Bio-diesel from Jatropha plantations on degraded land

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Land degradation has become a major threat to world food security with about 2000 million ha of soil, equivalent to 15 per cent of the Earth's land area (an area larger than the United States and Mexico combined), having been degraded through human activities (Fig. 1). The main types of soil degradation are water erosion (56 per cent), wind erosion (28 per cent), chemical degradation (12 per cent) and physical degradation (4 per cent). The UNEP lists the causes of soil degradation as overgrazing (35 per cent), deforestation (30 per cent), agricultural activities (27 per cent), overexploitation of vegetation (7 per cent) and industrial activities (1 per cent). A total of 305 million ha of soils ranged between 'strongly degraded' (296 million ha) and 'extremely degraded' (9 million ha, of which more than 5 million ha were in Africa). 'Extremely degraded' soils are beyond restoration. In the more severely affected regions land degradation threatens the economic and physical survival of the human population.

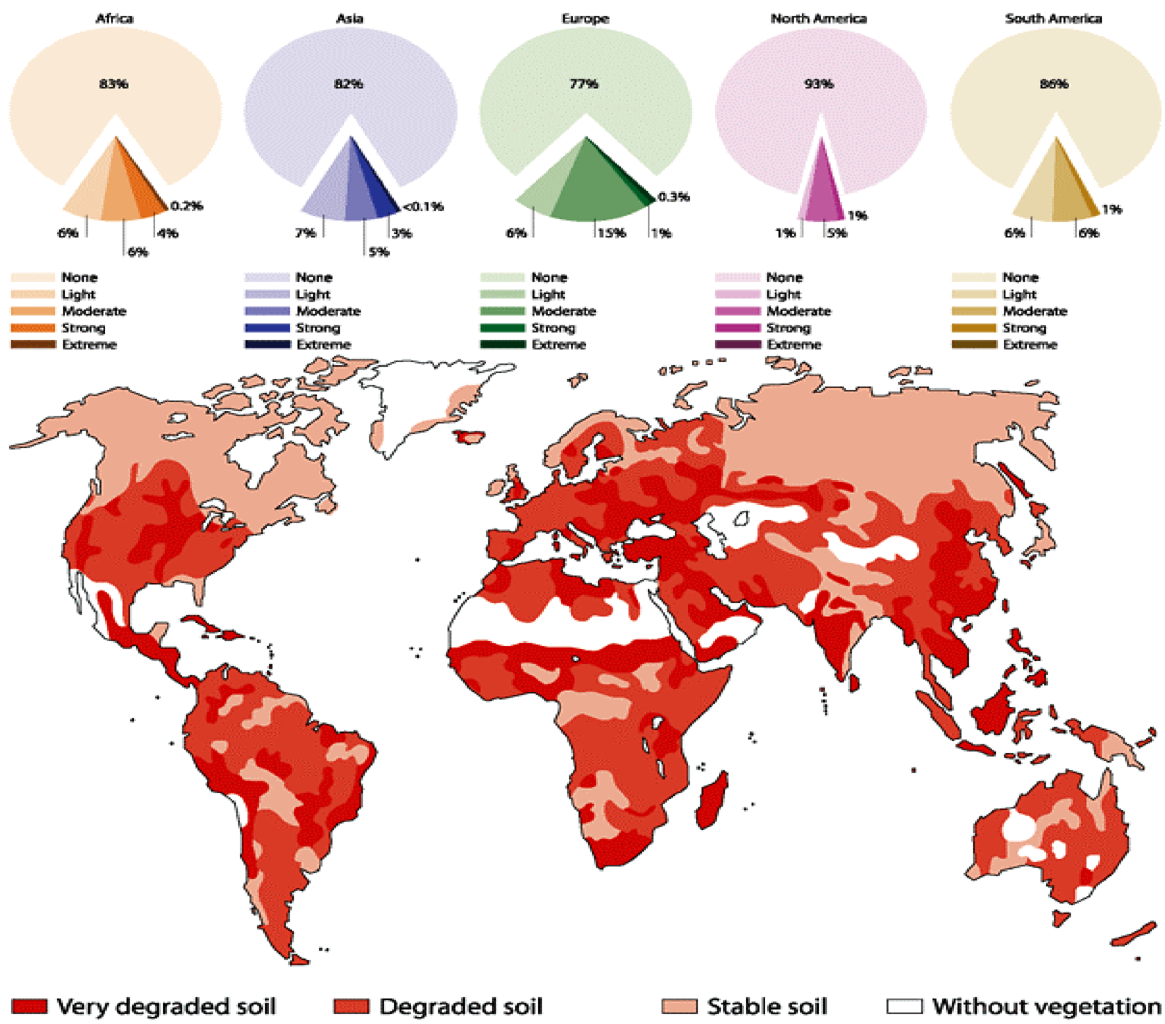

Fig. 1: Distribution of degraded land in the different continents (Source UNEP)

The predicted higher average rate of increase of the population in the developing countries over the next 50 years would decrease the land availability per capita in these regions. Conservative estimates predict global human population to grow to 8.9 billion from the current 6.3 billion (Cohen, 2003; Science 302, 1172-1175). According to the FAO, the world's land reserves accounts for 13.4 billion hectares out of which only about 1.5 billion hectares is cultivated presently. Mankind has already lost 2 billion hectares of soil during the historic period of its existence due to degradation (Fig. 2). Soil degradation is very intensive on arid lands occupying about 6.1 billion hectares, mainly in Asia and Africa.

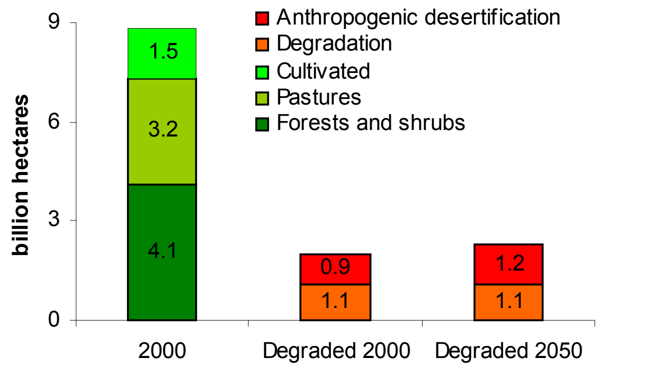

Fig. 2: Distribution of potentially usable land and projected progress of degradation

Cohen projects 59 people per km^2 in the developed countries and 93 people per km^2 in the developing countries by 2050 (Fig. 3). If only the arable land and loss due to degradation (6 million hectares desertification per year) are also taken into account, the per capita availability of land is set to shrink further (Fig. 4). In the second graph of fig. 4 degradation is assumed to progress proportionately in the developed and developing countries. In reality, however, it is likely to affect the developing countries more severely making the picture for these countries even more critical.

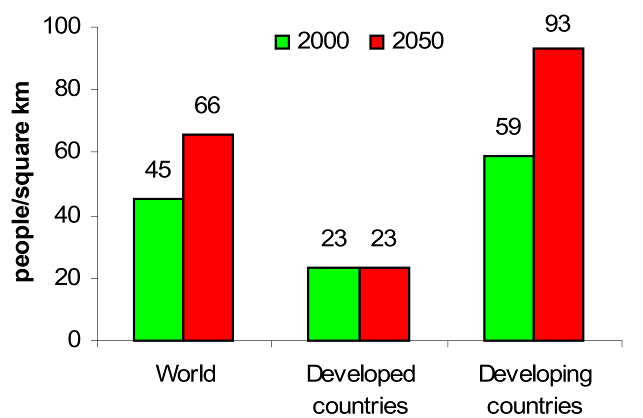

Fig. 3: Changes in the number of people per km^2 on the globe (Cohen, 2003)

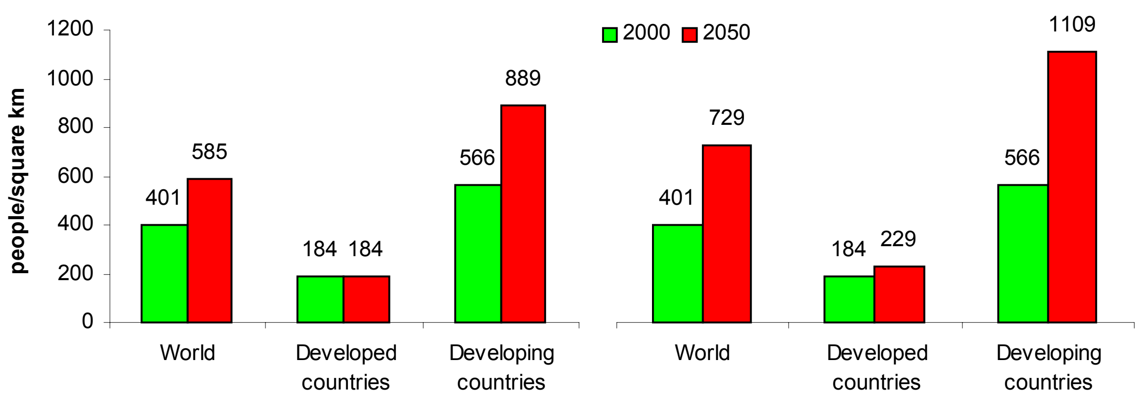

Fig. 4: Changes in number of people per square km of arable land | **Changes in number of people per square km of arable land after factoring in land degradation**

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Increasing population density and the additional decline in availability of productive land due to degradation would further fuel the large-scale migration of people into the already overpopulated metropolis in Asia and Africa in future, unless urgent corrective measures are adopted to increase rural incomes and generate new perspectives in the weaker regions.

Economic development in many developing countries has led to huge increases in the energy demand. As most of the countries now enjoying rapid development (China and India e.g. – both countries already rank among the top 5 net CO_2 emitters in the world) are also large petroleum importers, their dependence on external energy sources from highly unstable regions would increase to uncomfortable levels (Fig. 5). Energy security has thus become a key issue for many countries.

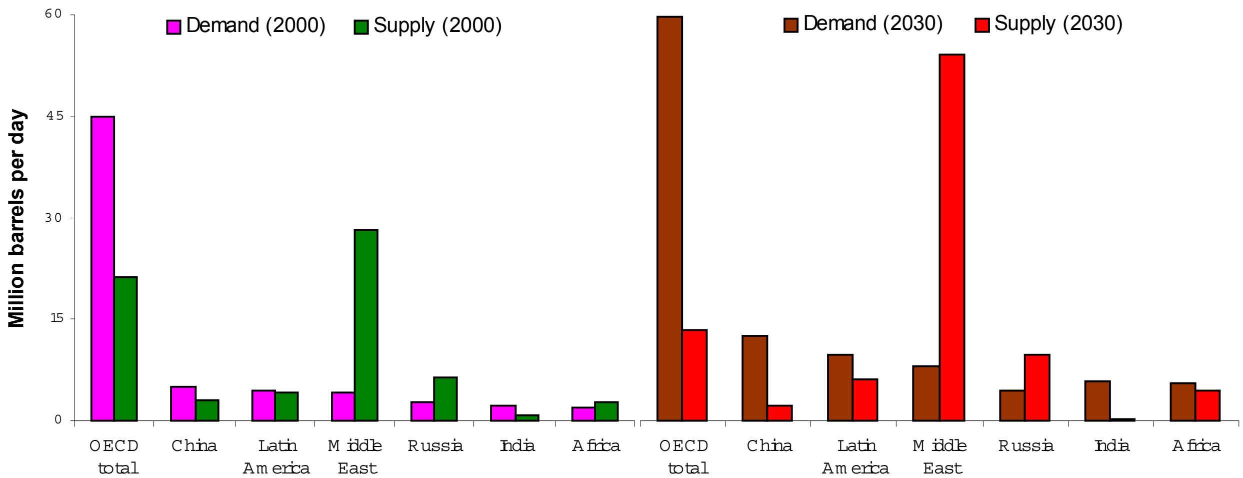

Fig. 5: Petroleum demand and supply in 2000 compared to 2030 (source IEA)

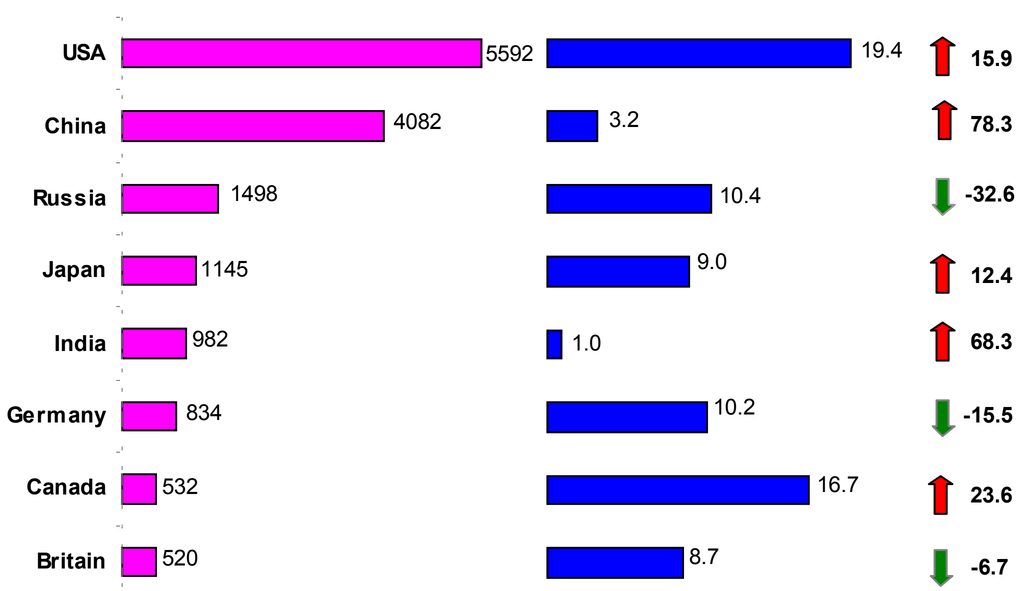

Fig 6:Energy related CO_2 emissions in 2002 (million tons)
Source: UN, IEA

Energy related per capita CO_2 emissions (tons) in 2002

% increase since 1990

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Increased consumption of energy and fuels has resulted in increased release of green house gases into the atmosphere (Fig. 6) not to speak of the other, mainly transport-related pollutant emissions. These have already exceeded critical levels in many overcrowded metropolis in the developing countries. A Harvard University study has come out with the dramatic figure of 1 death per hour in Delhi caused by air pollution.

The increased presence of green-house gases and the resultant climate change has dramatically increased the number of natural disasters that cost the world $60 billion already this year (Figs. 7 and 8). The severest effects of the natural calamities are known to affect the poorest people in the developing countries the most.

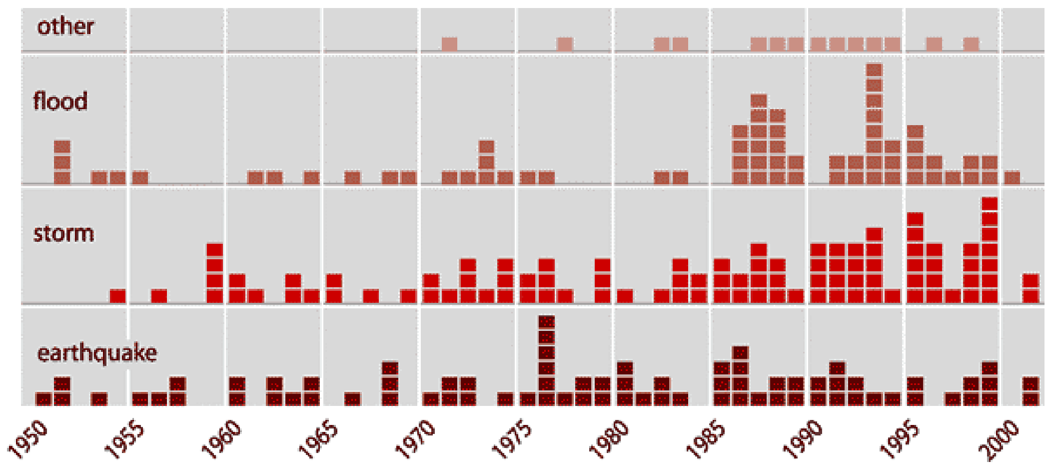

Fig. 7: The increasing trend in frequency of 'great' natural disasters (Source: UNEP)

Catastrophes are classed as great if the ability of the region to help itself is overtaxed, making inter-regional or international assistance necessary, as is usually the case when thousands of people are killed, hundreds of thousands made homeless or when a country suffers substantial economic losses

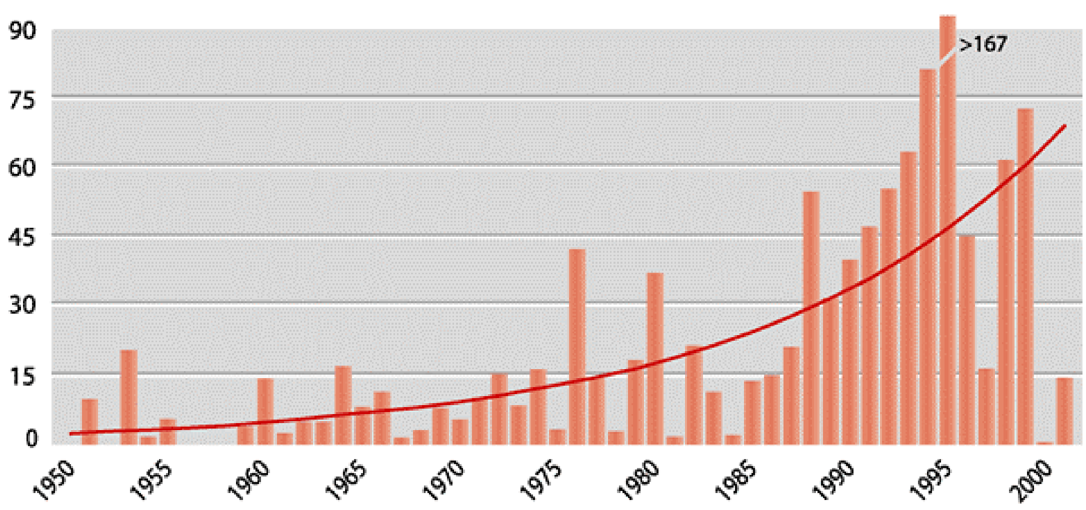

Fig. 8: Economic costs of great natural disasters (US $ billion), 1950–2000 (Source: UNEP)

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It is in this background that production of bio- diesel from Jatropha plantations set up on degraded land become highly relevant for energy importing developing countries with large tracts of land already degraded or under the threat of degradation. There is no loss of land for food production or other purposes as only degraded land where profitable food production would not be possible are foreseen to be used. On the other hand lack of urgent protective measures would lead to expansion of the degraded areas and hence intervention have to be taken up on a priority basis.

Reclamation of land using plants have been successfully tested in the past

Fig. 9: Example of saline wasteland reclamation in Aleppo, Syria using *Atriplex nummularia (Photos: K. Becker)*

A: arid and salty barren land with low rainfall; B: rows of Atriplex plants are first planted in rows; C: once they develop they stop water and wind erosion and act as wind breakers helping to sediment nutrient carrying topsoil particles carried by wind; they are then pruned and barley are cultivated in between; D: increase of organic matter and nutrient content in the soil by the plant products and the captured dust particles (the topsoil layer increases up to 0.7 cm per year) allowing healthy growth of cereal crops. Birds and rodents were observed to re-colonize the ecosystem in due time.

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Features of the Jatropha plant

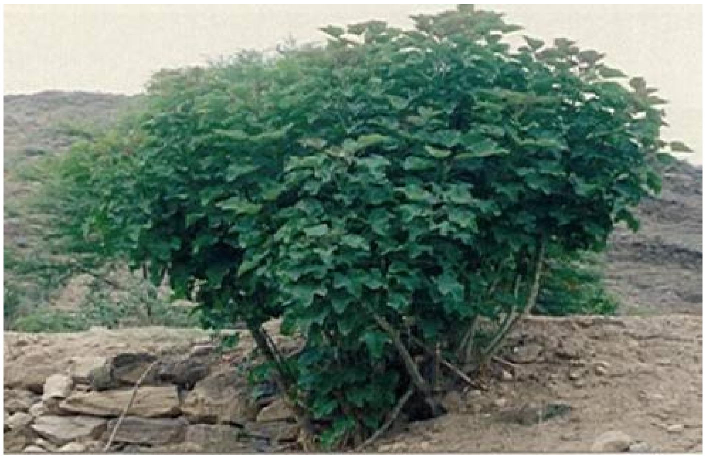

Fig. 10: Vigorously growing Jatropha plant on rocky substrate *(Photo supplied by P.K. Ghosh, CSMCRI, India)*

Fig. 11: Planted Jatropha cutting starts yielding in the 5th month *(Photo supplied by P.K. Ghosh, CSMCRI, India)*

Jatropha curcas (Gk: Jatros – physician and trophe – food; common name physic nut or purging nut; Figs. 10 and 11) belonging to the family Euphorbiaceae, is a low-growing tree that is native to S. America, but widely planted in South and Central America, Africa and Asia. It is a succulent plant that may shed its leaves during the dry season and attains a height of about 3 m in 3 years. Preparations of various parts of the plant have been used in traditional medicine and as pest repellents. The most important uses of Jatropha are erosion control and oil production. It finds traditional use principally as a living fence, protecting cropland from freely ranging cattle, sheep and goats in tropical countries.

Physic nut is adapted to higher temperatures and grows well in well drained soils receiving an average rainfall of 300 to 1000 mm. It can however tolerate slight frosts and years without rainfall and is well adapted to marginal soils with low nutrient content. Yields vary from 0.5 to 12 t/yr based on soil and rainfall conditions. If only poor soils with low nutrient contents are considered, a yield of about 0.5- 0.75 tonnes of oil that can be transesterified into bio-diesel; (see table 1 for properties of Jatropha bio-diesel) could be expected per hectare per year. Jatropha often starts yielding from the first year onwards, but yields are maximum from plants that are about 3-5 years old. The productive age of Jatropha is over 30 years. The dry seeds of Jatropha weigh around 750 mg and contain more than 30% by weight of oil that is suitable for conversion into bio-diesel. The kernel forms around 60% of the seed. The de-oiled seed cake has a crude protein content of between 53to over 60 % and a favourable amino acid profile.

Why Jatropha?

Jatropha has several advantages over other plants that can thrive under adverse conditions. It is not eaten by animals and is a vigorous, drought and pest resistant plant and when planted as a

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fence repels rodents and has phytoprotective action against pests and pathogens and thus provides additional protection to intercropped plants. Cattle have been found to graze in the space between Jatropha rows in large plantations. Jatropha plantations also attract nesting birds and honey seeking bees. They are also completely harmless to people looking after them or handling their seeds or seed cake.

Table 1. Characteristics of Jatropha bio-diesel compared to European specifications

Parameter	**Jatropha bio-diesel**	**European standard**
Density (g cm^{-3} at 20°C)	0,879	0.860 – 0.900
Flash Point (°C)	191	> 101
Cetane no. (ISO 5165)	57-62	> 51
Viscosity (mm^2/s at 40°C)	4.20	3.5 - 5 (40°C)
Net Cal. Val. (MJ/L)	32.80	-
Iodine No.	95-106	<120
Sulphated ash	0.014	<0.02
Carbon residue	0.025	<0.3

Source: unpublished own data and
Gübitz et al., Bioresource Technology 67, 73-82, 1999

The seed cake remaining after oil extraction is toxic and is currently used as a bio-fertilizer and a bio-pesticide. The toxicity is mainly due to the phorbol esters and other heat-sensitive antinutrients such as lectins, trypsin inhibitors etc. Once it can be viably detoxified it could be a highly nutritious feed material that could help in reducing the need to import high-protein concentrates (Table 2). Experimental projects have shown that Jatropha lends itself excellently to large-scale "energy" plantations and can be cultivated both in irrigated and rain fed conditions.

Table 2. Chemical composition of extracted meal (% dry matter) of *Jatropha curcas* (from Nicaragua) compared with soybean meal

	Kernel (60% of seed wt.)	**Shell (40 % seed wt.)**	**Meal**	**Soybean meal**
Crude protein	25.6	4.5	61.2	45.7
Lipid	56.8	1.4	1.2	1.8
Ash	3.6	6.1	10.4	6.4
Gross energy (MJ/kg)	30.5	19.5	18.3	19.4
Neutral Detergent Fibre	3.5	85.8	8.1	17.2
Acid detergent fibre	3.0	75.6	6.8	12.2
Acid detergent lignin	0.1	47.5	0.3	0.0

Source: Makkar et al. Food Chem. 62, 207-215, 1998.

Tests by the United States Environment Protection Agency (USEPA) have shown that the use of bio-diesel almost completely eliminates lifecycle carbon dioxide emissions. Jatropha bio-diesel can be used either in the pure form or as blends in conventional petro-diesel in automobiles without any major modifications (many modern cars available in the market are capable of running on 100 % bio-diesel). The USEPA data shows that use of 100% bio-diesel (produced from soybean oil) reduces vehicle emission of particulate matter by 40%, unburned hydrocarbons by 68%, carbon monoxide by 44%, sulphates by 100%, polycyclic aromatic hydrocarbons (PAHs) by 80%, and the carcinogenic nitrated PAHs by 90% on an average.

Fig. 12: Vegetables intercropped between rows of Jatropha plants *(Photo: K. Becker)*

Jatropha is thus unique among renewable energy sources in terms of the potential benefits that can be expected to result from its widespread use. Its cultivation is technologically simple and requires comparatively low capital investment. The large-scale cultivation of Jatropha should target the 296 million hectares of strongly degraded land that requires treatment before food production is possible on them again. Once the Jatropha trees establish themselves and fertilize the soil, their shade can be used for intercropping shade-loving vegetables such as red and green peppers, tomatoes etc. that would provide additional income for the farmers (see Fig. 12). Benefits from its large scale cultivation, in addition to the various positive effects on a macro-level, will accrue to a large extent to marginal land holders in many tropical countries, who despite being hapless victims of the vagaries of climate are the least organised and hence least favoured.

As legislation is put into place for compliance with the directions of the Kyoto protocol, plantations (such as those of Jatropha set up on wasteland) sequestering CO_2 would acquire an additional attraction as sources of “carbon dioxide emission credits” that could be purchased by countries that are unable to reduce their CO_2 emission reduction targets.

Jatropha research at the University of Hohenheim

The University of Hohenheim has played a pioneering role in research on the cultivation of Jatropha and the use of its products. The Department of Aquaculture Systems and Animal Nutrition (Prof. Dr. K. Becker), through its workgroup for research into underutilized multifunctional plants has been in the forefront of these activities for the last 10 years. The Department is currently involved in a pilot project along with DaimlerChrysler and the CSMCRI (an Indian Government owned industrial research institute) to demonstrate the viability of production of bio-diesel from Jatropha oil produced from wastelands in India. The Department has previously been involved in Jatropha projects in different countries, mainly in S. America and Africa. Contacts and interactions with Jatropha researchers from these previous projects are still maintained.

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Table 3. Cost-benefit analysis of Jatropha plantations over a productive period of 30 years (assumed values based on conditions of wasteland cultivation in India)

Item	Value	Remarks
Total plants per ha	1200	Plantation at about 2.9m x 2.9m distance
Production of dry seeds per plant/yr (kg)	1.5	With minimal inputs from year 5 onwards
Total production per ha per year from yr 5	1800	444, 1111, 1333 and 1556 kg for years 1, 2, 3 & 4
Price of dry seeds per kg ($)	0.1	
Total selling price per ha per year ($)	176	
Additional income from vegetable intercropping ($) starting from year 5	109	43 and 65 $ during years 3 and 4
Employment generation per hectare	200 person days during the first year and 50 person days thereafter for 29 years	
Establishment cost per ha. ($)	$435 during year 1	
Maintenance per ha	$109 per year subsequently for 29 years	
Out of this labour costs ($)	$261 during year 1 and $65 during the subsequent 30 years	
Present value of life-cycle costs/ha ($)	1459	
Present value of returns/ha ($)	2190	
Net present value ($)	731	
Internal rate of return (%)	20.6	

It could thus be seen that 1 ha of land could be reclaimed by cultivating Jatropha at an expenditure of $300 - $450 under typical developing country situations. The cost of leasing land at $20 per ha per year is factored into the establishment and maintenance costs. There is scope to increase productivity per hectare by improving the plant germplasm through selection and breeding as well as by optimising the agronomic treatments such as irrigation and fertilisation. Viable detoxification of the seed cake would also bring additional revenue into the system. The tradable emission credits, both through sequestration of CO_2 in plant biomass and through the use of CO_2 neutral bio-diesel derived from Jatropha seeds needs to be quantified. There is a need for further research into the various agronomic aspects and carbon dioxide sequestration patterns of Jatropha plantations on degraded soils and detoxification and use of the seed cake to maximise the returns and encourage adoption by small and marginal farmers in the tropics.

Summary of benefits of large-scale Jatropha plantations on wasteland

- ***Availability of CO_2 neutral fuel in remote rural areas***
- ***Potential availability of high quality protein concentrates locally***
- ***Wasteland reclamation for food production***
- ***Reduced atmospheric pollution***
- ***Carbon sequestration for emission trading***
- ***Employment generation and socioeconomic development***

Fig. 13: Bio-diesel carbon cycle