can be used as animal feed, after treatment. The leaves serve as feedstock for silk worms. It is also used as the live pole for supporting vines such as the vanillin plant. The plant attracts bees and thus it has a potential to produce honey. The remaining biomass can be used as a fire wood, green manure (compost), to produce biogas or charcoal. The fact, that *Jatropha curcas* can be grown mainly in developing countries, together with increasing demand of biofuels, means that *Jatropha curcas* can be a good source of income for small farmers in these countries. In this way, it can help to eradicate the rural poverty (Hambali, 2007b; Heller, 1996; Openshaw, 2000; Kumar and Sharma, 2008).

Picture 6 Uses of *Jatropha curcas*



Source: Kumar and Sharma, 2008

5.5.1 Medicinal uses of *Jatropha curcas*

Nearly every part of *Jatropha curcas* is known for curing some disease and new possibilities of using it in medicine are still being invented. Leafs are used to arrest bleeding and to cure wounds and piles. Decoction of leaves is used against cough and as an antiseptic. The tea of leaves is used for curing malaria. In Nigeria some tribes cleaned their teeth with the sticks of *Jatropha curcas*. The root bark is used in external application for sores. A decoction of the bark is given for rheumatism and leprosy (Dove Biotech Ltd., 2001; Heller, 1996).

But the most important product of this plant for medicinal uses is the oil. It helps to cure skin diseases (eczema, herpes, etc.) and the pain caused, for example by rheumatism. Apart from this, it has a strong purgative action. In Český herbář (1899), it is recommended to use 30 g of the nut with 8 g of sugar mixed and crushed to the powder to cure flatulence.

The ingredient, which is the source of nearly every above mentioned medicinal effects, is a proteolytic enzyme curcin, contained in the oil and latex. According to the research of Sichuan University in China (Lin et al., 2003), curcin has an obvious antitumour effect and its mechanisms are related to the *N*-glycosidase activity. Other recent studies brought interesting new results. I. T. Matsuse (1998) claimed: *„The water extract of the branches of Jatropha curcas inhibited strongly the HIV-induced cytopathic effects with low cytotoxicity.“*

5.5.2 Toxicity of *Jatropha curcas* parts

All parts of *Jatropha curcas* are poisonous, but the highest concentration of toxins is in the seeds. The main reason for this toxicity is curcin, which is not only a medicine, but is a strong poison at the same time. The other toxic substances are phorbol esthers. The effects of consumption of seeds are gastroenteritic – vomiting, diarrhoea, abdominal pain, and burning sensation in the throat, according to Kulkarni et al. (2005). *„The toxic dose is not known. In some instances consumption of as few as 3 seeds has produced toxic symptoms“*. Cases of death are rare. The toxicity can be useful in agriculture. The oil and aqueous extract from oil has potential as an insecticide. For instance it has been used in the control of insect pests of cotton including cotton bollworm and on pests of pulses, potato and corn (Kaushik and Kumar, 2004).

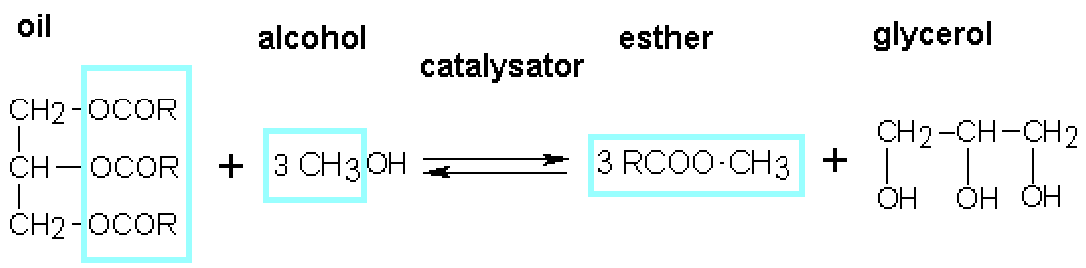
5.5.3 Oil and biodiesel properties

The possibility of using the plant oil for powering engines was the idea of Rudolf Diesel. In 1895 he invented the first diesel engine. He introduced it at the World exhibition in Paris in 1900 and as the fuel he used the oil made of peanuts. In 1912 he said: *„The use of vegetable oils (biodiesel) for engine may seem insignificant today. But such oils may become in course of time as important as petroleum and coal tar products of the present time."*

Plant oil can be used directly in some types of engines, but more often it is fabricated into biodiesel by transesterification (methylesterification or ethylesterification). Methylestefification means replacing of the alkoxy group of an ester with alcohol group of methanol or ethanol. During this reaction is glycerine and crude biodiesel are generated.

This crude biodiesel is purified and then mostly mixed with normal diesel. The blend named B30 is the most common and contains 30% of biodiesel. But also the diesel sold like normal diesel has to contain some percentage of biodiesel according to the new European law. From September 2007 the rate of biodiesel has to be 2%, from 2010 diesel will have to contain 5.75% of biodiesel, in 2015 it will be 8% and the last goal is to mix as much as 14% of biodiesel into normal diesel in 2020. Very little or no engine modification is required for blends up to 20% and only minor modification will be required for higher percentage blends, according to Kumar and Sharma (2008).

Picture 7 The formula of methylesterification



Source: University of Pardubice

These trends, which are aimed to slow down global warming, occur all over the developed world. But the demand for biofuels is so high, that it cannot be supplied from their own resources, which is why the majority is produced in developing countries. The plants used for the production of biofuels are, for example, corn and sugar cane (bioethanol), oil palm, soya beans, castor beans, sunflower, rape, and recently *Jatropha curcas* (biodiesel).

Jatropha curcas contains a non-edible, semi-dried triglyceride oil of a medium viscosity. According to the Royal Netherlands Academy of Arts and Sciences (2006), it was discovered that *Jatropha* oil has a significantly higher flashpoint (240ơC against 50ơC for diesel) and a slightly higher density in a direct comparison to diesel fuel. „*The higher flashpoint can be explained by the molecular structure, in particular, the high molecular weight of the triglycirides compared to the average molecular weight of the components contained in diesel. In order to broaden the use of these lipids s fuels, new technology is required to reduce the flashpoint. This potentially can be accomplished by applying* *familiar co-metathesis technology using low molecular weight olefins (like ethene, propene, butenes or pentenes)."*

The calorific value and cetane numbers are similar to the values for normal diesel. The big advantage of biodiesel in general is a low content of sulphur and heavy metals. In addition, it has a very good biodegradability (in a span of 21 days it degrades from 90%) (Sendzikiene, 2007).

For the simple press-machine which can be used for extracting of *Jatropha* oil, see Picture 20 (Appendixes). For the products which can be obtained from *Jatropha* seeds (oil, biodiesel, glycerol), see Picture 21 (Appendixes).

5.6 Advantages of *Jatropha curcas* growing for developing countries

Many experts in the *Jatropha curcas* field are very optimistic about the contribution of growing of *Jatropha curcas* on a rural economy and the wellbeing of farmers. The Society for Rural Initiatives for Promotion of Herbals (SRIPHL, 2007) summarized the economical effects of growing *Jatropha curcas* in this proclamation: *„Jatropha can help to increase rural incomes, self-sustainability and alleviate poverty for women, elderly, children and men, tribal communities, small farmers. (...) At the community level, farmers that produce dedicated energy crops can grow their incomes and grow their own supply of affordable and reliable energy. At the national level, producing more biofuels will generate new industries, new technologies, new jobs and new markets."*

German Development Cooperation (GTZ), which operated the *Jatropha* Project in Mali, promoted the integrated utilization of the *Jatropha* plant (as a hedge and an energetic plant at the same time). This integrated rural development system was called the *Jatropha* System, and it is based on four main principles: 1) use of renewable energy (oil for lamps, stationary motors), 2) erosion control and soil improvement, 3) promotion of women (through local soap production) and 4) poverty reduction (through income generation by way of trading soap, seeds, etc.) (Wiesenhütter, 2003). For scheme of *Jatropha* System, see Picture 22 (Appendixes).

R.K. Henning (1996), who directed the GTZ Jatropha Project, wrote: *„To illustrate this with a rough calculation, assume the average village of the pilot area has 15 km of Jatropha hedges, which represents 12 tons of seeds. These 12 tons of seeds may generate 1.800 USD of cash income when the oil is extracted and the products are sold"*. In this case the products can be: 9,000 kg of press cake (0.03 USD per kg * 9,000 = 270 USD), 2,400 litres of oil (0.60 USD per litre * 2,400 =1,440 USD) and 600 kg of sediment (0.15 USD per kg * 600 = 90 USD).

5.7 *Jatropha curcas* in Asia

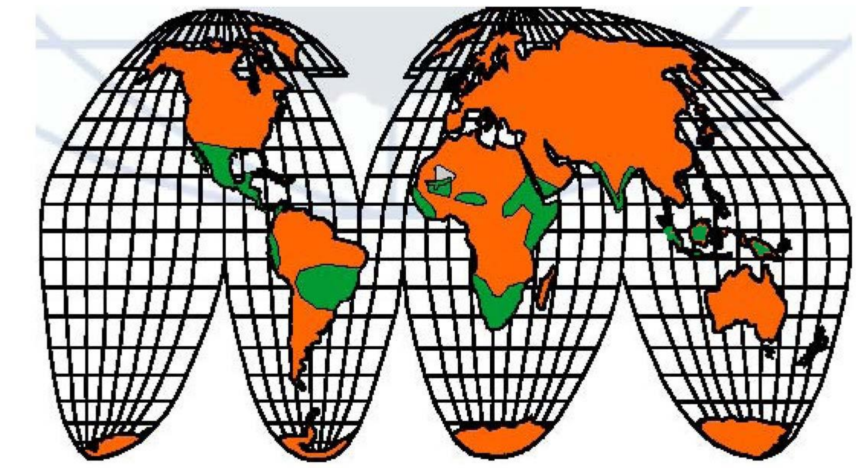
Nowadays, the empire of *Jatropha curcas* is India. Because of increasing energy consumption, the Indian government searched for some possibility to reduce the addiction to coal and petroleum. The Indian planning commission proclaimed the biodiesel made of the curcas oil as the best source of energy. The goal is to replace with it the 20% of India's diesel consumption by 2011. *Jatropha curcas* became the priority of national energetic programme. 400,000 km^2 of marginal land were selected to establish *Jatropha curcas* plantations there (Jatropha News Network, 2006). This opportunity was taken up by a British biodiesel company operating since 2005, D1 Oils. This company has large plantations all around the world and it is an important player on the market of this plant. According to the Economic Times (2007), the company intends to plant *Jatropha curcas* in 81,000 hectares of land together with two Indian partners. Some plantations will be held under the lease of this company, the other part of production will be ensured by the strategy of the Food Agricultural Organisation (FAO) - contract farming. The total area already cultivated by D1 Oils all around the world is about 200,000 hectares. Together with the other big partner, multinational oil company BP (formerly known as British Petroleum), it plans to have one million hectares of *Jatropha curcas* cultivation worldwide in four years.

China also plants *Jatropha curcas* in large quantities, but it is difficult to obtain specific information. According to Sun Xiaohua (2008), *Jatropha curcas* is currently grown on around two million hectares across the country. By 2010, China plans to plant an area the size of England (13 million hectares), with trees from which biofuel can be extracted (mainly *Jatropha curcas*). There are worries about forests of the southern provinces of China, because their biodiversity can be harmed by establishment of such large plantations.

Myanmar also intends to plant *Jatropha curcas* in large scale, according to Biopact (2006): *„The reclusive nation of Myanmar (Burma), which is governed by a ruthless military junta, hopes to replace all of its 40,000 barrels per day of conventional oil imports with a home-grown nut oil (Jatropha) within three years. The military regime is implementing a large-scale biofuel programme aimed at achieving oil independence"*. For this, the acreage of plantations has to reach 200,000 hectares. The human rights issue is a big problem here, because forced labour is used on these centrally planned plantations. Aside from this, special taxes are levied as a punishment for villages, which do not supply enough labourers.

The other Asian states, where *Jatropha curcas* is cultivated are Malaysia, Papua New Guinea, Laos, Cambodia, Vietnam, Thailand, Nepal, Sri Lanka, and many others (Henning, 2008).

Picture 8 Map of the spread of *Jatropha curcas* in the world



Source: Herák, 2008

5.8 *Jatropha curcas* cultivation in Indonesia

Jatropha curcas was introduced by the Japanese in 1942 in Indonesia. It was planted in gardens and used in lamps instead of kerosene. The Japanese used it as a fuel for war (Hambali et al., 2007b). Then no progress was done until recent years, when the possibilities of utilisation of *Jatropha* oil as a source of energy were rediscovered.

5.8.1 Distribution and current production of *Jatropha curcas* in Indonesia

Today *Jatropha curcas* is spread mainly on Java and Sulawesi. The other areas of cultivation of *Jatropha curcas* are: Nusa Tenggara Timur (East Nusa Tenggara - Flores, Sumba, and West Timor), Nusa Tenggara Barat (West Nusa Tenggara - Lombok and Sumbawa), Gorontalo (on Sulawesi), Bengkulu (on Sumatra), Sumatera Selatan (South Sumatra), and Lampung (on Sumatra). On Kalimantan and Papua the suitable areas are being searched (Sudradjat, 2006).

5.8.2 Role of the state on *Jatropha curcas* cultivation

Nowadays there are big efforts to decrease the dependence on petroleum, which has to be imported in large quantities. In the first half of 2006 the production of petroleum was 1.029 million barrels per day, but the consumption reached 1.3 million barrels per day. The deficit (270,000 barrels per day) represented the costs 18.9 million USD per day, at the price of one barrel equalled 70 USD (Hambali et al., 2007a). Now the prices are above 110 USD per barrel, which is why the Indonesian government intends to replace the part of diesel consumption with biodiesel. Although by far the greatest part of biodiesel is made from palm oil, the importance of *Jatropha curcas* is growing fast.

According to Charles Mkoka and Mike Shanahan (2005), the heads of six major energy companies gathered on March 2005 with the governor of the central bank, a dozen cabinet ministers and representatives of universities and local development organisations to sign a declaration supporting government plans to produce *Jatropha* oil on a large scale. *„According to the plan, by 2009 Indonesia will have ten million hectares of Jatropha plantations, each hectare yielding enough oil to produce 1,000 litres of biodiesel a year.“* The main goal is the use of *Jatropha* oil or biodiesel instead of fossil fuels in power plants managed by Perusahaan Listrik Negara (PLN, State Electricity Company), the state electricity company. The support investments of Clean Development Mechanism (one of the flexible mechanisms of Kyoto Protocol) are taken into account in this plan. This mechanism allows industrialised nations to offset their emissions of greenhouse gases by investing in non-polluting projects in developing countries.

The declaration issued in October 2005 (Declarasi Bersama) determined 10 million hectares of critical land, which should be rehabilitated by planting of *Jatropha curcas* (Sudradjat, 2006).

In 2006 president Susilo Bambang Yudhoyono set up two important decrees in this area. This year the Energetic Era II begins, characterised by the major focus on the use of renewable energies (Hambali, 2007a).

The presidential decree no.5 of 2006 concerned the National Energy Production and made production of biodiesel official policy. It stated goals, which should be attained by 2025. 17% of the total energy consumption should originate from renewable resources. Biodiesel should constitute 20% of total diesel consumption (Hambali, 2007a). For this to happen, Indonesia has to reach a production capacity of 10.22 million kilolitres of biodiesel (Maio, 2007).

By decree no.10 of 2006, a National Team for Biofuel Development (Tim Nasional Bahan Bakar Nabati, Timnas BBN) was set up, according to Jacqueline Vel (2008). *„The terminology of the decree indicates a top-down approach reminiscent of the New Order (the regime of President Suharto). Biofuel promotion includes the creation of 'self-sufficient energy villages', but the bulk of policy is geared towards the macro level, where consumption targets are set and where national legislation should be adapted for 'simplification of licensing issues',"* she wrote.

On 9 January 2007, 67 contracts were signed under the supervision of TIMNAS BBN. It is estimated that it will bring 17.4 billion USD for investment in the renewable energy sector. 5 billion USD will come from Indonesia's banks, and the rest will be provided by domestic and foreign companies. The main foreign investors are China, Malaysia, Japan, Brazil, and South Korea (Maio, 2007).

The biggest investors will be China and Malaysia. On April 2007, the new Investment Law was issued. It supports foreign investments because it permits foreign investors to buy land in Indonesia; it offers tax incentives and the possibility of creating special biofuel production zones. *„Some national parliamentarians protested that the legislation meant 'Indonesia is for sale'. They argued that the law provides inadequate protection to local* *entrepreneurs, and that the equal status it grants to foreign and domestic investments shows the government's historical apathy toward Indonesia's colonial past (Vel, 2008) .“*

5.8.3 Future plans for *Jatropha curcas* production

Table 2 shows the plans of the Indonesian government for setting-out of *Jatropha curcas* plants from 2006 to 2010 according to Indonesian provinces. The achievement of these goals was supported by government subsidies. The biggest acreage of *Jatropha curcas* should be on Sulawesi in 2010, according to this table.

Table 2 Plans for setting-out of *Jatropha curcas* plants from 2006 to 2010 by provinces [ha]

Province	2006	2007	2008	2009	2010	Total
Nusa Tenggara Timur	5,000	50,000	51,500	54,000	56,250	216,750
Nusa Tenggara Barat	5,000	50,000	51,500	54,000	56,250	216,750
Nusa Tenggara Total	10,000	100,000	103,000	108,000	112,500	433,500
Gorontalo	4,000	34,000	34,500	36,000	37,500	146,000
Sulawesi Utara	4,000	34,000	34,500	36,000	37,500	146,000
Sulawesi Selatan	4,000	25,000	24,500	25,200	26,250	104,950
Sulawesi Tenggara	3,000	25,000	24,500	25,200	26,250	103,950
Sulawesi Tengah	3,000	25,000	24,500	25,200	26,250	103,950
Sulawesi Total	18,000	143,000	142,500	147,600	153,750	602,850
Jawa Barat	2,000	14,000	14,500	14,400	15,000	59,400
Banten	1,500	10,000	10,000	10,800	11,250	43,550
Jawa Tengah	1,500	10,000	10,000	10,800	11,250	43,550
Jawa Timur	2,000	14,000	14,000	14,400	15,000	59,400
Jawa Total	7,000	48,000	48,500	50,400	52,500	205,900
Papua	5,000	50,000	51,500	54,000	56,250	216,750
Total	40,000	341,000	345,000	360,000	375,000	1,461,000

Source: Sudradjat, 2006

6 OIL PALM

6.1 General overview

Oil palm (*Elaeis guineensis Jacq.*) is a monocotyledonous plant, which belongs to the *Arecaceae* family, order *Arecales*. Two species of oil palm exist: *Elaeis guineensis*[2] is native to West Africa, while *Elaeis oleifera* comes from Central and South America. Nowadays African oil palm is widely cultivated, while American oil palm is relatively rare (Rarepalmseeds.com, 1997).

On Sumatra Island occurs the most important species of palm oil, *Elaeis guineensis*. The botanical name of *Elaeis guineensis* is derived from the Greek *elaion*, which means oil (the main product of oil palm). The specific name of guineensis indicates its Guinean origin (World Agroforestry Centre, no date)**.** The Indonesian name of oil palm is Kelapa sawit (Hambali, 2007a).

The origin of oil palm is West and Central Africa. Oil palm was first reported by the Portuguese sailor Eannes in 1434 and one of the earliest illustrations of the oil palm tree was made in 1763 by Nicholaas Jacquin. That is why he is remembered in its scientific name (Cyberlipid center, 2008).

In Africa, the main oil palm belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo, according to FAO (2002). „*Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavoured, is an essential ingredient in much of the traditional West African cuisine. The traditional process is simple, but tedious and inefficient.*" Outside Africa, oil palm was

2 The synonym in use for Elaeis guineensis Jacq. is Elaeis melanococcana Gaertn. Simultaneously, it has a lot of vernacular names: si-htan, si-ohn (Burmese); crocro, crocro guinee (Creole); African oil palm, guinea oil palm, oil palm, wild oil palm (English); corojo de Guinea, corossier, crocro, Crocro guinee, palmier a huile (French); olpalme, Steinfruchte (German); mubira, munazi (Luganda); kelapa sawit (Malay); tango, tee, tego, tengo (Mandinka); coroco, corojo de Guinea, corozo (Spanish); mchikichi, miwesi, mjenga (Swahili); pan namman (Thai). (World Agroforestry Centre, no date)

first introduced to Java by the Dutch in 19th century and later to Malaysia (1910) by the Britons (Rieger, 1990).

Mark Rieger (1990) affirmed that the first plantations of oil palm were established on Sumatra in 1911 and in 1917 in Malaysia. About this time oil palm plantations were also established also in tropical America and West Africa.

In 2003, palm oil production equalled the production of soybean, and became the number one oil crop. Nowadays about 85% of total palm oil production is situated in Indonesia and Malaysia (Green Car Congress, 2006).

6.2 Botanical description of oil palm

Oil palm can attain a height of 20 m or more at maturity. Its modified stem, called a pseudostem, is characterized by persistent, spirally arranged leaf bases. It bears a crown of 20-40 massive pinnate leaves (World Agroforestry Centre, no date). Each leaf can reach the length of 3 to 5 meters and it has about 250 leaflets in an irregular pattern on both sides of the petiole (Kashaka Information Systems Services and Networking, 2008). For oil palm habitus, see Picture 9, for oil palm tree and its parts, see Picture 23 (Appendixes).

Picture 9 Oil palm

Source: FAO, 1977

Similar to *Jatropha curcas*, the plant is monoecious, and it has racemose inflorescence. The inflorescence contains usually either male or female flowers, but sometimes it can be mixed. *„Inflorescences arise among the leaf bases in large, very dense clusters, with innumerable small flowers, enclosed in the bud stage in 2 large fibrous bracts, which finally become deciduous. Male flowers single or in pairs in recesses on the branchlets, each with 3 sepals, 3 petals with edges touching in bud, 6 stamens, and a small, sterile pistil. Female flowers subtended by 2-3 small bracts, with 3 sepals, 3 petals overlapping in bud in a ring of small, sterile stamens, and a 3-celled ovary with 3 spreading stigmas (World Agroforestry Centre, no date).“*

The infructescence can weigh 10 to 40 kg and contains 800 to 2000 fruits. Fruit type is drupe (FAO, 2002). One palm can bear 5 – 10 infructescences a year. The single fruit shape is ovoid or elongated. Its colour is dark, almost black before it ripens and orange red when ripe. The fruit has one seed (the kernel) (Kashaka Information Systems Services and Networking, 2008). For an average production of Fresh Fruit Bunches (FFB) from 3 to 19 years of plantation, see Table 22 (Appendixes).

Picture 10 The infructescence of oil palm

Source: Herák

„The individual fruit, ranging from 6 to 20 g, are made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix; a central nut consisting of a shell (endocarp); and the kernel, which itself contains an oil, quite different to palm oil, resembling coconut oil (FAO, 2002).“ For detail of seed, see Pictures 24 and 25 (Appendixes).

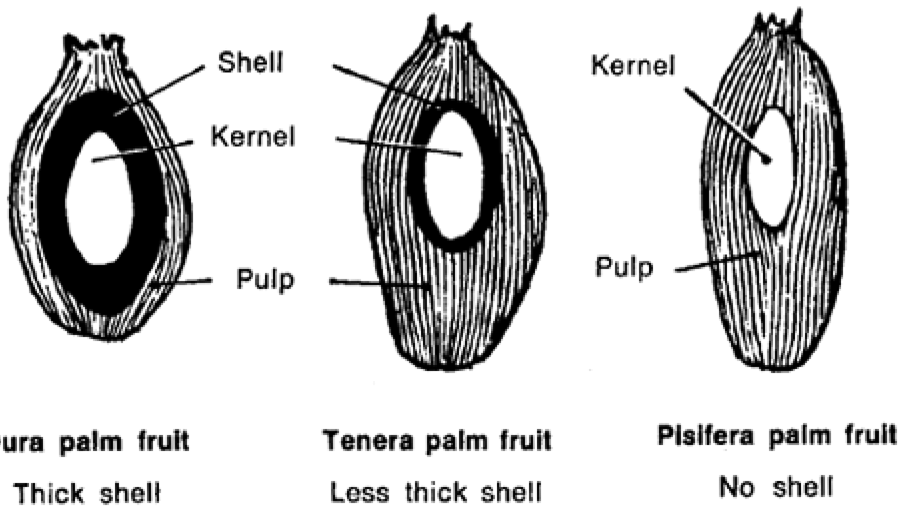
It could be either wind pollinated (anemophilous), or insect pollinated (entomophilous), according to Corley (1976). *„Due to presence of only one growing point, male and female inflorescences follow each other in time and only rarely will two inflorescences reach anthesis simultaneously on one palm. Thus cross-pollination is usually ensured,“* he wrote.

Bunches ripen 5 to 6 months after pollination (Diemer, 2004). From one palm as many as 2,000 fruits a year can be obtained. The production starts three to four years after plantation. The first crop is too small to harvest it. The plant reaches its production peak from 12 to 15 years of age and, like *Jatropha curcas,* it can bear until the age of 50 years, theoretically (Roecklein and Leung, 1987). In nature it can live longer than 150 years and reach the height of 25 meters. But cultivated palms are normally cut or poisoned when they are about 25 years old and around 10 meters high (Mongabay, 2007).

6.3 Varieties of oil palm

Three varieties of African oil palm exist – Dura, Pisifera and Tenera, according to FAO (2002). *„The wild oil palm groves of Central and West Africa consists mainly of a thick-shelled variety with a thin mesocarp, called Dura. Breeding work, particularly crosses between Dura and a shell-less variety (Pisifera), have led to the development of a hybrid with a much thicker mesocarp and a thinner shell, termed Tenera.“* Tenera is a commercially cultivated variety.

Picture 11 Varieties of oil palm

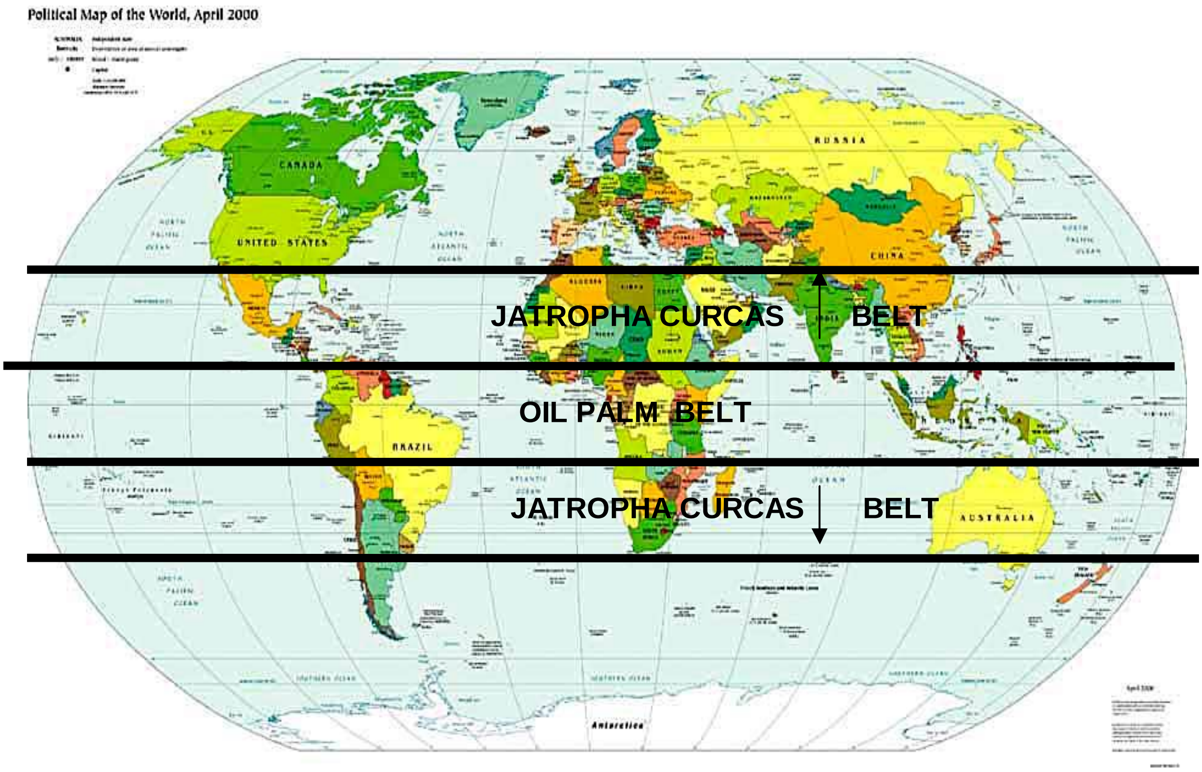


6.4 Ecology of oil palm

According to World Agroforestry Centre (no date): „ *It is difficult to determine the natural habitat of the oil palm because, while it does not grow in primeval forest, it flourishes in habitats where forests have been cleared. It requires a relatively open area to grow and reproduce itself and thrives best when soil moisture is maintained. Normally, E. guineensis occurs in disturbed forests and along rivers and streams, both in its native range in West Africa and in some introduced areas.*“ The ecological requirements are much higher than in the case of *Jatropha curcas*. The optimal mean annual temperature is 27 to 35oC, the optimal rainfall varies from 2000 to 3000 mm per year. Rainfall has to be evenly distributed with no month having rainfall below 150 mm. It thrives in altitudes up to 900 m (World Agroforestry Centre, no date). Like *Jatropha curcas*, it needs well drained soils, but it is dramatically more demanding for soil fertility.

Regarding altitudes, palm oil thrives well between 4oN and 8oS, while for growing of *Jatropha* trees a wider belt is suitable (from 30oN to 35oS), according to R.E.E. Jongschaap (2007).

Picture 12 Map of *Jatropha curcas* and oil palm belt



Source: Setyaningsih, 2007

6.5 Uses of oil palm

Oil palm is above all the most productive oil crop. For comparison of its productivity with other oil bearing crops, see Table 23 (Appendixes). There are two types of oil, extracted from oil palm fruit. Palm kernel oil (PKO) is pressed from endocarp (the seed) and it has a variety of industrial uses. But the main product of *Elaeis guineensis* is crude palm oil (CPO), obtained from mesocarp, which is the world's second major vegetable oil, after soybean (see table below).

Table 3 World production of oils in 2001

Type of oil	World production [t]
Soybean oil	27,829,000
Palm oil	23,575,000
Rapeseed oil	13,743,000
Tallow	8,195,000
Total (all 17 oils)	117,520,000

Source: Palm Oil World, 2002

Contrary to *Jatropha* oil, it is edible and so plentifully used in food industry. According to CER Srl (2007), it is cholesterol free and rich in vitamins A and E. It can be used for production of margarine and cooking fat. The other utilisation is in manufacture of biscuits, ice creams, soaps, detergents, and shampoos and also as frying fat.

Aside from this, palm oil is used for making of soaps, detergents, candles, cosmetics, lubricating greases, glues, printing inks, PVC, in textile and rubber industries, and so on. Both of these types of oils are used in chemical industry to get products such as fatty acids, fatty esters and fatty alcohols. In recent years the importance of palm oil has decreased mainly because of its utilisation as a biodiesel feedstock (Fedepalma, no date).

Apart from oil, there are also other products obtained from oil palm. Press cake can be used as livestock feed. The sap obtained from male inflorescence serves for making palm wine. *„The sap ferments quickly, and is an important source of Vitamin B complex in diet of people of West Africa. A mean annual yield per hectare of 150 palms of 4,000 litres is obtained, and is double in value to the oil and kernels from same number of palms.“* Central shoot or cabbage is eaten as a vegetable. Leaves are used for covering of roofs, petioles for fencing. The residues after stripping the infructescences can be used for mulching and manuring (Purdue University, 1996). Chipboard and plywood is produced from leaf fibres and empty fruit bunches. After plantations are cleared out, the trunks of old palms can be used to make furniture (Fedepalma, no date).

6.6 Oil and biodiesel properties

Palm oil is rich in carotenoids, from which it derives its deep red colour. *„The major component of its glycerides is the saturated fatty acid palmitic, hence it is a viscous semi-solid, even at tropical ambient, and a solid fat in temperate climates (FAO, 2002).“*

„In terms of plasticity of the natural oils and fats, palm oil has one of the highest melting points (Corley, 1976).“ It melts from 25 to 50°C (Purdue University, 1996).

For the summary of physical properties of *Jatropha curcas* and oil palm biodiesel, and diesel fuel, see Table 24 (Appendixes).

6.7 Oil palm cultivation in Indonesia

According to Derom Bangun (2006), oil palm was brought to Bogor (West Java) as an ornamental plant by the Dutch in 1848. At the beginning the oil was used only for soap production. The first plantations (in the world) were started in 1911 on the east Coast of Sumatra Island. Later also the production of palm oil started. *"By 1969, Indonesia produced 180.000 tons of palm oil and around 40.000 tons of palm kernels. Small quantity of palm oil might be used in domestic market and the balance was exported,"* he wrote in his study for National Institute of Oilseed Products. There did not exist any palm oil refinery or palm kernel crushing plant in Indonesia until late 1970's, therefore nearly whole production was exported. At first, palm cultivation was done by large plantation companies only. In 1974 the high price of palm oil in the international market (around 700 USD per ton) recruited small private companies and farmers to gain this business. Previously they chose to grow coconut or rubber trees because these crops were easily marketed, while for oil palm fruit bunches there was no local market. In 1975, the government founded a scheme called Nucleus Estate Scheme (NES), where state-owned plantation companies helped farmers with oil palm growing. They provided them seedlings and technical and financial assistance. In return farmers sell their crops to companies' mills. Thanks to this scheme there are not only large private (both foreign and domestic), and state owned companies involved in oil palm cultivation, but also the small holders do. According to Maryadi et al. (2004), there were 66.64% of plantations conducted by NES farmers, and 31.97% by private large-scale companies in South Sumatra in 2002. Only

0.26% of plantations were owned by public large-scale companies, and 1.13% by small holders. The expansion of area of palm oil plantation according to estate type in years 1975 to 1994 is shown in Table 25 (Appendixes).

6.7.1 Distribution and current production of oil palm in Indonesia

The oil palm plantation is no longer situated only on northern part of Sumatra Island but has diffused to Kalimantan (Borneo), Sulawesi (Celebes) and Irian Jaya (Papua), too. The acreage of oil palm on Java is the lowest of the main Indonesian islands. For the area of palm oil plantation in various provinces in 2006 see the table below.

Table 4 Area of Oil Palm Plantation by Provinces in 2006

Province	Area [million ha]
Nangroe Aceh Darusalam	0.22
North Sumatra	0.68
West Sumatra	0.20
Riau	1.40
The Rest of Sumatra	1.25
Total Sumatra	3.75
West Kalimantan	0.46
Central Kalimantan	0.34
South Kalimantan	0.20
East Kalimantan	0.20
Total Kalimantan	1.20
Sulawesi	0.12
Irian Jaya (Papua)	0.06
Java	0.02
Total	5.15

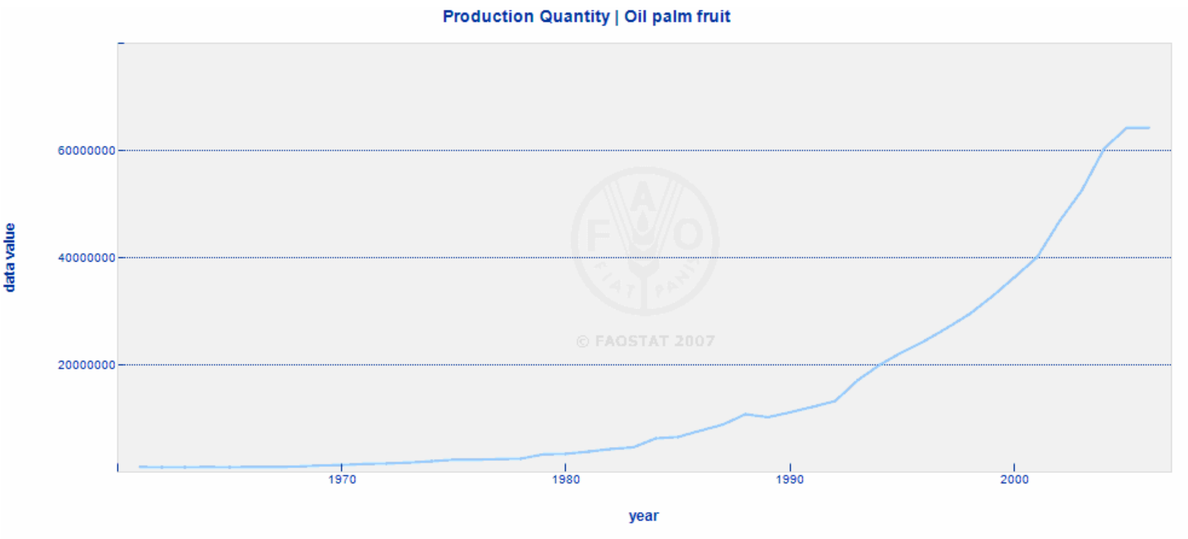
Source: Bangun, 2006

Out of the total cultivated area (5.15 million ha) about 4.15 million ha is mature or productive and the rest (1 million ha) is immature (Bangun, 2006).

Production of palm oil in Indonesia increased dramatically from 1975 until now. In 1975 it was about 400,000 tons of oil, twenty years later, in 1995 it was more than 4.4 million tons and in 2005 it reached 15 million tons of oil (Bangun, 2006). For the volume of production of CPO and PKO in Indonesia from 2001 to 2005, see Table 26 (Appendixes).

In Figure 1 the growing production of oil palm fruits in Indonesia is shown. The last value corresponds to year 2006, when 64,255,300 tons of oil palm fruit was produced.

Figure 1 Production of oil palm fruits in Indonesia, 1960 – 2006 [ton]



Source: FAOSTAT, 2007

In 2005 Indonesia was the biggest producer of palm oil in the world, but the second largest exporter (after Malaysia). The reason is that a relatively big part of palm oil is utilized for domestic food uses. The five biggest producers of palm oil and their values of export, import and domestic consumption in 2005 are shown in table below (Index Mundi, 2006).

Table 5 Palm oil statistics 2005 [1,000 t]

	Country	Beginning Stocks	Production	Imports	Exports	Industrial Domestical Consumption	Food Use Domestical Consumption	Feed Waste Consumption
1	Indonesia	750	15,000	5	10,500	500	3,875	80
2	Malaysia	1,636	14,800	400	13,100	1,900	636	200
3	Nigeria	26	800	210	4	200	805	0
4	Thailand	48	800	50	100	270	411	66
5	Colombia	12	690	16	220	60	413	15

Source: United States Department of Agriculture (from Index Mundi, 2006)

Approximately two thirds of palm oil production was exported in 2005. Major importers were India, the Netherlands, China, Pakistan, Bangladesh, the United Kingdom and Malaysia (Bangun, 2006).

According to the new energy policy of Indonesia, about 40% of CPO should be allocated for biodiesel production (Green Car Congress, 2006). But this intention is difficult to ensure, because for palm oil refineries it is much more profitable to sell the oil as food industry raw material than as the biodiesel feed-stock. There are no exact numbers, to show how much palm oil is truly used for biodiesel production.

6.7.2 Export taxes of palm oil

As the big part of palm oil produced in Indonesia is used for domestic consumption in food industry and the world prices of this commodity are growing, it is necessary to maintain the domestic prices artificially. *„The government currently uses three policy tools to affect domestic prices: 1) an export tax; 2) buffer stock operations; and 3) directed sales from public estates (Larson, 1996).“*

A huge increase of export taxes was used in 1998, for example. Around this time, when the international price of Crude Palm Oil (CPO) reached 600 USD per metric ton (CIF Rotterdam) and the Indonesian currency was weakened, the tariff of the export tax was increased to 40% (from 15%). *„Even such a high export tax was not sufficient to bring the local price of cooking oil to the expectation of the public.“* That is why the government increased the tax to 60%. That means, that the exporter received only 240 USD per ton (remaining 360 USD was the export tax). Later, as the price of CPO in international market declined and the Indonesian currency gained better exchange rate, the tax was reduced to 30%, then to 10%, then 5%, and to 3% in the end (Bangun, 2006).

6.7.3 Impact of palm oil plantation on deforestation

Indonesian forest constituted 2.7% of total world forests area in 2000. Total forest area in Indonesia was 104,986,000 hectares, and it comprised of cca 90% of natural forest area (95,116,000 hectares) and 10% of tree plantations (9,871,000 hectares). In the period from 1990 to 2000 the natural forest area decreased by 11%, while the area of plantations increased by 3%. The plantations, which are replacing the rain forest are mainly oil palm ones, but they certainly are not the only reason for deforestation. Equally or more important is logging, mining and obtaining of other products from the areas rich for natural resources. The exports of forest products reached the value of 4,583,498 thousand USD in period of 1996-1998, whereas the imports were only 903,805 thousand USD. This means that trade balance was positive, with the value of 3,679,693 thousand USD (World Resources Institute, 2003).

Deforestation on the two most threatened Indonesian islands Sumatra and Kalimantan (Borneo) is shown in the Pictures 26 and 27 (Appendixes). The general threat to Indonesian rain forests is best shown in the Picture 28 (Map of distribution of logging concessions, Appendixes).

Anne Casson (2000), the expert from Centre for International Forestry Research in Bogor, wrote that from 1967 to 1997 oil palm was one of the fastest growing sub-sectors of the Indonesian economy. This fact influences the situation in Indonesia not only in positive way, but it has also many harmful effects, mainly referring to the environment. *„While the growth of the oil palm sub-sector has conferred important economic benefits, it has posed an increasing threat to Indonesia's natural forest cover. Local communities have also been displaced by the large scale oil palm plantations and social conflict has resulted,"* she wrote.

Besides the Indonesian environment, the global environment is worsened, too. *„According to a 1993 World Bank report, Indonesia contributed between 1.6% and 1.8 % to the* *world's greenhouse gas emissions. Of this amount, about 75.9% result from changes in land use, 12.0% from energy use, 8.5% from methane emission and 3.6% from CFC's (UNDP, 1999).“*

According to the brochure of Wetlands International and Delft Hydraulics (2006), Indonesia was the third largest producer of GHGs after United States of America and China. The main cause of the production of GHGs in Indonesia (included in changes in land use) is this deforestation. More than 26% of oil palm concessions in Indonesia are in peat lands, where huge quantities of organic materials are stored, because of halted decomposition (by the absence of oxygen). Production of one tonne of palm oil results in emissions about 20 tonnes of CO_2 from peat decomposition alone (if fire exhalations and other sources of CO_2 during the process of palm oil production are not counted). That is why Indonesia emits 6.5 more CO_2 from degraded peat lands as it does from burning fossil fuels. Peat fires also cause the serious health problems.

Also, the burning of the forests causes a lot of forest fires. In 1997 more than 5 million hectares of forest were destructed by fire, which was caused mainly by their conversion to palm oil plantations (Forest Protection Portal, 1998).

There are two laws which restrict the conversion of forests to palm oil plantations, but there were set forth very lately. In 1999 the law on forestry no.41 was promulgated and the law on plantation was only introduced recently, in 2004. These two laws allow only certain forests to be cut down because of plantation. *“With those new laws already in place, the government has been taking measures to control the protection of forest and also endangered animals (Bangun,2006).“*

Another response to damaging the environment by palm oil plantations was the establishment of a forum called Roundtable on Sustainable Palm Oil (RSPO). The members are all stakeholders - companies involved at all stages of the palm oil industry and environmental and social non-governmental organizations. It was founded on 8th of April 2004. The seat is in Zurich and the secretariat is based in Kuala Lumpur. One of the fundamental rules of this organisation is that new plantations can not be established on places where the forest has been cut down after November 2005 (RSPO,2007). This theoretically means that after this date no forest can be replaced by oil palm plantations, but the reality is different.

„*So, in the long run, the production of palm oil in Indonesia can be sustainable with the purpose of fulfilling the world demand and at the same time provide job opportunities and improving the standard of living of 220 million of population which is still far behind those of many other countries,*“Derom Bangun (2006) stated.

6.8 Comparison of *Jatropha curcas* and oil palm cultivation in Indonesia

The cases of *Jatropha curcas* and oil palm differ in many aspects. We have to take in account mainly the fact, that *Jatropha curcas* cultivation is carried out generally in small holders conditions and on demonstration plots, because the cultivation practices aren't well explored and the market is not yet developed. On the contrary, palm oil cultivation has a long history in Indonesia and nowadays it is grown mainly on large scale plantations under the control of big corporations. The way into oil palm business is closed to small farmer newcomers, because it is fully controlled by big (mainly foreign) corporations. On the contrary there is no obstacle to start *Jatropha curcas* plantation, since it is supported by state by Presidential Decrees described in Chapter 5.8.2. The other differences are mentioned in Discussion.

7 RESULTS: PRODUCTION ANALYSIS OF *JATROPHA CURCAS* IN COMPARISON WITH OIL PALM

In this chapter, the task of profitability and feasibility of *Jatropha curcas* cultivation under specific social and economic conditions of small-holders will be discussed. Data used come from Bogor Agricultural University, Ing. David Herák Ph.D. and Satya Simanjuntag, SE, as mentioned in Methodology. For an idea of costsingness of *Jatropha curcas* seedling production, establishing and maintaining the plantation, harvesting and handling of seeds, the basic operations are described and compared with oil palm cultivation practices. It is important to understand that there are described ideal practices, which often significantly differ from the practices used in reality. The cultivation of *Jatropha curcas* is a new matter for the farmers and is often done in a very extensive way without dealing with recommended procedures.

7.1 Cultivation practices of *Jatropha curcas* in comparison with oil palm

7.1.1 Site preparation

Jatropha curcas is not demanding even for land preparation. It consists of only three basic processes: land clearing, marking and making seedling holes. Tools needed for land clearing are hoe, bush or grass knives, axes, spade or shovel, chainsaw (felling of trees), wheelbarrow (to transport cleared vegetation), and bamboo or wood stake (marking and making the seedling hole) (Hambali,2007b, Diemer,2004). In case of heavy soil deep ploughing is recommended (NIIR Board of Consultants and Engineers,2008). The site preparation of *Jatropha curcas* field requires about 14 days (Simanjuntag,2008). As to preparing the land for oil palm cultivation, the situation is similar. It also is not exacting for land preparing activities. If it is necessary to cut down the tropical forest, it is more complicated than land clearing of marginal soils used for *Jatropha curcas* cultivation, of course, but obtained wood products make this operation highly lucrative. Also burning is used often. The advantage of both these both crops in contrast to many other oil-bearing crops is their perennial growth. Once the plantation is established, there is minimal need of land cultivating practices.

7.1.2 Establishment of plantation

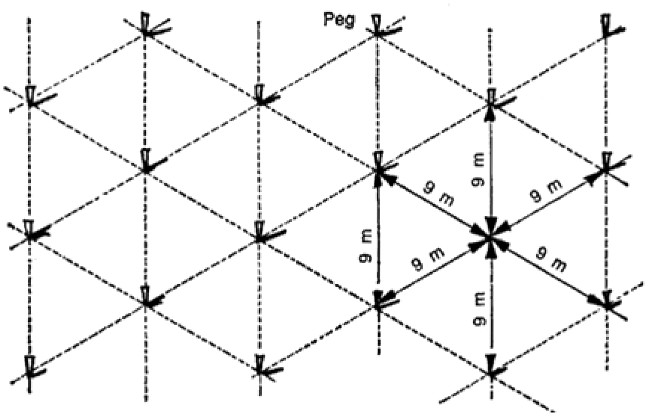
The methods of establishment of *Jatropha curcas* plantation are direct seeding, pre-cultivation of seedlings (nursery raising), transplanting of spontaneous wild plants and direct planting of cuttings. Their choice varies from region to region and also depends on climatic conditions (Heller, 1996). In Indonesia the most used method is the pre-cultivation of seedling in polybag filled with soil and manure (Herák, 2008). Two to three month after sowing, when the seedling attains the height more than 30 cm, it can be removed to the final station. Planting is done at the beginning of rainy season, from June to August (Hambali, 2007b; NIIR Board of Consultants and Engineers, 2008). It takes about 3 days to plant one hectare of *Jatropha curcas* field (Simanjuntag, 2008).

Also in the case of oil palm, farmers have to buy the planting material from companies specializing in breeding of this crop. The main reason is that seeds of commercially cultivated oil palm are produced by controlled crosses of *dura* and *pisifera* variety. This way F1 hybrid seed of *tenera* type is obtained (Mark Rieger). This has to be done expertly for obtaining the optimum results. The second difficulty is that oil palm seed goes through a period of dormancy, which has to be termined by heat treatment. It is a difficult process and that is why almost all seeds are sold to customers already germinated and ready for planting. As well as in the case of *Jatropha curcas*, it is important to schedule the planting to the beginning of the rainy season (Diemer, 2004). The price of oil palm seedling is similar to *Jatropha curcas* seedling (about 1,000 IDR/piece). If counted the population of 148 plants per hectare, the total purchase price of seedlings is 148,000 IDR, which is much lower than in the case of *Jatropha curcas* (Herák, 2008).

Jatropha curcas and oil palm nurseries and plantations are shown in the Pictures 29 to 32 (Appendixes).

Other important aspect when establishing the plantation is the planting pattern. The most frequently used planting patterns for *Jatropha curcas* are four: 3x3 m (1,039 plants/ha), 2x3m (1,600 plants/ha), 2x2 m (2,500 plants/ha) and 1,5x2m (3,300 plants/ha) (Hambali, 2007b). Wider spacing (3 m × 3 m) is reported to give larger yields of fruit, at least in early years (Heller, 1996). The oil palm planting patterns are shown in the Picture 13. The most frequently applied pattern is that with triangular distribution of plants, placed nine meters apart. This way the density of 148 plants/ha is achieved. This system allows maximum utilization of the land, nutrients, water and sunlight (Diemer, 2004).

Picture 13 Triangular oil palm planting pattern



Source: FAO, 1977

7.1.3 Maintenance of plantation

In Indonesian conditions it is not profitable or necessary to irrigate *Jatropha curcas*. As well in the case of oil palm irrigation is not practiced usually (Herák, 2008). For ensuring better moisture conservation, mulching is recommended (Diemer, 2004).

Weeding of *Jatropha curcas* plantation should be done in the early stage (three to four weeks of age of plantation) to avoid the competition of young plants with the weed. It is done usually manually by hoe, but it can be done also mechanically by harrow, or chemically using herbicides, according to Erliza Hambali (2007b). But mostly it is not pursued at all. Also in oil palm a plantation weeding is important mainly in first years, when light harrowing is recommended (NIIR Board of Consultants and Engineers, 2008). Later mainly the circle around the palm with radius about two meters is weeded. A good way to reduce weed growth is the use of organic mulch, which could be fallen or pruned leaves, and empty fruit bunches (Diemer, 2004). In both cases, special tools or mechanisation are not needed, the greatest part of weeding costs is constituted by the costs of labour.

Information about fertilising of *Jatropha curcas* is insufficient, recommended doses is not available yet. It's useful to carry it out 2 times a year (in the beginning and in the end of rainy season). The dose should be composed of some source of organic matter (manure, compost), and mineral fertilisers as additive source of nitrogen, phosphorus, kalium and magnesium (Hambali, 2007b). The price of mineral fertilizers and pesticide is very low in Indonesia, that is why it is used in huge quantities in belief that „the more the better“ (see Figure 5). This approach can be very harmful to the environment. Otherwise, in the case of *Jatropha curcas* it can be enough to use just barnyard manure (Herák, 2008). Successful trials were held with fertilising *Jatropha curcas* with the *Jatropha curcas* seed cake (the by-product obtained by pressing the seeds) (Jongschaap et al., 2007).

Jatropha curcas is not susceptible to pests, although in larger plantations different types of worms, grasshoppers, stem borers, caterpillars, mites and bugs can occur. Also bacterial diseases can emerge (Hambali et al., 2007b). As well as inorganic fertilisers, the pesticides are very cheap in Indonesia and the problem is not their lack, but their excessive use in some cases. In the case of *Jatropha curcas* pest and disease control also the second extreme is common – the absence of pests and disease control.

Pruning is done to increase the number of productive bunches and to maintain the height of tree optimal for harvesting. It should be done periodically (Hambali, 2007b). But in general this practice is not carried out. At oil palm plantations, it is important to maintain healthy palm canopies by removing old, dead, damaged and diseased leaves (Diemer, 2004).

7.1.4 Harvesting

The fruits ripen 90 days after flowering, but the plant flowers throughout the year. *„Continuous flowering results in a sequence of reproductive development stages on the same branch, from mature fruits at the base, to green fruits in the middle, and flowers at the top of the branch. This is problematic for mechanized harvesting (Jongschaap et al., 2007).“* It has to be done manually with picking the ripened fruits only. Fin order to be profitable, it is done when at least 50% of the fruits are ripe (Hambali, 2007b). The only tool needed is only a knife that is why the main part of harvesting costs is the costs of labour. If counted the harvest time of one tree as three minutes and the density of 1,089 plants per hectare, then 54.45 hours for one harvest are necessary. The working day in Indonesia could be 12 hours long, so 4.54 days are needed for one harvest. If three harvests are done during the year, 13.62 man-days are necessary.

Oil palm starts to bear in 3 to 4 years after planting in the field, but the harvest may be small and of poor quality. Harvesting is usually done once a week, for ensuring the continuous supply to refinery. Tools needed for harvesting oil palm fruits are a knife on a pole (e.g. wood or aluminium) for cutting ripe fruit bunches or chisels and a rope and ladder to reach the fruit. On large scale plantations a mechanisation is often used. Corley (1976) wrote: *„The use of power driven cutters on a moveable arm may be feasible, possibly with a device to catch and lower the bunch to the ground to prevent fruit scatter and bruising.“* Nowadays more methods of mechanised harvest have been developed, for example a device, which shakes fruits out of a tree (Herák, 2008). This means, that the costs of tools and mechanization are higher, but the costs of labour are lower, as it is much less labour demanding.

7.2 Summary of costs of *Jatropha curcas* growing

In this chapter a review of *Jatropha curcas* plantation costs will be performed. At first the costs of *Jatropha curcas* nursery will be examined, then the costs of plantation will follow.

7.2.1 Costs of *Jatropha curcas* nursery

The summary of costs of *Jatropha curcas* nursery in Indonesian conditions was elaborated by Surfactant and Bioenergy Research centre of the Bogor Agricultural University. In this case 125,000 seeds are sowed, the germination probability is rated as 80%, and consequently 100,000 seedlings are produced (Hambali et al., 2007).

Table 6 *Jatropha curcas* nursery: Costs of labour per one hectare

Operation	Number of man-days
Land preparation	250
Seedbed preparation	100
Polybag filling	300
Planting in polybag	150
Watering	120
Fertilising	75
Pest and disease control	75
Weed control	60
Seedling selection	100
Total	1,230
One-day wage [IDR]	20,000
Total price [IDR]	24,600,000

Source: Hambali, 2007b

Erliza Hambali (2007) considered labour, materials and seedling as three main parts of variable costs of seedlings production (in this case 100,000 seedlings). Fixed costs such as management are not taken in account. According to her, 1230 man-days of work are needed for all essential operations. She determined the wage of worker as 20,000 IDR per day, which is about 2.2 USD. Therefore the total cost of labour is 24.600.000 IDR, which constitutes 30.56% of total costs.

Table 7 *Jatropha curcas* nursery: Costs of materials

Material	Amount required	Unit price [IDR]	Total costs [IDR]
Polybag	1,250 pieces	17,500	21,875,000
Manure	2,500 kg	500	1,250,000
NPK	1,000 kg	3,500	3,500,000
Seed	250 kg	100,000	25,000,000
Bamboo	500 stems	5,000	2,500,000
Nail	5 kg	15,000	75,000
Total material costs [IDR]			54,200,000

Source: Hambali, 2007b

The costs of materials are the biggest part of *Jatropha curcas* nursery costs (they constitute 67,33% of total costs).

Table 8 *Jatropha curcas* nursery: Costs of tools

Tool	Amount required [pieces]	Unit price [IDR]	Total costs [IDR]
Sprayer	2	500,000	1,000,000
Hoe	10	25,000	250,000
Watering sprayer	10	25,000	250,000
Land fork	10	15,000	150,000
Measurement glass	2	25,000	50,000
Total tools costs [IDR]			1,700,000

Source: Hambali, 2007b

The last part of costs – costs of the tools – is 1,700,000 IDR and constitutes only 2,11% of total costs. The total costs of materials, tools and labour for this volume of production is 80,500,000 IDR. This means that the costs of production of one seedling are 805 IDR. This calculation covered only variable costs and was executed for large scale production of seedlings that is why for a smallholder is preferable to buy the seedlings than to produce it on their own.

7.1.2 The costs of *Jatropha curcas* plantation

7.1.2.1 Calculation of costs for the first year

The first year costs are notably higher than other years, because the costs of land acquisition, site preparation, and seedling purchase and planting included. The summary of costs for the first year is shown in table below.

Table 9 Costs in the first year of *Jatropha curcas* plantation

Item	Costs [IDR]
Land	10,000
Seedlings	1,239,000
Labour	
Site preparation	280,000
Planting	60,000
Maintenance	680,000
Harvesting	260,000
Materials	610,000
Tools	110,000
Total costs	3,249,000

Sources: Hambali, 2007b; Simanjuntag, 2008

Land acquisition

The plot for starting the *Jatropha curcas* plantation can be bought at the price approximately 10,000 IDR per hectare. The big advantage of *Jatropha curcas* is its modesty for soil properties and fertility and this fact is reflected in this calculation, of course. The land with high quality of soil, which is necessary in the case of oil palm, would costs about five times more (Herák, 2008).

Costs of planting material

The price of seedlings varies from 800 to 2,000 IDR/piece, according to amount required. For one hectare 1,039 seedlings and about 200 seedlings as a reserve are needed. On that amount the purchase price of one seedling would be about 1,000 IDR. This means that the total costs of seedlings will be about 1,239,000 IDR. The purchase price of seeds is only 500 IDR/kg (the minimal purchase price regulated by state). For direct sowing two seeds are put at each spot. When the seedlings are 4 weeks old, weaker seedlings should be removed (NIIR Board of Consultants and Engineers, 2008). This means that for the density of 1,089 plants per hectare 2,178 seeds are needed. If counted with the lowest value of seeds per one kilogram, which is usually alleged as 1,200 seeds per one kilogram, the weight of seeds needed is 1.82 kg. The total costs of seeds needed for one hectare of plantation are then 907.5 IDR. The reason why this cheapest method of propagation is not used very frequently is that the IPB cultivars of *Jatropha curcas* need special attention and conditions (soil fertility, pH, water availability, sunshine, etc.) in the first months of growth; otherwise they will never reach their potential productivity. These conditions can be best ensured in specialised nursery. To ensure it directly in the field is much more complicated, if not impossible.

Costs of labour

The extensive system of *Jatropha curcas* cultivation does not require a lot of material investments. The greatest part of costs is constituted by costs of labour. On the basis of interview with S. Simanjuntag, the site preparation without mechanisation (using hoes) takes about fourteen man-days. If the wage is set as 20,000 IDR per man-day, the costs of labour for site preparation will be 280,000 IDR. Planting of one hectare takes only three days, which means the costs of 60,000 IDR.

Maintenance of the plantation

Hambali (2007b) mentioned these four operations in her calculation: fertilising, weed control, pest and disease control and branch control. But according to Herák (2008), branch control is not necessary and is not practiced usually. That is why only the three first operations are included in my calculation (see table below).

Table 10 Labour costs in the first year of *Jatropha curcas* plantation

Operation	Number of man-days	Unit price [IDR]	Total costs [IDR]
Site preparation	14		280,000
Planting	3		60,000
Fertilising	12	20,000	240,000
Weed control	10		200,000
Pest and disease control	12		240,000
Total maintenance costs [IDR]			1,020,000

Source: Hambali, 2007b

To harvest one tree takes about three minutes (Simanjuntag). In the case of planting pattern with the density of 1,039 trees per hectare, 13 man-days for executing of three harvests are needed. The labour costs for harvesting of one hectare of plantation will be 260,000 IDR per year. As all the work is done usually by family members, all the costs of labour can be considered as their own revenue.

Cost of tools and materials

For costs of tools and materials, see table below.

Table 11 Costs of tools and materials of *Jatropha curcas* plantation

	Amount	Price [IDR]
NPK	150 kg	525,000
Pesticide	1 kg	85,000
Materials total		610,000
Sprayer	0.2 pieces	60,000
Hoe	2 pieces	50,000
Tools total		110,000

Source: Hambali, 2007b

7.1.2.2 Calculation of costs for next years

The costs of following years can be considered as similar to the first year, but the costs of plantation establishment are excluded (see table below).

Table 12 Costs of *Jatropha curcas* plantation from second year onwards

Item	Costs [IDR]
Labour	
Maintenance	680,000
Harvesting	260,000
Tools	110,000
Materials	610,000
Total	1,660,000

Sources: Hambali, 2007b; Simanjuntag, 2008

7.3 Summary of revenues of *Jatropha curcas* growing

Indonesian farmers sell *Jatropha* seeds for production of biodiesel and the other parts for pharmaceutical purposes. The remaining biomass can be reutilised on farm as compost, for example.

It would be much more profitable to sell *Jatropha* oil as the main product, but farmers usually do not have the possibility to extract oil themselves, that is why they have to sell non-processed seeds to oil companies. If the farmers dispose with press machine, they could sell not only *Jatropha* oil, but the seed cake, as well (Herák, 2008). The revenues in this case are shown in the next table.

Table 13 Revenues of *Jatropha curcas* oil and seed cake

Product	Yield per hectare	Price[2]	Revenue [IDR/ha]
Oil	1,500[1] l	3,000 IDR/l	4,500,000
Seed cake	3,681 kg	2,500 IDR/kg	9,202,500
Total revenue			13,702,500

Sources: [1]Henning, 1996; [2]Herák, 2008

This calculation counts with the seed yield of 5,000 kg per hectare and oil yield 1,500 l, which is 1,319 kg of oil. The seed cake weight will be then 3,681 kg, and total revenue 13,702,500 IDR per hectare.

The price of biomass is about 2,500 IDR per kilogram (Herák, 2008). But the real revenue from this source is hard to define. It depends on the pharmaceutical company, which might be interested only in specific parts, with a specific quality. Theoretically, if counted with harvest index of seeds of 0.35 and the yield of 5 tonnes, then the total biomass weight is 14.29 tons. But of course only a small part of the biomass could be used in order to maintain the plantation fertility. That is why the sale of biomass is not included in next calculations.

The next table shows the revenues of one hectare of *Jatropha curcas* and palm oil plantation. In this case seeds of *Jatropha curcas* and FFB of oil palm are considered as a main product.

Table 14 Revenues of *Jatropha curcas* and oil palm production

	Jatropha curcas	Oil palm
Plant density [plants/ha]	1,039	143
Yield [t/ha]	5 [1] (seeds)	15.5 [3] (FFB)
Purchasing price of seeds [IDR/kg]	500[2]	380[4]
Revenue [IDR/ha]	2,500,000	5,890,000

Sources: [1]Sudradjat, 2006; [2]Ardiya, 2006; [3]FAOSTAT, 2007; [4]Fauzi, 2007

The prospective farmer's cash inflow of one hectare of *Jatropha curcas* plantation could be about 2,500,000 IDR per hectare, but cash inflow of oil palm plantation is about two times higher. The reason is the higher productivity of oil palm plantation.

Revenues of oil palm plantation highly depend on the level of technology and the acreage of the plantation. Smallholders have a lower productivity than big companies, mainly because of inferior management. Some companies produce on average 23 tons of FFB, but small farmers produce much less (some of them only 13 tons of FFB) (Bangun, 2006). In this calculation the Indonesian average hectare yield of FFB (15.5 ton per hectare) was used.

7.4 Economical evaluation

In this chapter some important economic indicators related to one hectare of *Jatropha curcas* plantation are counted. Then Cost-benefit analysis will be performed.

7.4.1 Cash flow

Cash flow means the amount of cash being received and spent by farmer during a defined period of time. In this case it was counted for the first five years, because after the five years onwards the volume of seed production and production costs will be stable. This situation will continue for about 10 years, and then the production will decrease again (Herák, 2008). Annual profit from fifth year onwards is 740,000 IDR (see table below).

Table 15 Cash flow of *Jatropha curcas* production

The year of plantation	1	2	3	4	5 onwards
Productivity [t/ha]	1	2	3	4	5
Seed price [IDR/kg]	500	500	500	500	500
Revenue per year [IDR]	500,000	1,000,000	1,500,000	2,000,000	2,500,000
Production costs [IDR]	3,249,000	1,660,000	1,660,000	1,660,000	1,660,000
Infrastructure and maintenance costs [IDR]	800,000	100,000	100,000	100,000	100,000
Total costs [IDR]	4,049,000	1,760,000	1,760,000	1,760,000	1,760,000
Profit [IDR]	-3,549,000	-760,000	-260,000	240,000	740,000

According to Larson, the average costs of production of one ton of FFB in Socfindo estates in 1993 were 44,076 IDR. The average yield of FFB in Indonesia is 15,5 ton per hectare, which means that the hectare costs of oil palm plantation are 683,178. This value is very similar as the value for *Jatropha curcas* plantation, but the revenues and profit are much higher. For comparison of *Jatropha curcas* and oil palm cash flow, see table below.

Table 16 The profit of *Jatropha curcas* and oil palm plantation

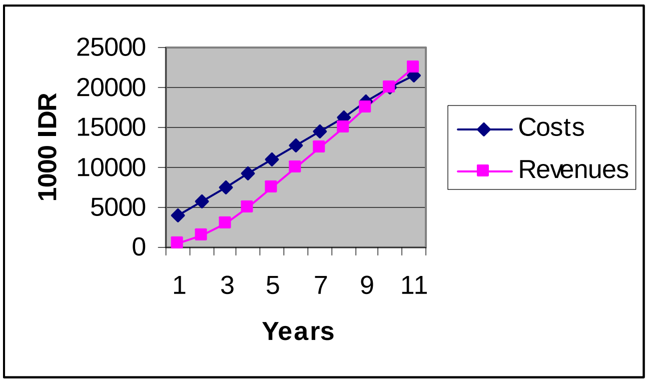
	Jatropha curcas	Oil palm
Costs [IDR/ha]	720,000	683,178
Revenues [IDR/ha]	2,500,000	5,890,000
Profit [IDR/ha]	1,780,000	5,206,822

Break-even point (BEP) is the point at which costs and revenue are equal. From this point the project starts to be profitable. Table 17 shows that the total revenues overgrow the total costs in the tenth year after establishing of plantation, in the case of the real seed purchasing price (500 IDR/kg). If the purchasing price is 800 IDR/kg of seeds, the payback period is only 5 years. If the price is as high as 1,000 IDR/kg, the payback period shorten to 4 years. In some cases, it is possible to get the sales revenue of 800 IDR/kg of seeds, according to Hambali (2007b), but more realistic is to count with the minimal and guaranteed revenue. In Figure 2 break-even point is shown as a crossing of costs and revenues line.

Table 17 Total costs and revenues cumulate for 10 years of plantation

Year	Total costs cumulate		Total revenues cumulate	
		purchasing price 500 IDR/kg	purchasing price 800 IDR/kg	purchasing price 1,000 IDR/kg
1	4,049,000	500,000	800,000	1,000,000
2	5,809,000	1,500,000	2,400,000	3,000,000
3	7,569,000	3,000,000	4,800,000	6,000,000
4	9,329,000	5,000,000	8,000,000	10,000,000
5	11,089,000	7,500,000	12,000,000	15,000,000
6	12,849,000	10,000,000	16,000,000	20,000,000
7	14,609,000	12,500,000	20,000,000	25,000,000
8	16,369,000	15,000,000	24,000,000	30,000,000
9	18,129,000	17,500,000	28,000,000	35,000,000
10	19,889,000	20,000,000	32,000,000	40,000,000
11	21,559,000	22,500,000	36,000,000	45,000,000

Figure 2 Costs, revenues and break-even point of *Jatropha curcas* plantation



7.4.2 Cost-benefit analysis

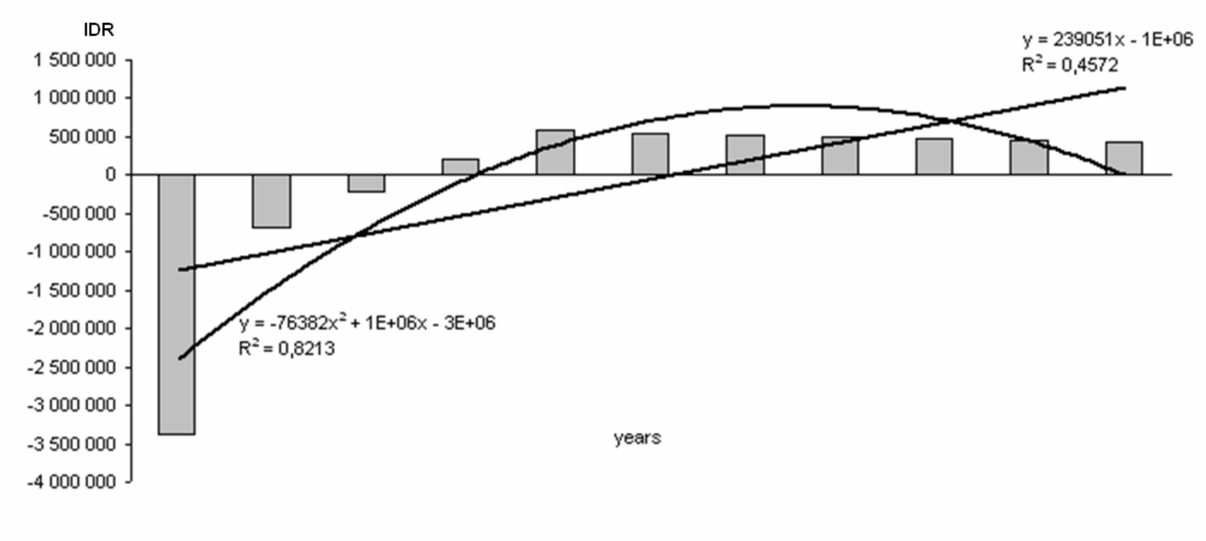
Cost-benefit analysis is analysis of the business benefit realized by existing cost. The key cost-benefit indicators are: present value of benefits, present value of costs, and net present value (Zeller, 2006). The net present value takes the time value of money into account, and so it is called a discounted cash flow method. The main indicators of cost-benefit analysis are shown in Table 18. Trend functions of the net present value shows Figure 3.

Table 18 Cost-benefit analysis by purchasing price 500 INR per kg [IDR]

Year	Present value of costs	Present value of benefits	B-C	Net present value	
				i=2.5	i=5
1	4,049,000	500,000	-3,549,000	-3,462,439	-3,380,000
2	1,760,000	1,000,000	-760,000	-723,379	-689,342
3	1,760,000	1,500,000	-260,000	-241,436	-224,598
4	1,760,000	2,000,000	240,000	217,428	197,449
5	1,760,000	2,500,000	740,000	654,052	579,809
6	1,760,000	2,500,000	740,000	638,100	552,199
7	1,760,000	2,500,000	740,000	622,536	525,904
8	1,760,000	2,500,000	740,000	607,352	500,861
9	1,760,000	2,500,000	740,000	592,539	477,011
10	1,760,000	2,500,000	740,000	578,087	454,296
11	1,760,000	2,500,000	740,000	563,987	432,663
	21,649,000	22,500,000	851,000	46,827	-573,748

Internal rate of return (IRR) indicates continuing annual revenue of investments. It is defined as any discount rate that results in a zero net present value for a series of future cash flows (present value of benefits and present value of costs are equal). In this case IRR is 2.69%. The payback period is about ten years.

Figure 3 Benefits vs. Costs balance for the time period of 2008-2028 (5% interest rate, purchasing price 500 INR per kg)



For shortening the payback period and improvement of the internal rate of return, it is necessary to increase the purchasing price of seeds. If it increases to 1000 IDR/kg, the payback period shortens to four years and the internal rate of return is 8.35% (see table below).

Table 19 Cost-benefit analysis by purchasing price 1,000 IDR per kg [IDR]

Year	Costs	Benefits	B-C	Net present value	
				i=5	i=10
1	4,049,000	1,000,000	-3,049,000	-2,903,810	-2,771,818
2	1,760,000	2,000,000	240,000	217,687	198,347
3	1,760,000	3,000,000	1,240,000	1,071,159	931,630
4	1,760,000	4,000,000	2,240,000	1,842,854	1,529,950
	9,329,000	10,000,000	671,000	227,890	-111,891

The other solution of the long payback period problem can propose some development project, which will provide farmers with the financial support for establishing of plantation. In that case payback period is counted as eight years and the internal rate of return as 7.72% (see table below).

Table 20 Cost – benefit analysis when initial cost provided by donor agency [IDR]

Year	Costs	Benefits	B-C	Net present value	
				i=5	**i=10**
1	1,760 000	500,000	-1,260,000	-1,200,000	-1,145,455
2	1,760 000	1,000,000	-760,000	-689,342	-628,099
3	1,760 000	1,500,000	-260,000	-224,598	-195,342
4	1,760 000	2,000,000	240,000	197,449	163,923
5	1,760 000	2,500,000	740,000	579,809	459,482
6	1,760 000	2,500,000	740,000	552,199	417,711
7	1,760 000	2,500,000	740,000	525,904	379,737
8	1,760 000	2,500,000	740,000	500,861	345,215
	14,080 000	15,000,000	920,000	242,282	-202,827

7.5 The evaluation of *Jatropha curcas* eligibility for Indonesian small farmer (in comparison with oil palm)

While evaluating the profitability and sustainability of *Jatropha curcas* and palm oil cultivation in Indonesia, it is necessary to state, that both these crops are in general very suitable for Indonesian climatic conditions.

For deciding which crop is more suitable and profitable for cultivating from perspective of Indonesian farmer, there is essential to examine many aspects, namely the acreage of land possessed, local climate (temperature, rainfall totals and distribution thorough the year), soil properties, availability of tools, mechanization, fertilizers, and pesticides needed for each crop, sufficiency of workers, the state of market, farmers access to market, the revenues, and many others.

The total revenues and net profits of oil palm from one hectare are higher, than in the case of *Jatropha curcas*, mainly because of its higher productivity (see Tables 14 and 16). But still there are still some factors, which the farmer has to take in account when establishing the oil palm plantation.

As shown in the Picture 12, Indonesia lies in an oil palm belt, which is ideal for *Jatropha curcas*, as well. But the zone optimal for oil palm cultivation is restricted by altitude, too. It thrives well only in altitudes up to 600 m above sea level, while *Jatropha curcas* can grow everywhere within the archipelago. Also the soil quality can mean a restriction for oil palm plantations, as the oil palm is very demanding for nutrient content, and other soil characteristics.

The climatic conditions are not the main obstacle. The biggest problem is that the oil palm industry is closed to new small farmers nowadays, because it is fully controlled by the big companies, mainly the Chinese ones.

The other problem with oil palm is that it starts to bear at the age of three years and reach the full productivity about tenth year of age, and a small farmer usually cannot wait for the revenues so long.

In case of *Jatropha curcas*, there is not a sufficient market developed. On Java, there operate only two specialised institutions, which buy back the seeds – IPB and Indonesian state-owned trading firm RNI (Rajawali Nusantara Indonesia). On Sumatra Island (North Tapanuli region) a new pressing plant was established last year. The lack of procurement centres brings additional transport costs to the farmer.

The second big disadvantage is, that only two cultivars of *Jatropha curcas* designated for Indonesian conditions are developed. There are breeded by the Bogor Agricultural University and named IPB1 and IPB2 are derived from Indian cultivars and are adapted for conditions of Java Island, where the Bogor Agricultural University is situated. For different conditions on other islands, for example Sumatra and Kalimantan, there does not exist any special cultivar.

If the farmer has the possibility to press the oil, he can sell it to these companies also or on the local market instead of kerosene or for soap making. But the demand is not as big and guaranteed as in case of palm oil, because of the non-edibility of *Jatropha* oil.

8 DISCUSSION

8.1 *Jatropha curcas* cultivation systems

The convenience of establishing *Jatropha curcas* plantation in larger scale is still being examined. There are worries of harmful effects, because the development of this field is very rapid and many factors are still not well documented. The minor fears are exuded by the extensive planting system which is common in African states. *Jatropha curcas* is planted mainly on the boundaries as a hedge to protect fields from grazing animals and to prevent erosion there. As additional value it could be used in traditional medicine, in soap making and promoting of rural energetic self-sufficiency. The oil can be used for cooking, lighting, fuelling engines of cars and electricity generators (it can substitute kerosene, diesel and fuel wood). The typical example of this approach is the projects of the German non-profit organisation GTZ (Gesellschaft für Technische Zusammenarbeit, Agency for Technical Cooperation) in Mali, where so-called Jatropha system was developed. But for profit-oriented organisations, the African continent is not very favourable, because of the unstable political climate, civil wars, insufficient infrastructure and many other problems. Nevertheless, in some localities the plantations are spread out, mainly under the control of the British biodiesel company D1 Oils (Mali, Malawi, Swaziland, etc.).

In contradistinction to Africa, the intensive systems of *Jatropha curcas* cultivation are being developed in Asia, mainly in India. In Indonesia the development is going this way, too. In these countries, there is a calmer political situation than in Africa, and better climatic conditions than in Latin America. The most important institutions, dealing with *Jatropha curcas* cultivation, arose in these two countries. In Indonesia it is the Bogor Agricultural University (Institut Pertanian Bogor, IPB), who plays the important role in *Jatropha curcas* research and development. The main difference between *Jatropha curcas* cultivation in India and Indonesia is, that in India the major plantations are held under the D1 Oils company (as the African ones), while in Indonesia the oil is used mainly for domestic purposes. Aside from this, in Indonesia this line of business is on notably lower stage of development than in India, where almost all progress in *Jatropha curcas* cultivation was done.

8.2 Problems and disputable tasks

The main problem during elaborating of this thesis was the lack of information, mainly about optimal agroclimatic conditions, and the prosperity of the plant in different environments. *„Data on production levels under well defined sub-optimal growth conditions are largely absent. This makes it practically impossible to predict future prediction potentials for marginal land, while especially the production on marginal land can contribute to the development of rural areas without competiting much with food production and biodiversity (Jongschaap et al., 2007).“* General information about *Jatropha curcas* is available, but the huge differences among some figures disclose the existing information gaps. This is caused mainly by the fact that big plantations of this plant were set up only recently and they already have not yet reached the production peaks. The best example of this problem is the task of the seed yield. The productivity of one tree is claimed as 0.2 to 2 kg of seeds per tree per year by Francis (2005), as 3 to 4 kg by Hambali (2007b) or even 15-20 kg of fruit per tree, according to the Centre for Jatropha Promotion (2004). The hectare productivity varies according to the climatic conditions and plant density from about 0.4 to over 12 ton of seeds per ha per year, according to Jones and Miller (1992). Also Hambali (2007b) describes the potential yields as high as 7.5 to 10 ton seeds per ha (the density of 2,500 plants per hectare) per year. Reinhard Henning, the expert of the Germany-based Jatropha Information Service is more sceptics: *"If you have very good conditions — soil, water, plants — you could get 5,000 kilograms of seeds per hectare per year, which can give 1,500 litres of oil per harvest. If the soil is not so good, you might only get half that (*Mkoka and Shanahan, 2008*).“*

The study of Plant Research International B.V. in Wageningen (the Netherlands) explains these differences this way: *„The positive claims on Jatropha .curcas high oil yields seem to have emerged from incorrect combinations of unrelated observations, often based on measurements of singular and elderly J.curcas trees. Extrapolation of such measurements to larger areas with J.curcas as a monoculture crop ignores the growth reduction in such systems occurring from the competition for natural resources, such as radiation, water, and nutrients. (...)In India, experiments on marginal soils yielded 0.6 (833 plants per ha) to 1.45 t of seeds/ha (1,667 plants per ha) after 2.5 years (Jongschaap et al., 2007).“*

Farmers have to fumble with many difficulties resulting from the undeveloped market and the lack of appropriate information about *Jatropha curcas* growing. According to Kumar and Sharma (2008) they are unable to achieve the optimum economic benefits from the plant, especially for its various uses. *„The markets of different products from this plant have not been properly explored or quantified. Consequently, the actual or potential growers including those in the subsistence sector do not have an adequate information base about the potential and economics of this plant to exploit it commercially."*

This problem does not exist with oil palm, but there are other problems resulting mainly from the massive expansion of oil palm plantation and the dominating authority of international corporations, which do not allow the small farmer to enter the business.

The reasons of *Jatropha curcas* expansion is not only its potential to replace the part of diesel consumption, to lower the emissions of GHGs, and to regenerate marginal lands, but *Jatropha curcas* is presented as a powerful instrument of reducing poverty, too. It provides a work and income for rural population, as described in chapter Production analysis. The requirement of labour is higher than on oil palm plantation, because harvest can be done only manually, while harvest of oil palm fruit is often partly mechanised. In addition, oil palm cultivation deepens the gap between the poor and the rich part of population. The prices of oil palm on international market are very high, but this fact is not reflected in the remunerations of plantation workers and farmers who cultivate it. On the contrary, profits of big corporations which process the seeds to oil and sell it on international stock exchange, are very high.

The necessity of clearing original rain forest, when establishing the plantation oil palm cultivation is an often discussed issue. Oil palm is the by far the most productive oil crop, its oil is used for many purposes, and the demand is still increasing. For Indonesian economy became oil palm cultivation very important and lucrative sector, and that is why the oil palm plantations are spreading over rapidly, mainly on Sumatra and Kalimantan. There exist new laws aimed to protect the forests, but in reality they hold only for small farmers, and big companies (mainly Chinese ones) do not respect it, because in Indonesia corruption is very common practice. Under these corporations the large monoculture plantations, which destroys the biodiversity and threaten a lot of plant and animal species, are established. When forests are cleared, the timber, which can be lucratively sold on international market, is logged first. Then the rest of wood is burnt down. By burning of forest there arises a danger of harming other areas with forest fires. In the fall of 1997 it was more than five million hectares of forest destructed by fire (Forest Protection Portal, 1998). On the contrary, for *Jatropha curcas* plantation the forest do not have to be cleared, because it is grown mainly on marginal land unsuitable for growing of other crops. In addition, it can regenerate these soils and protect them from erosion. But the disadvantage is that even if it is one on the highest yielding oil crops, the productivity of oil obtained from one hectare is about four times lower than from one hectare of oil palm plantation. This means that for replacing the palm oil production with *Jatropha* oil, there would be necessary to cut down the forests, as well. It is necessary to remember that mainly the European and American demand of palm oil (whether for the use in food or in biodiesel industry) is fuelling this problem. The best solution is that one offered by RSPO – not to buy the oil from new plantations, established on the place previously occupied by rain forests (namely after 1995, according to one of the RSPO rules).

The other problem is the competition of oil palm with food crops. Energetic crops take up valuable land that could be used for growing food crops. Researchers have found that if the price of petroleum is more than 50 USD per barrel, then any food material can be economically converted into biodiesel, according to Ojha (2008). The price of petroleum is two times higher nowadays. The role of biofuels in current food price increase confirms the World Bank (2008), too: *„Food prices have increased in response to many factors: higher energy and fertilizer prices; increased demand for biofuels, especially in the U.S. and the European Union; and droughts in Australia and other countries. World grain stocks are at record lows and next year's prices depend on the success of the next harvest in the northern hemisphere."* Indonesian food price hikes from 1997 to 1999 are shown in Figure 6. In contrast to oil palm, *Jatropha curcas* does not contribute to this problem, because it grows on infertile places, where it does not mean the competition for food crops.

The premission of carbon neutrality of biodiesel should be re-examined, too. Biodiesel burning is avouched as carbon neutral, because the amount of carbon dioxide released is the same as the amount of carbon dioxide sequestered by the growth of plants which are used as biodiesel feed-stock. In fact, this presumption ignores the energy requirements and carbon dioxide emissions, which emerge during the biofuel production (firing of the forest, use of fertilisers, pesticides and mechanisation during cultivation, processing, refining, and transport of biofuels). When taking in account all energy requirements, the final energetic balance of biofuels could be even negative. This means that more energy is consumed than produced. That is why many ecologists and scientists warn against the massive use of biofuels. The majority of carbon dioxide emissions arise by burning of the forests, where a lot of organic matter is accumulated. The production of green energy makes Indonesia paradoxically the third world largest producer of GHGs. In the case of *Jatropha curcas*, forests are not burnt out. That is why the total GHGs emissions are much lower. *„Since Jatropha curcas is considered a low input crop, implicating a low energy use for fertilisers, tillage and so on, the lifecycle carbon dioxide emissions for biodiesel can be low, likely 15% compared to petrol-diesel (Francis et al., 2005).“* This low value is real when the biodiesel is consumed in the country of origin.

8.3 Solutions of problems of *Jatropha curcas* growers

There are many challenges in the field of *Jatropha curcas* cultivation in Indonesia. Firstly many researches have to be executed to determine the optimal growth conditions and to propone the correct cultivation practices. Also the new cultivars have to be developed. This should be held by the local scientific organisation, like the Bogor Agricultural University. Also some private company should be involved in the research and development of this field, because biodiesel industry is becoming more and more important these days. Then there is necessary to transfer the available information to farmers. It could be done by some Agricultural Extension Programme, for example Training and Visit, Strategic Extension Campaign, Farmer Field School, or Farmer-to-Farmer Extension. Training and visit is not very suitable, because it miss the feed-back from farmers to the extension organisation. The last method (Farmer-to-Farmer Extension) could be optimal, because it is based on the presumption that farmers learn from each other, and so the dissemination of knowledge about new cultivation practices develops spontaneously. At first innovations are provided to selected farmer and if he finds them as valuable, he will spread these ideas among the other farmers.

Also Contract Farming, the extension method supported by FAO, should be the effective solution of this problem and of the problem of undeveloped market, on the same time. Contract farming means a special agreement between farmer and some processing firm, which ensures to farmer a guaranteed demand of his crop on predetermined prices. The firm also often provides him with credit, technical assistance, planting materials, fertilisers, pesticides, etc. The other possibility for securing the better marketing situation is creating of farmers union, because then their market power will increase.

The role of government is important, too. The state should support *Jatropha curcas* growers as more as possible, mainly by ensuring the higher purchasing price of *Jatropha curcas* seeds. I think that it should be increased to about 800 IDR per kg. Then infrastructure has to be improved and *Jatropha curcas* market developed. It is necessary to establish new procurement centres.

Other possibility is to enable farmers to produce the *Jatropha* oil themselves and use it locally for lighting and cooking (instead of kerosene and firewood), as an energy source for their vehicles (in the form of oil or biodiesel). It can be used also for making the village self-sufficient by creating its own electricity. For these purposes there have to be development programmes established, which will provide farmers with simple press machine, electricity generator, and special cookers.

9 CONCLUSIONS

Oil palm and *Jatropha curcas* are two oil crops of a great importance for the Indonesian oil industry nowadays. Both these crops are very suitable for Indonesian natural conditions, with some restrictions for oil palm.

CPO is the main Indonesian export commodity, while *Jatropha* oil is produced in relatively small quantities, but cultivation of this plant is experiencing the very sharp development and publicity nowadays. It can never reach the national production levels comparable with oil palm (mainly because of its lower oil yields), and so it can be considered only as additive source of oil and biodiesel for lowering the Indonesian petroleum imports.

Its main comparative advantage against oil palm is that *Jatropha curcas* can be domesticated on previously unused marginal lands. On these places it can also serve for erosion control and soil reclamation. It also can sever as additional source of income for farmers and therefore it helps to reduce the rural poverty. On the contrary oil palm industry contributes to deepening of the gab between the poor and rich part of Indonesian society.

Also from environmental point of view is the oil palm cultivation a very problematic task. As it has a big demands for space and soil quality, the cultivation induce the destruction of large areas, often the original rain forests. This crop also competes with food crops strongly and this fact causes the increase of food in Indonesia, which was 10.4% in February 2008 (far higher than overall inflation at 7.4%).

From economical point of view, the cultivation of oil palm was evaluated as more profitable. The farmer's expenses for one hectare of plantation are about the same value, but the revenues of harvested oil palm FFB are much higher, than the revenues of *Jatropha curcas* seeds. But it has to be taken in account, that oil palm industry is hardly attainable for small farmer newcomers, as it is fully controlled by big (mainly foreign) companies.

In case of *Jatropha curcas*, the main problem consists in low know-how of farmers and the undeveloped market of *Jatropha curcas* seeds and other products. This situation can be improved for example by extension campaigns (Farmer-to-Farmer Extension or Contract Farming) focused on the proper cultivation practices, and by establishing the functional system of seed procurement centres. Then it is important to enable farmers to press the oil and use it for themselves. It can be ensured by providing them by simple press machines and farm machinery which can be driven by the obtained oil.

The other serious question appears when the collective effort of extension organization will change the orientation from providing the inputs for farmers to help the farmers achieve the stronger negotiation position on purchasing price setting, which could represent an important step towards ensuring the farmers profitability. The figured payback period of *Jatropha curcas* plantation in the case of present purchasing price (500 IDR per kg) is ten years. This is a very long time for a small farmer, because he usually does not respond with reserve funds to bridge it over. When the price will increase to 1,000 IDR per kg, the payback period will be only four years.

The problematic issues that have appeared during elaboration of this thesis (e.g. the tedious accessibility of oil palm industry) have led to the conclusion that for small farmers is more convenient to start cultivation of *Jatropha curcas*, rather than oil palm. Also from the environmental point of view is *Jatropha curcas* the better alternative.

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11 APPENDIXES

11.1 Tables

Table 21 Indonesian GDP trends, 2002 – 2006

	2002	2003	2004	2005	2006
GDP [mld. IDR]	1,897,800	2,045,854	2,273,142	2,784,960	3,338,196
GDP [mld. USD]	200.1	234.8	254.3	281.3	350.2
GDP growth [%]	4.4	4.7	5.1	5.6	6.0

Zdroj: Bank Indonesia, 2008

Table 22 Production of FFB from 3 to 19 years of the plantation

Age	Annual production [tons FFB]	Number of bunches	Average bunch weight [kg]
3	6.5	1711	3.8
4	13	2281	5.7
5	18	2045	8.8
6	19.5	1806	10.8
7	21	1641	12.8
8	22.5	1531	14.7
9	24	1341	17.9
10	24	1250	19.2
11	24	1182	20.3
12	24	1121	21.4
13	24	1081	22.2
14	24	1043	23.0
15	24	1030	23.3
16	24	1008	23.8
17	24	996	24.1
18	24	905	24.3
19	24	857	24.5

Source: Diemer, 2004

Table 23 Oil productivity of selected plants

Plant	Productivity of oil [l/ha/year]
Oil palm (*Elaeis guineensis*)	5.950
Coconut palm (*Cocos nucifera*)	2.689
Brazil nut (*Bertholletia excelsa)*	2.392
Physic nut (*Jatropha curcas*)	1.892
Jojoba (*Simmondsia chinensis*)	1.818
Ricinus (*Ricinus communis*)	1.413
Olive (*Olea europaea*)	1.212
Rapeseed (*Brassica napus*)	1.190
Opium (*Papaver somniferum*)	1.163
Peanut (*Arachis hypogea*)	1.059
Sunflower (*Helianthus annuus*)	925
Sesame (*Sesamum indicum*)	696
Soybean (*Glycine max*)	446
Cotton (*Gossypium hirtusum*)	325
Maize (*Zea mays*)	172

Source: Hambali, 2007a

Table 24 Physical properties of *Jatropha* biodiesel, palm biodiesel and diesel fuel

Parameter	*Jatropha* biodiesel	Palm biodiesel	Diesel fuel
Density [g/cm^3, 20oC]	0.879	0.863	0.83
Kinematics viscosity [mm^2/s at 40oC]	4.84	5.3	5.2
Cloud point [oC]	5	16	18
Flash point [oC]	191	174	70
Calorific value [MJ/kg]	37-38	37-38	41
Sulfur content [ppm]	Max 50	Max 50	Max 500
Cetane number	51	62	42
Acid value [mg KOH/g]	198	209.7	N/A
Iodine number	95-107	45-62	N/A

Source: Hambali, 2007b

Table 25 Palm oil production in Indonesia according to the estate type, 1975-1994

Year	Production [t]			
	Public Estate	Private Estate	Smallholder	Total
1975	271,171	126,082	-	397,253
1976	286,096	144,910	-	431,006
1977	336,891	120,716	-	457,607
1978	336,224	165,060	-	501,284
1979	438,756	201,724	760	641,240
1980	498,858	221,544	770	721,172
1981	533,399	265,616	1,045	800,060
1982	598,653	285,212	2,955	886,820
1983	710,431	269,102	3,454	982,987
1984	814,015	329,144	4,031	1,147,190
1985	861,173	339,241	43,016	1,243,430
1986	912,306	384,919	53,504	1,350,729
1987	988,480	352,413	165,162	1,506,055
1988	1,102,692	454,495	156,148	1,713,335
1989	1,184,226	597,039	183,689	1,964,954
1990	1,247,156	788,506	376,950	2,412,612
1991	1,360,363	883,918	413,319	2,657,600
1992	1,489,745	1,076,900	699,605	3,266,250
1993	1,469,156	1,370,272	582,021	3,421,449
1994 *)	1,785,315	1,410,030	899,138	4,094,483

Source: Directorate General of Estates (from Larson, 1996)

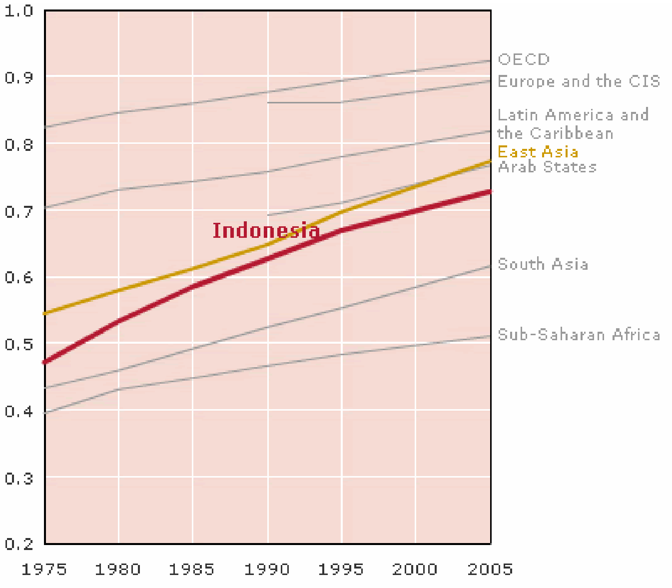
Table 26 The volume of production of CPO and PKO in Indonesia

Year	CPO [1,000 t]	PKO [1,000 t]
2001	9,200	1,476
2002	10,300	1,599
2003	11,500	1,594
2004	14,000	1,830
2005	15,000	1,853

Source: Palm Oil World, 2006

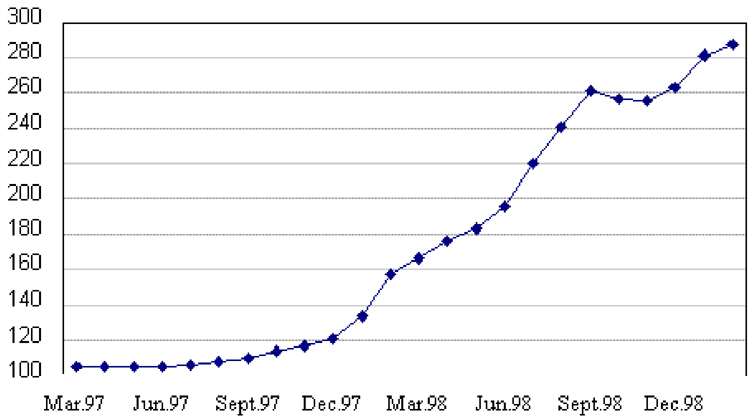
11.2 Figures

Figure 3 Indonesian HDI trends, 1975 – 2005



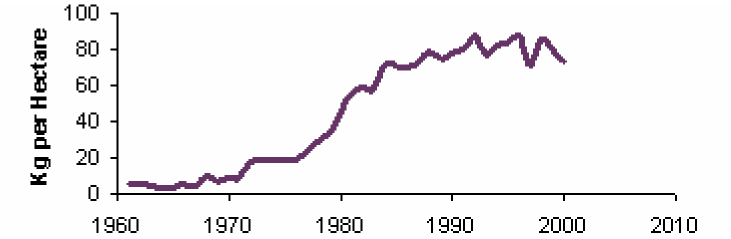
Source: UNDP, 2007/2008 Report

Figure 4 Food Price Index growth in Indonesia



Source: FAO, 1999a

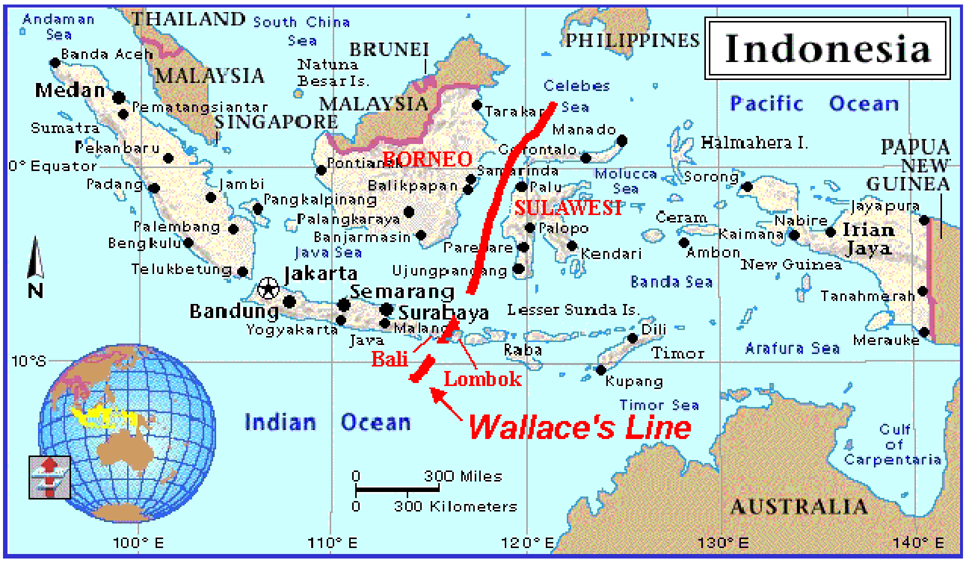
Figure 5 Fertiliser consumption in Indonesia, 1961-1998



Source: World Resources Institute, 2006

11.3 Pictures

Picture 14 Wallace's line



Source: Woodward, 1997

Picture 15 *Jatropha curcas* trees

Source: Setyaningsih, 2007

Picture 16 *Jatropha curcas* leaves

Source: Herák, 2008

Picture 17 *Jatropha curcas* flower

Source: Herák, 2008

Picture 18 *Jatropha curcas* branch with fruits

Source: Centre for Jatropha Promotion, 2004

Picture 19 *Jatropha curcas* seeds

Source: Centre for Jatropha Promotion, 2004

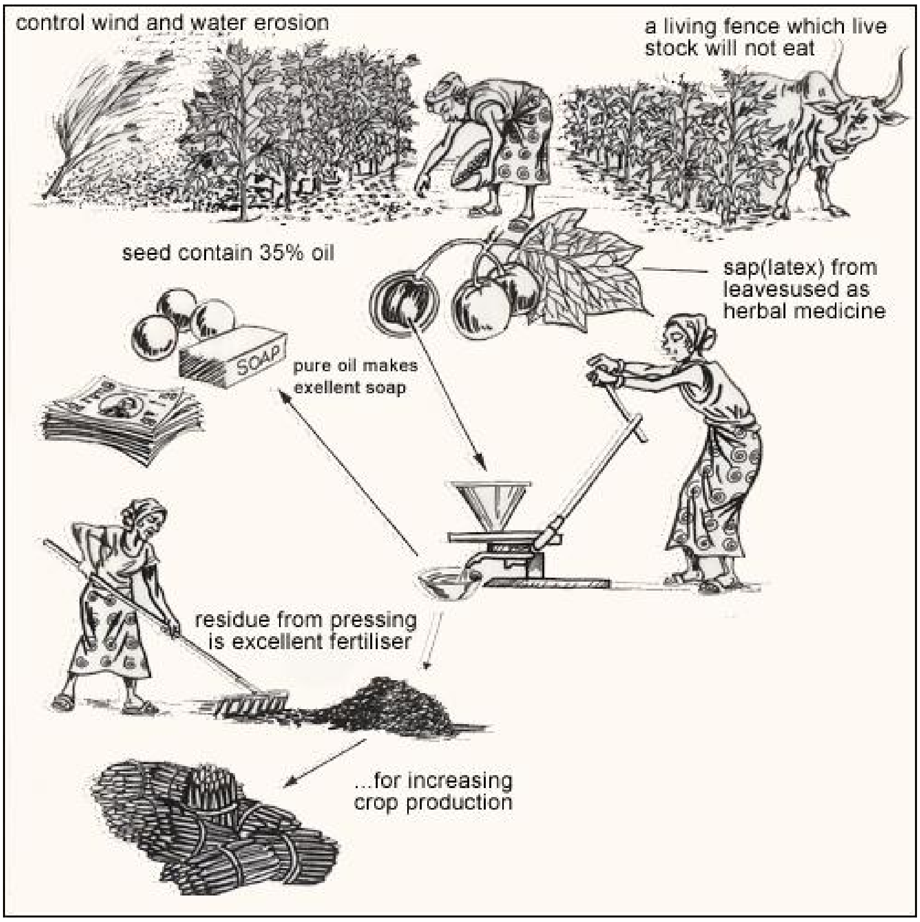
Picture 20 Press machine

Source: Mkoka and Shanahan, 2005

Picture 21 *Jatropha curcas* seeds and its products

Source: Herák, 2008

Picture 22 Scheme of Jatropha System

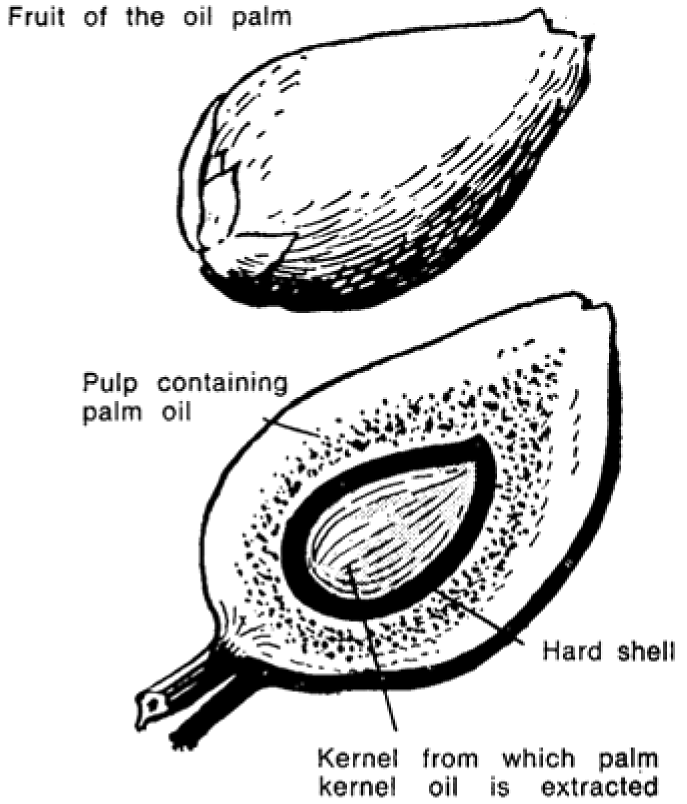


Source: Mouvement Sociétal, 2008

Picture 23 Oil palm and its parts

Source: Taylor, 2006

Picture 24 Scheme of oil palm fruit

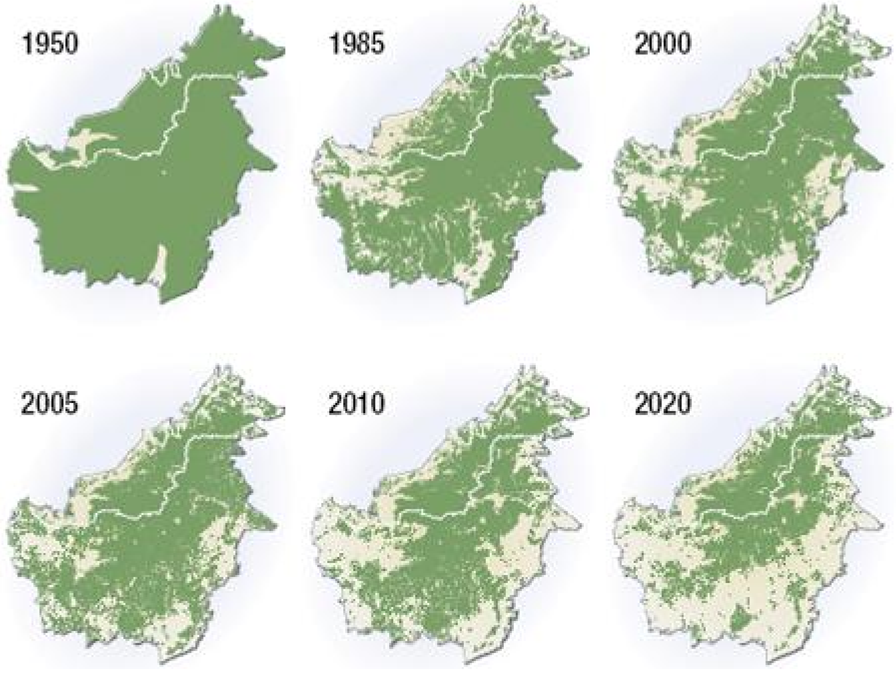


Source: FAO, 1977

Picture 25 Oil palm fruit

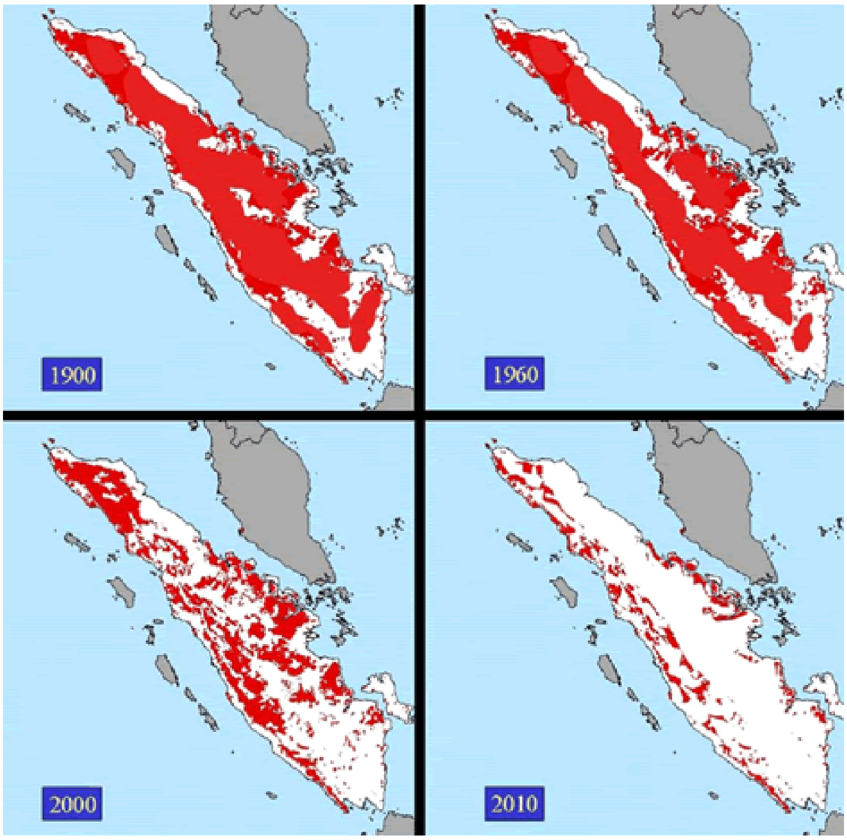
Source: Herák, 2008

Picture 26 Map of Deforestation Trends in Borneo



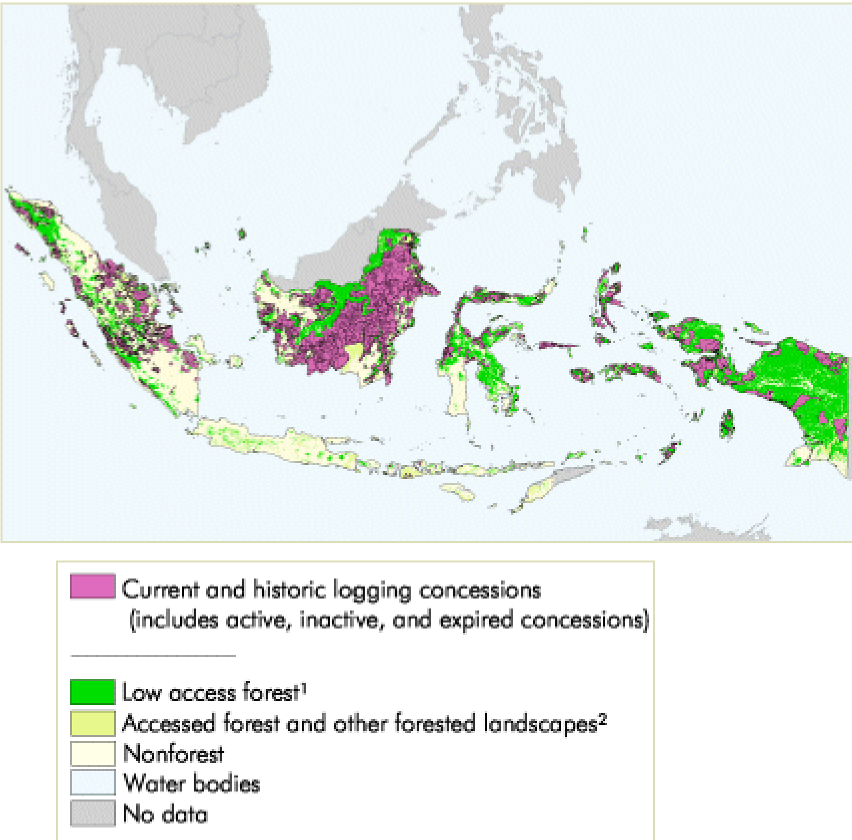
Source: UNEP, 2007

Picture 27 Deforestation Trends in Sumatra



Source: WWF, 2007

Picture 28 Extent and distribution of logging concessions



Source: World Resources Institute, 2003

Picture 29 *Jatropha curcas* nursery

Source: Herák, 2008

Picture 30 Oil palm nursery, Kalimantan

Source: Lyon, 2005

Picture 31 *Jatropha curcas* plantation

Source: Henning, 2004

Picture 32 Oil palm plantation, North Sumatra

Source: Herák, 2008